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FATIGUE CHARACTERISTICS OF FIELD HMA SURFACE MIXTURES CONTAINING RECYCLED ASPHALT PAVEMENT (RAP)

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Abstract

The use of the Reclaimed Asphalt Pavement (RAP) in asphalt mixes has existed for sometime. Experience has shown that recycling of asphalt pavements is highly beneficial from a technical, economical, and environmental perspective. Some of the main advantages of utilizing the RAP include conservation of asphalt and aggregate resources, conservation of energy, and reduction of construction costs. This report is mainly focused on field study of fatigue and rheological properties of asphalt mixtures with inclusion of different (0,10,20,30) percent of RAP. The objective of this study is to determine what maximum percent of RAP can be introduced into the Tennessee Department of Transportation (TDOT) mixture without affecting mixture properties.

Surface mixtures meeting the TDOT "D" mix criteria were evaluated at 0, 10, 20, and 30 percent of screened RAP materials. During the field study two mixes were evaluated (limestone and gravel) with two different types of binder (PG 64-22 and PG 76-22). Fatigue characteristics as well as the mixture properties were tested and evaluated. Tests used for fatigue evaluation of HMA mixture included indirect tensile strength, semi-circular bending, and beam fatigue tests.

From this study it was concluded that the inclusion of RAP discarded material, as well as long-term aging, will generally influence the stiffness of the mixture and in return affect its resistance to fatigue cracking. It was also noted that the fatigue properties of the mixtures with 30 percent of RAP material drastically changed the fatigue characteristics as compared to 0, 10, and 20 percent of RAP mixtures. At the higher percentages of RAP the mixture becomes stiffer and fatigue characteristics of the RAP mixture are compromised by adding RAP. Based on the results of the field mixtures, up to 20 percent

RAP can be used in TDOT surface mixtures without compromising the fatigue properties of the asphalt mixture.

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CHAPTER 1
INTRODUCTION

1.1 Background

Recycling of discarded asphalt pavement was common in the early 20th century, but the practice fell out as new refineries were built and caused the increase in supplies and decrease in cost. Due to the energy crisis in early 1970's the asphalt pavement industry was once again forced to reuse the discarded asphalt concrete by putting it back into the road. Today, asphalt pavement is America's most recycled material and has shown to be a highly beneficial approach from technical, economical, and environmental perspectives (NAPA, 2004). Some of the advantages that come from reusing the salvaged asphalt concrete include preservation of existing highway geometrics (pavement grade, drainage facilities, etc.), conservation of asphalt and aggregate resources, conservation of energy, and reduction of construction costs. Due to these advantages the recycling of the old pavement has been a way of life for most state highway agencies.

Recycled asphalt pavement is created by milling the top few inches of asphalt from a paved surface, generally in the process of preparing for repaving. Once milled the discarded material can either be processed on the construction site or batch processed at a stationary crusher location. The processed material can be reused as a replacement for some aggregates in hot batch mix where it is blended with virgin mixtures. Re-blending is done by a number of processes which include the following: hot-mix recycling, hot in-place recycling, cold in-place recycling, and full depth reclamation (Maher et al. 2005).

Hot-mix asphalt (HMA) recycling is a proven process that may be used to

upgrade worn-out pavements (AI 1981). This type of recycling, with minor modifications, can be successfully performed in batch, continuous, and dryer drum mix plants where the discarded stockpiled material is blended with new aggregate, asphalt, and recycling agent, when required. The hot-mix recycled asphalt can be designed for use in all types of pavements (Maher et al. 1981).

Hot in-place recycling is process where simple heater-scarification units, heat reforming systems, and special techniques have been developed for heating, scarifying, rejuvenating, and remixing of up to 50 mm (2 in) in depth of aged asphalt pavement to new hot mix quality overlay in one pass. This type of recycling can be used to treat surface defects like corrugation, rutting, and cracks (Kuennen, 2005).

Cold in-place recycling is based on the principle that in-place bituminous pavement is a source of materials that may be used to build a new bituminous layer. This is an on-site recycling process which reuses 100 % of the existing bituminous material to a depth of 65 to 125 mm (2 to 5 in). The recycled material is transformed into the bituminous aggregate, mixed with emulsion and recycling agent, and blended with new aggregates. The resulting mixture is than placed as the base/binder course with new wearing course placed later (Maher et al. 2005).

Full depth reclamation (FDR), often known as pulverizing, is a rehabilitation technique in which the full thickness of the asphalt pavement and predetermined portion of the underlying materials (base, and sometimes, sub-base) are uniformly pulverized and blended to provide an upgraded, homogeneous material. The reclaimed layer is then compacted to provide a uniform platform for the subsequent asphalt base course or surface course. FDR is an on-site process which does not use heat. Stabilizing additives

can be used in this process to enhance the properties of the reclaimed layer (Kuennen, 2005). Each one of the methods described above should be carefully chosen according to the existing pavement conditions prior to the construction of a project.

Since RAP generates savings associated with material and disposal cost, many state agencies have been moving toward increasing use of RAP in their hot mix asphalt pavements (Flynn, 1992). While RAP has been used most commonly in the range of 20 to 50 percent (Solaimanian et al. 1996), there have been cases where at least 80 percent of the hot mix asphalt pavement has consisted of discarded asphalt concrete pavement (Bloomquist et al. 1993). However it should be noted that high percentages of RAP are not used in normal practice. Most state highway agencies have noticed the reduction in the project cost when RAP was used. One Florida Department of Transportation experienced 15 to 30 percent reduction in cost compared to the conventional paving approach where only virgin material is used (Page, 1998). Currently the use of RAP in new asphalt mixtures is common practice.

Even though recycled material is a very valuable resource there are still some concerns about its performance. The main concerns about the use of RAP (especially in significant quantity) in surface or load carrying layers are the durability and long-term fatigue resistance. Adding too much RAP material to the virgin material could cause a mixture to become too stiff which in return would greatly affect the fatigue performance of asphalt mixtures. For this reason, most state Departments of Transportation (DOT) in the United States either limit or restrict the amount of RAP to be used in their surface layer mixtures, and also limit the percentage of RAP material to be used in structural layers.

In 2002, Tennessee Department of Transportation reported that approximately 1.32 million tons of asphalt meeting the "D" mix criteria was placed throughout the state of Tennessee (TDOT, 2002). With the incorporation of RAP material into the surface mixture, substantial savings could be generated by the state of Tennessee. Typically both, the construction cost and material cost are evaluated when doing a cost analysis of asphalt mixture. Construction cost variables are dependent on the location and type of milling operation. For the study presented in this thesis analysis of construction was omitted and focused on material cost savings. To determine the amount of savings that could be generated a detailed material cost analysis presented in appendix K was performed on a Tennessee surface "D" mix containing 5.7 percent of liquid asphalt. Figure 1 presents costs of asphalt mixtures per ton and their savings with inclusion of RAP processed material. In fiscal year 2004, mixtures with inclusion of 30 percent of RAP would generate savings of up to 20 percent or $3.56 per ton of asphalt mix. Since 2004, the price of ingredients (coarse and fine aggregates) for asphalt mixtures has increased, so the use of RAP would generate even higher savings. A cost of a mixture containing 30 percent of RAP increased up to $21.95 per ton of asphalt mixture. This generated savings of $6.20 per ton or 22 percent for a mixture containing 30 percent of RAP.

The University of Tennessee (UT) has been conducting research (Laboratory Fatigue Characteristics of HMA Mixtures Containing Recycled Asphalt Pavement) with the Tennessee Department of Transportation (TDOT) to study the laboratory fatigue

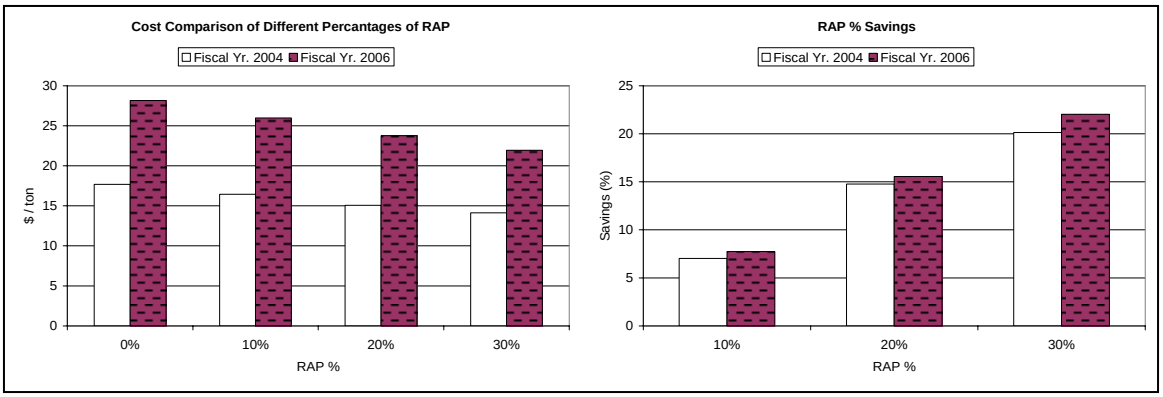


Figure 1. Cost Analysis for Mixtures With Inclusion of RAP

characteristics of HMA surface mixtures containing different percentages of screened asphalt recycled material (Kingery, 2004). The results from this study indicated that inclusion of RAP generally increased the stiffness and fatigue properties of the mixtures studied. Based on laboratory results of the Phase I study it was concluded that the fatigue resistance of the mixtures would not be compromised if 20 percent of RAP was incorporated into the mixture. Once 30 percent of RAP was introduced into the mixtures, significant property changes were noted in fatigue characteristics as compared to 0, 10, and 20 percent RAP mixtures. In order to validate the current TDOT specification and include the RAP in the HMA surface mixtures, field validations of the laboratory results were necessary.

Based on the research results from TDOT/UT, TDOT has revised the specifications and allowed the inclusion of RAP in surface “D” mixtures (high volume traffic surface mixture). According to the new TDOT specifications, the amount of RAP to be used with surface “D” mixture is limited based on the binder grade. Up to 15 percent of RAP is allowed in PG 64-22 surface “D” mixes, and 10 percent on mixes

using binders PG 70-22, PG 76-22, and PG 82-22. Besides the surface "D" mixture TDOT also allows 20 percent of RAP on Type "A" mixture and up to 30 percent on Type "B", "BM", "BM2", "C", "CW" mixtures (TDOT 2006). States such as Alabama, Georgia, Kentucky, and Virginia generally permit up to 30 percent of the RAP material in their surface mixtures.

However, the previous UT study (Laboratory Fatigue Characteristics of HMA Mixtures Containing Recycled Asphalt Pavement) used laboratory mixed mixtures to characterize the fatigue properties of the asphalt mixtures subjected to various tests in the laboratory. The mixtures prepared in the laboratory can sometimes be significantly different than those prepared in the HMA plants. In order to validate the finding from the previous study, a follow up study with plant mix seems necessary.

One important factor between laboratory and plant mixed HMA mixtures is their uniformity. Uniformity of hot mix asphalt with inclusion of RAP can also affect the mixture performance. For the asphalt mixtures to perform at its peak performance it is important that the RAP is mixed uniformly with the virgin mixture. A non-homogeneous mixture could potentially be affected by weather changes such as freeze-thaw (Lee et al., 1983). Fatigue properties of the asphalt mixtures could also be affected due to insufficient mixing and uniform dispersion of discarded material. "Asphalt Measurement of Mixing Efficiency in Pavement Recycling" was a study done by Lee et al. 1983 where it was proven that the plants can efficiently mix RAP material with virgin aggregate to a homogeneous state. However the variability of RAP could greatly be affected if high percentages of it were used in the asphalt mixtures. Solaimanian et al. (1995) did a study on variability of HMA containing high percentages of RAP material and determined that

high percentages of RAP may greatly influence the mixture properties. In this study the projects with high percentages of RAP exhibited a larger variation in asphalt content, gradation, air voids, and stabilities as compared to typical virgin HMA mixtures.

1.2 Objective

The primary objective of this research was to evaluate the fatigue characteristics and uniformity of hot-mix asphalt field mixtures with the inclusion of RAP materials. A typical TDOT surface "D" mixture was considered at 0, 10, 20, and 30 percent of (-No. 4) sieve screened RAP content. Fatigue crack and fracture resistance of the field mixtures was determined through extensive laboratory mixture performance tests. The uniformity of the field mixtures was evaluated through aggregate and binder testing. For this study two types of binder (PG 64-22 and PG 76-22) and aggregates (Limestone and Gravel) were used.

1.3 Scope of Study

The scope of this research was to evaluate the laboratory fatigue crack resistance of the plant surface "D" mixture with inclusion of RAP, and to evaluate the uniformity of screened (- No. 4) RAP materials and RAP mixtures. The two primary types of aggregates used to evaluate the fatigue performance of RAP mixtures were limestone and gravel mixed with two types of asphalt binders PG 64-22 and PG 76-22. Prior to testing, one half of the laboratory made specimens (limestone and gravel) were subjected to long-term ageing. The laboratory tests used to evaluate the fatigue performance of the

mixtures included tensile strength, semi-circular bending, and flexural beam fatigue tests (Table 1). During this study the mixtures containing 0, 10, 20, and 30 percent of RAP material were compared to the zero percent RAP virgin mixture (control mixture). The uniformity of the RAP material and RAP mixtures was also evaluated during this study. Four asphalt plant mixes were chosen for the RAP uniformity evaluation (Table 2). The aggregate and binder of both RAP and RAP mixtures were separated and tested for their properties. The aggregate tests included gradation analysis, specific gravity, and fine aggregate angularity. All of the extracted RAP binder was subjected to Dynamic Shear Rheometer (DSR) Testing where the fatigue properties of the asphalt binder were analyzed. The uniformity of the RAP mixtures was performed only on PG 64-22 limestone mixtures (Table 3). Three different truck loads at each RAP percentage were used to evaluate the uniformity of the RAP mixtures.

Table 1. Laboratory Fatigue Tests

Mixtures (meeting "D" Mix Criteria)				Laboratory Performance Tests					
Project No.	Aggregate	Asphalt Cement	RAP (%)	IDT	SCB	SCB Notched			Beam Fatigue
						0.5"	1.0"	1.5"	
1	Limestone	PG 76-22	0	x,y	x,y	x,y	x,y	x,y	x,y
			10	x,y	x,y	x,y	x,y	x,y	x,y
			20	x,y	x,y	x,y	x,y	x,y	x,y
			30	x,y	x,y	x,y	x,y	x,y	x,y
2	Limestone	PG 64-22	0	x,y	x,y	x,y	x,y	x,y	x,y
			10	x,y	x,y	x,y	x,y	x,y	x,y
			20	x,y	x,y	x,y	x,y	x,y	x,y
			30	x,y	x,y	x,y	x,y	x,y	x,y
3	Gravel	PG 70-22	0	x,y	x,y	x,y	x,y	x,y	x,y
			10	x,y	x,y	x,y	x,y	x,y	x,y
			20	x,y	x,y	x,y	x,y	x,y	x,y
			30	x,y	x,y	x,y	x,y	x,y	x,y
4	Gravel	PG 64-22	0	x,y	x,y	x,y	x,y	x,y	x,y
			10	x,y	x,y	x,y	x,y	x,y	x,y
			20	x,y	x,y	x,y	x,y	x,y	x,y
			30	x,y	x,y	x,y	x,y	x,y	x,y

Note: Each test was conducted on triplicate samples and the total number of tests was 576.
IDT – Indirect Tensile Strength Test;
SCB – Semi-circular Bending.
x – Short-term aged
y – Long-term aged

Table 2. Evaluation of Screened RAP Uniformity

RAP Sources	Mixture Test		Aggregate Test			Binder Test
	Extraction	Recovery	Gradation	S.G.	FAA	DSR
1	3	3	3	3	3	3
2	3	3	3	3	3	3
3	3	3	3	3	3	3
4	3	3	3	3	3	3

Note: S.G. – Specific Gravity
FAA – Fine Aggregate Angularity
DSR – Dynamic Shear Rheometer

Table 3. Evaluation of Plant Mix Uniformity of Asphalt Mixtures at Different RAP Content

RAP	Mixture Test		Aggregate Test			Binder Test
Percent	Extraction	Recovery	Gradation	S.G.	FAA	DSR
0	3	3	3	3	3	3
10	3	3	3	3	3	3
20	3	3	3	3	3	3
30	3	3	3	3	3	3

Note: S.G. – Specific Gravity
FAA – Fine Aggregate Angularity
DSR – Dynamic Shear Rheometer

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

For over a century most of the roads in the United States have been constructed and maintained using virgin materials for asphalt concrete mixtures. Due to decreased supply and increased cost of construction materials the asphalt industry is being forced to seek alternative methods for construction and replacement of the asphalt pavements. The recycling of the old material has proven to be an economically feasible and functionally successful solution to this dilemma which yields many benefits such as conservation of aggregates, binders, and energy as well as the preservation of the environment.

2.2 Uniformity of Hot Mix Asphalt With Inclusion of RAP

Virgin mixtures with incorporation of reclaimed asphalt pavement (RAP) have proven to perform similar to or even better than the virgin asphalt pavements. However, not much research has been performed on uniformity of the RAP material within the virgin mixture as well as the uniformity of the RAP itself. There is no known test that can be used to determine if the mixture is homogenous once the RAP is introduced into the virgin mixture.

Lee et al. (1983) conducted a research project to evaluate the plant mixing efficiency of virgin mixture with inclusion of RAP. They concluded that the performance of the recycled mixtures largely depends on how well the RAP mixes interact with the virgin material and asphalt binder. Most of the researches and development programs done in the past have concentrated on equipment, construction techniques and sequences,

mixture design, pavement performance and/or cost and energy considerations. There is very little information from the literature that addresses the mixing process and mixing efficiency. Mixing efficiency is the degree of attainment of equilibrium, respective of rate and cost (Lee et al. 1983). This means that uniform distribution of ingredients from sample to sample within a batch as well as within the sample itself should occur so that the design criteria can be met. Mixing efficiency can is generally measured by the appearance of a bituminous mixture in terms of distribution and coating. However, the detection of mixing efficiency can become very troublesome when rejuvenating agents and the virgin materials are combined. To resolve this problem a "Dye Print Technique" was developed by Lee et al. (1983), where the recycling agent was dyed with a beta-naphthol red dye. Two studies were done, laboratory and field. In the laboratory study sand particles were colored with the beta-naphthol to simulate reclaimed material and mixed with the virgin material. Once mixed the specimens were fabricated and sawed. The sawed face asphalt concrete pill sample was than placed against a chemically treated piece of fabric on which the dye print of the reclaimed material was developed. Lee et al. (1983) also used digital densitometer equipped with a microcomputer to determine the dispersion of the recycled material. This method enabled them to develop digitized plots of the dye print scans and to run statistical analysis for quantifying the dispersion of the dyed recycled material. Ten field studies were conducted where various plant types, pumping systems, productions rates, mixing temperatures and asphalt modifiers were encountered. Here dye was added to the new binder which was than introduced into a drum mixer or pug mill. After mixing all of the material a samples was obtained from the discharging outlet, from trucks or from the grade behind the paving machine. Specimens

were fabricated, sawed and the dye prints were obtained. Once again the overall mixing efficiency was evaluated based on distribution of dye spots visually or statistically. The researchers concluded that the plant mixes were mixed thoroughly. The use of the dye prints has proven to be a very effective method for determining the uniformity of RAP within the virgin mixture.

The uniformity of RAP within the stockpile is important as variability of RAP can greatly affect the mixture properties once it is combined with the virgin material. The variability of the RAP material can be due to stockpiling methods or may be inherent in the materials themselves. Solaimanian and Tahmoressi (1995) preformed a study on variability of the RAP material itself and its affect on the plant mixtures. Four projects were selected to determine variability in the RAP materials and the asphalt mixtures containing RAP. Two of the projects used 35 percent RAP material and the other two used 40 and 50 percent of the RAP material, respectively. During this study different laboratory tests were run to determine the properties of RAP asphalt mixtures with inclusion of RAP. These laboratory tests include aggregate gradation, asphalt content, air voids, stability values, viscosities, and penetration. The entire laboratory test results obtained showed that the RAP mixtures produced higher variation in results than typical plant mixtures with no RAP. Generally the gradations for the RAP mixtures had higher mean standard deviation than the no RAP mixtures for the two sieve sizes that were of interest, #10 and #200. The mean standard deviation was also higher for other tests which were air voids, stability, and viscosity. However the inclusion of RAP did not affect the density of the mixtures as much as it influenced the asphalt content and gradation. When determining the gradation it is important to use a similar procedure as

the field milling operation to obtain a RAP sample. RAP aggregate gradation from road cores can differ significantly from RAP aggregate gradation from the milling as the amount of finer material can increase due to crushing by the milling machine. RAP material can greatly influence the asphalt mixture properties. The use of the high percentages of RAP should be limited until the methods are available to reduce the mix variability at higher percentages of RAP material (Solaimanian et al. 1995).

2.3 Fatigue Cracking in Asphalt Pavement

It is often hard to characterize pavement damage because of the unpredictable distress that pavement experiences during its life. Distresses in pavement occur due to environment at exposure and repeated traffic loads. There are four major distresses in asphalt concrete pavements: fatigue cracking, thermal cracking, rutting, and moisture damage. This study is mainly concentrated on RAP asphalt mixture resistance to fatigue cracking. Discarded asphalt concrete material contains aged binder, which once blended with virgin binder produces a stiffer mixture (Huang 2004).

Structural distress by fatigue cracking is the main concern when designing asphalt with the inclusion of RAP. This type of distress often occurs in pavement mixes due to aging, excessive number and magnitude of applied loads during its design life, climate of the site (i.e. seasonal range and distribution of temperatures), and inadequate drainage (Hall 2001). The aging process of asphalt is initiated during the production of asphalt mixtures in the plant where it is exposed to the air and high temperatures. Once compacted in the field, the aging of asphalt continues at a slower rate until the end of its design life.

Excessive loading of asphalt develops tensile stresses and strains in the pavement layers which lead to initiation of micro cracks. The developed stresses continue to increase and multiply which leads to development of macro cracks and further damage to asphalt pavement (Metcalf, 2002). Until recently, load-associated fatigue cracking of hot-mix asphalt (HMA) concrete-surfaced pavements in the wheel path has been thought to always initiate at the bottom of the HMA layer and propagate to the surface. However, recent studies by Roque et al. (2001) have determined that load-related HMA fatigue cracks can also be initiated at the surface of the pavement and propagate downward through the HMA layer. The penetration of water and other foreign debris into these cracks can further accelerate the propagation of the crack through the HMA surface layer and permanently damage the pavement structure.

2.4 Characterizing Fatigue Life of HMA Mixtures

Pavement distress, caused by repeated bending or fatigue of asphalt pavements, has been an issue in the United States since 1948 (Hveem 1948). In order to address fatigue distress in mixtures, several tests are available to simulate field conditions. According to Tangella et al. (1990) these tests include diametric fatigue, beam flexural fatigue test, and tests employing fracture mechanics principals. Mode of loading, the primary factor affecting fatigue response, is usually stress-controlled or strain-controlled (Tangella 1990). Based on their study, the loading necessary for crack initiation can be measured by stress-controlled test. During this study they also noted that longer fatigue lives are recorded in strain-controlled tests because crack propagation can be observed.

2.4.1 Indirect Tensile Strength Test

For asphalt mixtures, the indirect tensile test (IDT) is one of the most popular tests used for HMA mixture characterization in evaluating pavement structures. The test is conducted by applying a compressive load to a cylindrical specimen through two diametrically opposed, arc shaped rigid platens (loading strips). This type of loading configuration develops a reasonably uniform tensile stresses along the diametric axis of the test specimen (Tangella 1990). In 1968 Kennedy and Hudson determined that a load of sufficient magnitude would cause the specimen to fail near the point of a load application due to compression. By distribution of load through a loading strip the compressive stresses are greatly reduced and a sufficiently large load will actually cause a tensile failure along the vertical diameter. During the indirect tensile test, both the vertical and horizontal stresses are developed at the center of the specimen, where the vertical compressive stress is three times the horizontal tensile stress (Tangella 1990).

Roque and Buttlar (1992) developed a procedure to accurately determine the prediction of pavement response and performance through the use of IDT set up. They concluded that the stress states induced in the vicinity of the center of the specimen's face are relevant for the prediction of both traffic-load induced and thermally-induced response at low in-service temperatures (< 30 ^{o}C (86 ^{o}F)). During this study they determined that the IDT mode has the unique advantage that the failure plane is known a priori at low in-service temperatures which allows for the failure limits to be measured directly on the failure plane. Roque and Buttlar (1992) concluded that the measurement and analysis system presented in their study would reduce or eliminate the effects of nonlinearity and damage on the asphalt concrete properties determined from the test.

They also suggested that more definitive analysis should be performed to verify this inference.

2.4.2 Semi-Circular Bending (SCB) Test

European and South African researchers have extensively investigated the semi-circular bending test as a simple tool for determination of the material characteristics needed for pavement design (Molenaar et al. 2002). Molenaar et al. (2002) used this test to obtain information on the modulus and the tensile characteristics of asphalt mixtures. The test specimen is produced with the aid of the gyratory compactor or taken from a core which is drilled from the pavement. A disc is then cut from the produced specimen and sawed into two equal parts resulting in two 1-inch thick semi-circular specimens. During this study researchers investigated and compared the advantages of using semi-circular bending test as oppose to indirect tensile test. They discovered that a nice crack develops at the bottom of the semi-circular disc causing the sample to fail in tension. Conversely, Indirect Tensile Test specimens typically fail in compression near the loading strip by wedging or shear failure. Even though semi-circular bending test is not a standard test method used to characterize pavement material behavior, it can still be used as a tool by researchers to evaluate the tensile characteristics of the mixture tested.

2.4.3 Semi-Circular Fracture Test

It has been commonly believed that the fatigue crack resistance of HMA is closely related to its fracture resistance. Hence, some researches apply fracture mechanics to evaluate the fatigue properties of HMA mixtures.

The fracture mechanics concept of J-integral was first introduced by Rice in 1968 as a path independent integration of strain energy around the crack (Rice 1968). Today researchers use the concept of J-integral as an ideal tool when evaluating the fracture mechanics of materials used for structures such as pressure vessels, aircraft, and bridges. Distresses such as cracking in pavements are mostly caused by repetitive loadings over time which makes asphalt pavements ideal candidates for the application of fracture mechanics principals (Sulaiman and Stock, 1995).

The first applications of fracture mechanics were based on linear elastic analysis and crack growth in ideal brittle materials. Therefore, fracture mechanics could only be applicable to asphalt at low, sub-zero temperatures, which limited evaluation of asphalt mixtures for the full range of pavement service conditions. However, further development of fracture mechanics found solutions for situations in which the crack tip was preceded by the development of a significant plastic zone, and the J-integral approach has become widely accepted as a solution for this situation. This allowed the use of fracture mechanics approach into the range of normal service conditions for pavements (Sulaiman, 1995).

The semi-circular fracture test for HMA was first introduced by Mull et al. (2002), where Mull used it to characterize the fracture resistance of crumb rubber modified asphalt mixtures. The fracture test was based on a fracture mechanics concept known as the J-integral (the critical strain energy release rate). Semi-circular specimens with various notch depths were subjected to three-point bending to characterize fracture resistance of different asphalt mixtures. The semi-circular notched specimens were loaded monotonically on an MTS machine at a cross-head speed of 0.5 mm/min (0.02

in/min) in a three point bend load configuration. A linear relationship between the total strain energy to failure and the notched depth of the asphalt mixtures was noted. Mull used this linear relationship to determine the fracture resistance of the asphalt mixtures by taking the slope of the fracture energy vs. various crack lengths (Mull et al., 2002).

Lee et al. (1995) used J-integral method to analyze ductile-to-brittle transition in both polyethylene modified and unmodified binders. The J-integral allowed them to see rapid changes (increase or decrease) in fracture energy for the modified binder relative to the unmodified binder. They determined that the fracture toughness of modified binder was two times higher than for unmodified binder. Lee et al. (1995) felt that the J-integral method was very useful when measuring the fracture energy in the brittle-to-tough transition region. However the attempts to measure J-integral outside of this range were unsuccessful.

2.4.4 Beam Fatigue Test

Flexural beam fatigue testing has been used to evaluate the fatigue life of flexible pavements under repeated flexural bending. This test uses digitally controlled, pneumatic beam fatigue equipment which subjects a beam specimen under repeated stress-controlled or strain-controlled loading which is applied at the center of the beam until failure occurs. During the stress controlled test, constant stress amplitude of cyclic load is being applied continuously to the beam creating a negative bending moment at the center of the beam such that the beam to return to its original position between each loading cycle. A cyclic loading which creates positive and negative moments with equal magnitude is applied to the center point of the beam until failure occurs. In a strain controlled test, a constant

strain is applied repeatedly to the center of the beam during each load cycle until a failure occurs. Some researchers believe that the stress-controlled testing is generally related to relatively thick pavement construction where high stiffness is the fundamental parameter that underpins fatigue life; strain controlled testing is thought to be associated with thin asphalt pavements where the elastic recovery properties of the material have fundamental effect on its fatigue life (Roberts et al. 1991). Recent studies generally recommend the strain-controlled test to evaluate the fatigue resistance of HMA mixes. In a strain-controlled test, the failure of the flexural fatigue test can be defined as a 50 percent reduction in initial stiffens which is measured from the center point of the beam after the 50th load cycle (Roberts et al.1991).

More recent studies (Carpenter et al., 2003; Ghuzlan and Carpenter, 2000; Shen and Carpenter, 2005) suggested that more consistent results can be achieved through the Ratio of Dissipated Energy Change (RDEC) where a Plateau Value (PV) is determined which presents the nearly constant value of RDEC. This PV value represents a period where there is a constant percent of input energy being turned into damage. The smaller the PV values the longer the fatigue life for a mixture. This value is mixture and load/strain input related. The PV value is a function of the load inputs for any mixture, and it varies with mixture type for similar load inputs. This value is significant because it provides a unique relationship with fatigue life for different mixtures, loading modes and loading levels (Shen et al. 2005).

2.5 Characterizing Fatigue Properties of Asphalt Binder

Asphalt binder performance is critical to the fatigue crack resistance of HMA mixtures. Bonnetti et al. (2002) developed a test method for evaluating fatigue properties of modified asphalt binders. Their method was based on the dissipated energy theory that allows simulation of extreme pavement loading conditions. They implemented the use of the Dynamic Shear Rheometer (DSR) to determine the fatigue properties of the asphalt binders.

Two variables were used to analyze the fatigue properties of the asphalt binders. The number of cycles to crack propagation (N_p) was used to define the fatigue criterion of asphalt binders, and initial dissipated energy per cycle (W_i) was used as the main independent variable for modeling the fatigue of binders. They defined failure as 20 percent reduction in initial stiffness of the asphalt binder. It was concluded that initial dissipated energy, testing frequency, and temperature should be chosen carefully as they present important factors in determining the fatigue life of binder.

Mohammad et al. (2004) evaluated the correlation of toughness index (TI) value with G*sin (δ) (fatigue parameter) at a temperature of 25°C for a mixtures containing different percent of recycled polymer modified asphalt. The TI values decreased correspondingly to the G*sin (δ) values showing a high potential for fatigue cracking. Based on this study it was concluded that the binder properties are reflected in the mixture fatigue properties, and that the G*sin (δ) (binder fatigue parameter) is sensitive to the fatigue properties of asphalt mixtures containing recycled asphalt binders (Mohammad et al., 2002).

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Introduction

This chapter provides information on the type of materials and procedures for the production of the HMA samples in the laboratory. Also presented is a summary of the testing procedures and instrumentation used to analyze fatigue characteristics of asphalt mixtures with the inclusion of RAP material.

3.2 Design and Production of Mixtures Specimens

This section provides information on the aggregates and the asphalt binder used in the production of the HMA samples. The mixture designs for both limestone and gravel with three types of binders PG 64-22, PG 70-22, and PG 76-22 are also provided within this section.

3.2.1 Aggregates

Two main aggregates (D-rock) were used in this study, namely, limestone and gravel with nominal maximum aggregate size of 3/4-inch. Both of these aggregates are main ingredients used for the surface 411-D mixtures designed by TDOT. The mixtures also consist of the fine material which includes No. 10 screenings, natural sand, manufactured sand, agricultural lime, and screened RAP (material passing #4 sieve sizes). RAP material used in this study was obtained from both limestone and gravel sources and has served as a substitute for sand and/or screenings. Two types of the

asphalt binder were used in this study, unmodified PG 64-22 and polymer modified PG 70-22 and PG 76-22. Both of the binders meet the Supperpave specifications.

3.2.2 Types of HMA Mixtures

Eight types of HMA mixtures with inclusion of 0, 10, 20, and 30 percent of RAP material were used for this study. These were produced from the coarse and fine blend of the limestone and gravel aggregates and recycled RAP. Limestone mixtures were designed at 5.0 percent asphalt content, while the gravel mixtures were designed at 5.8 percent of asphalt content. Job mix formula for both limestone and gravel control mixtures is presented in Tables 4 and 5.

The screened RAP (-No. 4) material used in this study was substituted for the fine material in equal proportions for both mixtures (limestone and gravel). The gradations, designed in Phase I study, for the two mixtures are presented in Figures 2 and 3. From the two figures it can be noted that the gradations were kept in narrow band so that the similar aggregate structure could be retained for all of the mixtures.

3.2.3 Preparation of Asphalt Specimens

Two different methods of compaction were used in this study. Beam specimens were compacted with the aid of a vibratory compactor, while 6-inch specimens were compacted with Superpave gyratory compactor (SGC). All of the pills (round gyratory specimens) were compacted to a 4±1 percent air voids and all beam specimens were compacted to 6±1 percent air voids.

Table 4. Limestone Job Mix Formula

Sieve Size	Limestone D-Rock	No. 10 Screenings	Natural Sand	Manufactured Sand	JMF	Design Range
Percent Used	50%	15%	25%	10%	100	100
5/8"	100	100	100	100	100	100
1/2"	97	100	100	100	99	95-100
3/8"	70	100	100	100	85	80-93
#4	21	92	98	99	59	54-76
#8	7	61	93	82	44	35-57
#30	4	29	63	28	25	17-29
#50	3	21	13	17	10	10-18
#100	2.0	20.0	2.0	9.0	5.4	3-10
#200	1.8	16.0	1.0	5.0	4.1	0-6.5
Asphalt Content	Gmm	Gmb	Air Voids	VMA	Stability (lbs)	Flow (.01")
5.0	2.456	2.356	4.0	16	2607	9.7

Table 5. Gravel Job Mix Formula

Sieve Size	Gravel D-Rock	No. 10 Soft Screenings	Natural Sand	Ag. Lime	JMF	Design Range
Percent Used	55%	10%	25%	10%	100	100
5/8"	100	100	100	100	100	100
1/2"	95	100	100	100	97	95-100
3/8"	77	100	100	100	87	80-93
#4	40	91	96	98	65	54-76
#8	22	60	84	92	48	35-57
#30	8	30	60	64	29	17-29
#50	5	21	8	52	12	10-18
#100	3.0	16.0	1.0	41.0	7.6	3-10
#200	2.0	14.0		34.0	5.9	0-6.5
Asphalt Content	Gmm	Gmb	Air Voids	VMA	Stability (lbs)	Flow (.01")
5.8	2.360	2.265	4.0	17	2972	10.9

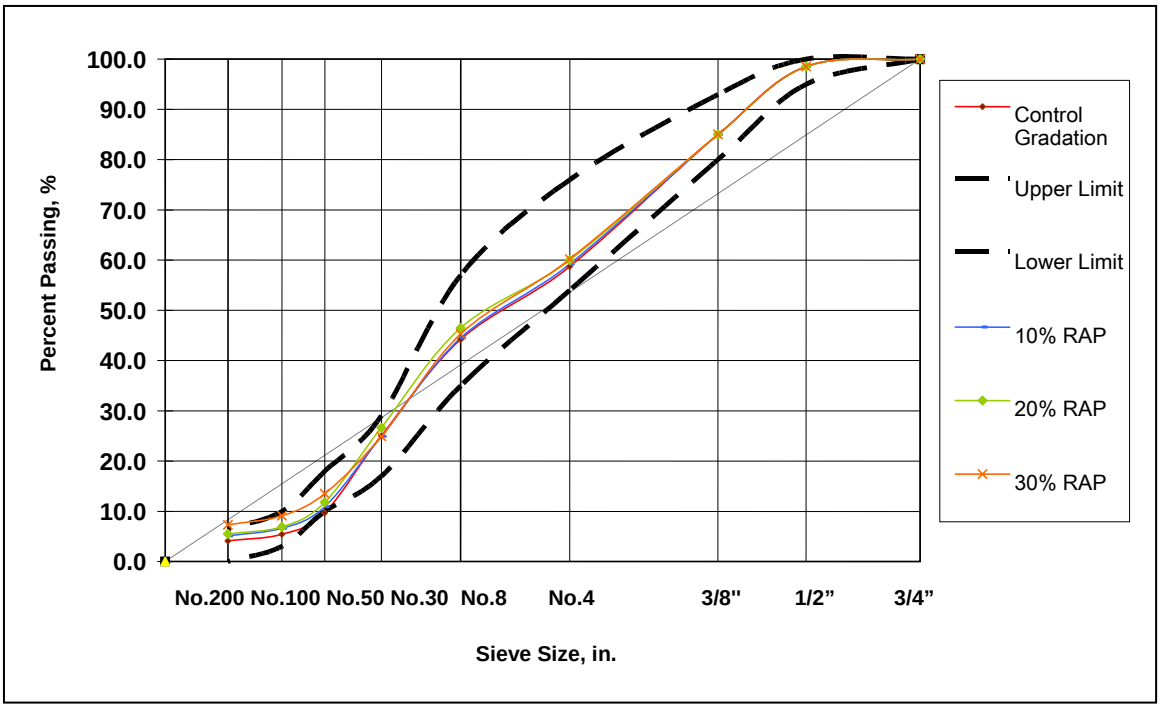


Figure 2. Limestone Mixture Gradations

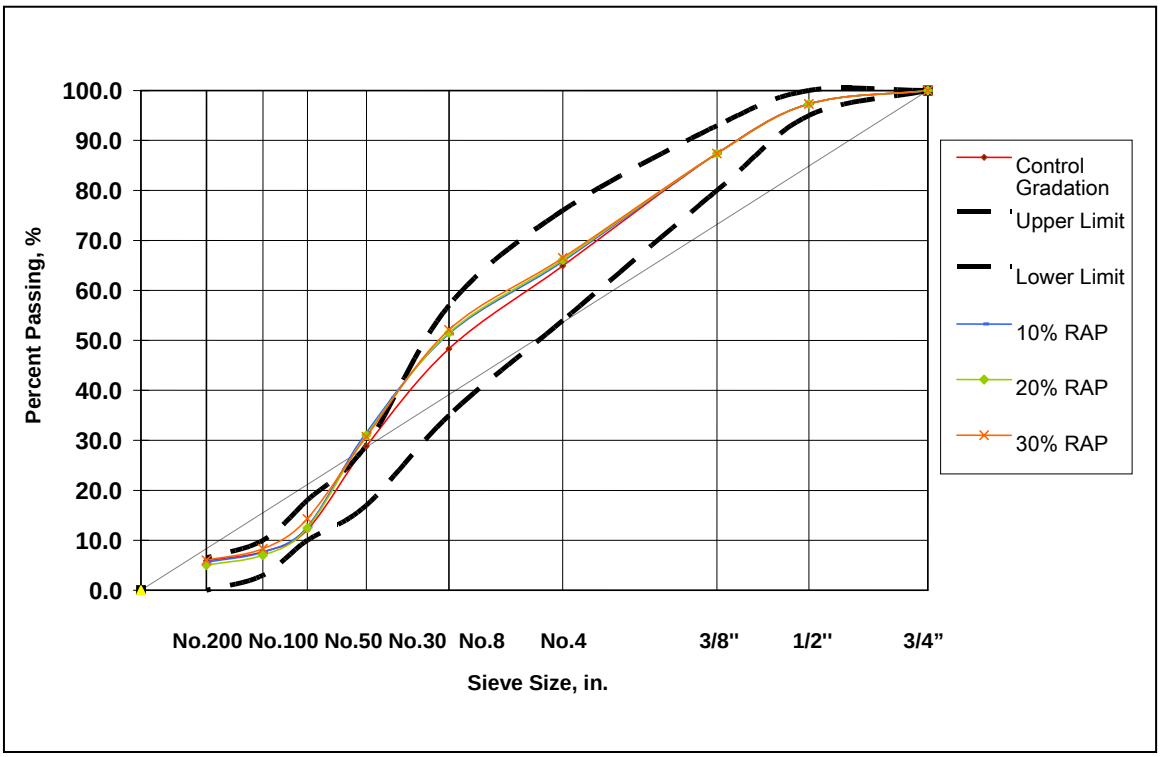


Figure 3. Gravel Mixture Gradations

Once compacted, the specimens were checked for air voids in accordance with AASHTO T269-97 (Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures) to validate proper air void requirements. All of the specimens that did not meet the air void criteria were discarded and replaced with new ones. Specimens that did meet the air void criteria were cut using a wet saw-blade into their respective sizes for each test, Figure 4. One-half of the cut specimens were placed in the oven for 5 days at 85°C to simulate the long-term aging of the asphalt mixtures.

Prior to testing, all short-term aged and long-term aged specimens were stored at 25°C for a minimum of two hours for conditioning. All tests performed in this study were conducted at 25°C.

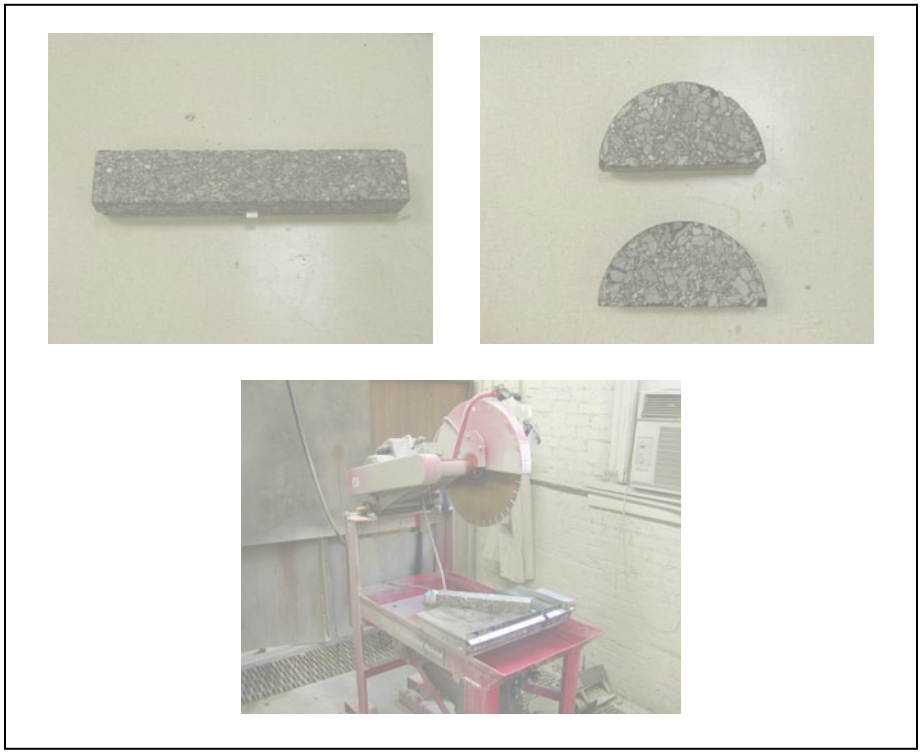


Figure 4. Prepared Test Specimens and Saw

3.3 Testing of HMA Mixtures

This section gives a detailed description of the test methodology used to evaluate the fatigue characteristics of the laboratory compacted specimens. Tests such as Indirect Tensile Strength (IDT), Semi-circular Bending (SCB), and Beam Fatigue were used to analyze the properties of Tennessee surface "D" mixtures with inclusion of RAP.

3.3.1 Resilient Modulus

To evaluate the fatigue characteristics of the HMA mixtures with inclusion of RAP, the resilient modulus test was conducted on 0, 10, 20, and 30 percent RAP mixtures. The test was conducted on triplicate two-inch thick IDT specimens at 77°F (25°C) which were compacted to 4 ± 1% air voids. The specimens were obtained by slicing off one and half inch from the ends of 4500 g-samples and then dividing the resulting sample into two equal parts. For this test strain gages were incorporated to obtain vertical and horizontal strain readings. The strain gages were placed on the specimen with the aid of the brass gage points (1.097" gage length) which were glued on to the specimen prior to testing. A special alignment plate was used to place the gage points in vertical and horizontal axis. Care was taken to align the loading head of the system with the vertical axis marked on the specimen.

The resilient modulus testing procedure was done according to the IDT System developed by Roque et al. (1997). Tests were performed on the samples by applying a repeated peak-load resulting in horizontal deformations within the range of 200-300 micro strain. Each load cycle consisted of 0.1-second load application followed by a 0.9-second rest period.

Figure 5 illustrates typical deformation time plot. The time, load, and vertical deformation were continuously recorded and resilient modulus was calculated with following equation:

$$M_r = \frac{P * GL}{\Delta H * t * D * C_{cmpl}} \quad (1)$$

$$C_{cmpl} = 0.6354 * \left(\frac{x}{y}\right)^{-1} - 0.332 \quad (2)$$

where,

M_r – Resilient modulus, psi;
P – Applied Load;
GL – Gage length, in;
ΔH - Horizontal deformation, in;
t – Thickness of specimen, in;
D – Diameter of specimen, in;
C_{cmpl} – Non-dimensional creep compliance factor;
(x/y) – Ratio of horizontal to vertical deformation.

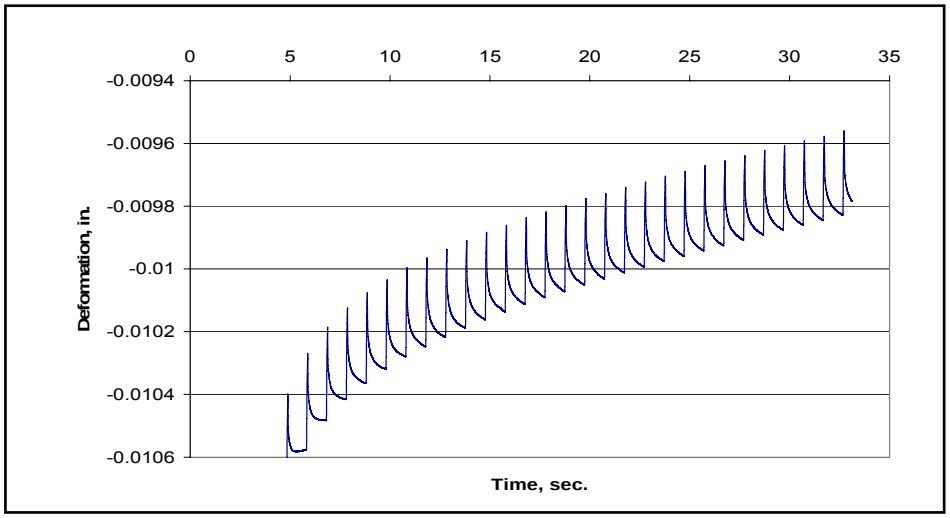
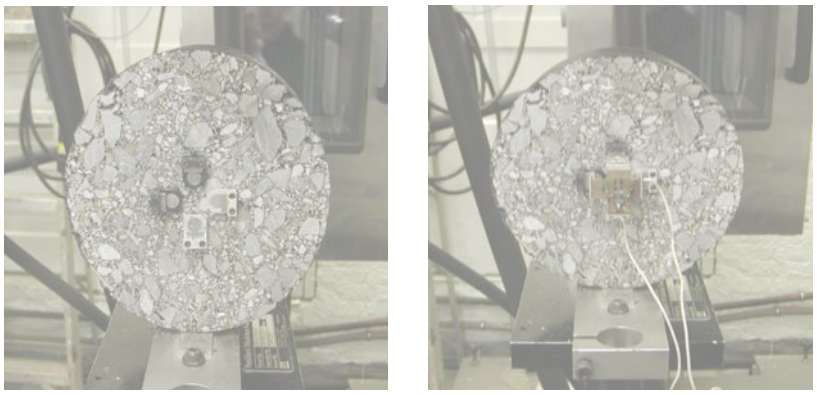


Figure 5. Typical Resilient Modulus Plot

Resilient modulus (Mr) can be used to evaluate the fatigue properties of the asphalt mixtures, where the higher resilient modulus values reflect the stiffer mixtures. The stiff mixtures are more brittle than the flexible mixtures and tend to crack earlier than the flexible mixtures.

3.3.2 Indirect Tensile Strength and Strain Test (IDT)

The indirect tensile test (IDT) was used to determine tensile strength and strain of the mixture specimens compacted to 4 ± 1% air voids. Figure 6 presents typical test setup of the Superpave IDT test. Cylindrical shape specimens with 6-inches (150 mm.) in diameter and 2-inches (50.8-mm.) in thickness were monotonically loaded along the vertical diametric axis at a rate of 3 in. /min. (76.2 mm/min.). This type of loading configuration, which develops a relatively uniform tensile stress perpendicular to the direction of the applied load and along the vertical diametric plane, causes the specimen to fail by splitting along the vertical diameter (Roberts et al. 1991). All of the IDT testing



(a) Without strain gages (b) With strain gages

Figure 6. Typical Setup for IDT test

was done on triplicate short-term and long-term aged specimens at a temperature of 25°C (77°F).

During the testing the load and deformation were continuously recorded where maximum load carried by the specimen was determined and used to compute indirect tensile stress at failure with following equation:

$$\sigma_x = \frac{2 \cdot P_{ult}}{\pi \cdot D \cdot t} \tag{3}$$

where,

σ_x – Horizontal tensile stress at center of specimen, psi;
P_{ult} – Peak load, lbs;
D – Diameter of the specimen, in;
t – Thickness of specimen, in.

The toughness index (TI) was calculated from the indirect tensile test results. This parameter characterizes the toughening characteristics of the mixture specimens in the post-peak region of stress-strain curve. Figure 7 presents a typical normalized indirect tensile stress vs. strain curve which is used to calculate the TI value.

The following equation was used to calculate a dimensionless tensile toughness index where TI is defined as follows (Sobhan and Mashnad, 2002):

$$TI = \frac{A_\varepsilon - A_p}{\varepsilon - \varepsilon_p} \tag{4}$$

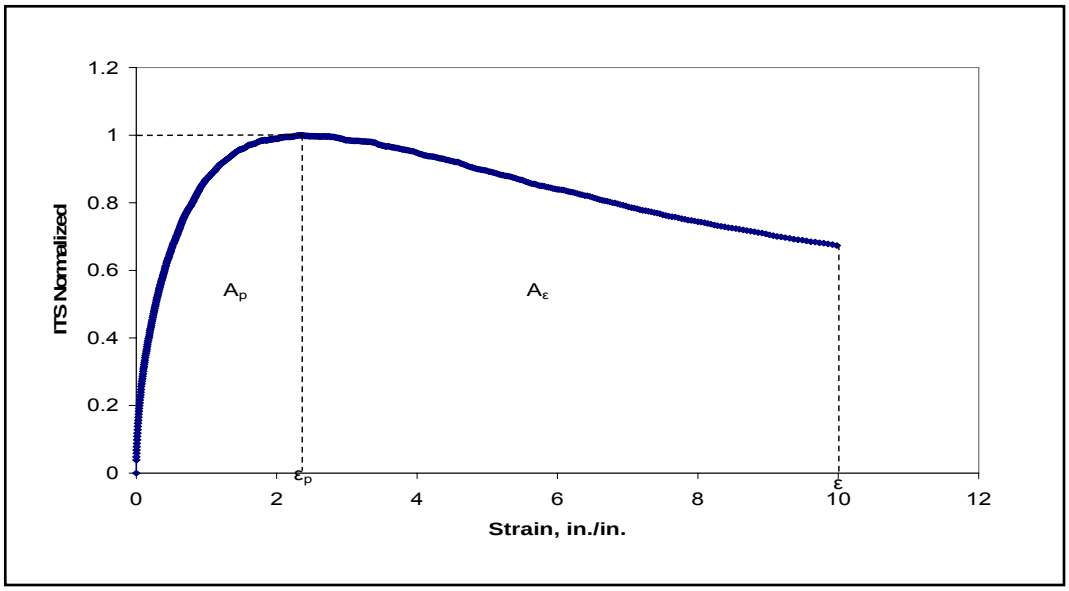


Figure 7. Normalized ITS Curve for TI Calculation

where,

TI – Toughness index;
A_ε – Area under the normalized stress-strain curve up to strain ε;
A_p – Area under the normalized stress-strain curve up to strain ε_p;
ε – Strain at the point of interest;
ε_p – Strain corresponding to the peak stress.

The TI value compares the performance of a specimen where TI of 1 presents an elastic perfectly plastic reference material. On the other hand a TI that equals 0 presents ideal brittle material which does not have the post-peak load carrying capacity. For this study it was decided that TI index should be calculated up to ten percent tensile strain. Any strain level that is higher than the strain corresponding to the peak stress can be used to calculate the TI value. In this study the IDT test and TI calculation presented a simple

way of characterizing the fatigue properties of the asphalt mixtures with inclusion of 0, 10, 20 and 30 percent RAP material.

3.3.3 Dissipated Creep Strain Energy ($DCSE_f$)

Since the 1970s, fracture mechanics theory has been used to analyze the fatigue behavior in HMA mixtures (Majidzadeh et al., 1971; Salam et al., 1972). In recent years, comprehensive laboratory and field studies were conducted by Roque et al. to characterize the crack growth rate of HMA mixtures using the Superpave Indirect tension (IDT) test (Roque et al., 1999; Roque et al., 2002; Zhang et al., 2001). They used Superpave IDT tests (IDT strength test and resilient modulus test) and developed a viscoelastic fracture mechanics-based crack growth law for HMA mixtures. In addition, they introduced two thresholds, the dissipated creep strain energy (DCSE) limit and the fracture energy (FE) limit, to account for the crack development and propagation in HMA mixtures, Figure 8. Below two thresholds, only healable micro-damage occurs. Non-healable macro-damage appears if one of the thresholds is exceeded. This suggests that the higher the values of DCSE or FE, the longer the fatigue life of HMA mixtures (Roque et al., 2002).

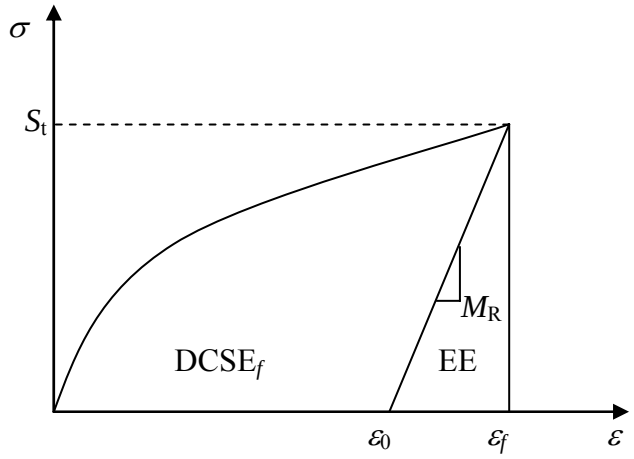


Figure 8. Determination of Creep Strain Energy Threshold ($DCSE_f$)

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With the stress strain response from the IDT strength test, the dissipated creep strain energy threshold (DCSE*f*) was determined as follows:

$$S_t = \frac{2 \times P \times C_{sx}}{\pi \times t \times D} \tag{5}$$

where, S_t = Indirect tensile strength;
P = Failure load;
C_{sx} = Horizontal stress correction factor.

$$C_{sx} = 0.948 - 0.01114 \times (t/D)^2 - 0.2693 \times \nu + 1.436 \times (t/D) \times \nu \tag{6}$$

where,

ν = Poisson's ratio.

$$\nu = -0.1 + 1.480 \times (X/Y)^2 - 0.778 \times (t/D)^2 \times (X/Y)^2 \tag{7}$$

$$DCSE_f = FE - EE \tag{8}$$

where,

FE - Fracture energy (area under the stress strain curve to the failure strain ε_f), psi.;

EE - Elastic energy (psi);

X – Horizontal deformation;

Y – Vertical deformation.

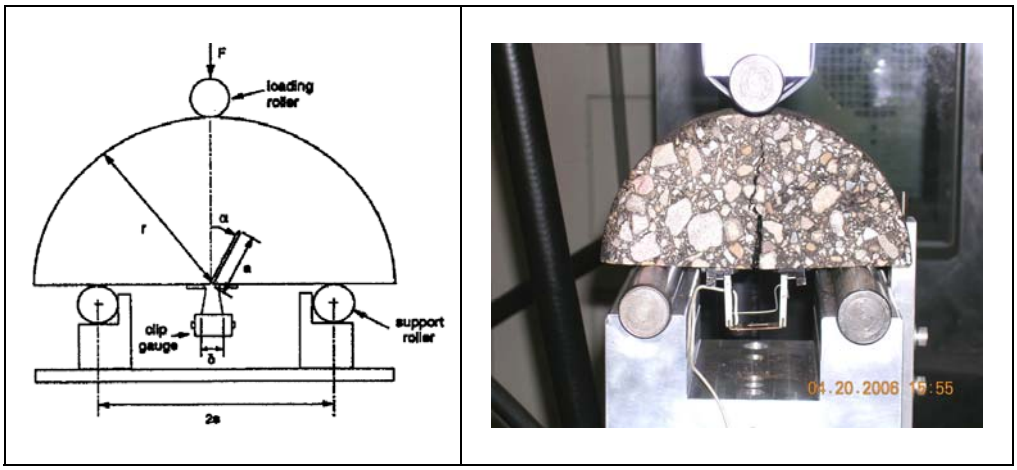
Elastic energy is determined with the equation presented below:

$$EE = \frac{1}{2} S_t (\varepsilon_f - \varepsilon_0) \tag{9}$$

$$\varepsilon_0 = \frac{\varepsilon_f * M_r - S_t}{M_r} \tag{10}$$

3.3.4 Semi-Circular Bending (SCB) Test

The semi-circular bending (SCB) test can be used to obtain information on the tensile characteristics and fracture resistance of asphalt mixtures. This simple test is mostly used in Europe and South Africa and can be performed on any loading frame that is capable of applying monotonic or dynamic loading (Molenaar et al. 2002 and Van de Ven et al. 1997). Figure 9 shows a typical setup of an SCB test. A three-point SCB test fixture was fabricated for an easy attachment to both the load frame and load cell. The distance between the supports (2a) at the bottom is 4-inches (100mm). The test specimens were produced by means of the super pave gyratory compactor. Once compacted, the 6-inch (150-mm) diameter cylindrical specimens were cut in half and than sliced into 1-inch (25-mm) thick specimens for testing. Testing was done on



δ – Gage Length of the Strain Gage

Figure 9. Typical SCB Setup

triplicate short-term and long-term aged specimens at a temperature of 77°F (25°C). The long-term aged specimens were placed in a forced draft oven and subjected to 85°C for five days.

3.3.4.1 SCB Tensile Strength Test

In this study the SCB test was used to determine tensile characteristics for HMA mixtures. Similar to the IDT test, SCB test was set up for monotonic loading where the specimen was loaded at a constant rate of 2 in./min. (50 mm./min.) until failure occurs. Load (F) and deformation (δ) at bottom of the specimen were continuously recorded during the testing. The deformation of the tested specimens was collected using strain gages mounted at the bottom of the specimens, Figure 9. The big advantage of the SCB test over the IDT test is that a nice crack develops in the SCB without wedging near the loading strip that helps characterize the tensile characteristics of the mixture (Ven et al., 1997).

Analytical solutions for the SCB test can be accomplished through the proper application of loading and supporting conditions to the constitutive equations of the asphalt mixture. However, even the linear elastic solution between the load and bottom deflection requires complicated mathematical derivation (Van de Ven et al., 1997). Huang et al. (2004) used the following equation to evaluate the properties of the asphalt RAP mixtures:

$$\sigma_x = 3.564 * \frac{P_{ult}}{D * t} \tag{11}$$

where,

σ_x – Maximum tensile stress at the bottom of the specimen;
P_{ult} – Load per unit width of the specimen at failure;
D – Diameter of specimen;
t – Thickness of specimen.

It should be noted that the equation (11) above is only valid if the distance between the two bottom supports equals 0.67 times of the diameter of specimen. TI parameter used to analyze IDT specimens fatigue properties was also used for the analysis of the toughening characteristics of SCB mixture specimens.

3.3.4.2 SCB Notched Fracture Test

Similar to the SCB test, the semi-circular notched fracture test was conducted at a constant displacement. This test has been used in the past by the researchers to evaluate the fracture resistance of the asphalt mixtures through J-integral (Mull et al. 2002). The first concept of J-integral was introduced by Rice in 1968. Rice defined a J-integral as a

path-independent line integral obtained by integrating strain energy density, traction, and displacement along an arbitrary contour around the tip of the crack in counter clockwise direction (Rice 1968). Mull et al. 2002 has used the J-integral concept in the Fracture Resistance Characterization of Chemically Modified Crumb Rubber Asphalt Pavement study to characterize fracture resistance of the asphalt mixtures with different notch depths. He noted that at least two different notched depths should be used to calculate the J-integral which represents the fracture energies of different notch depths.

Mull et al. 2002 used the following equation to calculate the J-integral:

$$J_c = \left(\frac{U_1}{b_1} - \frac{U_2}{b_2} \right) * \frac{1}{a_2 - a_1} \tag{12}$$

where,

U - Strain energy to failure (area underneath the load-deformation curve up to the peak load;
b - Specimen thickness;
a – Notch depth.

The subscripts 1 and 2 refer to different notch depths 1 and 2 respectively. Mull et al. 2002 noted that the J-integral value does not reflect the durability or fatigue lifetime of the asphalt mixture.

To increase the accuracy of a J-integral it was decided that three notched depths should be used for this study, 0.5 in. (12.5mm), 1.0 in. (25.4-mm), and 1.5 in. (38-mm). All of the semi-circular notched specimens were loaded monotonically on an MTS machine at a cross-head speed of 0.02 in/min (0.5-mm/min), as shown in Figure 10.

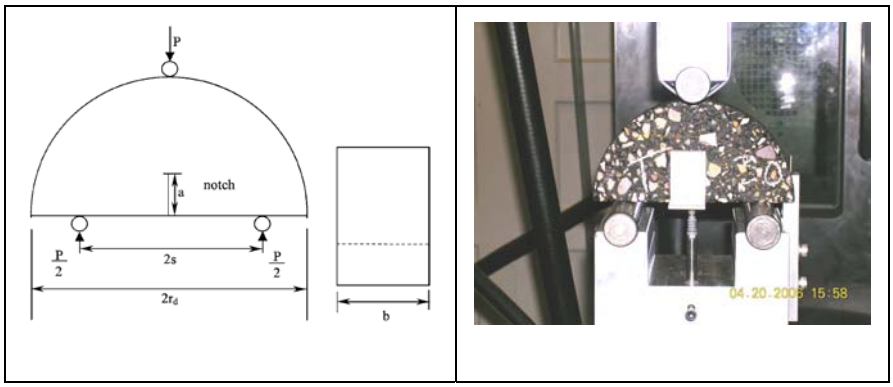


Figure 10. SCB Notched Fracture Test Setup

The load (P) was applied on the top of the specimen that was symmetrically supported by two rollers at the bottom with a span (2s) of 4 in. (100-mm), Figure 10. The bottom of the fixture was drilled through to create a hole used for mounting the LVDT to the bottom of the specimen so that the deflection on the bottom flat surface can be measured. Each specimen had a diameter ($2r_d$) of 6 in. (150-mm), and the thickness (b) was approximately 1in. (25.4-mm). The loading rate for the semi-circular notched specimens was chosen according to Mull et al. 2002. All of the semi-circular notched specimens were tested at ambient temperature of 25°C.

Figure 11 presents a plot of fracture energy per unit thickness versus notched depth. The slope of the lines presented in Figure 11, is the fracture resistance J-integral. The fracture resistance consistently increases with the J-integral for any given mixture during the semi-circular notched test.

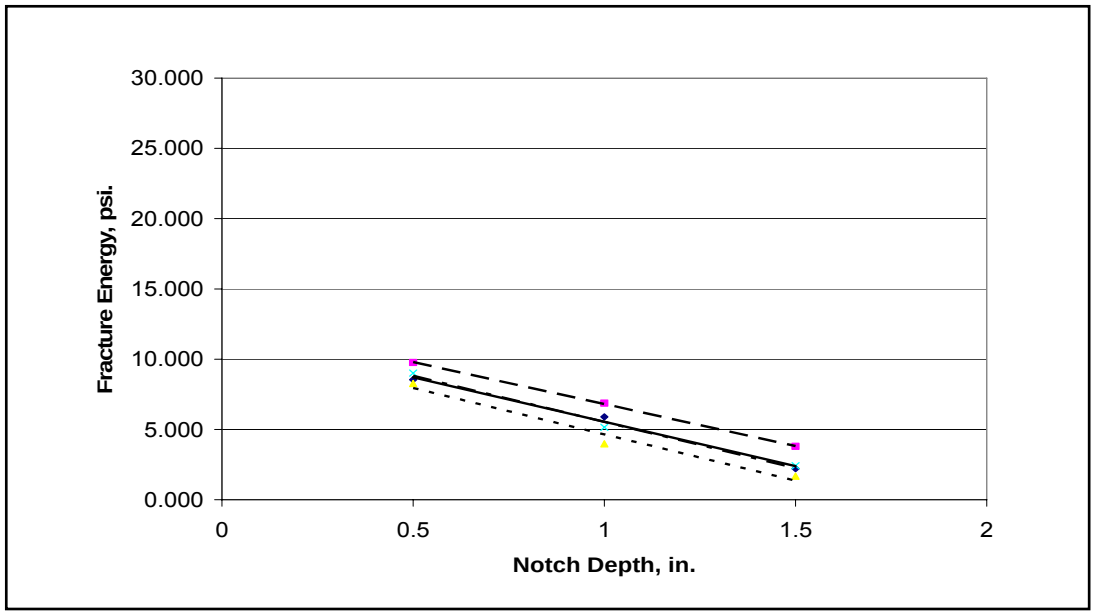


Figure 11. J-Integral for Different Notched Depths

3.3.5 Beam Fatigue Test

The flexural beam fatigue test is used to determine the fatigue life of 15 in. long by 2 in. thick by 2.5 in. wide beam specimens subjected to continuous cyclic loading at the center of the specimen until failure occurs. The applied cyclic load can be either stress or strain controlled. This testing method was developed under the SHRP A-003A program, which was later modified in SHRP-A-404 to improve simplicity and reliability. Shen et al. (2005) designed new parameter to evaluate beam fatigue performance of asphalt mixtures.

Based on AASHTO T 321-03, Standard Test Method for Determining the FatigueLife of Compacted Hot Mix Asphalt (HMA) Subjected to Repeated Flexural Bending, all of the beam specimens were compacted using the vibratory compactor to 6±1 percent air voids and tested at a temperature of 25°C.

The beam fatigue fixture used for this study allows four points bending with free rotation and horizontal translation at both reaction and load points, Figure 12. The load applied to the specimens being tested in this study was controlled by the MTS closed loop computer controlled data acquisition system. All of the beam specimens in this study were subjected to strain controlled loading at 10 Hz until failure occurred. Beam deflections were measured during each loading cycles which were used to determine maximum tensile stress, maximum tensile strain, phase angle, stiffness, dissipated energy, and cumulative dissipated energy. The fatigue life failure was characterized by a plateau value (PV) and a number of loading cycles at 50 percent of initial stiffness failure. PV represents a period where there is a constant percent of input energy being turned into damage, Figure 13. It was found that 500,000 cycle load repetitions were sufficient to ensure that a stable plateau stage is reached (Shen et al. 2005). Lower PV value represents longer fatigue life of the mixture.

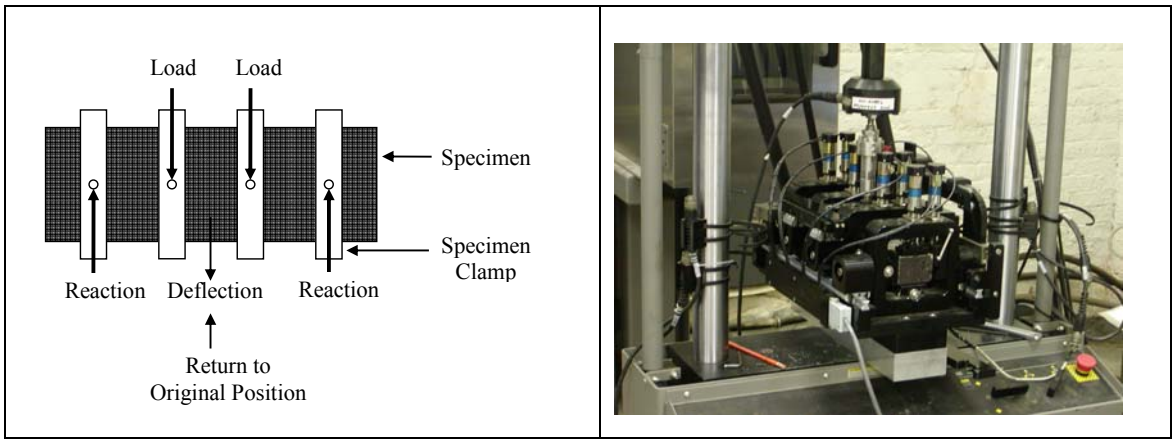


Figure 12. Beam Fatigue Fixture

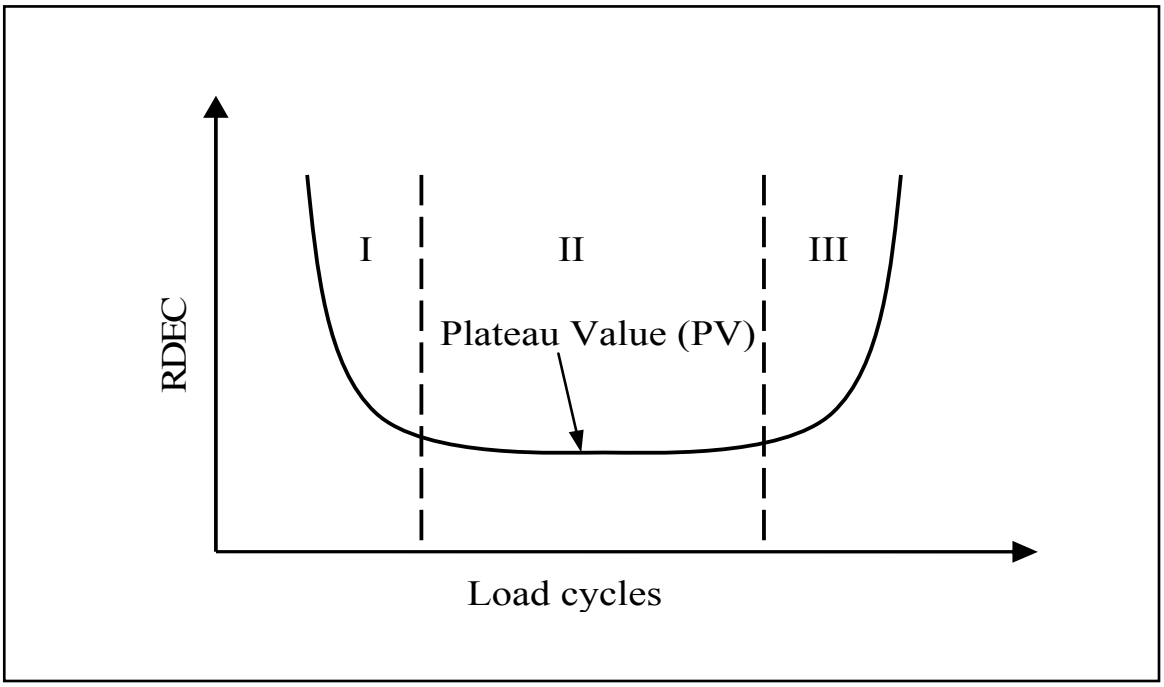


Figure 13. Typical RDEC Plot With Three Behavior Zones (After Carpenter et al., 2003)

Figure 14 presents a typical stiffness versus load cycle plot using automated fatigue. The parameters above were computed based on beam deflections (collected at each cycle) as follows:

Maximum Tensile Stress, psi:

$$\sigma = \frac{3 * a * P}{w * h^2} \tag{13}$$

P = Load applied by actuator, lbs;
w = width of beam, in;
h = specimen height, in.

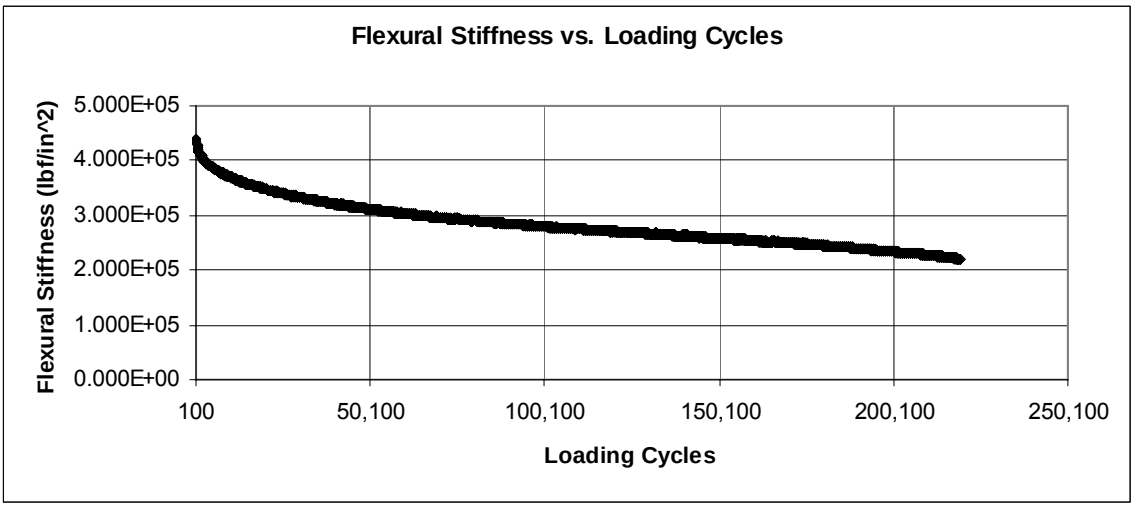


Figure 14. Flexural Stiffness vs. Loading Cycles (Automated Software)

Maximum Tensile Strain, psi:

$$\varepsilon = \frac{12 * h * \delta}{3 * L^2 - 4 * a^2} \tag{14}$$

δ = Maximum deflection at center of beam, in;
a = Space between inside clamps, 4.684 in;
L = Length of beam between outside clamps.

Flexural Stiffness, psi:

$$S = \frac{\sigma}{\varepsilon} \tag{15}$$

Phase Angle, deg:

$$\Phi = 360 * f * s \tag{16}$$

f = Load frequency, Hz;
s = Lag time between maximum load and deflection, sec.

Dissipated Energy per cycle n, psi:

$$DE_n = 0.25 * \pi * \varepsilon^2 * S * \sin(\Phi) \quad (17)$$

ε = Strain at load cycle n, in./in.;
S = Stiffness at load cycle n, psi;
Φ = Phase angle between stress and strain at load cycle n.

Ratio of Dissipated Energy Change:

$$RDEC = \frac{(DE_a - DE_b)}{DE_a * (b - a)} \quad (18)$$

DE_a = Dissipated energy produced in load cycle a;
DE_b = Dissipated energy produced in load cycle b;
a = Load Cycle a;
b = Load cycle b.

3.3.6 Asphalt Mixture (Limestone PG 64-22) Uniformity Testing

Uniformity of the asphalt mixtures with different percentages of RAP material were evaluated through binder and aggregate testing. All of the asphalt binder used for the evaluation of mixture uniformity with different percentages of RAP material was obtained using the AASHTO T 319-03 extraction and recovery method, Figure 15. Once recovered, the binder was tested and the rheological properties used in Superpave system were determined and evaluated. During this study, binder tests were conducted on blended PG 64-22 limestone mixtures containing 0, 10, 20, and 30 percent of RAP, where the uniformity of three different truck loads within the same RAP mixture was evaluated.

The Dynamic Shear Rheometer (DSR) was used to determine the rheological properties of the RAP mixtures and RAP material. Binder from each mixture was tested at selected low (0, -6, and -12 ^{o}C) and higher temperatures (28, 52, and 76 ^{o}C). All of the

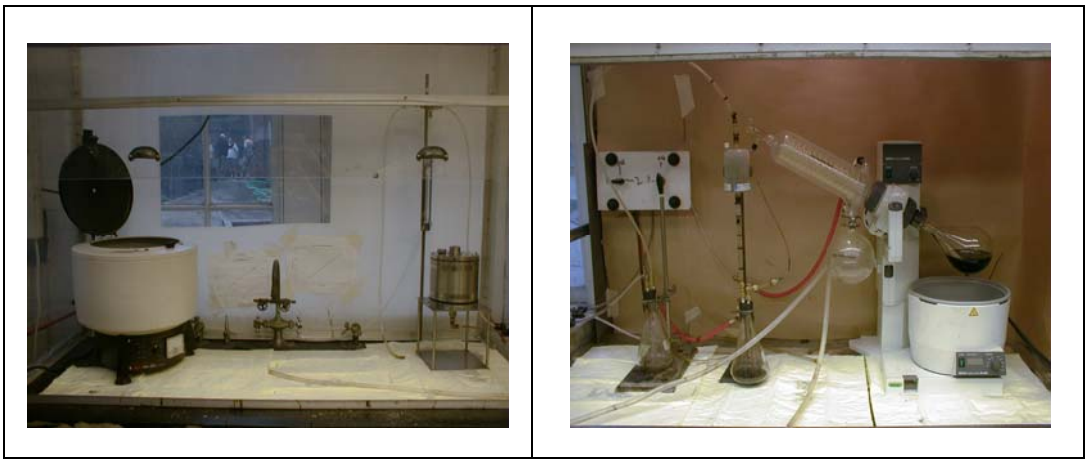


Figure 15. Typical Setup for Rotavapor Extraction and Recovery of Binder

samples were short term aged (RTFO) prior to testing. DSR machine measured a fatigue parameter (G*sin δ), G*, and Phase Angle (^{o}) in accordance with AASHTO T 315-05. Once tested the uniformity of the three trucks at each RAP percentage was evaluated for their uniformity.

The uniformity of the aggregate properties of the limestone mixtures was also evaluated through gradation, specific gravity, and fine aggregate angularity. Each of three aggregate tests were done in triplicates. Gradation of the limestone mixtures was obtained with the aid of the mechanical sieve shakers. According to AASHTO T 27-99 all of the limestone mixture aggregate material was sieved for 10 minutes. Once sieved the gradation of the 0, 10, 20, and 30 percent limestone mixtures was obtained. A specific gravity and fine aggregate angularity of RAP material were done according to AASHTO T 84-00 and T 85-91 and AASHTO T 304-96, respectively.

3.3.7 Screened RAP Uniformity Testing

The uniformity of the screened (-No. 4) RAP material was evaluated during this study. The variability of the RAP material can greatly affect the mixtures properties of virgin mixtures and usually occurs due to stockpiling methods or may be inherent in the materials themselves. Properties such as the age, percent of asphalt binder, and aggregate size of the RAP are one of the most important factors that influence the properties of the RAP material. To avoid the inconsistency of RAP material it is recommended to maintain sheltered, blended RAP stockpiles and, if needed, to reprocess, or fractionate, the RAP into individual gradations.

Evaluation of the screened (⅜") RAP material was done through aggregate and binder testing. The RAP material was subjected to extraction and recovery prior to testing. To evaluate the aggregate properties of the RAP material, gradation, specific gravity, and fine aggregate angularity tests were implemented during this study. All three of the aggregate tests were done in triplicates.

Gradation of the RAP aggregate was done according to AASHTO T 30-93 using mechanical sieve shakers. Each aggregate batch was sieved for 10 minutes and than the percent retained on each sieve size was recorded. A specific gravity and fine aggregate angularity of RAP material were done according to AASHTO T 84-00 and T 85-91 and AASHTO T 304-96 respectively. Binder of the RAP material was evaluated through DSR testing where the fatigue properties ($G^*\sin\delta$), G^*, and Phase Angle of the RAP material were determined and evaluated according to AASHTO T 315-05.

CHAPTER 4
SUMMARY AND ANALYSIS OF LABORATORY RESULTS

4.1 Introduction

This chapter provides a discussion of the laboratory mixture and binder testing results. Mixture fatigue properties obtained were the tensile strength, indirect tensile strength, semi-circular bending, and flexural fatigue of the mixtures. A summary of the binder properties obtained by a dynamic shear rheometer are also presented within this chapter. The results on uniformity of the RAP and RAP mixtures can also be found within this chapter.

4.2 Mixture Testing

4.2.1 Indirect Tensile Strength Testing

Initial laboratory fatigue study of mixtures with inclusion of RAP, done at the University of Tennessee asphalt lab, analyzed fatigue behavior of the asphalt mixtures through the indirect tensile strength (ITS) and toughness index values (TI). This is a traditional way of determining properties of the asphalt material assuming it is an elastic plastic material. Roque et al. (1992) used $DSCE_f$ and FE to evaluate the IDT specimens where the higher the values of DCSE or FE represent longer the fatigue life of HMA mixtures.

4.2.1.1 Tensile Strength

Indirect tensile strength was used in this study to evaluate fatigue properties of the asphalt mixtures based on two assumptions. One of the assumptions is that the material

has elastic plastic properties (ITS and TI) and second that it has viscoelastic properties (FE and $DSCE_f$). Both of the assumptions have shown that the inclusion of RAP will have some effect on the mixture properties where more RAP would compromise the fatigue properties of the asphalt mixtures.

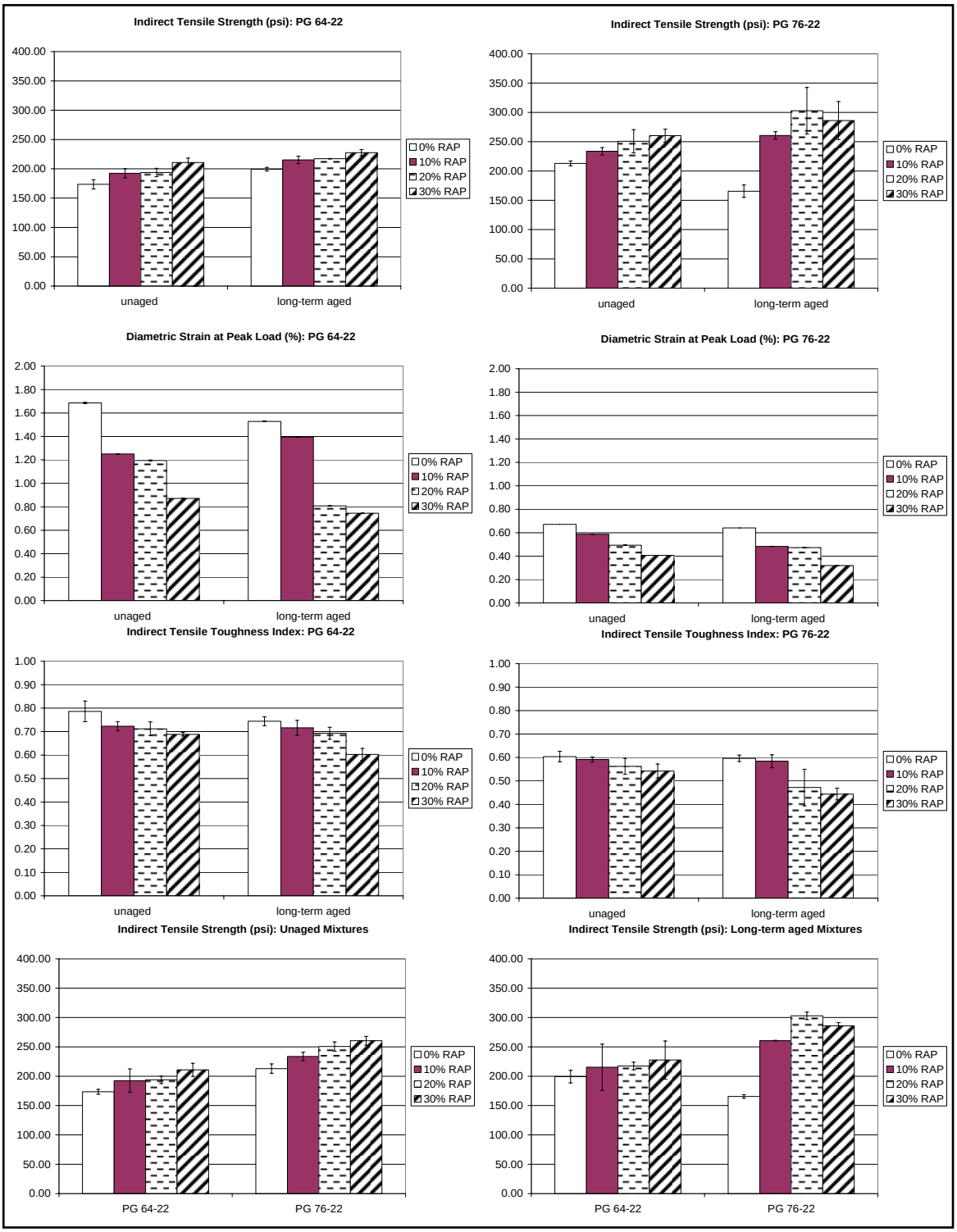
ITS and TI were evaluated for both types of aggregate and binder with inclusion of RAP, Table 6. The results from IDT testing for limestone mixtures are presented in Figure 16. Generally the inclusion of RAP increased the tensile strength but significantly changed the post failure characteristics for short-term aged and long-term aged asphalt mixtures. Mixtures subjected to the long-term aging showed increase in tensile strength and decrease of strain at peak load and toughness indices. The polymer modified binder PG 76-22 increased the tensile strength of the mixtures when compared to the non-modified binder PG 64-22. However, the post failure characteristics were higher for the non-modified PG 64-22 binder.

Table 6. Results for the IDT Limestone Mixtures

PG 64-22	Indirect Tensile Strength, psi.				Strain at Failure, in./in.				Toughness Index			
% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)
Control	174	4.6	199	1.6	0.0169	35.2	0.0153	4	0.786	5.6	0.744	2.6
10	192	4.1	215	3.0	0.0125	18.8	0.0140	1.8	0.723	2.6	0.716	4.5
20	194	3.7	217	0.2	0.0120	31	0.0081	2.3	0.712	4.1	0.693	3.7
30	211	3.5	228	2.3	0.0087	12.7	0.0074	6.3	0.689	1.1	0.603	4.2

PG 76-22	Indirect Tensile Strength, psi.				Strain at Failure, in./in.				Toughness Index			
% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)
Control	213	2	166	6.4	0.0067	17	0.0064	6.9	0.604	3.7	0.596	2.3
10	234	2.7	261	2.5	0.0059	12.1	0.0048	32.9	0.591	1.8	0.584	4.7
20	251	7.9	303	13	0.0049	13.2	0.0047	27	0.562	6.1	0.472	16.5
30	260	4.3	286	11.3	0.0041	4.5	0.0032	10.6	0.536	5.5	0.444	5.6

UA - un-aged
LT-A - long-term aged
un-aged = short-term aged



un-aged = short-term aged

Figure 16. Test Results for IDT Limestone Mixtures

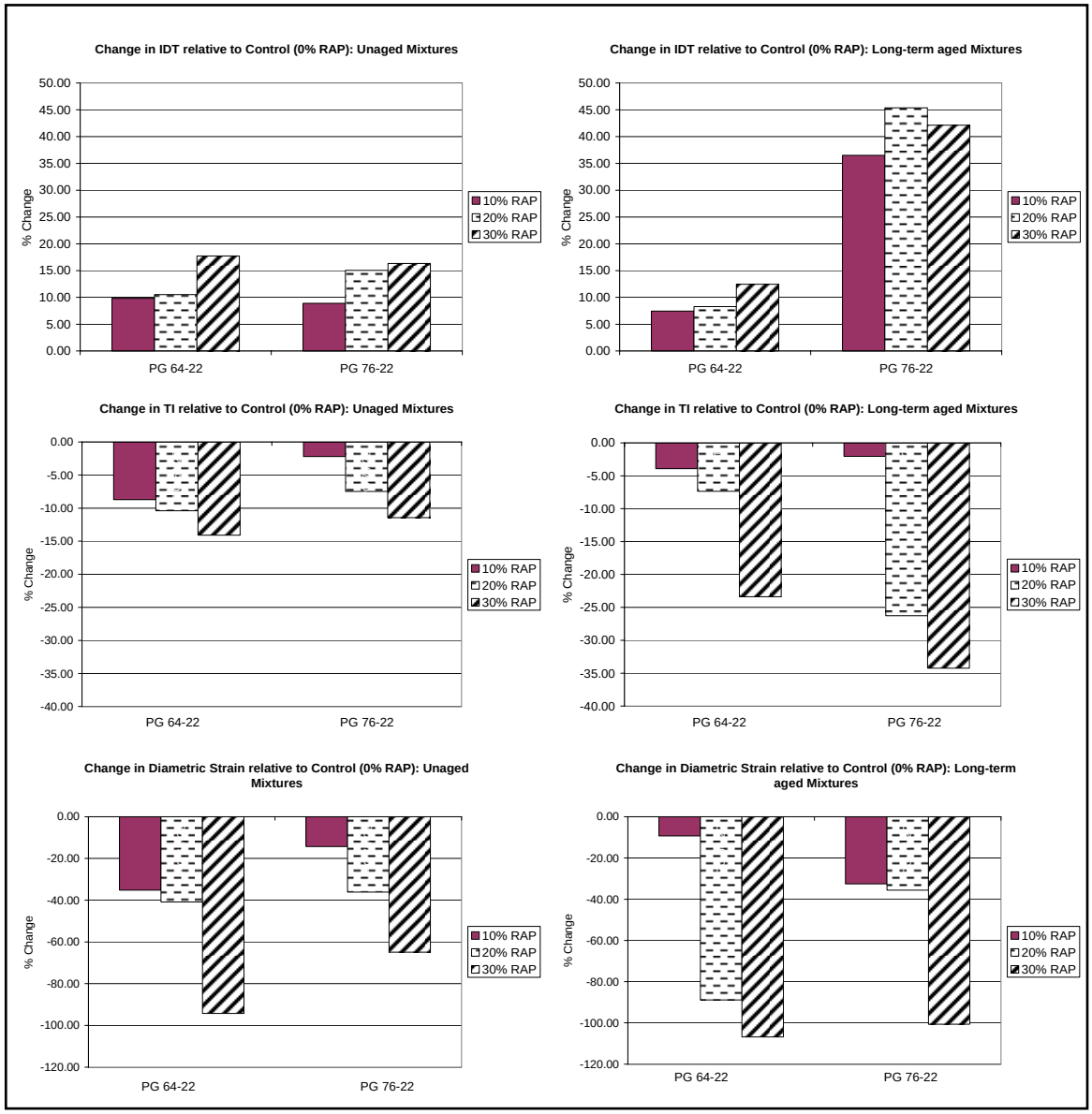
To further understand the influence of RAP material on mixtures, a percent change of IDT fatigue properties was evaluated on both types of binders for short-term and long-term aged mixtures containing RAP. As it can be seen from Table 7 mixtures containing 10 percent of RAP material showed no critical change between ITS, diametric strain, and post failure for short-term aged and long-term aged mixtures when compared to the 0 percent RAP mixtures. However, mixtures containing 20 and 30 percent of RAP caused significant changes in tensile strength and post failure characteristics when compared to the virgin (control) mixture, Figure 17. The results of the mixture properties for the short-term aged PG 64-22 indicated higher properties changes than those with PG 76-22. This is mostly true for the short-term aged mixtures containing higher percentages of RAP. Mixtures containing PG 64-22 binder showed higher strengths, TI values, and diametric strain when compared to PG 76-22 RAP mixtures. On the other hand PG 76-22 mixtures that were subjected to the long-term aging showed higher percent change than the PG 64-22 RAP mixtures. The tensile strength and TI showed significant increase for the long-term aged PG 76-22 mixtures when compared to PG 64-22 mixtures. Long-term aged PG 64-22 mixtures resulted in higher diametric strain at 20 and 30 percent of RAP inclusion than those with PG 76-22. However PG76-22 long-term aged mixtures had higher diametric strain at 10 percent of RAP when compared to PG 64-22 long-term aged mixtures.

Table 8 presents properties results for the Gravel mixtures with inclusion of RAP. Generally the inclusion of RAP material has shown to increase the tensile properties and to the control mixture.

Table 7. Percent Change of IDT Fatigue Properties for Limestone Mixtures

%IDT ± / %RAP	Indirect Tensile Strength				Strain at Failure				Toughness Index			
	PG 64-22		PG 76-22		PG 64-22		PG 76-22		PG 64-22		PG76-22	
	UA	LT-A	UA	LT-A	UA	LT-A	UA	LT-A	UA	LT-A	UA	LT-A
10	10	7	9	36	-35	-9	-14	-33	-9	-4	-2	-2
20	11	8	15	45	-41	-89	-36	-36	-10	-7	-7	-26
30	18	12	16	42	-94	-107	-65	-101	-14	-23	-11	-34

Note: The values in the Table indicated the increase or decrease of properties relative to the control mix (0% RAP)
un-aged = short-term aged



un-aged = short-term aged

Figure 17. Percent Change of IDT Fatigue Properties for Limestone Mixtures

Table 8. Results for the IDT Gravel Mixtures

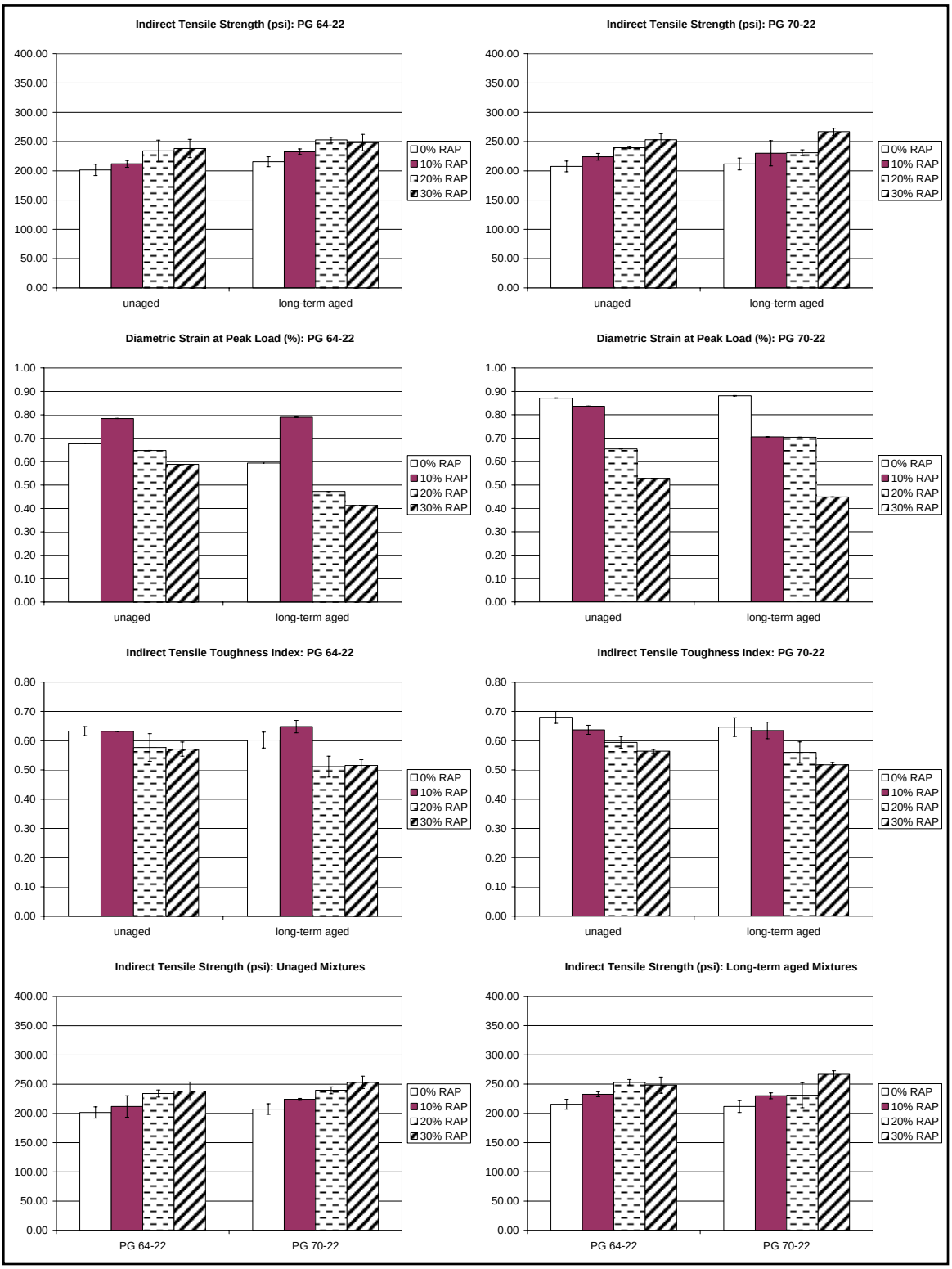
PG 64-22	Indirect Tensile Strength, psi.				Strain at Failure, in./in.				Toughness Index			
% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)
Control	202	4.8	216	3.9	0.0068	2.9	0.0059	9.3	0.633	2.4	0.602	4.6
10	212	2.8	233	2	0.0078	7.7	0.0079	16	0.632	0.0	0.648	3.3
20	234	7.9	253	1.8	0.0065	1.8	0.0047	18.4	0.577	8.1	0.511	7
30	238	6.5	248	5.6	0.0059	7.3	0.0041	17.5	0.571	4.3	0.515	3.7

PG 70-22	Indirect Tensile Strength, psi.				Strain at Failure, in./in.				Toughness Index			
% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)
Control	208	4.4	212	4.8	0.0087	13.5	0.0088	12	0.680	3	0.647	4.9
10	224	2.6	230	9.4	0.0084	11.6	0.0071	21.7	0.637	2.4	0.635	4.5
20	240	0.7	231	2.2	0.0065	2.2	0.0070	10.9	0.594	3.5	0.560	6.4
30	253	4.2	267	2.3	0.0053	6	0.0045	18.3	0.564	1	0.518	1.5

UA - un-aged
LT-A - long-term aged
un-aged = short-term aged

As expected, the polymer modified binder PG 70-22 produced higher tensile strength when compared to the non-modified binder PG 64-22, while the post failure characteristics have shown to be decrease with inclusion of RAP for both of the binder types (PG 64-22 and PG 76-22), Figure 18.

Similar to limestone mixtures, gravel mixtures experienced no significant changes for IDT, diametric strain, and TI fatigue parameters for 0 and 10 percent mixtures, Table 9. However the mixtures containing 30 percent of RAP demonstrated different fatigue characteristics, Figure 19. Long term-aged 30 percent RAP mixtures containing PG 70-22 binder experienced increase in strength when compared to the control mixture. This was also true for the diametric strain (PG 70-22 short-term aged and long term aged mixture) which was significantly increased in comparison to the other RAP mixtures. Short-term aged mixtures containing PG 70-22 also experienced higher change in TI with inclusion of RAP relative to control mixture than those of PG 64-22. However, there were no significant TI changes between PG 64-22 and PG 70-22 gravel mixtures.



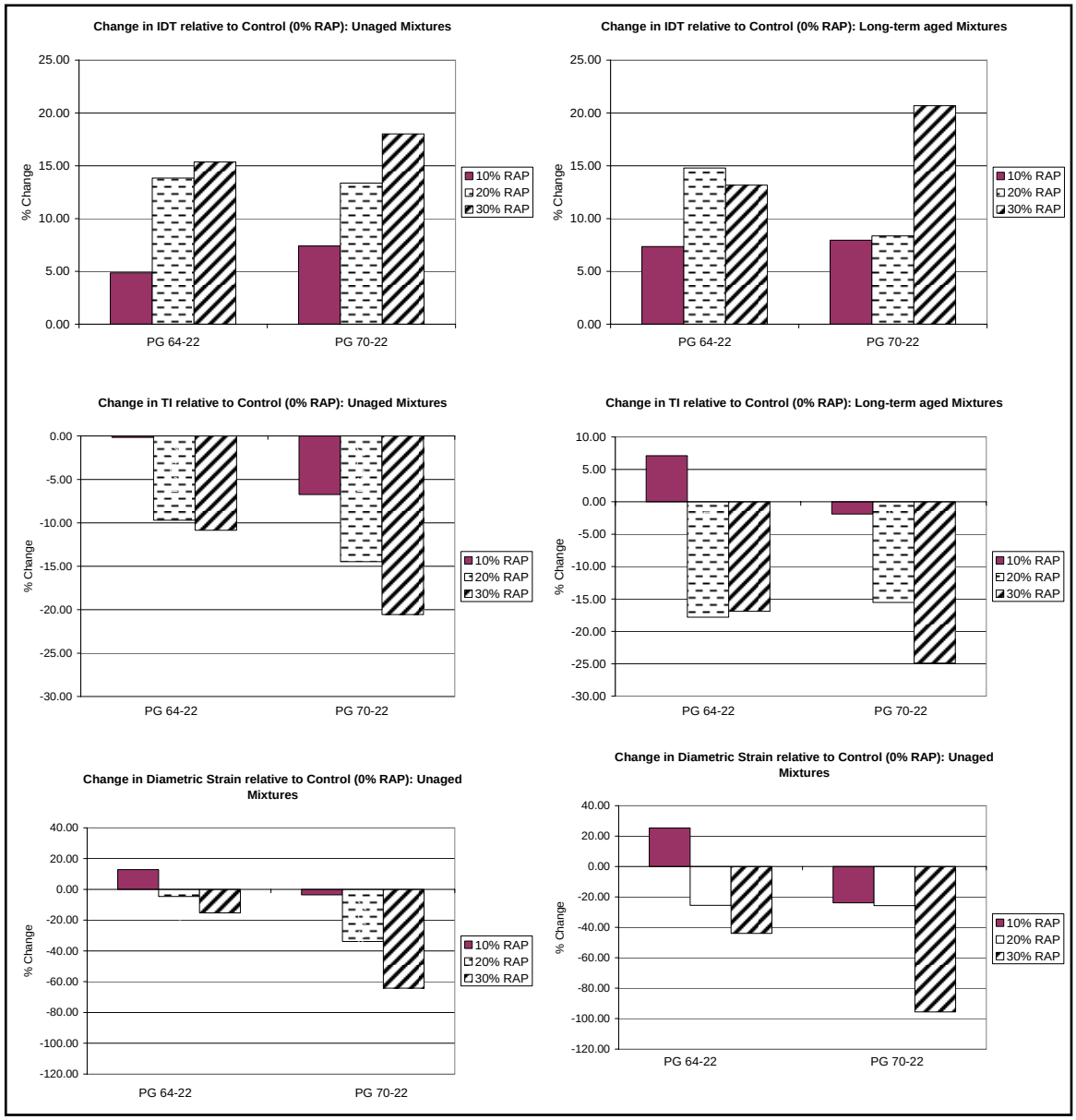
un-aged = short-term aged

Figure 18. Test Results for IDT Gravel Mixtures

Table 9. Percent Change of IDT Fatigue Properties for Gravel Mixtures

%IDT ± / %RAP	Indirect Tensile Strength				Strain at Failure				Toughness Index			
	PG 64-22		PG 70-22		PG 64-22		PG 70-22		PG 64-22		PG 70-22	
	UA	LT-A	UA	LT-A	UA	LT-A	UA	LT-A	UA	LT-A	UA	LT-A
10	5	7	7	8	13	25	-4	-24	0	7	-7	-2
20	14	15	13	8	-5	-26	-34	-26	-10	-18	-14	-16
30	15	13	18	21	-15	-44	-64	-96	-11	-17	-21	-25

Note: The values in the Table indicated the increase or decrease of properties relative to the control mix (0% RAP)
un-aged = short-term aged



un-aged = short-term aged

Figure 19. Percent Change of IDT Fatigue Properties for Limestone Mixtures

4.2.1.2 Resilient Modulus and Dissipated Creep Strain Energy

Resilient modulus (Mr), Fracture Energy (FE), and Dissipated Creep Strain Energy ($DSCE_f$) were used in this study to evaluate the fatigue properties of the asphalt mixtures with inclusion of RAP where the stiffer mixtures would produce higher Mr, FE, and $DSCE_f$ values. The Mr, FE, and $DSCE_f$ were evaluated only for the Limestone mixtures with both types of binder with inclusion of RAP. Table 10 presents the results from tensile strength testing for limestone mixtures.

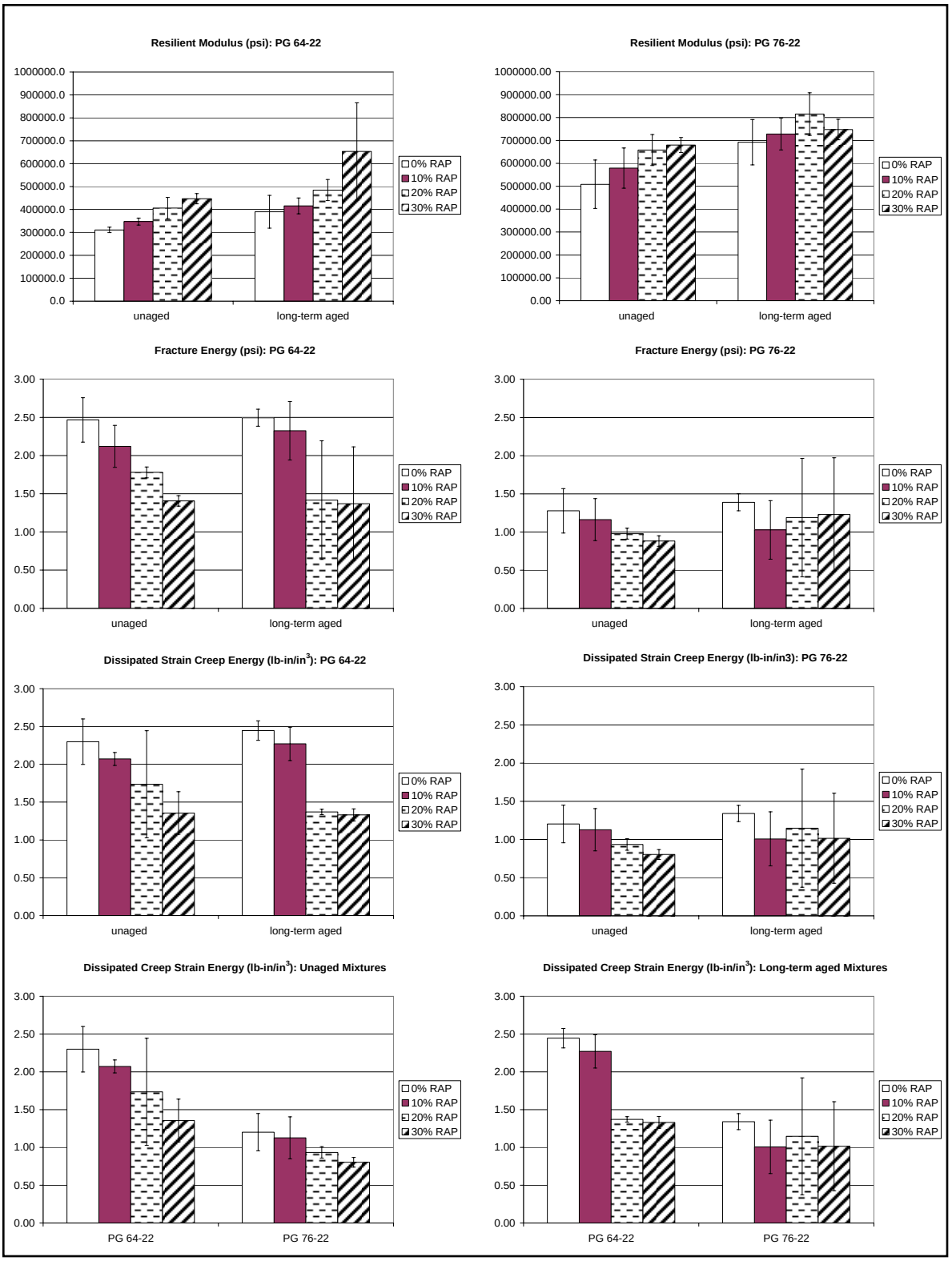
Mixtures subjected to long-term aging had higher Mr Values than short-term aged mixtures. As shown in Figure 20 the inclusion of RAP increased the resilient modulus of the asphalt mixtures, which means that the stiffness of the mixtures increases with inclusion of RAP. The mixtures containing PG 76-22 binder resulted in higher resilient modulus than the mixtures with lower binder grade PG 64-22. Mixtures containing 0 and 10 percent of RAP showed modest difference between Mr, FE, and $DSCE_f$ for short-term aged and long-term aged mixtures.

Table 10. Tensile Strength Results, Limestone Mixtures

PG 64-22	Resilient Modulus Mr, psi.				FE, psi.				DSCEf, psi.			
% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)
Control	310710	3.9	389925	18.4	2.4659	12.3	2.4949	4.9	2.419	12.7	2.446	5.3
10	347313	4.4	415783	8.3	2.1204	4	2.3244	9.6	2.071	4.1	2.271	9.7
20	406286	11.5	484811	9.5	1.7796	39.9	1.4154	2.4	1.735	40.8	1.370	2.6
30	446953	5	653283	32.6	1.4059	20	1.3695	6.5	1.361	20.8	1.331	6

PG 76-22	Resilient Modulus Mr, psi.				FE, psi.				DSCEf, psi.			
% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)
Control	508604	20.8	692266	14.3	1.2775	22.8	1.3893	8.1	1.202	20.5	1.341	7.9
10	579345	15.2	725559	9.5	1.1621	23.7	1.0284	37.3	1.127	24.6	1.007	35.1
20	658274	10.3	815159	11.4	0.9784	7.3	1.1882	65.3	0.935	8.1	1.147	67.4
30	680240	4.8	747691	6	0.8820	7.8	1.2291	60.6	0.803	6.4	1.016	58

UA - un-aged
LT-A - long-term aged
un-aged = short-term aged



un-aged = short-term aged

Figure 20. Test Results for IDT Limestone Mixtures

However the addition of RAP at higher percentages (20-30 percent) resulted in significant changes in Mr, FE, and $DSCE_f$ when compared to control mixture, Table 11. This indicates that the increase of RAP material significantly increases the strength, and decreases the fatigue life of the HMA mixtures. This was most notable at PG 64-22 limestone mixtures subjected to short-term and long-term aging where Mr significantly increased at 20 and 30 percent of RAP and fatigue life (FE and $DSCE_f$) noticeably decreased, Figure 21.

4.3 Semi-Circular Bending (SCB) Test

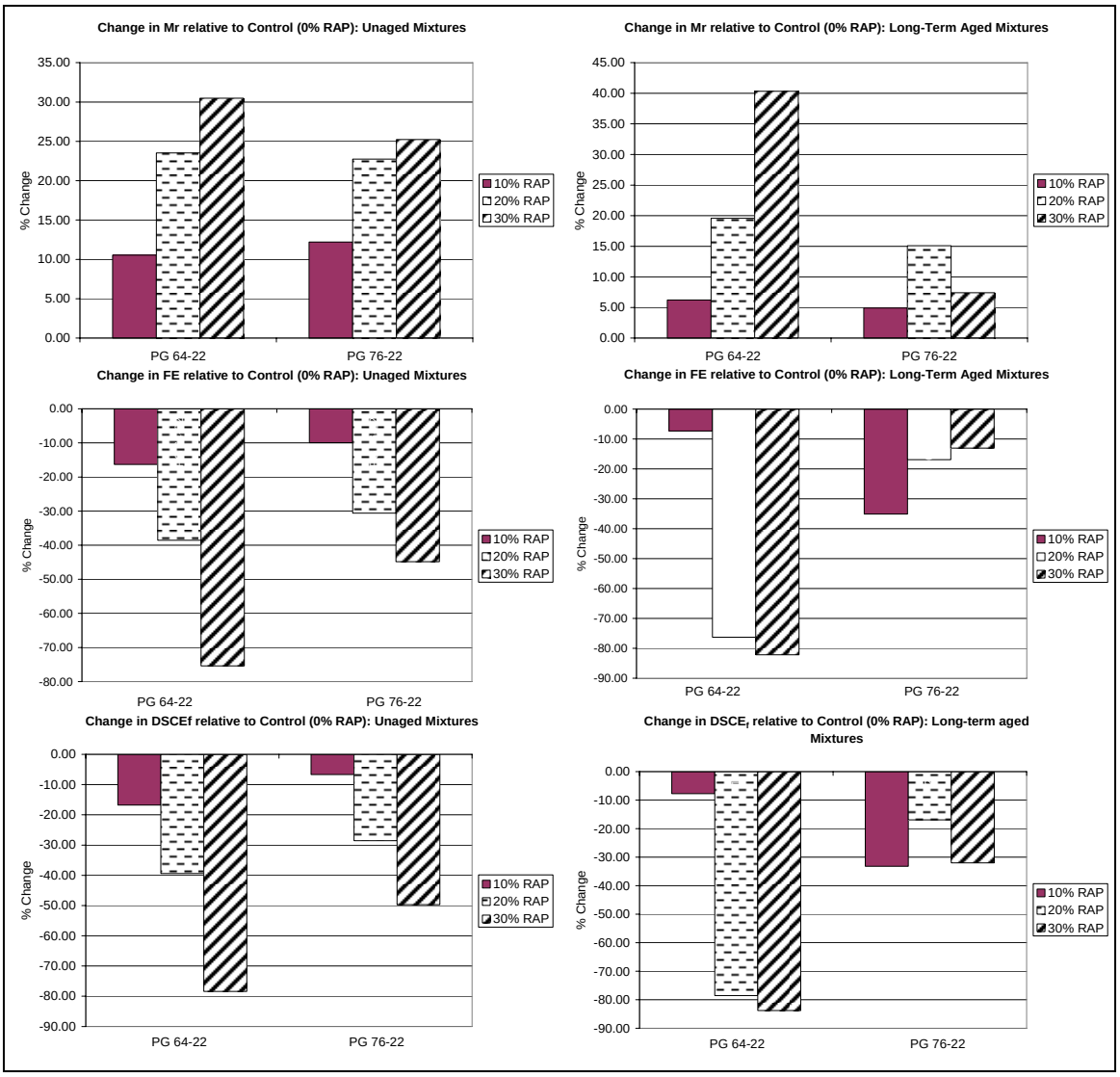
4.3.1 SCB Tensile Strength Test

Table 12 summarizes the results from IDT-SCB testing for limestone mixtures. ITS, Strain, and TI were evaluated for both types of aggregate and binder with inclusion of RAP. Mixtures subjected to long-term aging resulted in higher tensile strengths, lower strains at peak load, and lower toughness indices when compared to the short-term aged mixtures, Figure 22. Generally, the addition of RAP increased the tensile strength but significantly changed the post failure characteristics of the mixtures.

Table 11. Percent Change of Tensile Strength Properties, Limestone Mixtures

%IDT ±	Resilient Modulus Mr, psi.				FE, psi.				DSCEf, psi.			
	PG 64-22		PG 76-22		PG 64-22		PG 76-22		PG 64-22		PG 76-22	
%RAP	UA	LT-A	UA	LT-A	UA	LT-A	UA	LT-A	UA	LT-A	UA	LT-A
10	11	6	12	5	-16	-7	-10	-35	-17	-8	-7	-33
20	24	20	23	15	-39	-76	-31	-17	-39	-79	-29	-17
30	30	40	25	7	-75	-82	-45	-13	-78	-84	-50	-32

Note: The values in the Table indicated the increase or decrease of properties relative to the control mix (0% RAP)
un-aged = short-term aged



un-aged = short-term aged

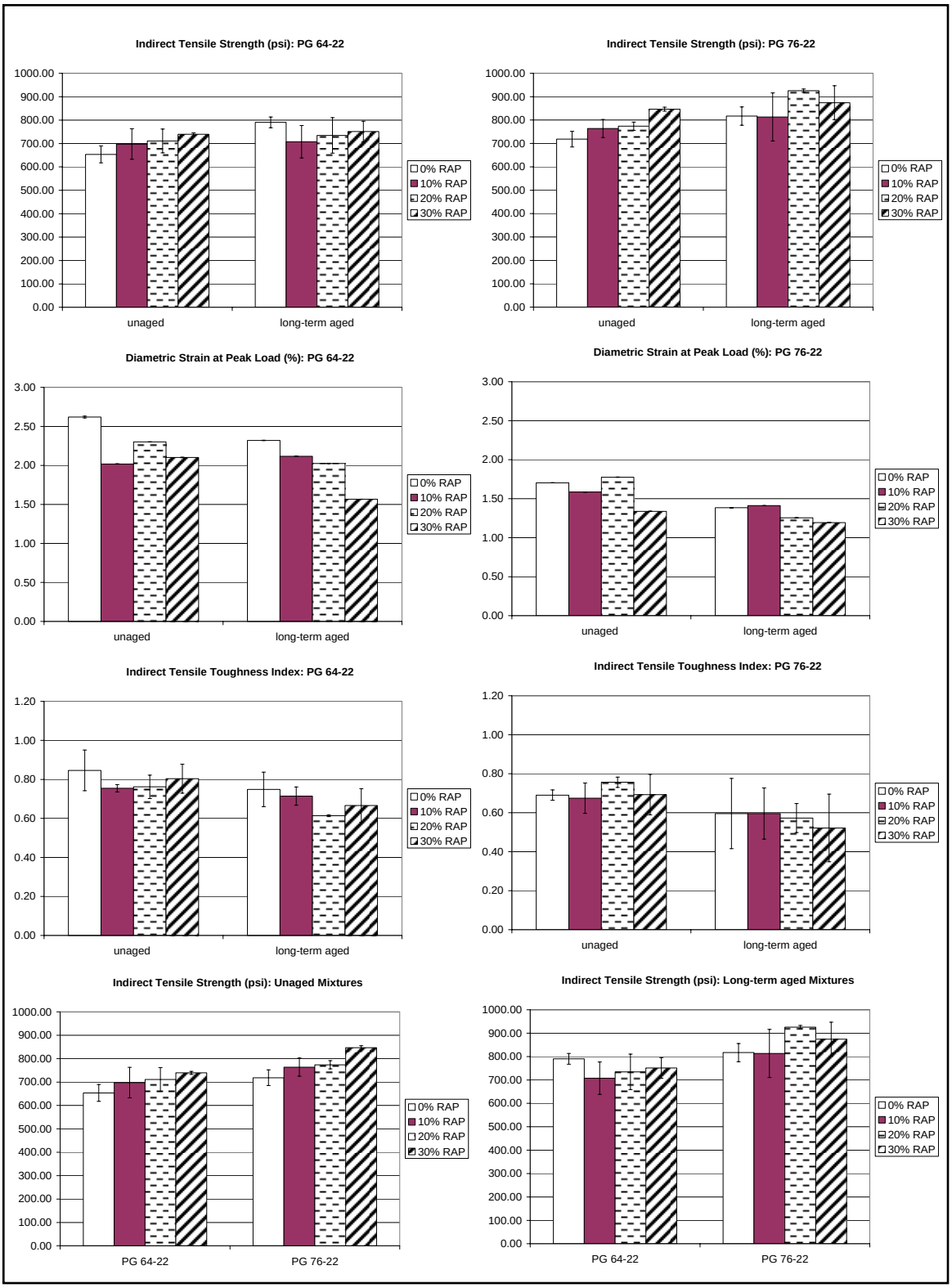
Figure 21. Percent Change of Tensile Strength Fatigue Properties for Limestone Mixtures

Table 12. IDT SCB Results, Limestone Mixtures

PG 64-22	Indirect Tensile Strength, psi.				Strain at Failure, in./in.				Toughness Index			
% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)
Control	654	5.5	790	2.9	0.0262	42.9	0.0232	8.7	0.846	12.3	0.769	7.9
10	698	9.3	708	9.8	0.0202	13.5	0.0212	12.2	0.755	2.5	0.715	6.6
20	711	7.2	735	10.3	0.0230	10.3	0.0202	17.5	0.762	7.9	0.614	0.8
30	739	0.9	751	5.9	0.0210	18.6	0.0157	4.1	0.804	9.2	0.666	13

PG 76-22	Indirect Tensile Strength, psi.				Strain at Failure, in./in.				Toughness Index			
% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)
Control	719	4.7	817	4.8	0.0170	6.1	0.0138	31.1	0.690	3.8	0.596	30.3
10	764	5.1	813	12.6	0.0159	8.2	0.0141	2.6	0.674	11.5	0.595	22
20	774	2.3	926	0.8	0.0178	12.8	0.0126	8.8	0.756	3.5	0.573	13
30	847	1.0	874	8.3	0.0134	13.7	0.0119	18.7	0.693	15	0.522	33.3

UA - un-aged
LT-A - long-term aged
un-aged = short-term aged



un-aged = short-term aged

Figure 22. SCB IDT Test Results, Limestone Mixtures

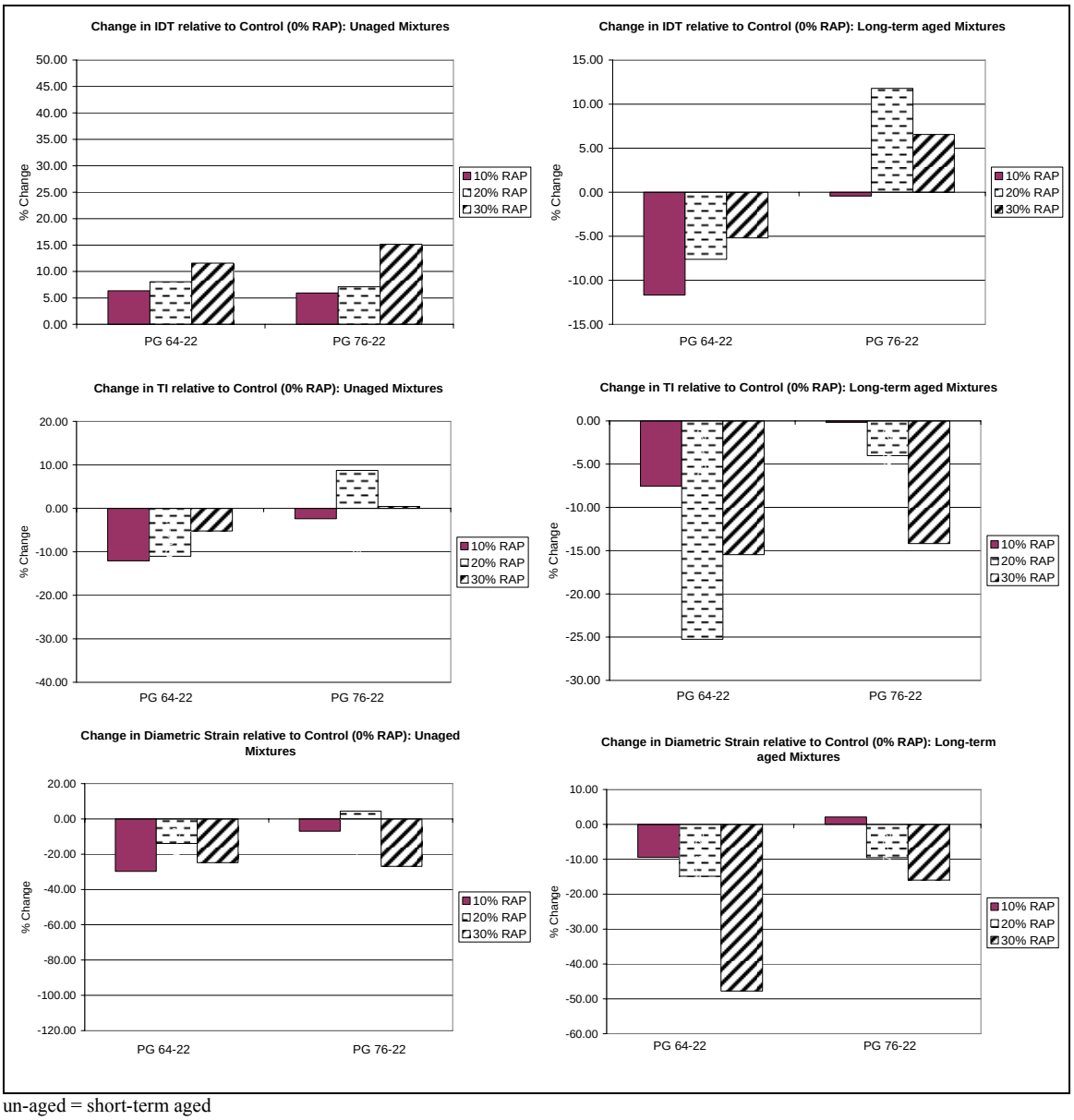
Table 13 presents differences in IDT-SCB characteristics for both types of binders relative to the control (0% RAP) mixtures. Generally, there were no significant differences between the 0 and 10 percent RAP mixtures for the short-term aged mixtures. However mixtures containing 20 and 30 percent of RAP resulted in noticeable differences in tensile strength and post failure characteristics when compared to the control mixture, Figure 23. Mixtures containing PG 76-22 binder resulted in higher tensile strengths and lower post failure characteristics. Both PG 64-22 and PG 76-22 had similar post failure characteristics. From Figure 23 it can be concluded that higher percentages of RAP had more influence on the post failure characteristics PG 64-22 than mixtures with PG 76-22 asphalt binder.

Table 14 summarizes the IDT SCB testing results for gravel mixtures. Mixtures subjected to the long-term aging resulted in higher tensile strength and lower post failure characteristics.

Table 13. Percent Change of IDT SCB Properties, Limestone Mixtures

%IDT ±	Indirect Tensile Strength				Strain at Failure				Toughness Index			
	PG 64-22		PG 76-22		PG 64-22		PG 76-22		PG64-22		PG 76-22	
%RAP	UA	LT-A	UA	LT-A	UA	LT-A	UA	LT-A	UA	LT-A	UA	LT-A
10	6	-12	6	0	-30	-9	-7	2	-12	-8	-2	0
20	8	-8	7	12	-14	-15	4	-10	-11	-25	9	-4
30	12	-5	15	7	-25	-48	-27	-16	-5	-15	0	-14

Note: The values in the Table indicated the increase or decrease of properties relative to the control mix (0% RAP)
un-aged = short-term aged



un-aged = short-term aged

Figure 23. Percent Change in SCB IDT Properties, Limestone Mixtures

Table 14. IDT SCB Results, Gravel Mixtures

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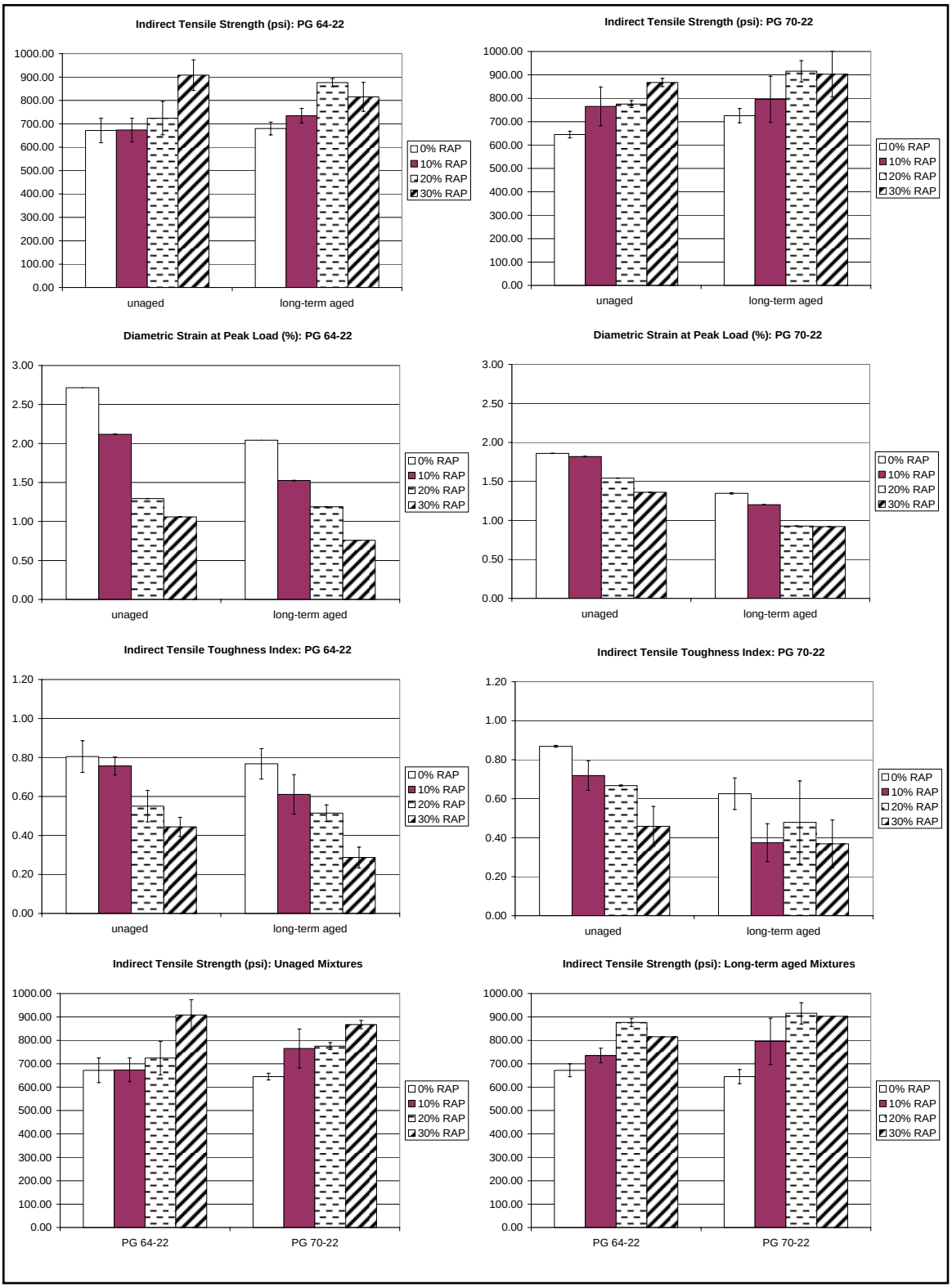
PG 64-22	Indirect Tensile Strength, psi.				Strain at Failure, in./in.				Toughness Index			
% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)
Control	672	7.8	680	4	0.0272	12.4	0.0204	13.2	0.805	10.1	0.768	10.2
10	674	7.5	735	4.2	0.0212	9.7	0.0153	28.9	0.756	6.1	0.611	16.6
20	724	9.9	877	2	0.0129	11.4	0.0119	37.1	0.551	14.7	0.515	8.3
30	908	7.2	815	7.6	0.0106	8.1	0.0076	12.6	0.444	11.2	0.287	18.6

PG 70-22	Indirect Tensile Strength, psi.				Strain at Failure, in./in.				Toughness Index			
% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)
Control	645	2.2	726	4.2	0.0186	16.8	0.0135	61.1	0.869	0.6	0.626	
10	765	10.9	795	12.4	0.0182	16.3	0.0120	21.5	0.719	10.5	0.375	25.9
20	867	2.0	915	5.0	0.0154	13.7	0.0093	15.5	0.459	22.2	0.479	44.5
30	775	1.9	903	10.8	0.0136	9.4	0.0092	8.2	0.667	0.4	0.369	33.4

UA - un-aged
LT-A - long-term aged
un-aged = short-term aged

As shown in Figure 24, the addition of screened RAP increased the tensile strength but significantly changed the post failure characteristics for short-term aged and long-term aged mixtures. Mixtures containing polymer modified binder (PG 70-22) resulted in higher tensile strengths when compared to non-modified binder mixtures (PG 64-22). Change in IDT relative to control (0 percent RAP mixture) is presented in Table 15. Generally, addition of 20 and 30 percent of RAP increased tensile strength but significantly decreased strain at peak load and toughness indices for short-term aged and long-term aged mixtures, Figure 25. However, both gravel long-term aged 30 percent HMA mixtures experienced decrease in tensile strength.

Generally, there were no significant differences between the 0 and 10 percent short-term and long-term aged PG 64-22 RAP mixtures. However, inclusion of 30 percent of RAP showed significant increase in tensile strength. PG 64-22 mixtures experienced higher post failure characteristics when compared to the PG 70-22 mixtures.



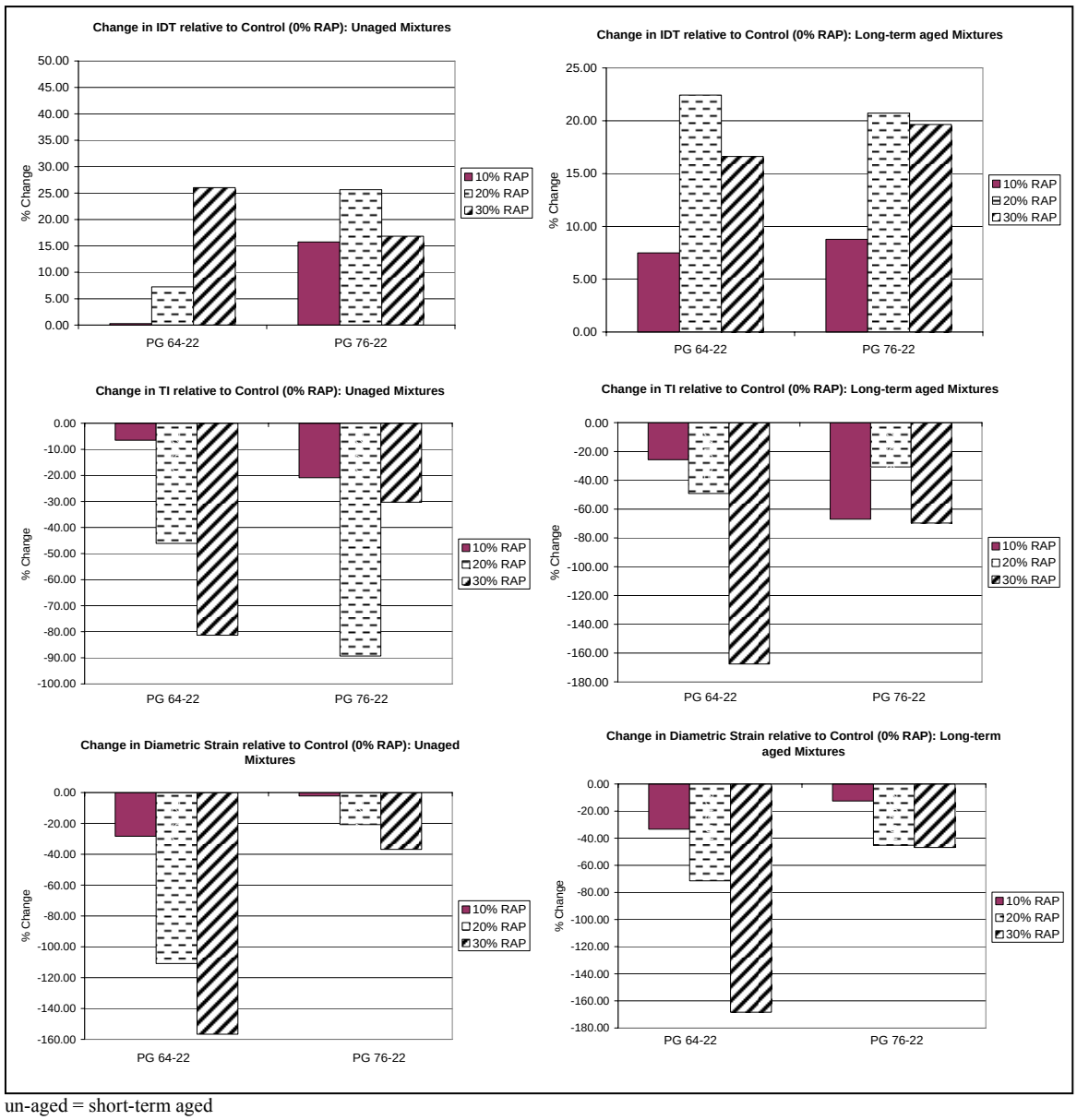
un-aged = short-term aged

Figure 24. SCB IDT Test Results, Gravel Mixtures

Table 15. Percent Change of IDT SCB Properties, Gravel Mixtures

%IDT ± / %RAP	Indirect Tensile Strength				Strain at Failure				Toughness Index			
	PG 64-22		PG 70-22		PG 64-22		PG 70-22		PG 64-22		PG70-22	
	UA	LT-A	UA	LT-A	UA	LT-A	UA	LT-A	UA	LT-A	UA	LT-A
10	0.3	7	16	9	-28	-33	-2	-13	-6	-26	-21	-67
20	7	22	26	21	-111	-71	-21	-45	-46	-49	-89	-31
30	26	17	17	20	-157	-168	-37	-47	-81	-168	-30	-70

Note: The values in the Table indicated the increase or decrease of properties relative to the control mix (0% RAP)
un-aged = short-term aged

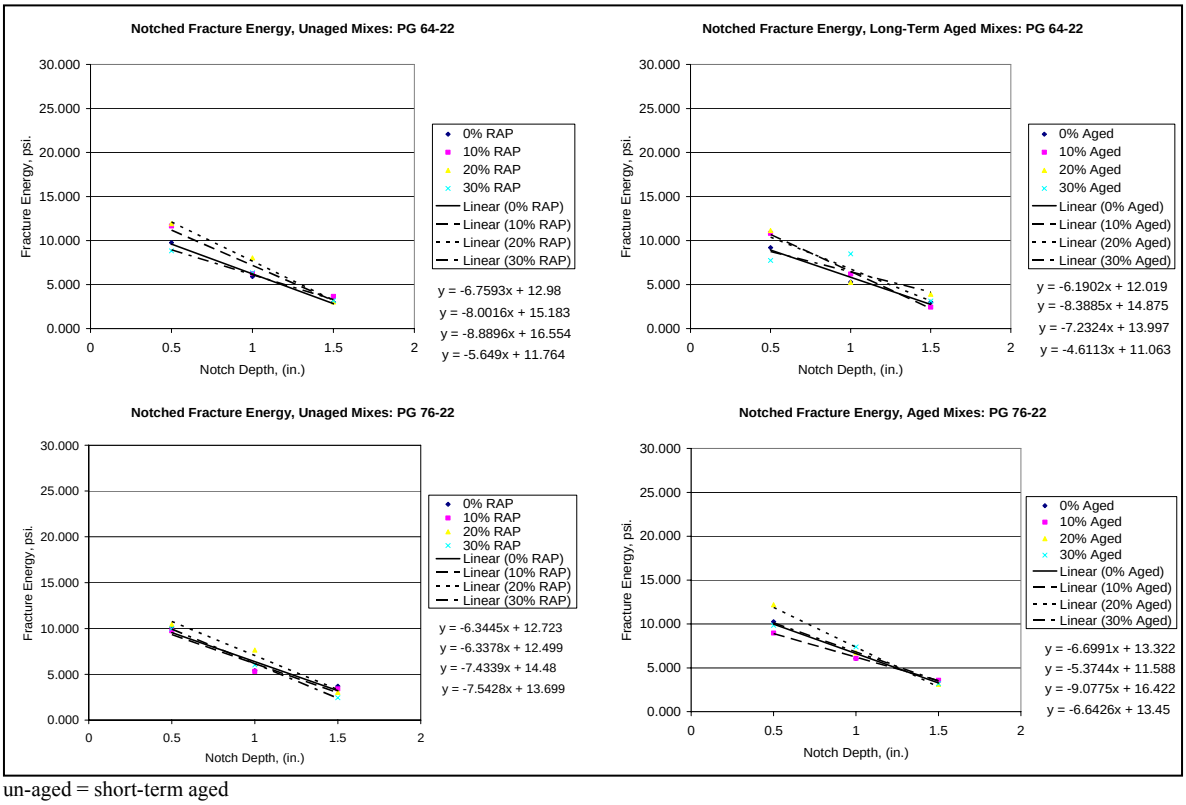


un-aged = short-term aged

Figure 25. Percent Change in SCB IDT Properties, Gravel Mixtures

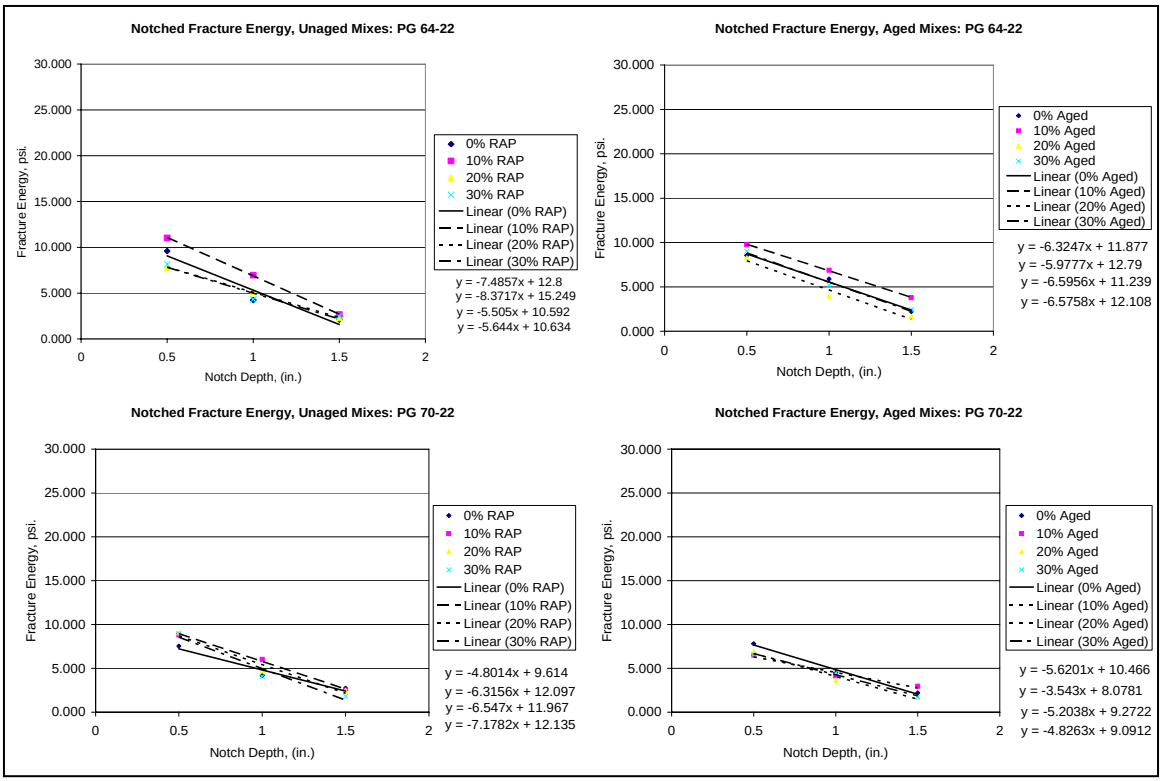
4.3.2 SCB Notched Fracture Resistance Test

Fracture energy was evaluated for both mixtures (Limestone and Gravel) including two types of binders (PG 64-22 and PG 76-22). The results from the SCB notched fracture test for limestone and gravel mixtures is presented in Figure 26 and 27. Three notched depths were used to evaluate the fracture resistance of the four mixtures 0.5, 1.0, and 1.5 inches. The slope of the fracture energy vs. notch depth represents the J-integral, where the higher the J-integral reflects higher fracture resistance of the mixture being tested.



un-aged = short-term aged

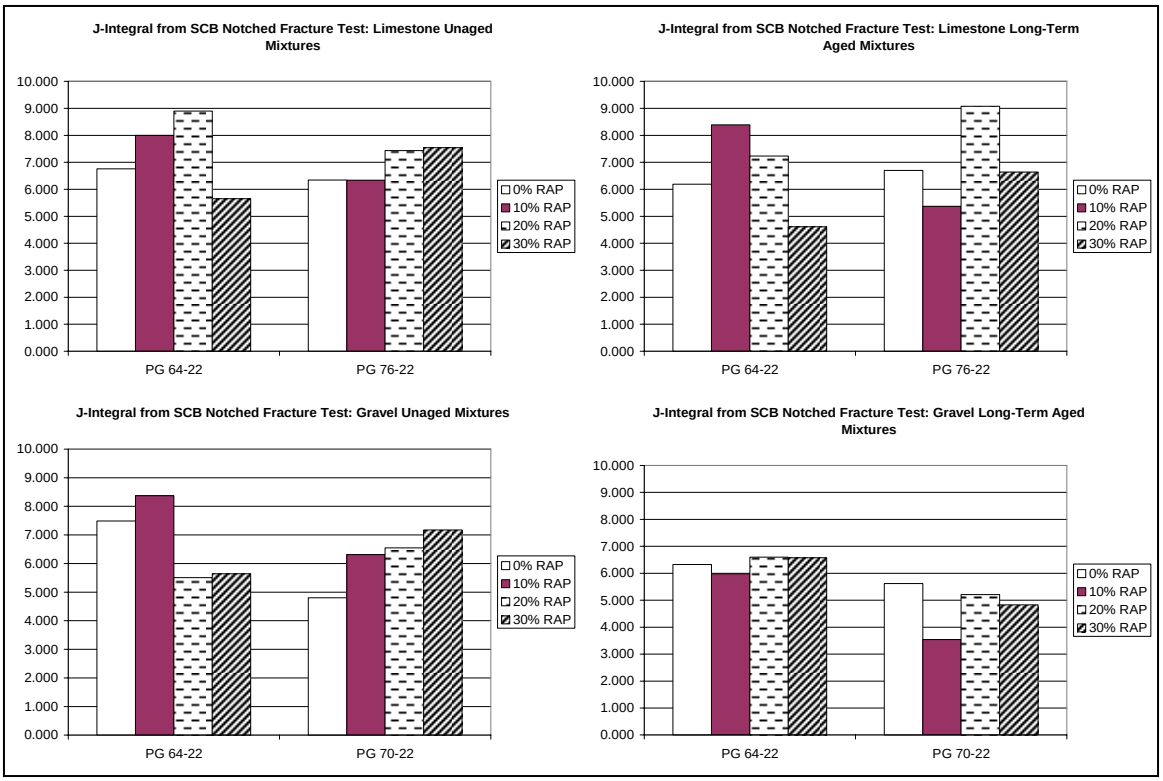
Figure 26. Limestone SCB Notched Fracture Energy



un-aged = short-term aged

Figure 27. Gravel SCB Notched Fracture Energy

Summary of the limestone J-integral of all mixtures is presented in Figure 28. Generally the inclusion of 30 percent of RAP for both short-term aged and long-term aged mixtures exhibited lower J-integral values when compared to the control mixtures (0 percent RAP mixtures). Both of the short-term aged 10, and 20 percent limestone binder mixtures experienced higher J-integral than the mixtures without RAP. The J-integral for the 10 percent PG 76-22 RAP limestone mixtures decreased once they were subjected to long-term aging. Limestone mixtures containing 20 percent of RAP resulted in higher J-integral values when compared to non-modified PG 76-22 asphalt mixtures.



un-aged = short-term aged

Figure 28. Semi-circular Notched Fracture Test (J-Integral)

Gravel mixtures experienced similar J-integral values to those of limestone mixtures. The J-integral of the 30 percent RAP gravel PG 64-22 mixtures decreased and than increased once it was long-term aged when compared to the control (virgin) mixture, Figure 28. The PG 70-22 gravel mixtures did just the opposite of the PG 64-22 gravel mixtures. The J-integral increased for the short-term aged 30 percent RAP mixtures and decreased for the mixtures subjected to long-term aging when compared to the 0 percent RAP mixtures. Short-term aged gravel mixtures with 10 percent of the RAP material experienced higher J-integral than those of the control mixture. However once they were subjected to the long-term aging the J-integral value decreased. J-integral for 20 percent of RAP mixtures (PG 64-22) was lower when compared to control mixture but increased

once it was long-term aged. Gravel mixture with PG 70-22 binder was higher for short-term aged mixture when compared to control mixture, but once long-term aged it became lower. Gravel mixtures with inclusion of 20 percent of RAP for both types of binders experienced similar results to the mixtures with 30 percent of rap.

Generally all of the mixtures with inclusion of the 30 percent of RAP experienced lower J-integral value, and therefore a lower resistance to cracking. This means that the fracture resistance will decrease for the mixtures containing high percentages of RAP material. The mixtures with 30 percent of RAP material become more brittle, experiencing higher strength when compared to the 0 percent RAP mixtures. However mixtures with 10 and 20 percent of RAP generally showed increase of resistance to cracking when compared to control mixtures (0 percent RAP).

4.4 Flexural Beam Fatigue Testing

Flexural beam fatigue testing was evaluated on both types of aggregate and binder with inclusion of different percentages of RAP material. Each specimen was loaded with 600 micro-strains at center of the beam until a stable Plateau Value (PV) region was reached. Once the specimen exited the PV region it was considered to be damaged and the test was stopped. Another method that was used to evaluate the fatigue life of the asphalt mixtures was through the AASHTO T 321-03 test method. Here the specimen was considered to be damaged once it reached 50 percent reduction of its initial stiffness. Half of the limestone and gravel beams were subjected to long-term aging in forced draft oven prior to testing.

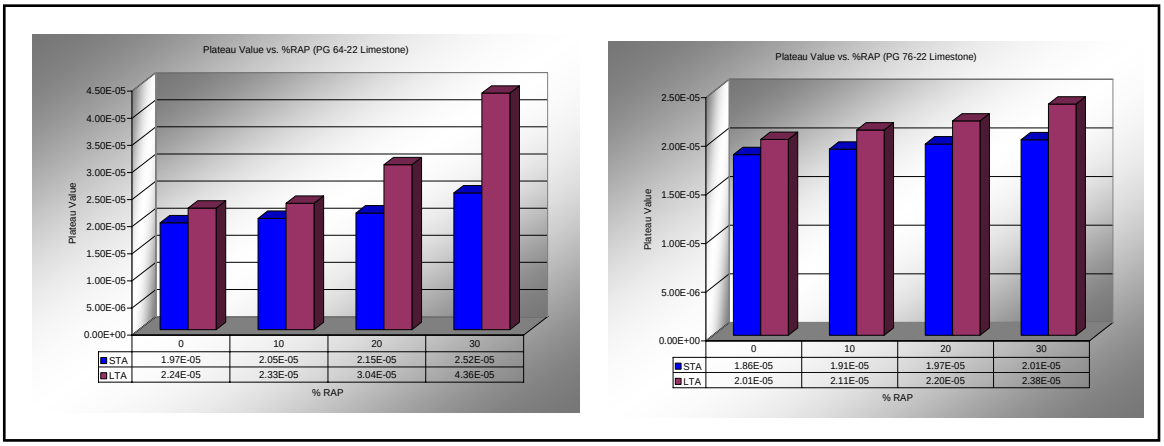
4.4.1 Beam Fatigue Based on Plateau Value

The beam flexural fatigue beam results for the limestone mixtures are presented in Table 16. These results present the PV values for the limestone mixtures with both types of binder PG 64-22 and PG 76-22, Figure 29. Lower PV value represents longer fatigue life, and higher PV value represents shorter fatigue life of the mixture. Generally, the inclusion of RAP and long-term aging decreased the fatigue life for the PG 64-22 mixtures. The inclusion of RAP decreased the fatigue life of the short-term aged PG 64-22 asphalt mixture. For long-term aged PG 64-22 mixtures, the inclusion of 20 and 30

Table 16. Beam Fatigue Test Results (Plateau Value), Limestone Mixtures

Plateau Value									
PG 64-22 Limestone					PG 76-22 Limestone				
% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)
Control	1.969E-05	8.0	2.241E-05	6.0	Control	1.857E-05	4.0	2.013E-05	8.0
10	2.055E-05	2.0	2.329E-05	12.0	10	1.913E-05	1.0	2.110E-05	8.0
20	2.148E-05	17.0	3.043E-05	12.0	20	1.967E-05	5.0	2.203E-05	7.0
30	2.521E-05	11.0	4.358E-05	41.0	30	2.010E-05	11.0	2.377E-05	3.0

UA - un-aged
LT-A - long-term aged
un-aged = short-term aged



un-aged = short-term aged

Figure 29. Beam Fatigue Summary (Plateau Value), Limestone Mixtures

percent RAP significantly decreased the fatigue life when compared to mixtures with less than 10 percent of RAP material. With inclusion of 30 percent of RAP the fatigue life of asphalt mixture decreased by factor of two when compared to the mixtures with less than 10 percent of RAP. The addition of RAP to the virgin asphalt mixtures decreased the fatigue life of the mixtures when compared to the mixtures without RAP. Short-term and long-term aged PG 64-22 mixtures with inclusion of 10 and 20 percent of RAP resulted in no significant difference when compared to control mixture (virgin mixture).

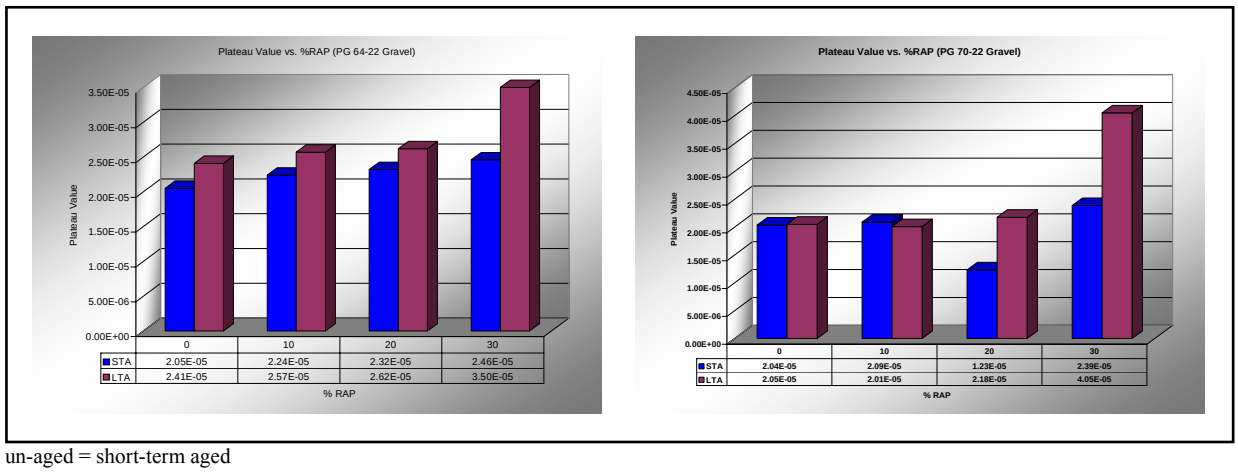
Limestone PG 76-22 mixtures had different trends than the PG 64-22 mixtures. The inclusion of RAP decreased the fatigue life of RAP mixtures. Long-term and short-term aged mixtures showed no significant change when compared to the control mixtures. However, long-term aged PG 76-22 30 percent mixture showed higher PV value when compared to the 0, 10, and 20 percent of RAP mixtures. As expected all of the long-term aged mixtures resulted in higher PV when compared to the short-term aged material.

The results of the beam fatigue gravel mixtures for both types of binders PG 64-22 and PG 70-22 is presented in Table 17 and Figure 30. Fatigue life significantly decreased for the 30 percent PG 64-22 mixture compared to the control mixture. There was no significant change between 20 and 30 percent PG 64-22 mixtures. However, PV for 10 and 20 percent of RAP mixtures did notably increased when compared to the control mixture.

Table 17. Beam Fatigue Test Results (Plateau Value), Gravel Mixtures

Plateau Value									
PG 64-22 Gravel					PG 70-22 Gravel				
% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)
Control	2.054E-05	4.0	2.410E-05	5.0	Control	2.037E-05	3.0	2.050E-05	6.0
10	2.238E-05	7.0	2.570E-05	6.0	10	2.090E-05	11.0	2.009E-05	1.0
20	2.318E-05	5.0	2.621E-05	1.0	20	1.233E-05	18.0	2.176E-05	9.0
30	2.459E-05	3.0	3.500E-05	11.0	30	2.388E-05	11.0	4.050E-05	56.0

UA - un-aged
LT-A - long-term aged
un-aged = short-term aged



un-aged = short-term aged

Figure 30. Beam Fatigue Summary (Plateau Value), Gravel Mixtures

Long-term aged PG 70-22 mixtures with inclusion of 10 and 20 percent of RAP showed no significant difference when compared to the control mixture. However, mixtures with inclusion of 30 percent of RAP resulted in significantly larger PV as oppose to 0, 10, and 20 percent RAP mixtures. It was also noted that the 10 percent RAP PG 70-22 long-term aged mixture was lower than the short-term aged mixture. The PV for the 20 percent short-term aged mixture decreased when compared to the 0 and 10 percent RAP mixtures.

4.4.2 Beam Fatigue Based on 50% Initial Stiffness Failure

Fatigue testing results for the limestone mixtures (according to 50 percent initial stiffness failure criterion) with both PG 64-22 and PG 76-22 binder types are presented in Table 18. Generally, the inclusion of RAP into virgin mixtures increased the fatigue life for PG 64-22 mixtures. The cumulative dissipated energy also increased with the inclusion of RAP for short and long term aged mixtures. Inclusion of 30 percent of RAP material significantly increased the fatigue life for both short and long term aged mixtures. Fatigue life for the long term aged PG 64-22 mixture increased once 20 percent of RAP material was introduced.

Generally, the inclusion of RAP and laboratory long-term aging increased the fatigue life for PG 64-22 mixtures, Figure 31. For long-term aged mixtures, the inclusion of 30 percent of RAP significantly increased the fatigue life when compared to mixtures with less than 20 percent of RAP. Fatigue life for both long-term aged and short-term aged PG 76-22 mixtures decreased with inclusion of up to 20 percent of RAP and increased for 30 percent RAP mixtures. As expected, mixtures with PG 76-22 asphalt had a longer fatigue life when compared to PG 64-22 mixtures. Dissipated energy increased with inclusion of RAP for both PG 64-22 and PG 76-22 asphalt mixes.

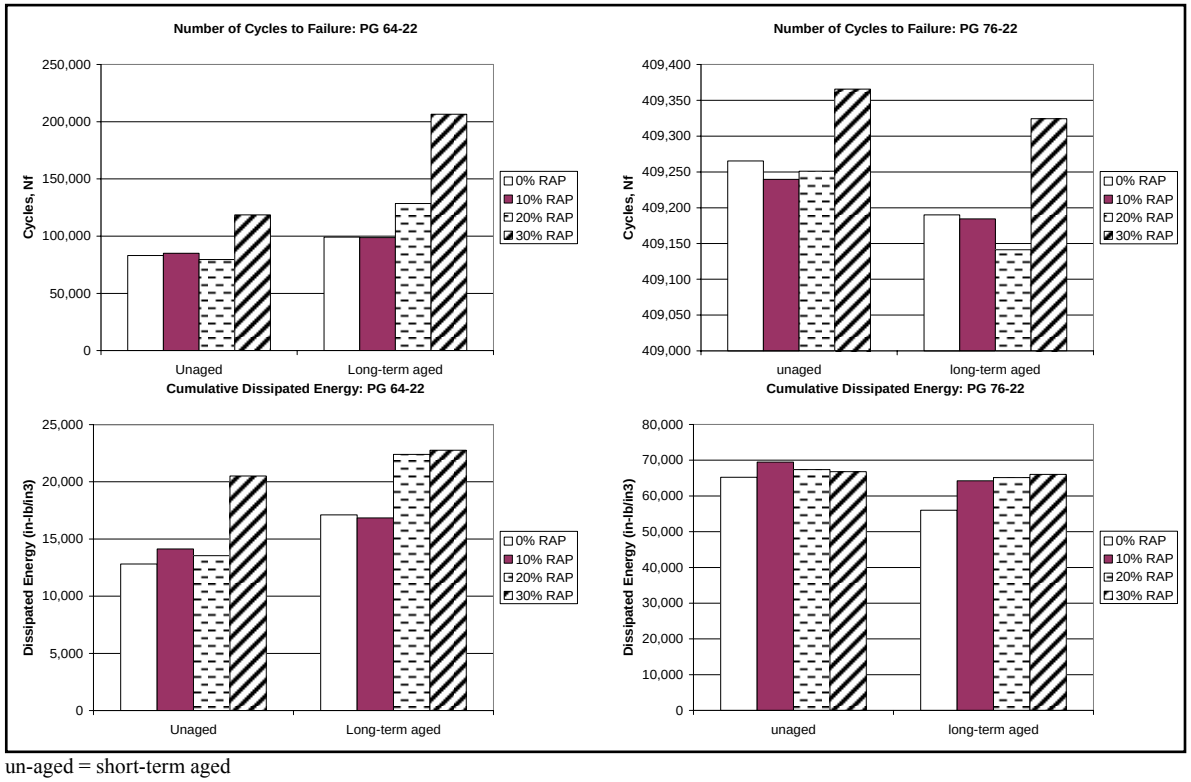
Figure 32 presents the stiffness vs. cycles for the studied mixtures. It was observed that the inclusion of RAP increased both the stiffness and fatigue life for both mixtures (PG 64-22 and PG 76-22) when compared to the control mixtures which contained no RAP.

Table 18. Beam Fatigue Test Results, Limestone Mixtures

PG 64-22	Cycles to failure				Initial Stiffness, psi.				Cumm. Dissipated Energy, psi.			
% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)
Control	83032	33.0	99123	8.0	406063	9.0	564473	5.0	12817	29	17106	9.0
10	84942	41.0	98665	61.0	487128	3.0	567550	12.0	14135	43	16843	62.0
20	79624	35.0	128575	24.0	480301	10.0	575965	12.0	13540	37	22405	22.0
30	118537	2.0	206556	57.0	628594	14.0	661114	6.0	20505	4	22751	35.0

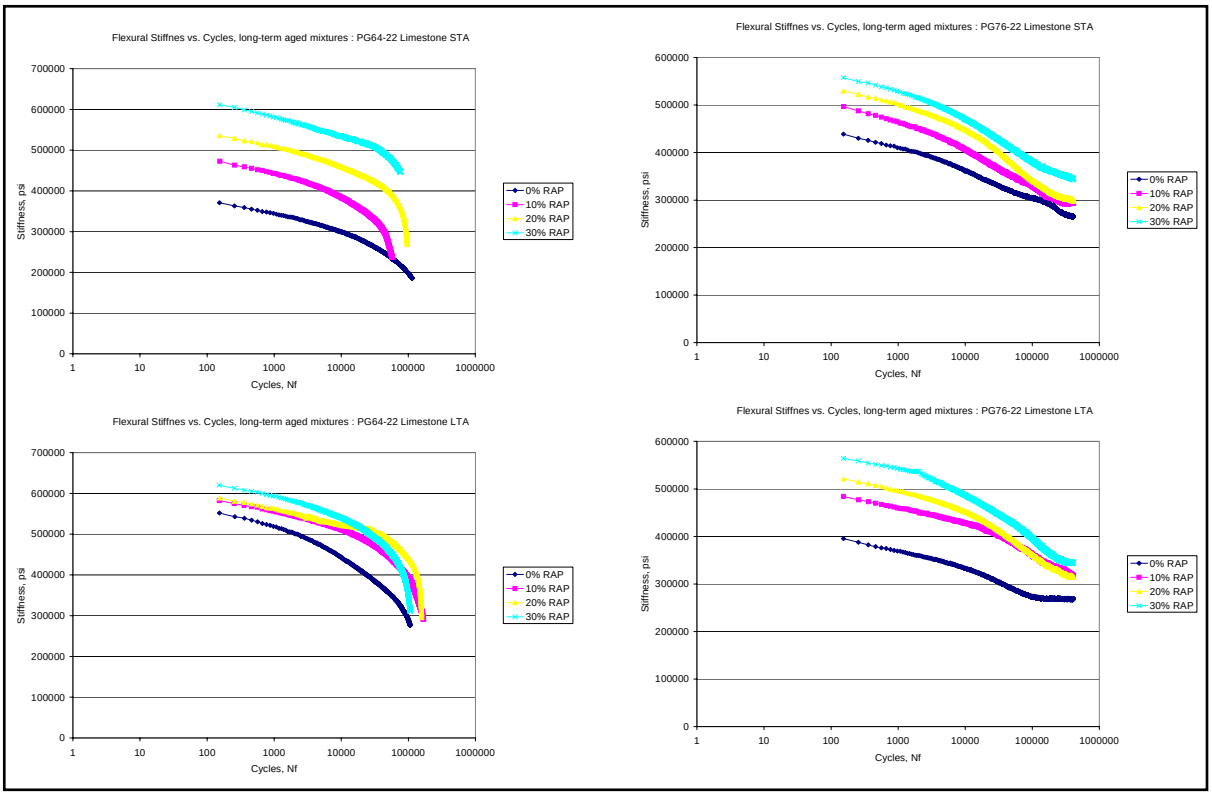
PG 76-22	Cycles to failure				Initial Stiffness				Cumm. Dissipated Energy, psi.			
% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)
Control	409265	0.0	409190	0.0	430216	9.0	432837	9.0	65216	7	56018	4.0
10	409240	0.0	409184	0.0	506086	6.0	452757	7.0	69469	4	64214	10.0
20	409251	0.0	409141	0.0	536762	11.0	531772	2.0	67379	6	65121	8.0
30	409366	0.0	409324	0.0	500716	12.0	560033	6.0	66787	5	66012	2.0

UA - un-aged
LT-A - long-term aged
un-aged = short-term aged



un-aged = short-term aged

Figure 31. Beam Fatigue Summary, Limestone Mixtures



un-aged = short-term aged

Figure 32. Flexural Stiffness vs. Loading Cycles, Limestone Mixtures

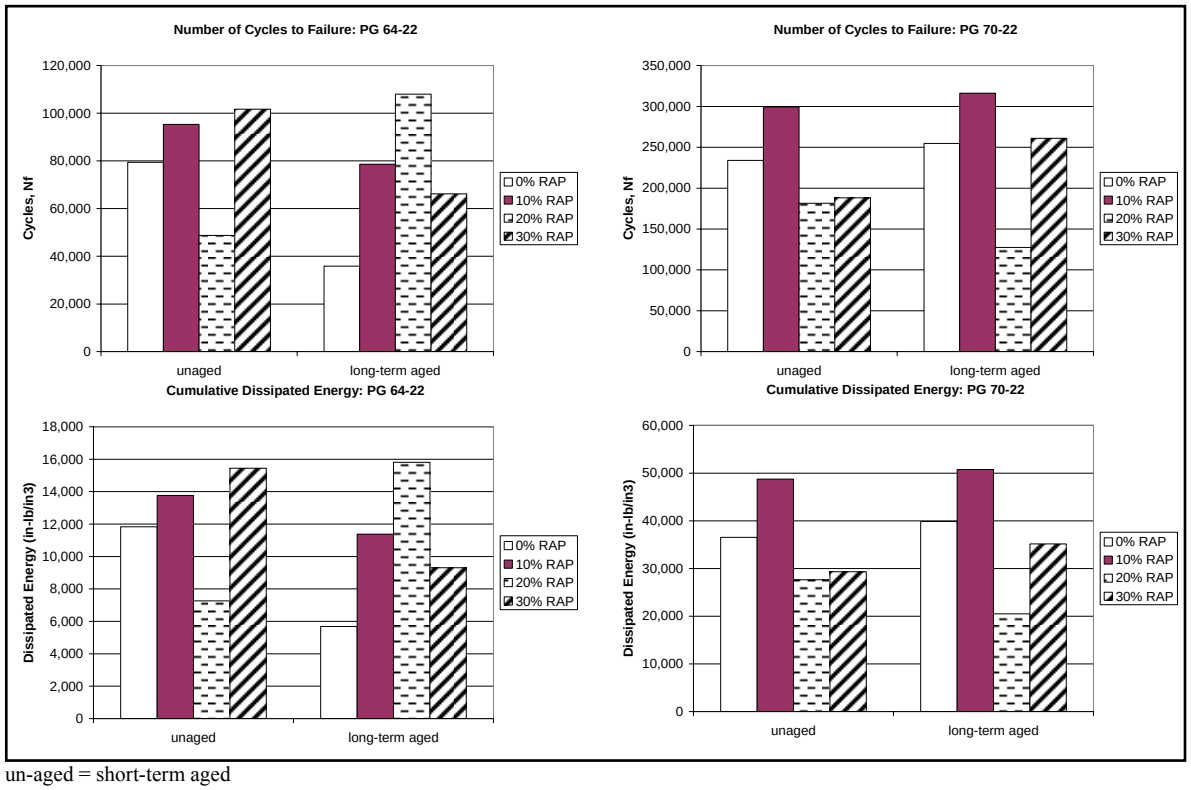
Gravel PG 64-22 and PG 70-22 mixture results are presented in Table 19. Generally, inclusion of 30 percent of RAP into virgin mixtures increased the fatigue life of the mixtures. With inclusion of 20 percent of RAP the fatigue life significantly decreased for all of the mixtures except for the long term aged PG 64-22 mixtures, Figure 33. Fatigue life for the short term aged PG 70-22 mixtures decreased with inclusion of 30 percent of RAP. Cumulative dissipated energy followed the trend of the fatigue life of the gravel mixtures. The inclusion of RAP increased the mixtures stiffness for both long and short term aged mixtures, Figure 34. Fatigue life also increased with inclusion of RAP except for the short term aged PG 70-22 mixture.

Table 19. Beam Fatigue Test Results, Gravel Mixtures

PG 64-22	Cycles to failure				Initial Stiffness, psi.				Cumm. Dissipated Energy, psi.			
% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)
Control	7946	2	35861	45	468064	1	476237	4	11835	9	5683	43
10	95324	31	78583	76	473255	4	531471	11	13768	32	11386	76
20	48743	28	107998	16	498143	6	571849	5	7262	26	15817	15
30	101722	24	66157	14	535033	4	663795	11	15451	22	9306	15

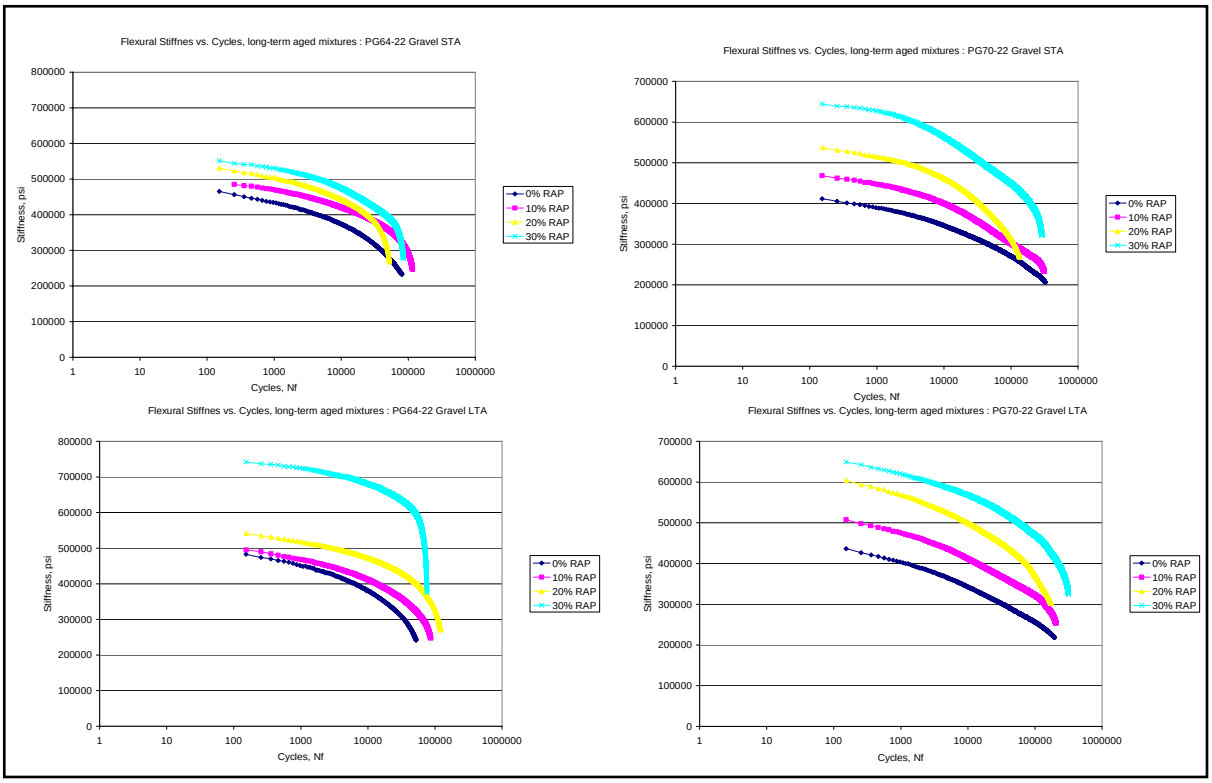
PG 70-22	Cycles to failure				Initial Stiffness				Cumm. Dissipated Energy, psi.			
% RAP	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)	UA	Coef. Of Var. (%)	LT-A	Coef. Of Var. (%)
Control	233879	40.0	254719	21.0	482327	14.0	465429	7	36542	39	39863	29
10	299379	40.0	316180	33.0	459902	5.0	492296	3	48749	42	50731	34
20	181509	107.0	127466	17.0	324713	22.0	406933	2	27639	104	20507	29
30	188202	59.0	260926	70.0	578960	11.0	685875	10	29329	63	35152	67

UA - un-aged
LT-A - long-term aged
un-aged = short-term aged



un-aged = short-term aged

Figure 33. Beam Fatigue Summary, Gravel Mixtures



un-aged = short-term aged

Figure 34. Flexural Stiffness vs. Loading Cycles, Gravel Mixtures

4.5 Uniformity

The uniformity of RAP as well as RAP mixtures was evaluated during this project. Both RAP and RAP mixtures were subjected to extraction and recovery of the asphalt binder and aggregate. Once recovered, aggregate and binder material were subjected to several tests which included gradation, specific gravity (S.G), fine aggregate angularity (FAA), and dynamic shear rheometer (DSR). The collected data were evaluated and presented below.

4.5.1 Uniformity of Plant Mixtures (Limestone PG 64-22)

The uniformity of 0, 10, 20, and 30 percent plant-prepared mixtures was evaluated during this study. Numerous aggregate and binder tests were conducted to evaluate the properties of the mixtures and their uniformity. The samples were collected from three different trucks at different percentages of RAP. To make sure that there would be no contamination between 0, 10, 20, and 30 percent RAP mixtures truck loads were picked from the middle of each RAP mixture. All of the samples were collected at the plant.

Figure 35 presents the results from the sieve analysis of limestone PG 64-22 mixtures with inclusion of 0, 10, 20, and 30 percent of RAP material.

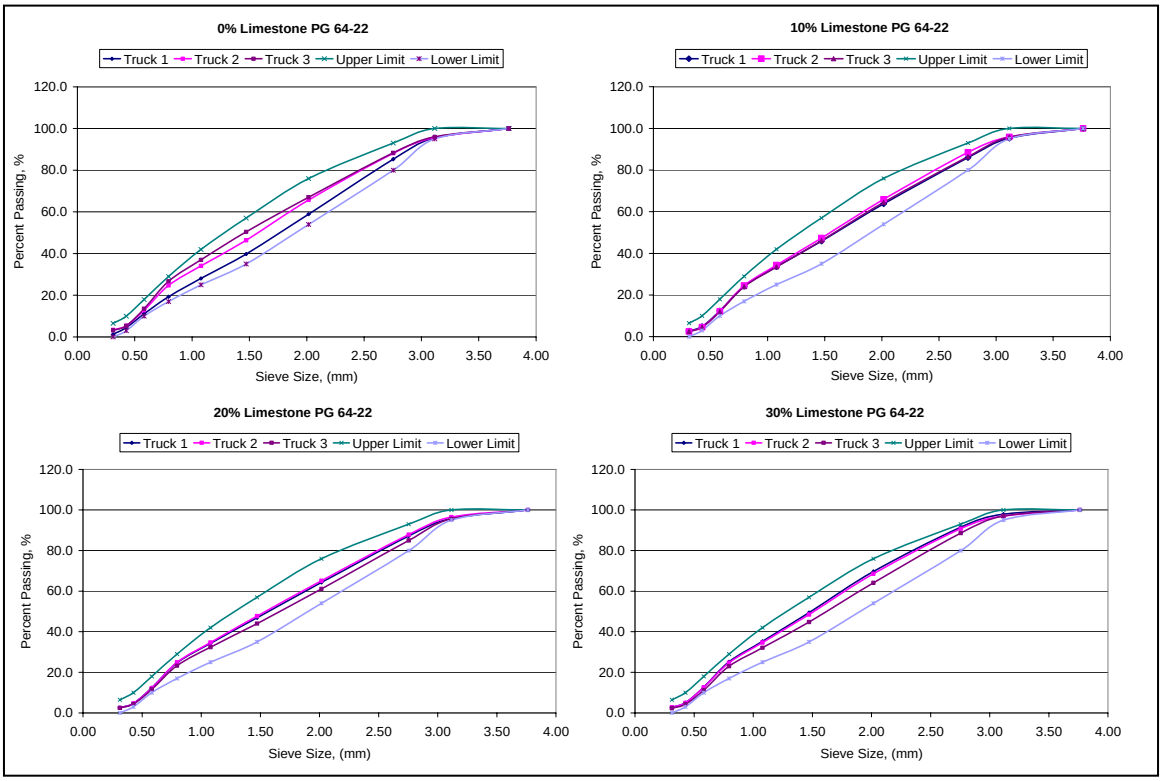


Figure 35. Gradation Analysis for the Limestone PG 64-22 Mixtures

To make sure that the mixtures meet the criteria of the TDOT mix design, the upper and lower limits for the surface "D" mix were also plotted. From the sieve analysis results it can be concluded that all of the PG 64-22 mixtures were uniform and that they met the TDOT requirements. The virgin mixture showed some slight variation for truck 3 when compared to the other two trucks.

The properties of the aggregate for each of the mixtures were analyzed through FAA, and S.G. of fine and coarse aggregate material. The results for FAA and S.G. are presented in Figure 36. As it can be seen there is no significant difference in FAA and S.G. between the mixtures themselves as well as between each of the mixtures (0, 10, 20, and 30 percent RAP). However, truck 2 did have a higher S.G. for the fine material when compared to the other trucks at 20 percent of RAP mixture.

The uniformity of the mixtures was also evaluated through the binder testing. Prior to testing, asphalt binder was recovered using the rotavapor (centrifuge) extraction method. Parameters such as fatigue parameter (G*sin (delta)), complex modulus (G*), and phase angle (^{o}) were obtained from the DSR and used to analyze the uniformity of RAP asphalt mixtures. Figure 37 shows the results for the G*sin (delta) for each truck at different percentages of RAP. The binder material was tested at high (28°C, 52°C, and 76°C) and low (0°C, -6°C, and -12°C) temperatures.

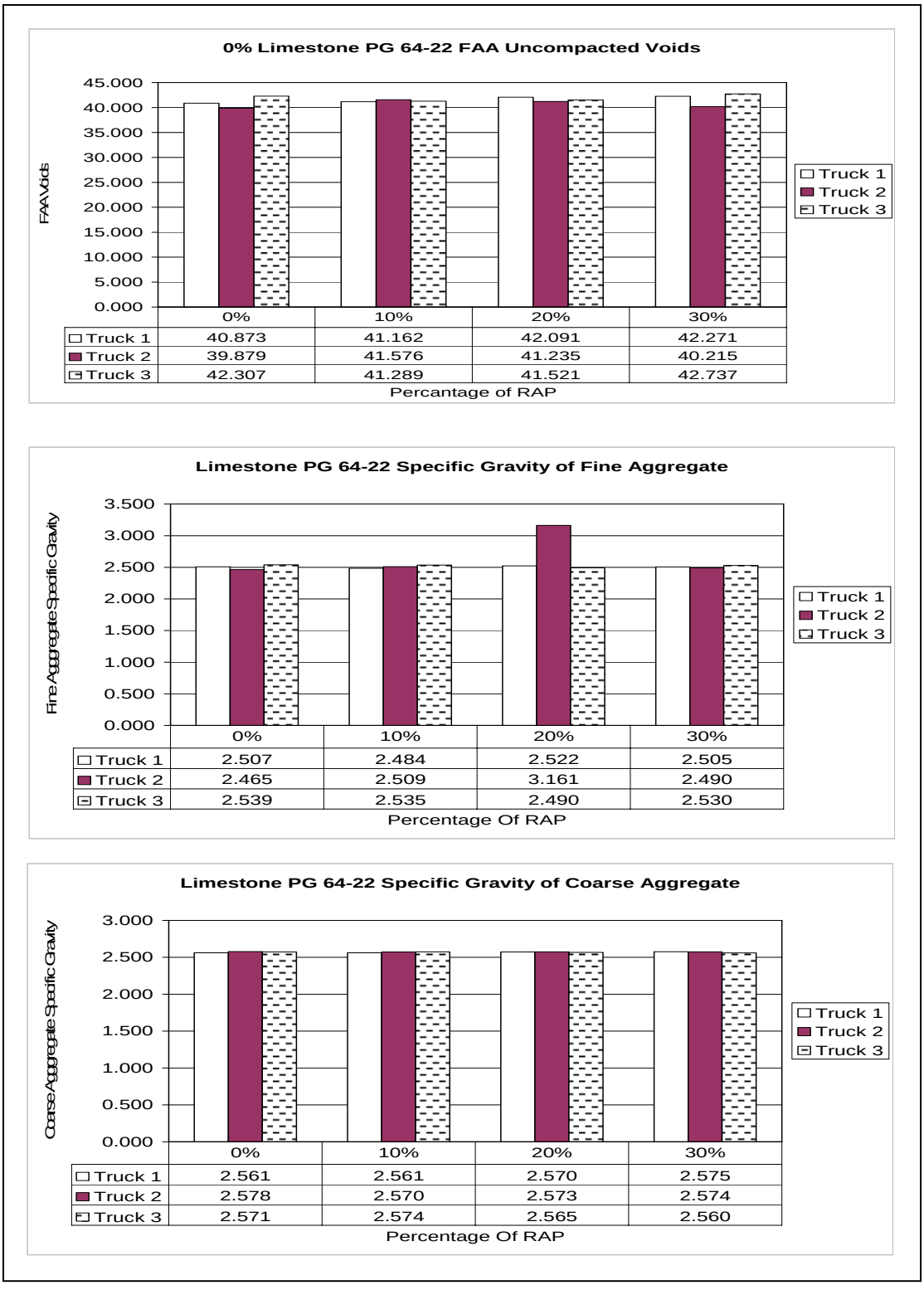


Figure 36. S.G. and FAA for PG 64-22 Limestone Mixtures

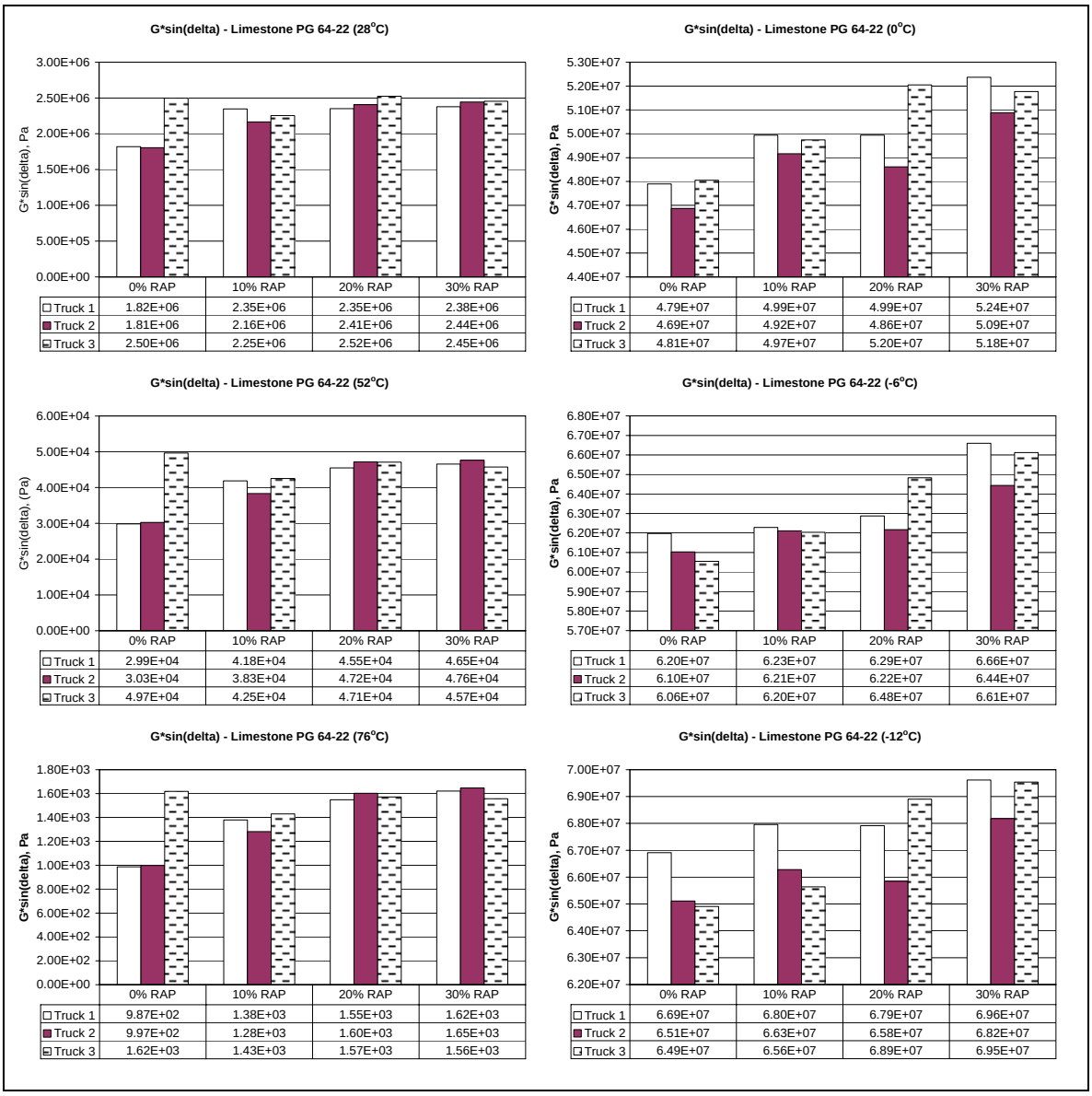


Figure 37. G*sin (delta) for the Limestone PG 64-22 Mixtures

Generally the values for the G*sin (δ) were uniform for each of the truck loads for RAP mixture. However, at high temperatures G*sin (δ) for truck 3 for the 0 percent RAP mixture was significantly higher when compared to the other trucks. The reason for this phenomenon could be the batch plants which mix the asphalt store it prior to the loading causing it to age over time. The testing of the binder at the lower temperatures showed no significant change between each truck load at different percents of RAP. Figure 38 shows results for the complex modulus of the asphalt binder which had similar trend to the G*sin (δ). For both parameters (G*sin (δ) and G*) increased at higher percentages of RAP. This means that with the increase of the RAP the resistance to fatigue cracking decreases correspondingly. Phase angle between each of the trucks at different RAP percentages showed to be uniform except for the truck 3 at 0 percent RAP mixture. The phase angle significantly decreased for the truck 3 when compared to the other two trucks, Figure39.

4.5.2 Uniformity of RAP Material

Similar to the plant mixture uniformity, the RAP material was also evaluated for its uniformity using aggregate and binder testing. The testing material was obtained from each of the four jobsites (CNC 294, CNC 297, CNC 302, CNC 186). At each jobsites three different places of the RAP pile were chosen to obtain the sample and test the uniformity within the stockpiles.

The sieve analysis of the RAP material is presented in Figure 40. From the sieve analysis it can be determined that the RAP material is very consistent.

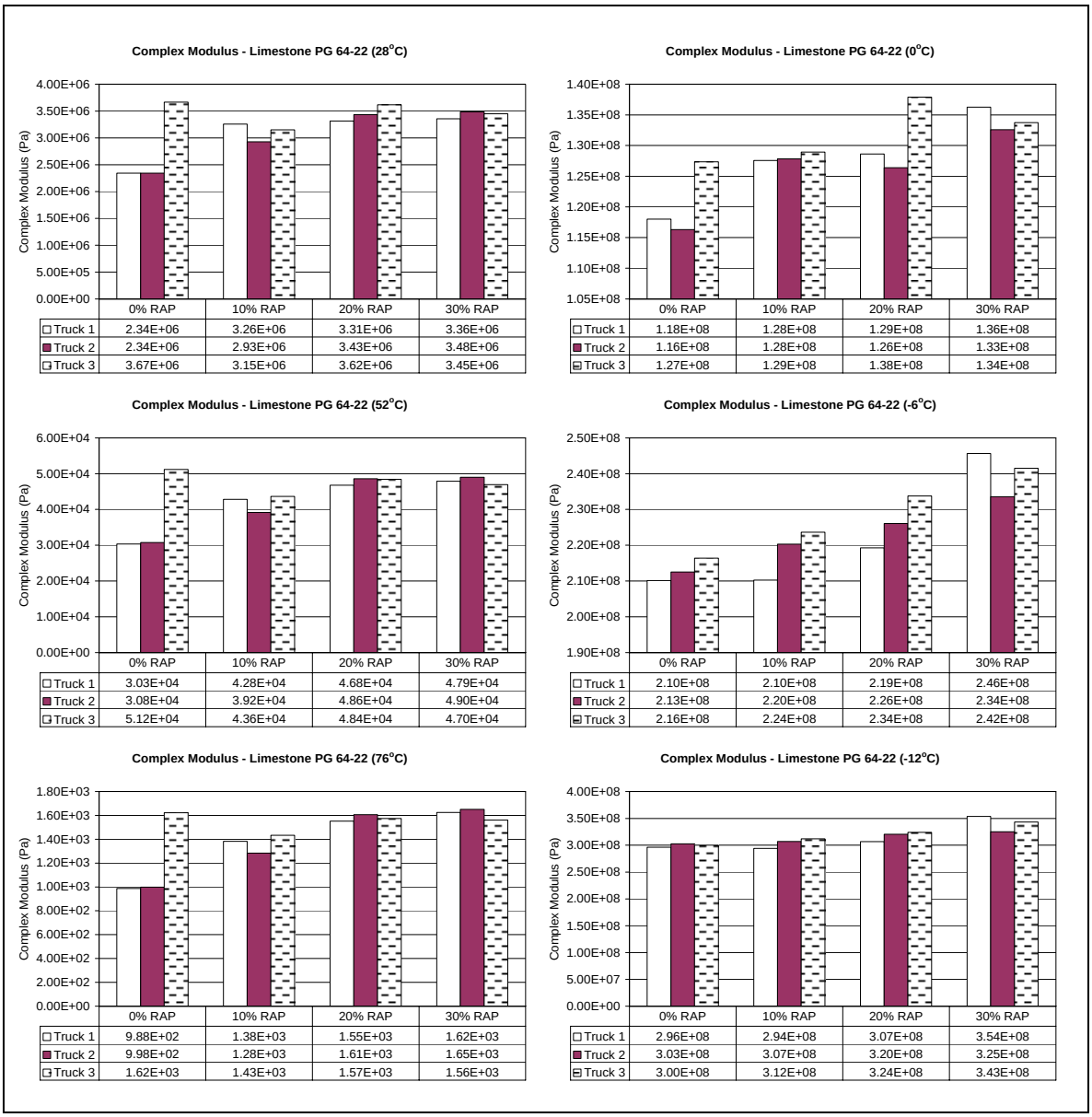


Figure 38. Complex Modulus for the Limestone PG 64-22 Mixtures

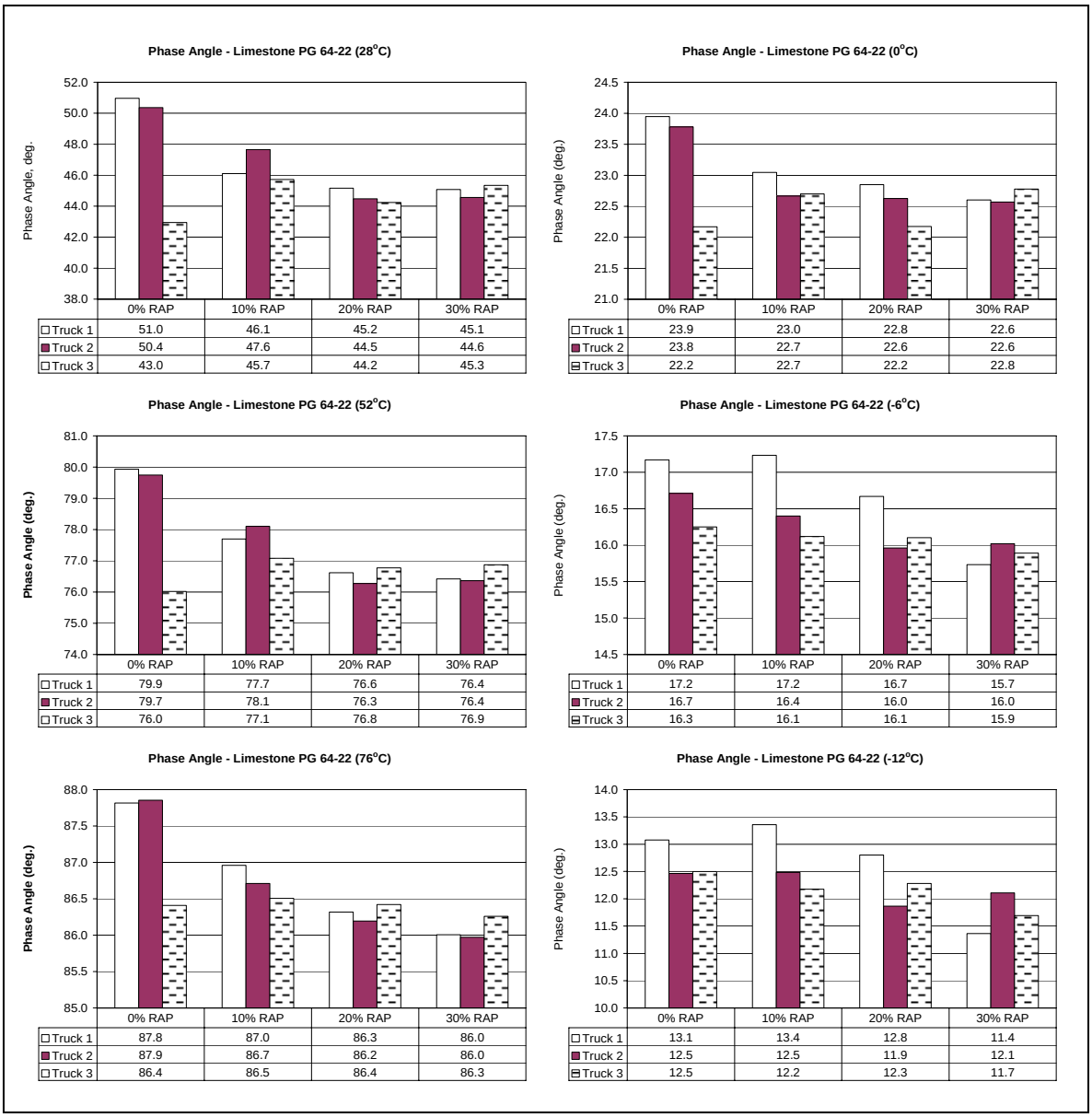


Figure 39. Phase Angle for the Limestone PG 64-22 Mixtures

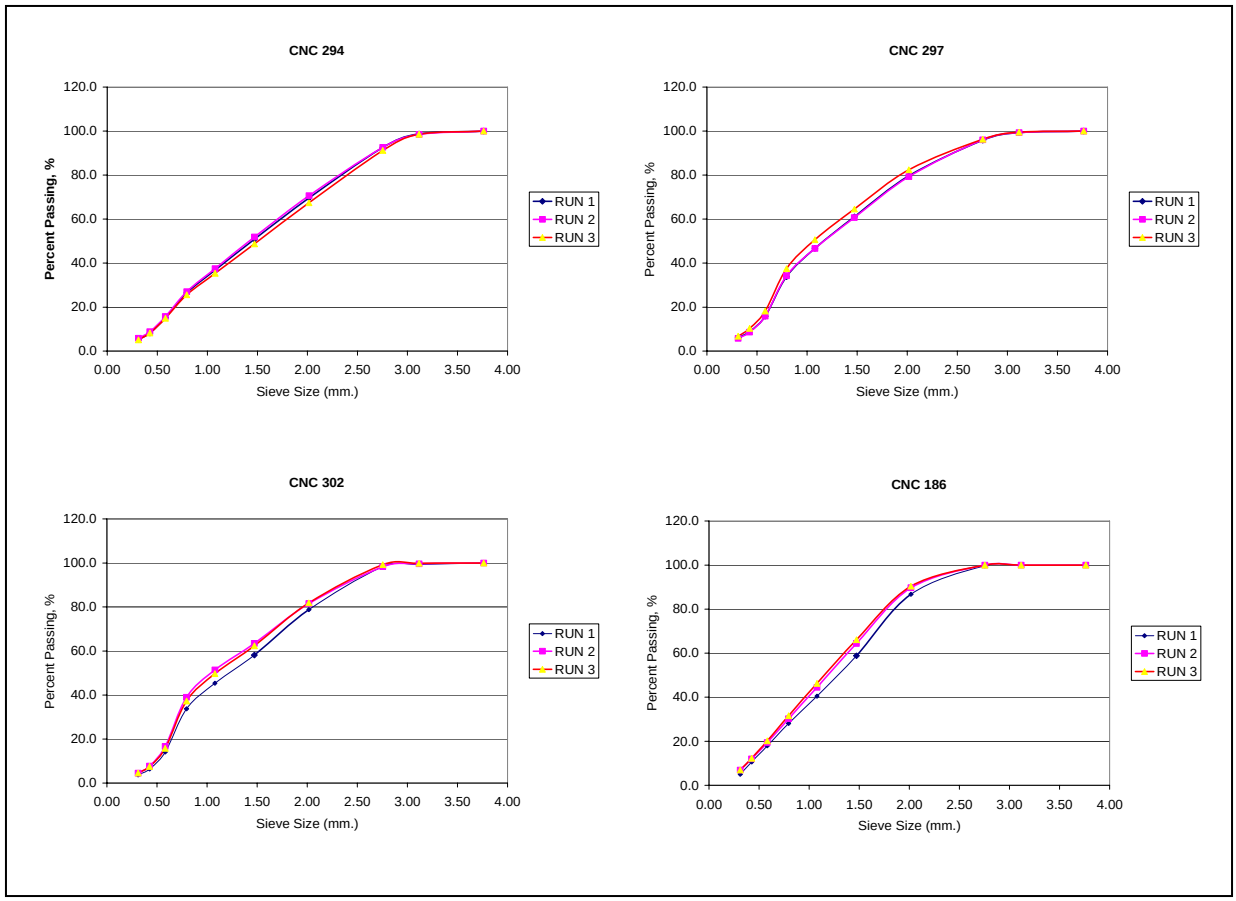


Figure 40. Gradation Analysis for the RAP at Different Jobsites

There were no significant gradation differences between the stock piles at each jobsite. Figure 41 presents S.G. and FAA values for the samples collected at three different places of RAP stockpiles. There was no significant difference between the three samples collected at different places of the stockpiles.

The result for the G*sin (δ) is presented in Figure 42. From the results it can be concluded that the RAP was uniform within the stockpiles but not so uniform between the jobsites themselves. The G*sin (δ) was much higher for the CNC 302 jobsite when compared to the other three job sites. There was not significant difference between

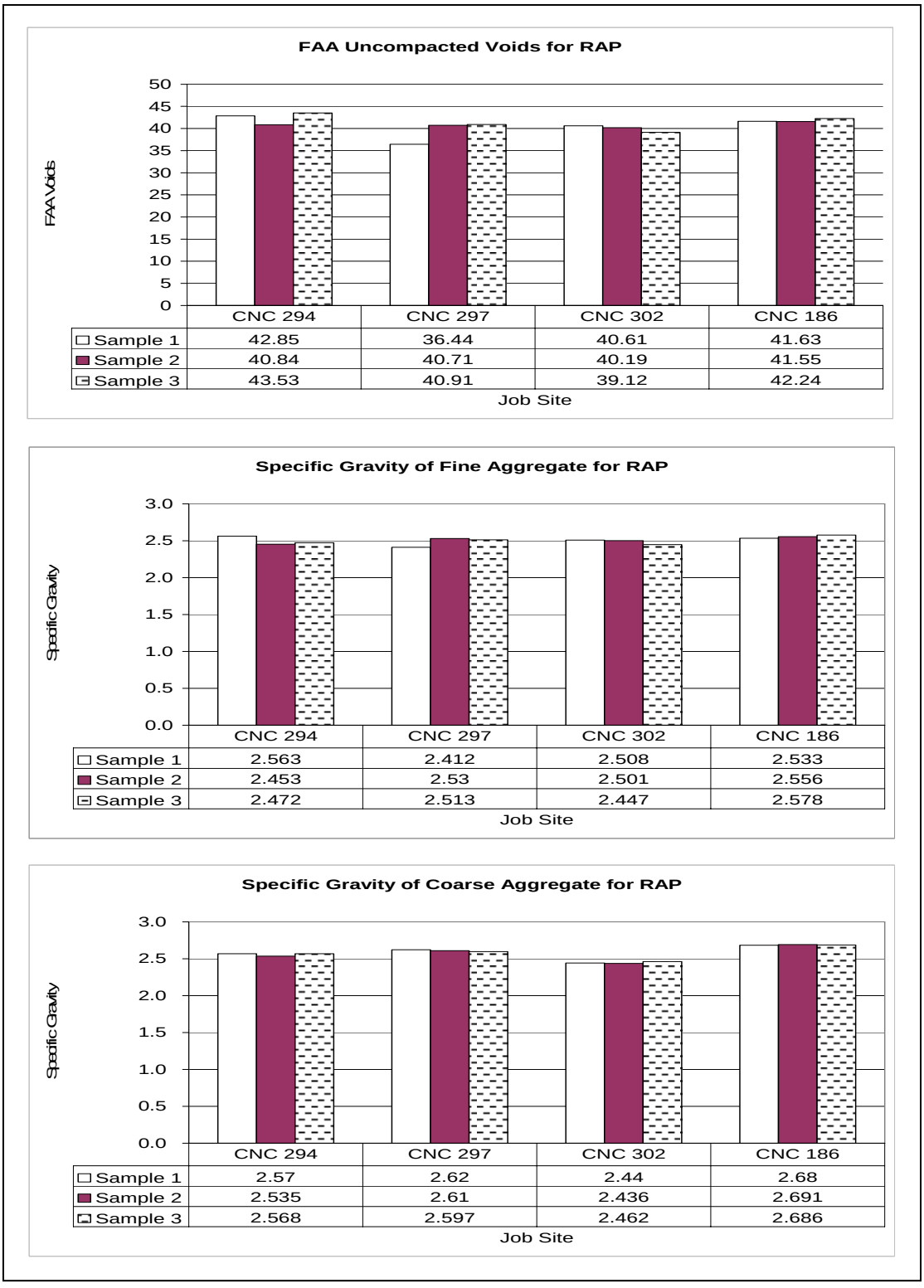


Figure 41. S.G. and FAA for the RAP at Different Jobsites

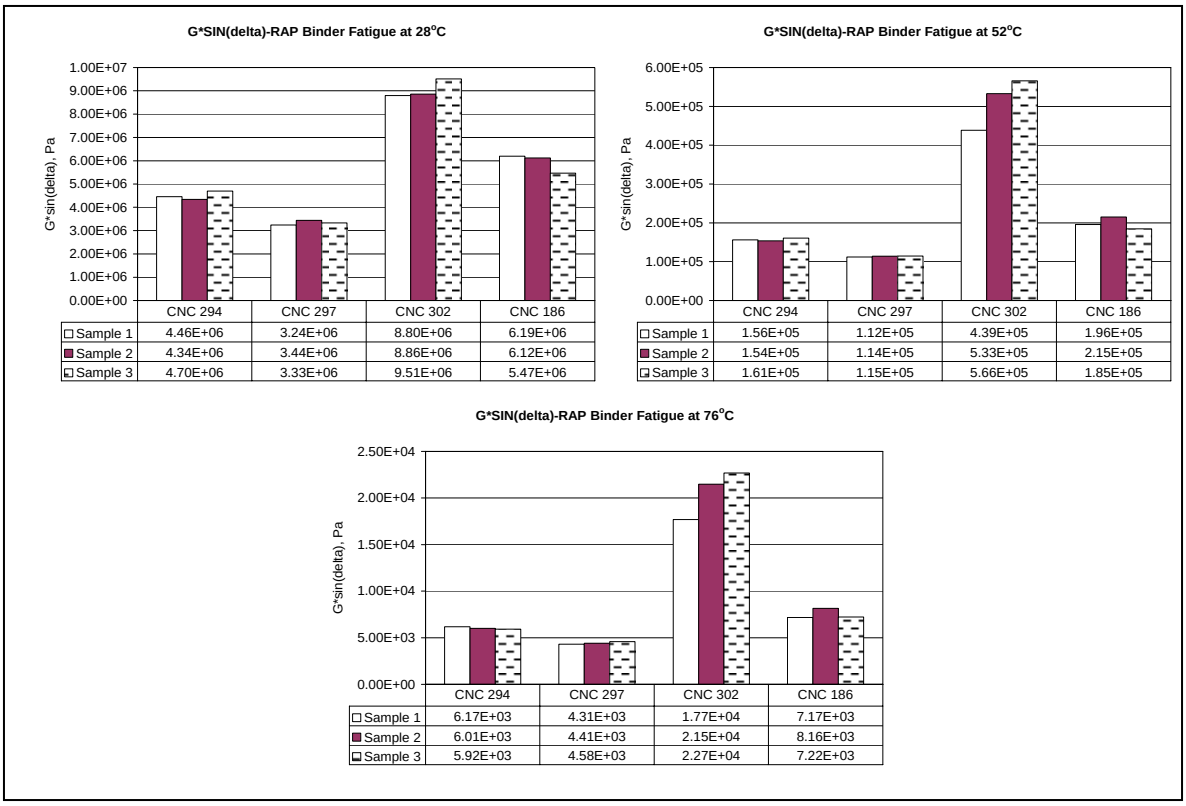


Figure 42. G*sin (delta) for the RAP Material at Different Jobsites

CNC 294 and CNC 297 jobsites. Complex modulus was also evaluated for the RAP mixtures. The results for the complex modulus followed were similar to the results of G*sin (δ).

Figure 43 shows that CNC 302 jobsite resulted in the significantly higher shear modulus when compared to CNC 294, CNC 297, and CNC 186 jobsites. However there was some variation within CNC 302 stockpile itself. Phase angle was also evaluated for the uniformity of RAP. Both jobsites CNC 294 and CNC 297 had similar phase angles. Once again CNC 302 resulted in much smaller phase angle when compared to the other three job sites, Figure 44. CNC 186 showed slightly lower phase angle when compared to CNC 294 and CNC 297.

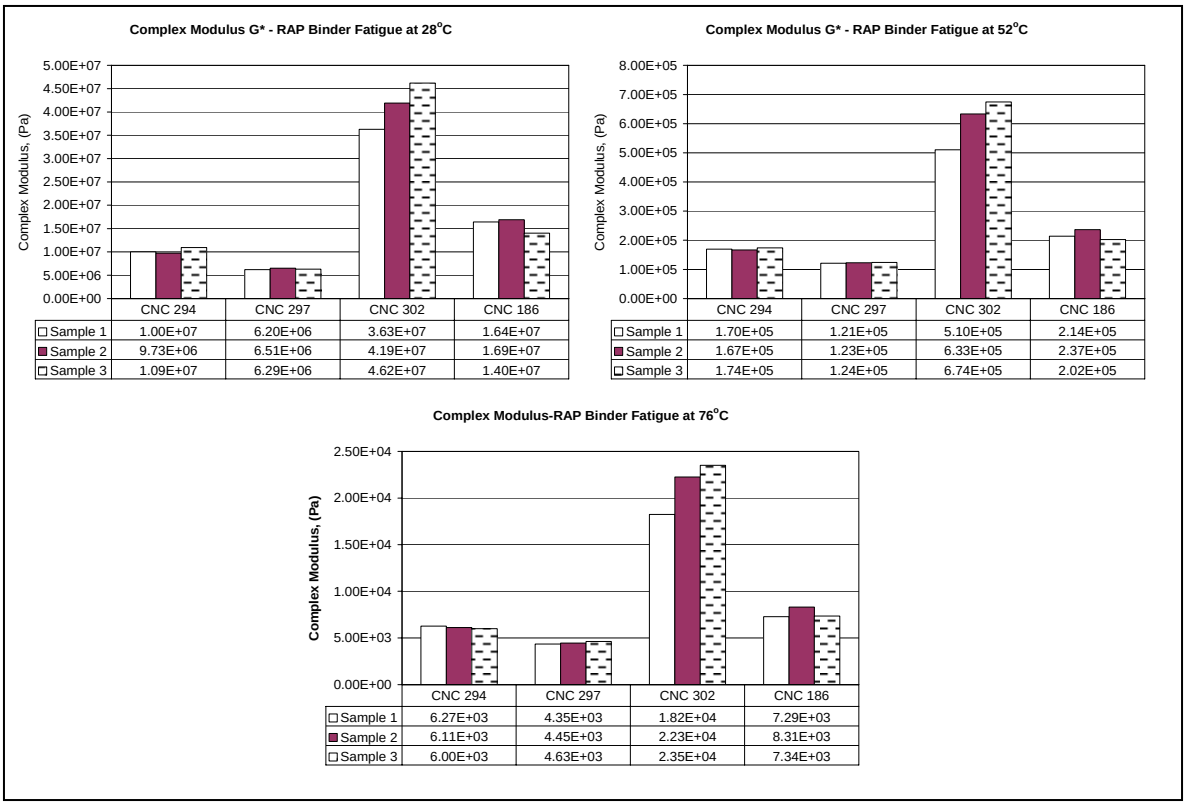


Figure 43. Complex Shear Modulus for RAP Material at Different Jobsites

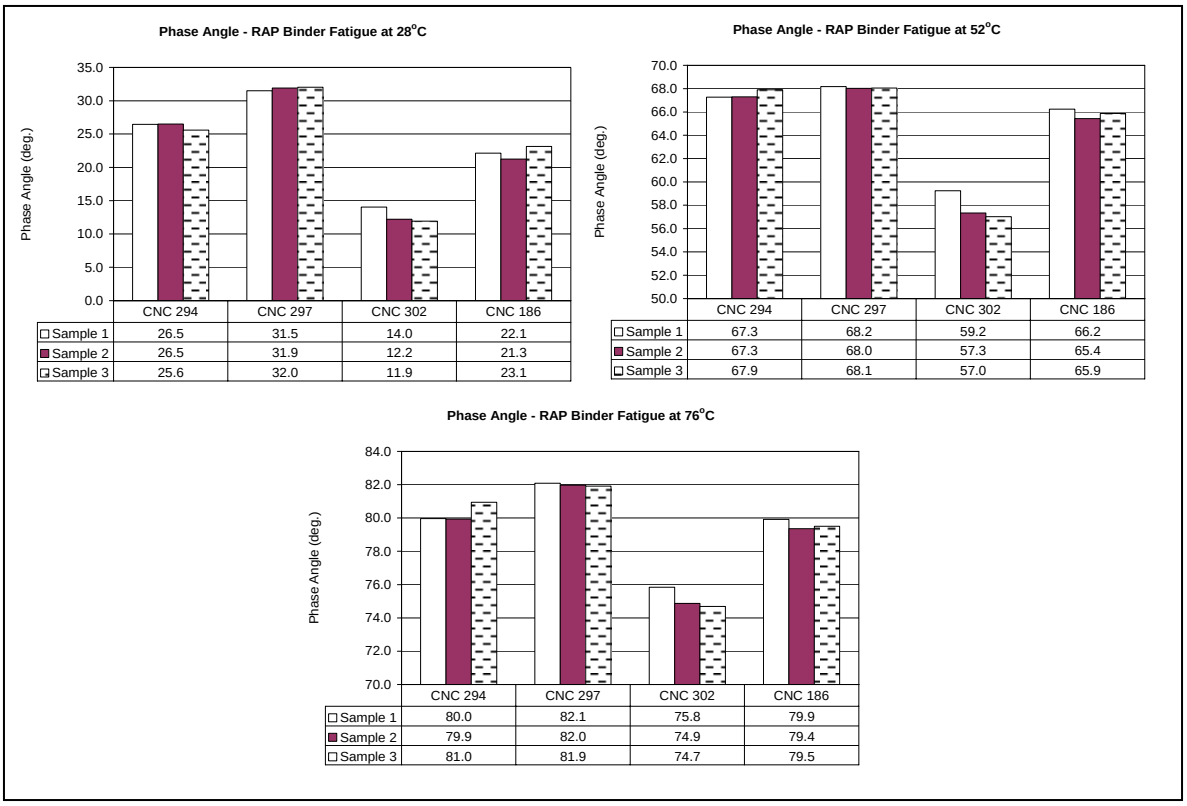


Figure 44. Phase Angle for RAP Material at Different Jobsites

CHAPTER 5
CONCLUSIONS AND RECOMANDATIONS

5.1 Conclusions

The analysis of fatigue characteristics of the Tennessee surface "D" mixtures containing RAP was performed on field mixtures. Four types of mixtures, meeting TDOT "D" mix specifications, were used in this study which consisted of limestone and gravel with three different types of binders (PG 64-22, PG 70-22, and PG 76-22). Each of the mixtures contained four different percentages of RAP (0, 10, 20, and 30 percent). Results from the study show that higher percentages of RAP will influence the fatigue properties of the mixtures studied and lower their performance to resist fatigue cracking. Based on the findings from this study, the following conclusions were made about the effects of RAP material on surface virgin mixes:

1) For limestone mixtures, the inclusion of RAP material increased the tensile strength and decreased the toughness index of the mixtures. Mixtures with higher percentage of RAP became stiffer and more brittle which resulted in decrease of their fatigue life. Generally, long-term aging significantly affected the ITS and post failure characteristics of the limestone mixtures. The long-term aged mixtures experienced higher increase in ITS and lower decrease in diametric strain and toughness index when compared to the short-term aged mixtures. Gravel PG 64-22 mixtures resulted in higher ITS and lower post failure characteristics when compared to the limestone PG 64-22 mixtures. On the other hand, gravel mixtures (PG 70-22) resulted in lower tensile strength and higher post failure characteristics than those of PG 76-22 binder. The inclusion of 30 percent of RAP significantly changed the mixture ITS properties.

Generally, the stiffness of the mixtures increased with inclusion of RAP which in return made mixtures more brittle and therefore decreased their fatigue life. Mixtures containing PG 76-22 and PG 70-22 asphalt binder had higher strengths than PG 64-22 mixtures.

2) Based on M_r and $DSCE_f$ the fatigue life decreased with inclusion of RAP. Mr significantly increased with inclusion of RAP for long-term aged mixtures. This means that the inclusion of RAP significantly increases the stiffness of the mixtures and therefore makes them brittle and prone to fatigue failure. As expected, mixtures with polymer modified binder PG 76-22 experienced higher M_r values than those of PG 64-22. $DSCE_f$ and FE decreased with inclusion of RAP for both mixtures (PG 64-22 and PG 76-22). This means that the mixtures with 0 percent of RAP had higher fatigue life than those with 10, 20, and 30 percent RAP.

3) Similar to the IDT results, the SCB IDT results indicate that inclusion of RAP will increase the tensile strength and decrease the toughness index of the mixtures. Long-term aged mixtures resulted in higher tensile strength and lower post failure characteristics for both limestone and gravel. There was no significant difference between 0 and 10 percent RAP mixtures. However, with inclusion of 20 and 30 percent of RAP significantly increases tensile strength and decreases strain at peak load and toughness indices. With inclusion of 30 percent of RAP gravel mixtures resulted in higher tensile strength and lower post failure characteristics when compared to limestone mixtures. Generally limestone mixtures resulted in higher tensile strength and post failure characteristics when compared to the gravel mixtures.

4) Generally, SCB notched fracture test showed a decrease for mixture resistance to fracture failure for mixtures containing 30 percent of RAP. However 10 and 20 percent showed increase of fracture energy and J-integral for both limestone and gravel mixtures. Mixtures with inclusion of 20 percent of RAP experienced higher fracture J-integral values than those with 10 percent of RAP.

5) The results of the beam fatigue test were analyzed using two methods PV and 50 percent initial stiffness failure criterion. According to the analyzed data using PV seemed to provide more consistent results in ranking the mixtures in this study. RAP had shown to decrease the fatigue life of the mixtures tested. Limestone PG 64-22 mixtures resulted in significantly higher change of fatigue life for mixtures with inclusion of 30 percent of RAP when compared to gravel PG 64-22 mixtures. Both limestone and gravel mixtures with PG 70-22 and PG 76-22 asphalt binder performed better than PG 64-22 mixtures. The inclusion of 30 percent of RAP significantly decreased fatigue properties for both aggregate mixtures used in beam fatigue test. However, when examining the results using the 50 percent initial stiffness failure the mixtures with higher percentages of RAP had shown to perform better than the control\virgin mixture. This method of evaluating the results indicates that more RAP is better since it increases the fatigue life properties for all mixtures tested in this study. Mixtures with PG 76-22 and PG 70-22 asphalt binder performed better than PG 64-22 mixtures. Generally, based on 50 percent initial stiffness failure 30 percent of RAP significantly increased the fatigue properties for both aggregate mixtures used in the beam fatigue test.

6) Uniformity of the RAP material was analyzed through aggregate and binder testing. Sieve analysis, specific gravities, and FAA laboratory tests were performed on

recovered aggregate material to determine its uniformity. All of these tests indicated that the RAP aggregate is very uniform within stockpiles themselves as well as between stockpiles of each jobsite used for this study. However binder analysis has shown some non-uniformity between the jobsites. CNC 302 jobsite resulted in significantly stiffer binder material when compared to the other three jobsites. Jobsites CNC 294 and CNC 297 had somewhat similar results while CNC 186 jobsite resulted in noticeably stiffer asphalt binder.

7) Limestone PG 64-22 mixture was analyzed for uniformity between the truck loads at same RAP percentages. Sieve analysis, specific gravity, and FAA did not show any significant difference between the truckloads. However the sieve analysis for virgin mixtures showed some deviation for first truck when compared to the other two trucks. Asphalt binder was also analyzed for all of the trucks at each RAP percentage for its uniformity. All of the trucks at different percents of RAP were uniform except truck 1 at 0 percent of RAP which had shown increase in stiffness of the binder. The reason for this could have been that the binder was either over aged in the lab during extraction and recovery or the mixture was over aged at the plant prior to loading of the truck.

5.2 Recommendations

All of the results presented in this study were done on laboratory prepared field mixture samples. The fatigue tests used for this study indicated that the fatigue life will decrease with inclusion of RAP. The inclusion of 30 percent of RAP significantly decreased the fatigue life and mixture performance of the mixtures studied. The results from most fatigue tests used in this study indicate that 20 percent of screened RAP

material would not compromise the mixture properties and therefore would be recommended for use in TDOT surface “D” mixtures.

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APPENDICES

APPENDIX A: JOB MIX FORMULAS

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

01/10/03

Project Ref. No.	0% RAP Limestone PG 64-22	**Date**	07/16/2002
Project No.		**Region**	
Contract No.		**County**	
Contractor		**Date of Letting**	
State Route No.		**Roadway Surface**	
Hot-mix Producer			

Type ACS-HM **Mix** 411-D PG 64-22 **Item**

Serial No.:	Design No.:

Material	Size or Grade	Producer and Location	Percent Used
D Rock(Limestone)	Coarse Aggregate	Vulcan Materials Co.	47.500
#10 (Soft)	Screenings	Vulcan Materials Co.	14.250
Natural Sand	Natural Sand	Ingram	23.750
Manufactured Sand	Manufactured Sand	Vulcan Materials Co.	9.500
RAP	RAP		
Asphalt Cement	PG 64-22		5.000

Percent AC in RAP:	5.5	**Optimum AC Content:**		5.0	**Total**	100.000
Anti-Strip Additive:					**Dosage:**	
AC Contribution:	**Virgin AC**	5.00	**RAP AC**		**Percent Virgin AC:**	100.0
Asphalt Sp. Gravity:		1.03		**Dust to Asphalt Ratio:**		0.81

% Fracture Face on CA:	N/A	**% Glassy Particles on CA:**	N/A
Gravity of RAP Agg:		**Eff. Gravity of Agg:**	2.650

Theo. Gravity:	2.457	**T.S.R.:**		**Lbs/Ft^3:**	153.3
L.O.I.:	#VALUE!			**Ignition Oven Corr. Factor:**	N/A
ADT	**Log Miles**	**Beginning:**		**Ending:**	

Mixing Temp Range(°F):	**Compaction Temp Range(°F):**
Mixing Temperature(°F):	**Compaction Temperature(°F):**

	Percents Used								
Sieve	**D Rock(Limestone)**	**#10 (Soft)**	**Natural Sand**	**Manufactured Sand**			**RAP**	**% Req.**	**Design**
Size	50.0	15.0	25.0	10.0				**100**	**Range**
2"	100	100	100	100				**100**	**100**
1.5"	100	100	100	100				**100**	**100**
1.25"									**100**
1"	100	100	100	100				**100**	**100**
3/4"	100	100	100	100				**100**	**100**
5/8"	100	100	100	100				**100**	**100**
1/2"	97	100	100	100				**99**	**95-100**
3/8"	70	100	100	100				**85**	**80-93**
No.4	21	92	98	99				**59**	**54-76**
No.8	7	61	93	82				**44**	**35-57**
No.16									
No.30	4	29	63	28				**25**	**17-29**
No.50	3	21	13	17				**10**	**10-18**
No.100	2.0	20.0	2.0	9.0				**5.4**	**3-10**
No.200	1.8	16.0	1.0	5.0				**4.1**	**0-6.5**

Requested: _____ Contractor Personnel and Lab Tech Cert No.

Approved: _____ Regional Materials and Tests Supervisor

Approved: _____ Regional Construction Supervisor

Approved: _____ Headquarters Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

01/10/03

Project Ref. No.	10% RAP Limestone PG 64-22	**Date**	07/16/2002
Project No.		**Region**	
Contract No.		**County**	
Contractor		**Date of Letting**	
State Route No.		**Roadway Surface**	
Hot-mix Producer			

Type ACS-HM **Mix** 411-D PG 64-22 **Item**

Serial No.:	Design No.:

Material	Size or Grade	Producer and Location	Percent Used
D Rock(Limestone)	Coarse Aggregate	Vulcan Materials Co.	47.500
#10 (Soft)	Screenings	Vulcan Materials Co.	9.500
Natural Sand	Natural Sand	Ingram	19.000
Manufactured Sand	Manufactured Sand	Vulcan Materials Co.	9.500
RAP	RAP		10.053
Asphalt Cement	PG 64-22		4.447

Percent AC in RAP:	5.5	**Optimum AC Content:**		5.0	**Total**	100.000
Anti-Strip Additive:					**Dosage:**	
AC Contribution:	**Virgin AC**	4.45	**RAP AC**	0.55	**Percent Virgin AC:**	88.9
Asphalt Sp. Gravity:		1.03			**Dust to Asphalt Ratio:**	1.03

% Fracture Face on CA:	N/A	**% Glassy Particles on CA:**	N/A
Gravity of RAP Agg:		**Eff. Gravity of Agg:**	2.645

Theo. Gravity:	2.453	**T.S.R.:**		**Lbs/Ft^3:**	153.1
L.O.I.:	#VALUE!			**Ignition Oven Corr. Factor:**	N/A
ADT	**Log Miles**	**Beginning:**		**Ending:**	

Mixing Temp Range(°F):	**Compaction Temp Range(°F):**
Mixing Temperature(°F):	**Compaction Temperature(°F):**

	Percents Used								
Sieve	**D Rock(Limestone)**	**#10 (Soft)**	**Natural Sand**	**Manufactured Sand**			**RAP**	**% Req.**	**Design**
Size	50.0	10.0	20.0	10.0			10.0	**100**	**Range**
2"	100	100	100	100			100	**100**	**100**
1.5"	100	100	100	100			100	**100**	**100**
1.25"									**100**
1"	100	100	100	100			100	**100**	**100**
3/4"	100	100	100	100			100	**100**	**100**
5/8"	100	100	100	100			100	**100**	**100**
1/2"	97	100	100	100			100	**99**	**95-100**
3/8"	70	100	100	100			100	**85**	**80-93**
No.4	21	92	98	99			100	**59**	**54-76**
No.8	7	61	93	82			81	**44**	**35-57**
No.16									
No.30	4	29	63	28			46	**25**	**17-29**
No.50	3	21	13	17			30	**11**	**10-18**
No.100	2.0	20.0	2.0	9.0			23.2	**6.6**	**3-10**
No.200	1.8	16.0	1.0	5.0			19.3	**5.1**	**0-6.5**

Requested: _____ Contractor Personnel and Lab Tech Cert No.

Approved: _____ Regional Materials and Tests Supervisor

Approved: _____ Regional Construction Supervisor

Approved: _____ Headquarters Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

01/10/03

Project Ref. No.	20% RAP Limestone PG 64-22	**Date**	07/16/2002
Project No.		**Region**	
Contract No.		**County**	
Contractor		**Date of Letting**	
State Route No.		**Roadway Surface**	
Hot-mix Producer			

Type ACS-HM **Mix** 411-D PG 64-22 **Item**

Serial No.:	Design No.:

Material	Size or Grade	Producer and Location	Percent Used
D Rock(Limestone)	Coarse Aggregate	Vulcan Materials Co.	47.500
#10 (Soft)	Screenings	Vulcan Materials Co.	
Natural Sand	Natural Sand	Ingram	19.000
Manufactured Sand	Manufactured Sand	Vulcan Materials Co.	9.500
RAP	RAP		20.106
Asphalt Cement	PG 64-22		3.894

Percent AC in RAP:	5.5	**Optimum AC Content:**		5.0	**Total**	100.000
Anti-Strip Additive:					**Dosage:**	
AC Contribution:	**Virgin AC**	3.89	**RAP AC**	1.11	**Percent Virgin AC:**	77.9
Asphalt Sp. Gravity:		1.03			**Dust to Asphalt Ratio:**	1.09

% Fracture Face on CA:	N/A	**% Glassy Particles on CA:**	N/A
Gravity of RAP Agg:		**Eff. Gravity of Agg:**	2.656

Theo. Gravity:	2.462	**T.S.R.:**		**Lbs/Ft^3:**	153.6
L.O.I.:	#VALUE!			**Ignition Oven Corr. Factor:**	N/A
ADT	**Log Miles**	**Beginning:**		**Ending:**	

Mixing Temp Range(°F):	**Compaction Temp Range(°F):**
Mixing Temperature(°F):	**Compaction Temperature(°F):**

	Percents Used								
Sieve	**D Rock(Limestone)**	**#10 (Soft)**	**Natural Sand**	**Manufactured Sand**			**RAP**	**% Req.**	**Design**
Size	50.0		20.0	10.0			20.0	**100**	**Range**
2"	100		100	100			100	**100**	**100**
1.5"	100		100	100			100	**100**	**100**
1.25"									**100**
1"	100		100	100			100	**100**	**100**
3/4"	100		100	100			100	**100**	**100**
5/8"	100		100	100			100	**100**	**100**
1/2"	97		100	100			100	**99**	**95-100**
3/8"	70		100	100			100	**85**	**80-93**
No.4	21		98	99			100	**60**	**54-76**
No.8	7		93	82			81	**46**	**35-57**
No.16									
No.30	4		63	28			46	**27**	**17-29**
No.50	3		13	17			30	**12**	**10-18**
No.100	2.0		2.0	9.0			23.2	**6.9**	**3-10**
No.200	1.8		1.0	5.0			19.3	**5.5**	**0-6.5**

Requested: _____ Contractor Personnel and Lab Tech Cert No.

Approved: _____ Regional Materials and Tests Supervisor

Approved: _____ Regional Construction Supervisor

Approved: _____ Headquarters Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

01/10/03

Project Ref. No.	30% RAP Limestone PG 64-22	**Date**	07/16/2002
Project No.		**Region**	
Contract No.		**County**	
Contractor		**Date of Letting**	
State Route No.		**Roadway Surface**	
Hot-mix Producer			

Type ACS-HM **Mix** 411-D PG 64-22 **Item**

Serial No.:	Design No.:

Material	Size or Grade	Producer and Location	Percent Used
D Rock(Limestone)	Coarse Aggregate	Vulcan Materials Co.	47.500
#10 (Soft)	Screenings	Vulcan Materials Co.	
Natural Sand	Natural Sand	Ingram	9.500
Manufactured Sand	Manufactured Sand	Vulcan Materials Co.	9.500
RAP	RAP		30.159
Asphalt Cement	PG 64-22		3.341

Percent AC in RAP:	5.5	**Optimum AC Content:**		5.0	**Total**	100.000
Anti-Strip Additive:					**Dosage:**	
AC Contribution:	**Virgin AC**	3.34	**RAP AC**	1.66	**Percent Virgin AC:**	66.8
Asphalt Sp. Gravity:		1.03			**Dust to Asphalt Ratio:**	1.46

% Fracture Face on CA:	N/A	**% Glassy Particles on CA:**	N/A
Gravity of RAP Agg:		**Eff. Gravity of Agg:**	2.664

Theo. Gravity:	2.468	**T.S.R.:**		**Lbs/Ft^3:**	154.0
L.O.I.:	#VALUE!			**Ignition Oven Corr. Factor:**	N/A
ADT	**Log Miles**	**Beginning:**		**Ending:**	

Mixing Temp Range(°F):	**Compaction Temp Range(°F):**
Mixing Temperature(°F):	**Compaction Temperature(°F):**

	Percents Used								
Sieve	**D Rock(Limestone)**	**#10 (Soft)**	**Natural Sand**	**Manufactured Sand**			**RAP**	**% Req.**	**Design**
Size	50.0		10.0	10.0			30.0	**100**	**Range**
2"	100		100	100			100	**100**	**100**
1.5"	100		100	100			100	**100**	**100**
1.25"									**100**
1"	100		100	100			100	**100**	**100**
3/4"	100		100	100			100	**100**	**100**
5/8"	100		100	100			100	**100**	**100**
1/2"	97		100	100			100	**99**	**95-100**
3/8"	70		100	100			100	**85**	**80-93**
No.4	21		98	99			100	**60**	**54-76**
No.8	7		93	82			81	**45**	**35-57**
No.16									
No.30	4		63	28			46	**25**	**17-29**
No.50	3		13	17			30	**14**	**10-18**
No.100	2.0		2.0	9.0			23.2	**9.1**	**3-10**
No.200	1.8		1.0	5.0			19.3	**7.3**	**0-6.5**

Requested: _____ **Approved:** _____
Contractor Personnel and Lab Tech Cert No. Regional Materials and Tests Supervisor

Approved: _____ **Approved:** _____
Regional Construction Supervisor Headquarters Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

01/10/03

Project Ref. No.	0% RAP Limestone PG 76-22	**Date**	07/16/2002
Project No.		**Region**	
Contract No.		**County**	
Contractor		**Date of Letting**	
State Route No.		**Roadway Surface**	
Hot-mix Producer			

Type ACS-HM **Mix** 411-D PG 76-22 **Item**

Serial No.:	Design No.:

Material	Size or Grade	Producer and Location	Percent Used
D Rock(Limestone)	Coarse Aggregate	Vulcan Materials Co.	47.500
#10 (Soft)	Screenings	Vulcan Materials Co.	14.250
Natural Sand	Natural Sand	Ingram	23.750
Manufactured Sand	Manufactured Sand	Vulcan Materials Co.	9.500
RAP	RAP		
Asphalt Cement	PG 76-22		5.000

Percent AC in RAP:	5.5	**Optimum AC Content:**		5.0	**Total**	100.000
Anti-Strip Additive:					**Dosage:**	
AC Contribution:	**Virgin AC**	5.00	**RAP AC**		**Percent Virgin AC:**	100.0
Asphalt Sp. Gravity:		1.03		**Dust to Asphalt Ratio:**		0.81

% Fracture Face on CA:	N/A	**% Glassy Particles on CA:**	N/A
Gravity of RAP Agg:		**Eff. Gravity of Agg:**	2.648

Theo. Gravity:	2.455	**T.S.R.:**		**Lbs/Ft^3:**	153.2
L.O.I.:	#VALUE!			**Ignition Oven Corr. Factor:**	N/A
ADT	**Log Miles**	**Beginning:**		**Ending:**	

Mixing Temp Range(°F):	**Compaction Temp Range(°F):**
Mixing Temperature(°F):	**Compaction Temperature(°F):**

	Percents Used								
Sieve	**D Rock(Limestone)**	**#10 (Soft)**	**Natural Sand**	**Manufactured Sand**			**RAP**	**% Req.**	**Design**
Size	50.0	15.0	25.0	10.0				**100**	**Range**
2"	100	100	100	100				**100**	**100**
1.5"	100	100	100	100				**100**	**100**
1.25"									**100**
1"	100	100	100	100				**100**	**100**
3/4"	100	100	100	100				**100**	**100**
5/8"	100	100	100	100				**100**	**100**
1/2"	97	100	100	100				**99**	**95-100**
3/8"	70	100	100	100				**85**	**80-93**
No.4	21	92	98	99				**59**	**54-76**
No.8	7	61	93	82				**44**	**35-57**
No.16									
No.30	4	29	63	28				**25**	**17-29**
No.50	3	21	13	17				**10**	**10-18**
No.100	2.0	20.0	2.0	9.0				**5.4**	**3-10**
No.200	1.8	16.0	1.0	5.0				**4.1**	**0-6.5**

Requested: _____ **Approved:** _____
Contractor Personnel and Lab Tech Cert No. Regional Materials and Tests Supervisor

Approved: _____ **Approved:** _____
Regional Construction Supervisor Headquarters Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

01/10/03

Project Ref. No.	10% RAP Limestone PG 76-22	**Date**	07/16/2002
Project No.		**Region**	
Contract No.		**County**	
Contractor		**Date of Letting**	
State Route No.		**Roadway Surface**	
Hot-mix Producer			

Type ACS-HM **Mix** 411-D PG 76-22 **Item**

Serial No.:	Design No.:

Material	Size or Grade	Producer and Location	Percent Used
D Rock(Limestone)	Coarse Aggregate	Vulcan Materials Co.	47.500
#10 (Soft)	Screenings	Vulcan Materials Co.	9.500
Natural Sand	Natural Sand	Ingram	19.000
Manufactured Sand	Manufactured Sand	Vulcan Materials Co.	9.500
RAP	RAP		10.053
Asphalt Cement	PG 76-22		4.447

Percent AC in RAP:	5.5	**Optimum AC Content:**		5.0	**Total**	100.000
Anti-Strip Additive:					**Dosage:**	
AC Contribution:	**Virgin AC**	4.45	**RAP AC**	0.55	**Percent Virgin AC:**	88.9
Asphalt Sp. Gravity:		1.03			**Dust to Asphalt Ratio:**	1.03

% Fracture Face on CA:	N/A	**% Glassy Particles on CA:**	N/A
Gravity of RAP Agg:		**Eff. Gravity of Agg:**	2.645

Theo. Gravity:	2.453	**T.S.R.:**		**Lbs/Ft^3:**	153.1
L.O.I.:	#VALUE!			**Ignition Oven Corr. Factor:**	N/A
ADT	**Log Miles**	**Beginning:**		**Ending:**	

Mixing Temp Range(°F):	**Compaction Temp Range(°F):**
Mixing Temperature(°F):	**Compaction Temperature(°F):**

	Percents Used								
Sieve	**D Rock(Limestone)**	**#10 (Soft)**	**Natural Sand**	**Manufactured Sand**			**RAP**	**% Req.**	**Design**
Size	50.0	10.0	20.0	10.0			10.0	**100**	**Range**
2"	100	100	100	100			100	**100**	**100**
1.5"	100	100	100	100			100	**100**	**100**
1.25"									**100**
1"	100	100	100	100			100	**100**	**100**
3/4"	100	100	100	100			100	**100**	**100**
5/8"	100	100	100	100			100	**100**	**100**
1/2"	97	100	100	100			100	**99**	**95-100**
3/8"	70	100	100	100			100	**85**	**80-93**
No.4	21	92	98	99			100	**59**	**54-76**
No.8	7	61	93	82			81	**44**	**35-57**
No.16									
No.30	4	29	63	28			46	**25**	**17-29**
No.50	3	21	13	17			30	**11**	**10-18**
No.100	2.0	20.0	2.0	9.0			23.2	**6.6**	**3-10**
No.200	1.8	16.0	1.0	5.0			19.3	**5.1**	**0-6.5**

Requested: _____ Contractor Personnel and Lab Tech Cert No.

Approved: _____ Regional Materials and Tests Supervisor

Approved: _____ Regional Construction Supervisor

Approved: _____ Headquarters Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

01/10/03

Project Ref. No.	20% RAP Limestone PG 76-22	**Date**	07/16/2002
Project No.		**Region**	
Contract No.		**County**	
Contractor		**Date of Letting**	
State Route No.		**Roadway Surface**	
Hot-mix Producer			

Type ACS-HM **Mix** 411-D PG 76-22 **Item**

Serial No.:	Design No.:

Material	Size or Grade	Producer and Location	Percent Used
D Rock(Limestone)	Coarse Aggregate	Vulcan Materials Co.	47.500
#10 (Soft)	Screenings	Vulcan Materials Co.	
Natural Sand	Natural Sand	Ingram	19.000
Manufactured Sand	Manufactured Sand	Vulcan Materials Co.	9.500
RAP	RAP		20.106
Asphalt Cement	PG 76-22		3.894

Percent AC in RAP:	5.5	**Optimum AC Content:**		5.0	**Total**	100.000
Anti-Strip Additive:					**Dosage:**	
AC Contribution:	**Virgin AC**	3.89	**RAP AC**	1.11	**Percent Virgin AC:**	77.9
Asphalt Sp. Gravity:		1.03		**Dust to Asphalt Ratio:**		1.09

% Fracture Face on CA:	N/A	**% Glassy Particles on CA:**	N/A
Gravity of RAP Agg:		**Eff. Gravity of Agg:**	2.656

Theo. Gravity:	2.462	**T.S.R.:**		**Lbs/Ft^3:**	153.6
L.O.I.:	#VALUE!			**Ignition Oven Corr. Factor:**	N/A
ADT	**Log Miles**	**Beginning:**		**Ending:**	

Mixing Temp Range(°F):	**Compaction Temp Range(°F):**
Mixing Temperature(°F):	**Compaction Temperature(°F):**

	Percents Used								
Sieve	**D Rock(Limestone)**	**#10 (Soft)**	**Natural Sand**	**Manufactured Sand**			**RAP**	**% Req.**	**Design**
Size	50.0		20.0	10.0			20.0	**100**	**Range**
2"	100		100	100			100	**100**	**100**
1.5"	100		100	100			100	**100**	**100**
1.25"									**100**
1"	100		100	100			100	**100**	**100**
3/4"	100		100	100			100	**100**	**100**
5/8"	100		100	100			100	**100**	**100**
1/2"	97		100	100			100	**99**	**95-100**
3/8"	70		100	100			100	**85**	**80-93**
No.4	21		98	99			100	**60**	**54-76**
No.8	7		93	82			81	**46**	**35-57**
No.16									
No.30	4		63	28			46	**27**	**17-29**
No.50	3		13	17			30	**12**	**10-18**
No.100	2.0		2.0	9.0			23.2	**6.9**	**3-10**
No.200	1.8		1.0	5.0			19.3	**5.5**	**0-6.5**

Requested: _____ Contractor Personnel and Lab Tech Cert No.

Approved: _____ Regional Materials and Tests Supervisor

Approved: _____ Regional Construction Supervisor

Approved: _____ Headquarters Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

01/10/03

Project Ref. No.	30% RAP Limestone PG 76-22	**Date**	07/16/2002
Project No.		**Region**	
Contract No.		**County**	
Contractor		**Date of Letting**	
State Route No.		**Roadway Surface**	
Hot-mix Producer			

Type ACS-HM **Mix** 411-D PG 76-22 **Item**

Serial No.:	Design No.:

Material	Size or Grade	Producer and Location	Percent Used
D Rock(Limestone)	Coarse Aggregate	Vulcan Materials Co.	47.500
#10 (Soft)	Screenings	Vulcan Materials Co.	
Natural Sand	Natural Sand	Ingram	9.500
Manufactured Sand	Manufactured Sand	Vulcan Materials Co.	9.500
RAP	RAP		30.159
Asphalt Cement	PG 76-22		3.341

Percent AC in RAP:	5.5	**Optimum AC Content:**		5.0	**Total**	100.000
Anti-Strip Additive:					**Dosage:**	
AC Contribution:	**Virgin AC**	3.34	**RAP AC**	1.66	**Percent Virgin AC:**	66.8
Asphalt Sp. Gravity:		1.03			**Dust to Asphalt Ratio:**	1.46

% Fracture Face on CA:	N/A	**% Glassy Particles on CA:**	N/A
Gravity of RAP Agg:		**Eff. Gravity of Agg:**	2.664

Theo. Gravity:	2.468	**T.S.R.:**		**Lbs/Ft^3:**	154.0
L.O.I.:	#VALUE!			**Ignition Oven Corr. Factor:**	N/A
ADT	**Log Miles**	**Beginning:**		**Ending:**	

Mixing Temp Range(°F):	**Compaction Temp Range(°F):**
Mixing Temperature(°F):	**Compaction Temperature(°F):**

	Percents Used								
Sieve	**D Rock(Limestone)**	**#10 (Soft)**	**Natural Sand**	**Manufactured Sand**			**RAP**	**% Req.**	**Design**
Size	50.0		10.0	10.0			30.0	**100**	**Range**
2"	100		100	100			100	**100**	**100**
1.5"	100		100	100			100	**100**	**100**
1.25"									**100**
1"	100		100	100			100	**100**	**100**
3/4"	100		100	100			100	**100**	**100**
5/8"	100		100	100			100	**100**	**100**
1/2"	97		100	100			100	**99**	**95-100**
3/8"	70		100	100			100	**85**	**80-93**
No.4	21		98	99			100	**60**	**54-76**
No.8	7		93	82			81	**45**	**35-57**
No.16									
No.30	4		63	28			46	**25**	**17-29**
No.50	3		13	17			30	**14**	**10-18**
No.100	2.0		2.0	9.0			23.2	**9.1**	**3-10**
No.200	1.8		1.0	5.0			19.3	**7.3**	**0-6.5**

Requested: _____ **Approved:** _____
Contractor Personnel and Lab Tech Cert No. Regional Materials and Tests Supervisor

Approved: _____ **Approved:** _____
Regional Construction Supervisor Headquarters Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

1/22/2003(r4)

Project Ref. No.	0% RAP Gravel PG 64-22	**Date**	11/03/2003
Project No.		**Region**	
Contract No.		**County**	
Contractor		**Date of Letting**	
State Route No.		**Roadway Surface**	
Hot-mix Producer			

Type ACS-HM **Mix** 411-D PG 64-22 **Item**

Serial No.:	Design No.:

Material	Size or Grade	Producer and Location	Percent Used
D Rock(Gravel)	Coarse Aggregate	Standard Const. Frank Road	51.810
Ag. Lime	Ag. Lime	Vulcan Mtl. Savannah, TN.	9.420
#10 (Soft)	Screenings	Vulcan Mtl. Savannah, TN.	9.420
Natural Sand	Natural Sand	Standard Const. Frank Road	23.550
RAP	RAP		
Asphalt Cement	PG 64-22	MARATHON ASHLAND, KNOXVILLE	5.800

Percent AC in RAP:	5.8	**Optimum AC Content:**		5.8	**Total**	100.000
Anti-Strip Additive:					**Dosage:**	0.3%
AC Contribution:	**Virgin AC**	5.80	**RAP AC**		**Percent Virgin AC:**	100.0
Asphalt Sp. Gravity:		1.03			**Dust to Asphalt Ratio:**	1.02

% Fracture Face on CA:	80.4	**% Glassy Particles on CA:**	N/A
Gravity of RAP Agg:		**Eff. Gravity of Agg:**	2.573

Theo. Gravity:	2.367	**T.S.R.:**	90.0	**Lbs/Ft^3:**	147.7
L.O.I.:	8.0			**Ignition Oven Corr. Factor:**	0.55
ADT	**Log Miles**	**Beginning:**		**Ending:**	

Mixing Temp Range(°F):	310-350	**Compaction Temp Range(°F):**	290-330
Mixing Temperature(°F):	330	**Compaction Temperature(°F):**	310

	Percents Used								
Sieve	**D Rock(Gravel)**	**Ag. Lime**	**#10 (Soft)**	**Natural Sand**			**RAP**	**% Req.**	**Design**
Size	55.0	10.0	10.0	25.0				**100**	**Range**
2"	100	100	100	100				**100**	**100**
1.5"	100	100	100	100				**100**	**100**
1.25"									**100**
1"	100	100	100	100				**100**	**100**
3/4"	100	100	100	100				**100**	**100**
5/8"	100	100	100	100				**100**	**100**
1/2"	95	100	100	100				**97**	**95-100**
3/8"	77	100	100	100				**87**	**80-93**
No.4	40	98	91	96				**65**	**54-76**
No.8	22	92	60	84				**48**	**35-57**
No.16									
No.30	8	64	30	60				**29**	**17-29**
No.50	5	52	21	8				**12**	**10-18**
No.100	3.0	41.0	16.0	1.0				**7.6**	**3-10**
No.200	2.0	34.0	14.0					**5.9**	**0-6.5**

Requested: _____ **Approved:** _____
Contractor Personnel and Lab Tech Cert No. Regional Materials and Tests Supervisor

Approved: _____ **Approved:** _____
Regional Construction Supervisor Headquarters Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

1/22/2003(r4)

Project Ref. No.	10% RAP Gravel PG 64-22	**Date**	11/03/2003
Project No.		**Region**	
Contract No.		**County**	
Contractor		**Date of Letting**	
State Route No.		**Roadway Surface**	
Hot-mix Producer			

Type ACS-HM **Mix** 411-D PG 64-22 **Item**

Serial No.:	Design No.:

Material	Size or Grade	Producer and Location	Percent Used
D Rock(Gravel)	Coarse Aggregate	Standard Const. Frank Road	51.810
Ag. Lime	Ag. Lime	Vulcan Mtl. Savannah, TN.	
#10 (Soft)	Screenings	Vulcan Mtl. Savannah, TN.	9.420
Natural Sand	Natural Sand	Standard Const. Frank Road	23.550
RAP	RAP		10.000
Asphalt Cement	PG 64-22	MARATHON ASHLAND, KNOXVILLE	5.220

Percent AC in RAP:	5.8	**Optimum AC Content:**		5.8	**Total**	100.000
Anti-Strip Additive:					**Dosage:**	0.3%
AC Contribution:	**Virgin AC**	5.22	**RAP AC**	0.58	**Percent Virgin AC:**	90.0
Asphalt Sp. Gravity:		1.03			**Dust to Asphalt Ratio:**	0.62

% Fracture Face on CA:	80.4	**% Glassy Particles on CA:**	N/A
Gravity of RAP Agg:		**Eff. Gravity of Agg:**	2.573

Theo. Gravity:	2.367	**T.S.R.:**	90.0	**Lbs/Ft^3:**	147.7
L.O.I.:	8.0			**Ignition Oven Corr. Factor:**	0.55
ADT	**Log Miles**	**Beginning:**		**Ending:**	

Mixing Temp Range(°F):	310-350	**Compaction Temp Range(°F):**	290-330
Mixing Temperature(°F):	330	**Compaction Temperature(°F):**	310

	Percents Used								
Sieve	**D Rock(Gravel)**	**Ag. Lime**	**#10 (Soft)**	**Natural Sand**			**RAP**	**% Req.**	**Design**
Size	55.0		10.0	25.0			10.0	**100**	**Range**
2"	100		100	100			100	**100**	**100**
1.5"	100		100	100			100	**100**	**100**
1.25"									**100**
1"	100		100	100			100	**100**	**100**
3/4"	100		100	100			100	**100**	**100**
5/8"	100		100	100			100	**100**	**100**
1/2"	95		100	100			100	**97**	**95-100**
3/8"	77		100	100			100	**87**	**80-93**
No.4	40		91	96			100	**65**	**54-76**
No.8	22		60	84			90	**48**	**35-57**
No.16									
No.30	8		30	60			57	**28**	**17-29**
No.50	5		21	8			27	**10**	**10-18**
No.100	3.0		16.0	1.0			14.8	**5.0**	**3-10**
No.200	2.0		14.0				10.8	**3.6**	**0-6.5**

Requested: _____ Contractor Personnel and Lab Tech Cert No.

Approved: _____ Regional Materials and Tests Supervisor

Approved: _____ Regional Construction Supervisor

Approved: _____ Headquarters Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

1/22/2003(r4)

Project Ref. No.	20% RAP Gravel PG 64-22	**Date**	11/03/2003
Project No.		**Region**	
Contract No.		**County**	
Contractor		**Date of Letting**	
State Route No.		**Roadway Surface**	
Hot-mix Producer			

Type ACS-HM **Mix** 411-D PG 64-22 **Item**

Serial No.:	Design No.:

Material	Size or Grade	Producer and Location	Percent Used
D Rock(Gravel)	Coarse Aggregate	Standard Const. Frank Road	51.810
Ag. Lime	Ag. Lime	Vulcan Mtl. Savannah, TN.	4.710
#10 (Soft)	Screenings	Vulcan Mtl. Savannah, TN.	
Natural Sand	Natural Sand	Standard Const. Frank Road	18.840
RAP	RAP		20.000
Asphalt Cement	PG 64-22	MARATHON ASHLAND, KNOXVILLE	4.640

Percent AC in RAP:	5.8	**Optimum AC Content:**		5.8	**Total**	100.000
Anti-Strip Additive:					**Dosage:**	0.3%
AC Contribution:	**Virgin AC**	4.64	**RAP AC**	1.16	**Percent Virgin AC:**	80.0
Asphalt Sp. Gravity:		1.03			**Dust to Asphalt Ratio:**	0.85

% Fracture Face on CA:	80.4	**% Glassy Particles on CA:**	N/A
Gravity of RAP Agg:		**Eff. Gravity of Agg:**	2.573

Theo. Gravity:	2.367	**T.S.R.:**	90.0	**Lbs/Ft^3:**	147.7
L.O.I.:	8.0			**Ignition Oven Corr. Factor:**	0.55
ADT	**Log Miles**	**Beginning:**		**Ending:**	

Mixing Temp Range(°F):	310-350	**Compaction Temp Range(°F):**	290-330
Mixing Temperature(°F):	330	**Compaction Temperature(°F):**	310

	Percents Used							
Sieve	**D Rock(Gravel)**	**Ag. Lime**	**#10 (Soft)**	**Natural Sand**			**RAP**	**% Req.**	**Design**
Size	55.0	5.0		20.0			20.0	**100**	**Range**
2"	100	100		100			100	**100**	**100**
1.5"	100	100		100			100	**100**	**100**
1.25"									**100**
1"	100	100		100			100	**100**	**100**
3/4"	100	100		100			100	**100**	**100**
5/8"	100	100		100			100	**100**	**100**
1/2"	95	100		100			100	**97**	**95-100**
3/8"	77	100		100			100	**87**	**80-93**
No.4	40	98		96			100	**66**	**54-76**
No.8	22	92		84			90	**51**	**35-57**
No.16									
No.30	8	64		60			57	**31**	**17-29**
No.50	5	52		8			27	**12**	**10-18**
No.100	3.0	41.0		1.0			14.8	**6.9**	**3-10**
No.200	2.0	34.0					10.8	**5.0**	**0-6.5**

Requested: _____ **Approved:** _____
Contractor Personnel and Lab Tech Cert No. Regional Materials and Tests Supervisor

Approved: _____ **Approved:** _____
Regional Construction Supervisor Headquarters Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

1/22/2003(r4)

Project Ref. No.	30% RAP Gravel PG 64-22	**Date**	11/03/2003
Project No.		**Region**	
Contract No.		**County**	
Contractor		**Date of Letting**	
State Route No.		**Roadway Surface**	
Hot-mix Producer			

Type ACS-HM **Mix** 411-D PG 64-22 **Item**

Serial No.:	Design No.:

Material	Size or Grade	Producer and Location	Percent Used
D Rock(Gravel)	Coarse Aggregate	Standard Const. Frank Road	51.810
Ag. Lime	Ag. Lime	Vulcan Mtl. Savannah, TN.	4.710
#10 (Soft)	Screenings	Vulcan Mtl. Savannah, TN.	
Natural Sand	Natural Sand	Standard Const. Frank Road	9.420
RAP	RAP		30.000
Asphalt Cement	PG 64-22	MARATHON ASHLAND, KNOXVILLE	4.060

Percent AC in RAP:	5.8	**Optimum AC Content:**		5.8	**Total**	100.000
Anti-Strip Additive:					**Dosage:**	0.3%
AC Contribution:	**Virgin AC**	4.06	**RAP AC**	1.74	**Percent Virgin AC:**	70.0
Asphalt Sp. Gravity:		1.03			**Dust to Asphalt Ratio:**	1.04

% Fracture Face on CA:	80.4	**% Glassy Particles on CA:**	N/A
Gravity of RAP Agg:		**Eff. Gravity of Agg:**	2.573

Theo. Gravity:	2.367	**T.S.R.:**	90.0	**Lbs/Ft^3:**	147.7
L.O.I.:	8.0			**Ignition Oven Corr. Factor:**	0.55
ADT	**Log Miles**	**Beginning:**		**Ending:**	

Mixing Temp Range(°F):	310-350	**Compaction Temp Range(°F):**	290-330
Mixing Temperature(°F):	330	**Compaction Temperature(°F):**	310

	Percents Used								
Sieve	**D Rock(Gravel)**	**Ag. Lime**	**#10 (Soft)**	**Natural Sand**			**RAP**	**% Req.**	**Design**
Size	55.0	5.0		10.0			30.0	**100**	**Range**
2"	100	100		100			100	**100**	**100**
1.5"	100	100		100			100	**100**	**100**
1.25"									**100**
1"	100	100		100			100	**100**	**100**
3/4"	100	100		100			100	**100**	**100**
5/8"	100	100		100			100	**100**	**100**
1/2"	95	100		100			100	**97**	**95-100**
3/8"	77	100		100			100	**87**	**80-93**
No.4	40	98		96			100	**67**	**54-76**
No.8	22	92		84			90	**52**	**35-57**
No.16									
No.30	8	64		60			57	**31**	**17-29**
No.50	5	52		8			27	**14**	**10-18**
No.100	3.0	41.0		1.0			14.8	**8.2**	**3-10**
No.200	2.0	34.0					10.8	**6.0**	**0-6.5**

Requested: _____ Contractor Personnel and Lab Tech Cert No.

Approved: _____ Regional Materials and Tests Supervisor

Approved: _____ Regional Construction Supervisor

Approved: _____ Headquarters Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

1/22/2003(r4)

Project Ref. No.	0% RAP Gravel PG 76-22	**Date**	11/03/2003
Project No.		**Region**	
Contract No.		**County**	
Contractor		**Date of Letting**	
State Route No.		**Roadway Surface**	
Hot-mix Producer			

Type ACS-HM **Mix** 411-D PG 76-22 **Item**

Serial No.:	Design No.:

Material	Size or Grade	Producer and Location	Percent Used
D Rock(Gravel)	Coarse Aggregate	Standard Const. Frank Road	51.810
Ag. Lime	Ag. Lime	Vulcan Mtl. Savannah, TN.	9.420
#10 (Soft)	Screenings	Vulcan Mtl. Savannah, TN.	9.420
Natural Sand	Natural Sand	Standard Const. Frank Road	23.550
RAP	RAP		
Asphalt Cement	PG 76-22	MARATHON ASHLAND, KNOXVILLE	5.800

Percent AC in RAP:	5.8	**Optimum AC Content:**		5.8	**Total**	100.000
Anti-Strip Additive:					**Dosage:**	0.3%
AC Contribution:	**Virgin AC**	5.80	**RAP AC**		**Percent Virgin AC:**	100.0
Asphalt Sp. Gravity:		1.03			**Dust to Asphalt Ratio:**	1.02

% Fracture Face on CA:	80.4	**% Glassy Particles on CA:**	N/A
Gravity of RAP Agg:		**Eff. Gravity of Agg:**	2.573

Theo. Gravity:	2.367	**T.S.R.:**	90.0	**Lbs/Ft^3:**	147.7
L.O.I.:	8.0			**Ignition Oven Corr. Factor:**	0.55
ADT	**Log Miles**	**Beginning:**		**Ending:**	

Mixing Temp Range(°F):	310-350	**Compaction Temp Range(°F):**	290-330
Mixing Temperature(°F):	330	**Compaction Temperature(°F):**	310

	Percents Used								
Sieve	**D Rock(Gravel)**	**Ag. Lime**	**#10 (Soft)**	**Natural Sand**			**RAP**	**% Req.**	**Design**
Size	55.0	10.0	10.0	25.0				**100**	**Range**
2"	100	100	100	100				**100**	**100**
1.5"	100	100	100	100				**100**	**100**
1.25"									**100**
1"	100	100	100	100				**100**	**100**
3/4"	100	100	100	100				**100**	**100**
5/8"	100	100	100	100				**100**	**100**
1/2"	95	100	100	100				**97**	**95-100**
3/8"	77	100	100	100				**87**	**80-93**
No.4	40	98	91	96				**65**	**54-76**
No.8	22	92	60	84				**48**	**35-57**
No.16									
No.30	8	64	30	60				**29**	**17-29**
No.50	5	52	21	8				**12**	**10-18**
No.100	3.0	41.0	16.0	1.0				**7.6**	**3-10**
No.200	2.0	34.0	14.0					**5.9**	**0-6.5**

Requested: _____ **Approved:** _____
Contractor Personnel and Lab Tech Cert No. Regional Materials and Tests Supervisor

Approved: _____ **Approved:** _____
Regional Construction Supervisor Headquarters Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

1/22/2003(r4)

Project Ref. No.	10% RAP Gravel PG 76-22	**Date**	11/03/2003
Project No.		**Region**	
Contract No.		**County**	
Contractor		**Date of Letting**	
State Route No.		**Roadway Surface**	
Hot-mix Producer			

Type ACS-HM **Mix** 411-D PG 76-22 **Item**

Serial No.:	Design No.:

Material	Size or Grade	Producer and Location	Percent Used
D Rock(Gravel)	Coarse Aggregate	Standard Const. Frank Road	51.810
Ag. Lime	Ag. Lime	Vulcan Mtl. Savannah, TN.	9.420
#10 (Soft)	Screenings	Vulcan Mtl. Savannah, TN.	
Natural Sand	Natural Sand	Standard Const. Frank Road	23.550
RAP	RAP		10.000
Asphalt Cement	PG 76-22	MARATHON ASHLAND, KNOXVILLE	5.220

Percent AC in RAP:	5.8	**Optimum AC Content:**		5.8	**Total**	100.000
Anti-Strip Additive:					**Dosage:**	0.3%
AC Contribution:	**Virgin AC**	5.22	**RAP AC**	0.58	**Percent Virgin AC:**	90.0
Asphalt Sp. Gravity:		1.03			**Dust to Asphalt Ratio:**	0.96

% Fracture Face on CA:	80.4	**% Glassy Particles on CA:**	N/A
Gravity of RAP Agg:		**Eff. Gravity of Agg:**	2.573

Theo. Gravity:	2.367	**T.S.R.:**	90.0	**Lbs/Ft^3:**	147.7
L.O.I.:	8.0			**Ignition Oven Corr. Factor:**	0.55
ADT	**Log Miles**	**Beginning:**		**Ending:**	

Mixing Temp Range(°F):	310-350	**Compaction Temp Range(°F):**	290-330
Mixing Temperature(°F):	330	**Compaction Temperature(°F):**	310

	Percents Used							
Sieve	**D Rock(Gravel)**	**Ag. Lime**	**#10 (Soft)**	**Natural Sand**			**RAP**	**% Req.**	**Design**
Size	55.0	10.0		25.0			10.0	**100**	**Range**
2"	100	100		100			100	**100**	**100**
1.5"	100	100		100			100	**100**	**100**
1.25"									**100**
1"	100	100		100			100	**100**	**100**
3/4"	100	100		100			100	**100**	**100**
5/8"	100	100		100			100	**100**	**100**
1/2"	95	100		100			100	**97**	**95-100**
3/8"	77	100		100			100	**87**	**80-93**
No.4	40	98		96			100	**66**	**54-76**
No.8	22	92		84			90	**51**	**35-57**
No.16									
No.30	8	64		60			57	**32**	**17-29**
No.50	5	52		8			27	**13**	**10-18**
No.100	3.0	41.0		1.0			14.8	**7.5**	**3-10**
No.200	2.0	34.0					10.8	**5.6**	**0-6.5**

Requested: _____ Contractor Personnel and Lab Tech Cert No.

Approved: _____ Regional Materials and Tests Supervisor

Approved: _____ Regional Construction Supervisor

Approved: _____ Headquarters Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

1/22/2003(r4)

Project Ref. No.	20% RAP Gravel PG 76-22	**Date**	11/03/2003
Project No.		**Region**	
Contract No.		**County**	
Contractor		**Date of Letting**	
State Route No.		**Roadway Surface**	
Hot-mix Producer			

Type ACS-HM **Mix** 411-D PG 76-22 **Item**

Serial No.:	Design No.:

Material	Size or Grade	Producer and Location	Percent Used
D Rock(Gravel)	Coarse Aggregate	Standard Const. Frank Road	51.810
Ag. Lime	Ag. Lime	Vulcan Mtl. Savannah, TN.	4.710
#10 (Soft)	Screenings	Vulcan Mtl. Savannah, TN.	
Natural Sand	Natural Sand	Standard Const. Frank Road	18.840
RAP	RAP		20.000
Asphalt Cement	PG 76-22	MARATHON ASHLAND, KNOXVILLE	4.640

Percent AC in RAP:	5.8	**Optimum AC Content:**		5.8	**Total**	100.000
Anti-Strip Additive:					**Dosage:**	0.3%
AC Contribution:	**Virgin AC**	4.64	**RAP AC**	1.16	**Percent Virgin AC:**	80.0
Asphalt Sp. Gravity:		1.03			**Dust to Asphalt Ratio:**	0.85

% Fracture Face on CA:	80.4	**% Glassy Particles on CA:**	N/A
Gravity of RAP Agg:		**Eff. Gravity of Agg:**	2.573

Theo. Gravity:	2.367	**T.S.R.:**	90.0	**Lbs/Ft^3:**	147.7
L.O.I.:	8.0			**Ignition Oven Corr. Factor:**	0.55
ADT	**Log Miles**	**Beginning:**		**Ending:**	

Mixing Temp Range(°F):	310-350	**Compaction Temp Range(°F):**	290-330
Mixing Temperature(°F):	330	**Compaction Temperature(°F):**	310

	Percents Used								
Sieve	**D Rock(Gravel)**	**Ag. Lime**	**#10 (Soft)**	**Natural Sand**			**RAP**	**% Req.**	**Design**
Size	55.0	5.0		20.0			20.0	**100**	**Range**
2"	100	100		100			100	**100**	**100**
1.5"	100	100		100			100	**100**	**100**
1.25"									**100**
1"	100	100		100			100	**100**	**100**
3/4"	100	100		100			100	**100**	**100**
5/8"	100	100		100			100	**100**	**100**
1/2"	95	100		100			100	**97**	**95-100**
3/8"	77	100		100			100	**87**	**80-93**
No.4	40	98		96			100	**66**	**54-76**
No.8	22	92		84			90	**51**	**35-57**
No.16									
No.30	8	64		60			57	**31**	**17-29**
No.50	5	52		8			27	**12**	**10-18**
No.100	3.0	41.0		1.0			14.8	**6.9**	**3-10**
No.200	2.0	34.0					10.8	**5.0**	**0-6.5**

Requested: _____ **Approved:** _____
Contractor Personnel and Lab Tech Cert No. Regional Materials and Tests Supervisor

Approved: _____ **Approved:** _____
Regional Construction Supervisor Headquarters Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

1/22/2003(r4)

Project Ref. No.	30% RAP Gravel PG 76-22	**Date**	11/03/2003
Project No.		**Region**	
Contract No.		**County**	
Contractor		**Date of Letting**	
State Route No.		**Roadway Surface**	
Hot-mix Producer			

Type ACS-HM **Mix** 411-D PG 76-22 **Item**

Serial No.:	Design No.:

Material	Size or Grade	Producer and Location	Percent Used
D Rock(Gravel)	Coarse Aggregate	Standard Const. Frank Road	51.810
Ag. Lime	Ag. Lime	Vulcan Mtl. Savannah, TN.	4.710
#10 (Soft)	Screenings	Vulcan Mtl. Savannah, TN.	
Natural Sand	Natural Sand	Standard Const. Frank Road	9.420
RAP	RAP		30.000
Asphalt Cement	PG 76-22	MARATHON ASHLAND, KNOXVILLE	4.060

Percent AC in RAP:	5.8	**Optimum AC Content:**		5.8	**Total**	100.000
Anti-Strip Additive:					**Dosage:**	0.3%
AC Contribution:	**Virgin AC**	4.06	**RAP AC**	1.74	**Percent Virgin AC:**	70.0
Asphalt Sp. Gravity:		1.03			**Dust to Asphalt Ratio:**	1.04

% Fracture Face on CA:	80.4	**% Glassy Particles on CA:**	N/A
Gravity of RAP Agg:		**Eff. Gravity of Agg:**	2.573

Theo. Gravity:	2.367	**T.S.R.:**	90.0	**Lbs/Ft^3:**	147.7
L.O.I.:	8.0			**Ignition Oven Corr. Factor:**	0.55
ADT	**Log Miles**	**Beginning:**		**Ending:**	

Mixing Temp Range(°F):	310-350	**Compaction Temp Range(°F):**	290-330
Mixing Temperature(°F):	330	**Compaction Temperature(°F):**	310

	Percents Used							
Sieve	**D Rock(Gravel)**	**Ag. Lime**	**#10 (Soft)**	**Natural Sand**			**RAP**	**% Req.**	**Design**
Size	55.0	5.0		10.0			30.0	**100**	**Range**
2"	100	100		100			100	**100**	**100**
1.5"	100	100		100			100	**100**	**100**
1.25"									**100**
1"	100	100		100			100	**100**	**100**
3/4"	100	100		100			100	**100**	**100**
5/8"	100	100		100			100	**100**	**100**
1/2"	95	100		100			100	**97**	**95-100**
3/8"	77	100		100			100	**87**	**80-93**
No.4	40	98		96			100	**67**	**54-76**
No.8	22	92		84			90	**52**	**35-57**
No.16									
No.30	8	64		60			57	**31**	**17-29**
No.50	5	52		8			27	**14**	**10-18**
No.100	3.0	41.0		1.0			14.8	**8.2**	**3-10**
No.200	2.0	34.0					10.8	**6.0**	**0-6.5**

Requested: _____ **Approved:** _____
Contractor Personnel and Lab Tech Cert No. Regional Materials and Tests Supervisor

Approved: _____ **Approved:** _____
Regional Construction Supervisor Headquarters Materials and Tests

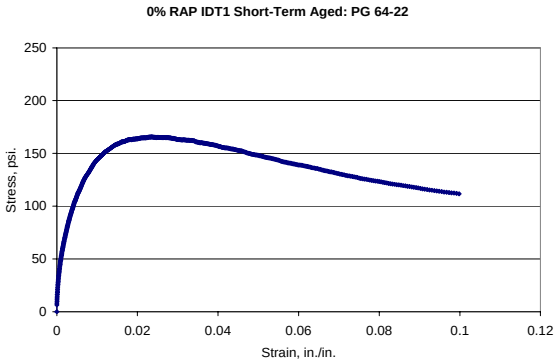
APPENDIX B: INDIRECT TENSILE STRENGTH TEST DATA

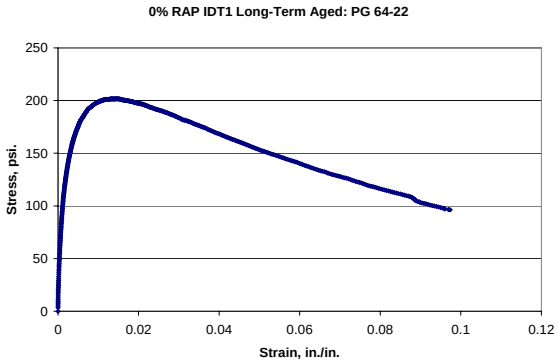
Limestone Mixtures

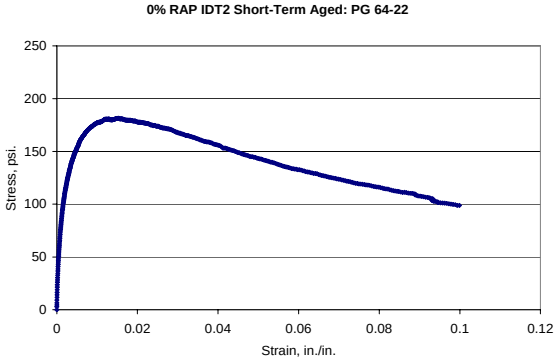
6 in. IDT: PG 64-22				Stress			Strain				TI		
Virgin	Stress, psi.	Strain, in./in.	TI	avg	std	COV	avg	std	diam strain %	COV	avg	std.	COV
U-1	165.6	0.023406	0.84										
U-2	181.5	0.015330	0.76										
U-3	173.5	0.011839	0.76	173.5	7.9	4.6	0.0169	0.0059	1.686	35.2	0.786	0.044	5.6
A-1	201.7	0.014587	0.72										
A-2	195.8	0.015634	0.75										
A-3	200.4	0.015633	0.76	199.3	3.1	1.6	0.0153	0.0006	1.528	4.0	0.744	0.019	2.6
10% RAP	Stress, psi.	Strain, in./in.	TI										
U-1	193.9	0.009936	0.71										
U-2	184.0	0.014532	0.72										
U-3	199.3	0.013049	0.74	192.4	7.8	4.1	0.0125	0.0023	1.251	18.8	0.723	0.019	2.6
A-1	210.7	0.013776	0.69										
A-2	223.2	0.011379	0.71										
A-3	219.8	0.014128	0.74	215.3	6.4	3.0	0.0140	0.0002	1.395	1.8	0.716	0.032	4.5
20% RAP	Stress, psi.	Strain, in./in.	TI										
U-1	193.5	0.016038	0.75										
U-2	186.9	0.008814	0.69										
U-3	201.2	0.011011	0.70	193.9	7.1	3.7	0.0120	0.0037	1.195	31.0	0.712	0.029	4.1
A-1	217.4	0.007860	0.68										
A-2	217.8	0.008217	0.67										
A-3	216.8	0.008148	0.72	217.3	0.5	0.2	0.0081	0.0002	0.807	2.3	0.693	0.026	3.7
30% RAP	Stress, psi.	Strain, in./in.	TI										
U-1	218.4	0.007899	0.70										
U-2	203.5	0.009979	0.69										
U-3	210.8	0.008262	0.68	210.9	7.5	3.5	0.0087	0.0011	0.871	12.7	0.689	0.008	1.1
A-1	223.9	0.007111	0.58										
A-2	194.8	0.007574	0.65										
A-3	231.2	0.007779	0.62	227.6	5.2	2.3	0.0074	0.0005	0.745	6.3	0.603	0.025	4.2

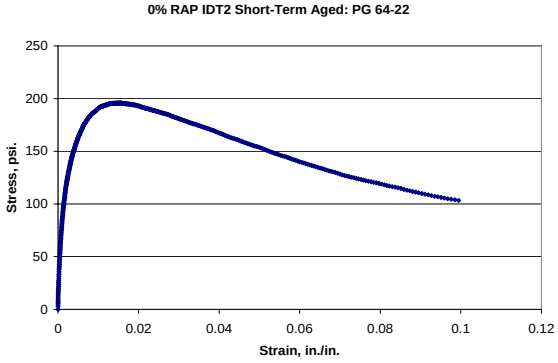
6 in. IDT: PG 76-22				Stress			Strain				TI		
Virgin	Stress, psi.	Strain in./in.	TI	avg	std	COV	avg	std	Diam. Strain,%	COV	avg	std.	COV
U-1	213.1	0.006271	0.58										
U-2	208.7	0.005855	0.60										
U-3	217.0	0.008007	0.63	212.9	4.2	2.0	0.0067	0.0011	0.671	17.0	0.604	0.022	3.7
A-1	240.2	0.006390	0.58										
A-2	256.4	0.006848	0.60										
A-3	260.4	0.005966	0.61	252.3	10.7	4.2	0.0064	0.0004	0.640	6.9	0.596	0.014	2.3
10% RAP	Stress, psi.	Strain in./in.	TI										
U-1	226.4	0.005223	0.59										
U-2	237.0	0.006632	0.60										
U-3	237.6	0.005758	0.58	233.7	6.3	2.7	0.0059	0.0007	0.587	12.1	0.591	0.011	1.8
A-1	265.2	0.005954	0.60										
A-2	256.1	0.003706	0.56										
A-3				260.6	6.4	2.5	0.0048	0.0016	0.483	32.9	0.584	0.028	4.7
20% RAP	Stress, psi.	Strain in./in.	TI										
U-1	233.0	0.005373	0.59										
U-2	246.7	0.005238	0.57										
U-3	272.3	0.004187	0.52	250.6	19.9	7.9	0.0049	0.0006	0.493	13.2	0.562	0.034	6.1
A-1	330.0	0.004601	0.40										
A-2	257.6	0.006058	0.56										
A-3	321.0	0.003512	0.46	302.9	39.5	13.0	0.0047	0.0013	0.472	27.0	0.472	0.078	16.5
30% RAP	Stress, psi.	Strain in./in.	TI										
U-1	259.0	0.004197	0.52										
U-2	250.0	0.003938	0.56										
U-3	272.3	0.004225	0.52	260.4	11.2	4.3	0.0041	0.0002	0.412	3.8	0.536	0.024	4.4
A-1	263.1	0.003430	0.43										
A-2	308.9	0.002952	0.46										
A-3	305.6	0.006833	0.62	286.0	32.4	11.3	0.0032	0.0003	0.319	10.6	0.444	0.025	5.6

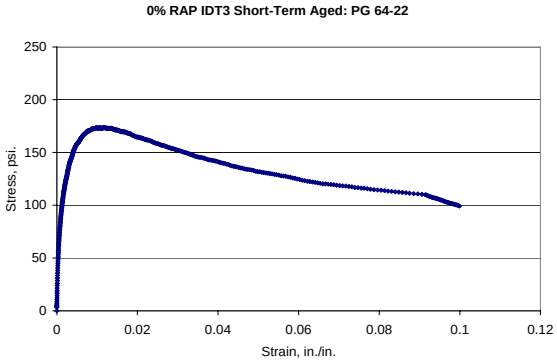
Bad Specimen

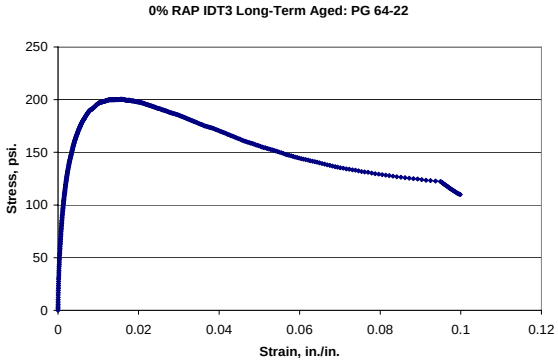

0% RAP IDT1 Short-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

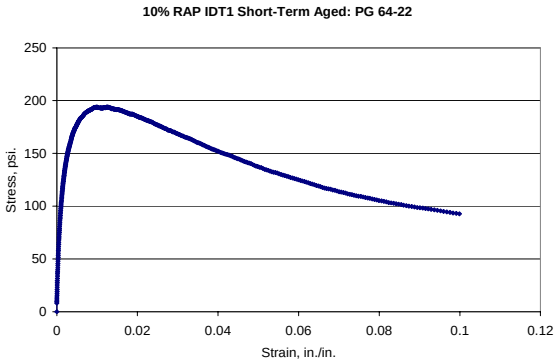

0% RAP IDT1 Long-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

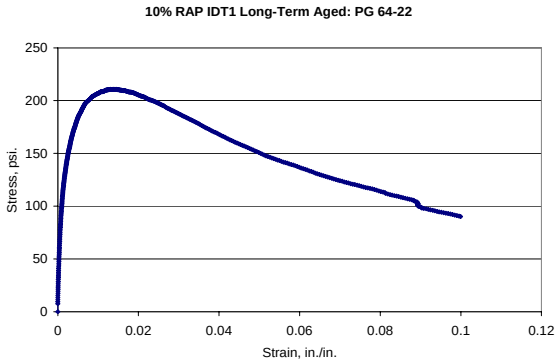

0% RAP IDT2 Short-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

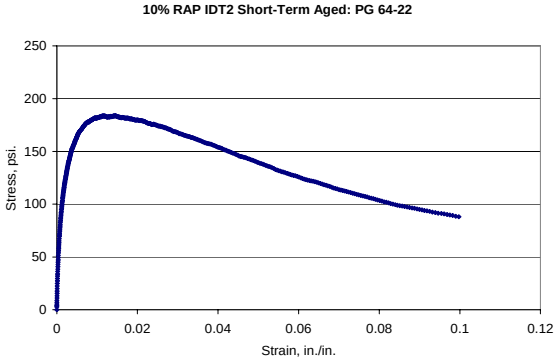

0% RAP IDT2 Short-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

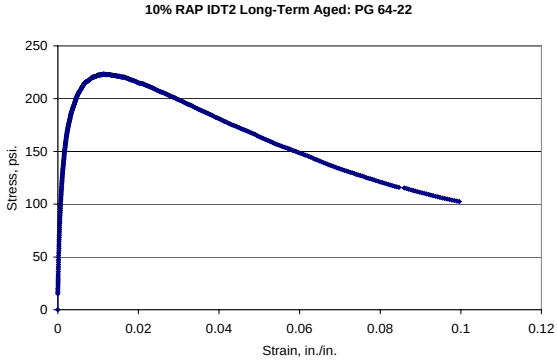

0% RAP IDT3 Short-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

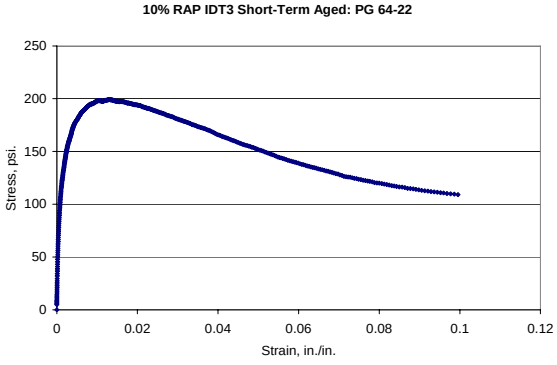

0% RAP IDT3 Long-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

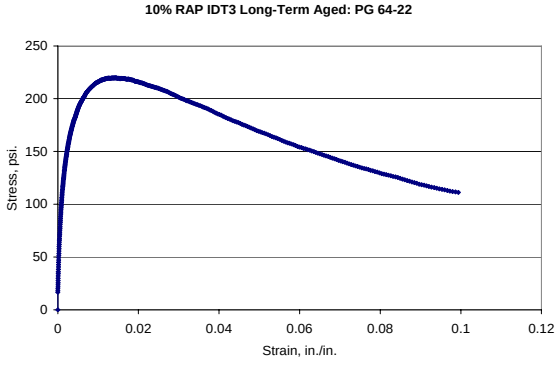

10% RAP IDT1 Short-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

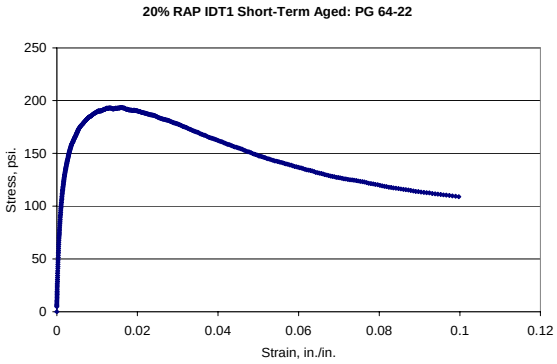

10% RAP IDT1 Long-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

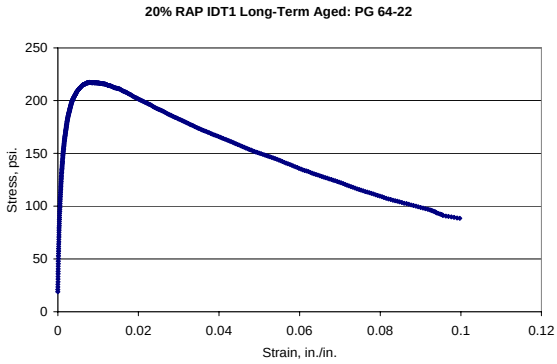

10% RAP IDT2 Short-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

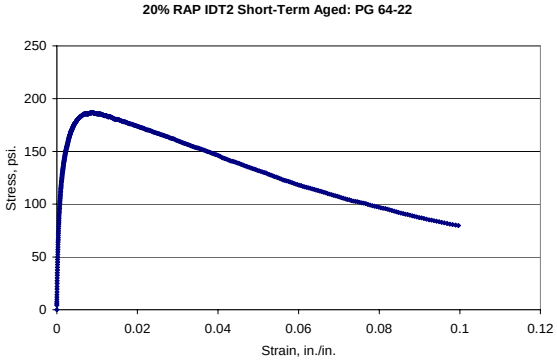

10% RAP IDT2 Long-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

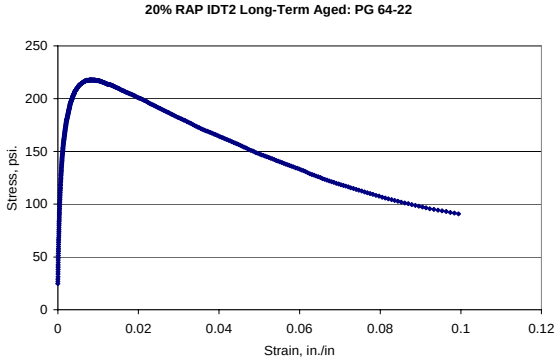

10% RAP IDT3 Short-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

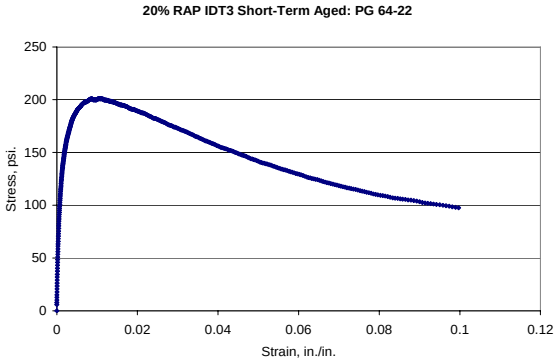

10% RAP IDT3 Long-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

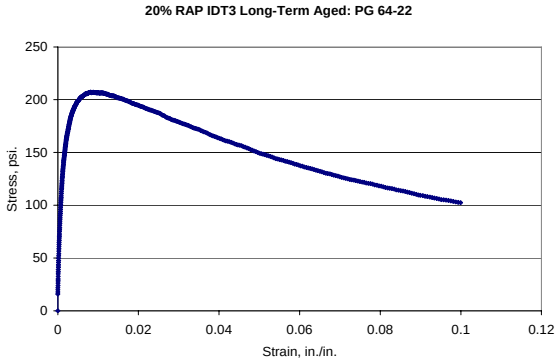

20% RAP IDT1 Short-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

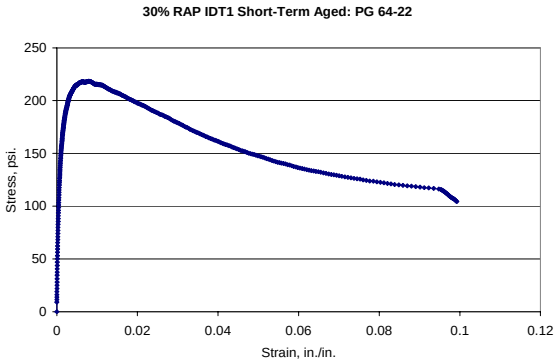

20% RAP IDT1 Long-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

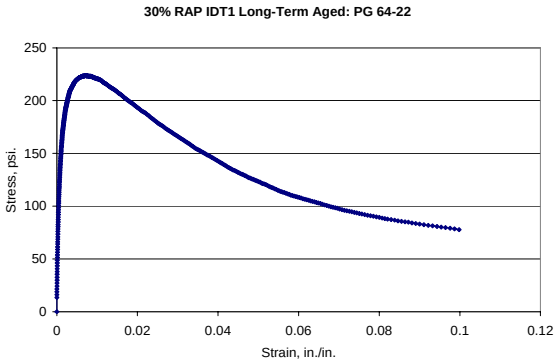

20% RAP IDT2 Short-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

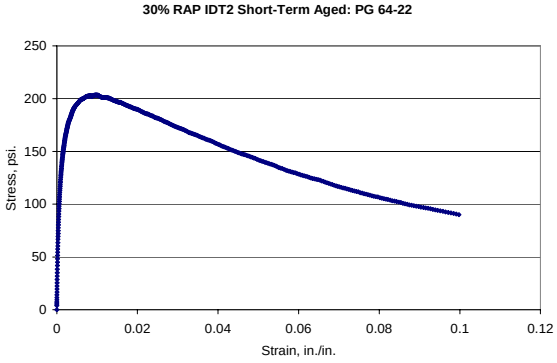

20% RAP IDT2 Long-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in

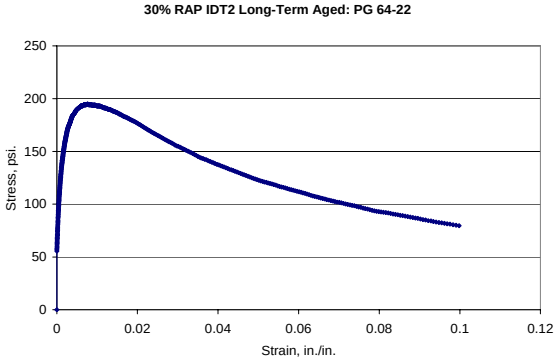

20% RAP IDT3 Short-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

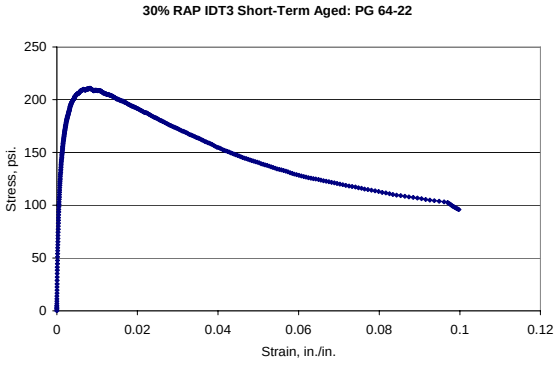

20% RAP IDT3 Long-Term Aged: PG 64-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

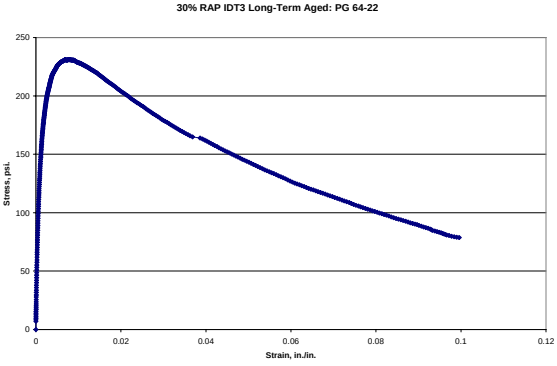

30% RAP IDT1 Short-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
0
0.02
0.04
0.06
0.08
0.1
0.12

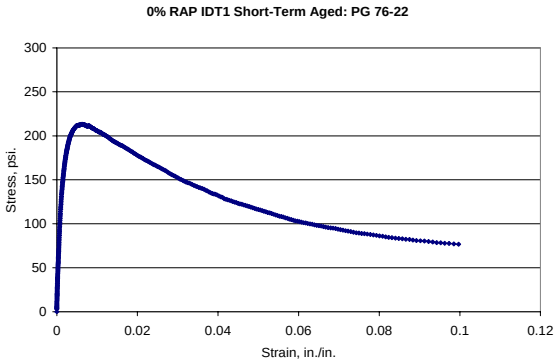

30% RAP IDT1 Long-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
0
0.02
0.04
0.06
0.08
0.1
0.12

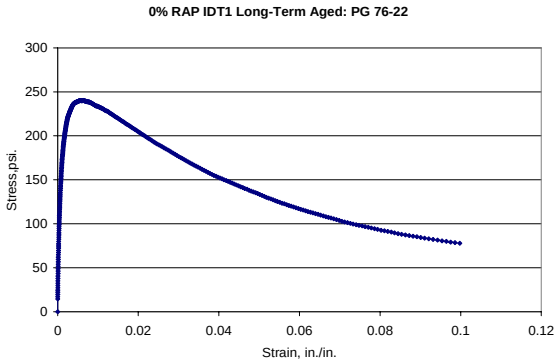

30% RAP IDT2 Short-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
0
0.02
0.04
0.06
0.08
0.1
0.12

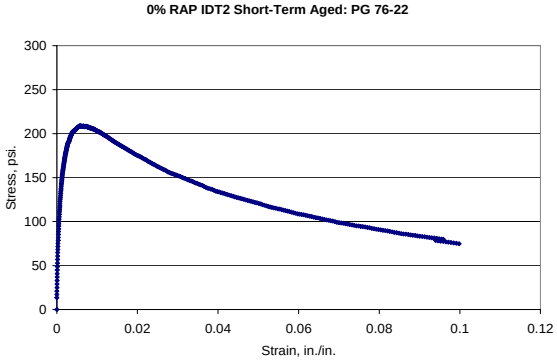

30% RAP IDT2 Long-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
0
0.02
0.04
0.06
0.08
0.1
0.12

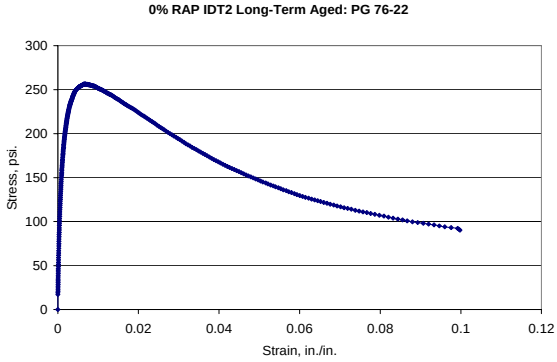

30% RAP IDT3 Short-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
0
0.02
0.04
0.06
0.08
0.1
0.12

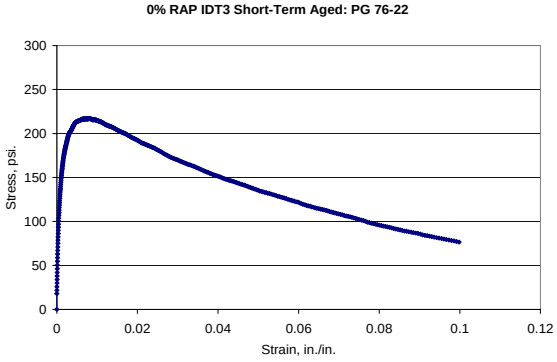

30% RAP IDT3 Long-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
0
0.02
0.04
0.06
0.08
0.1
0.12

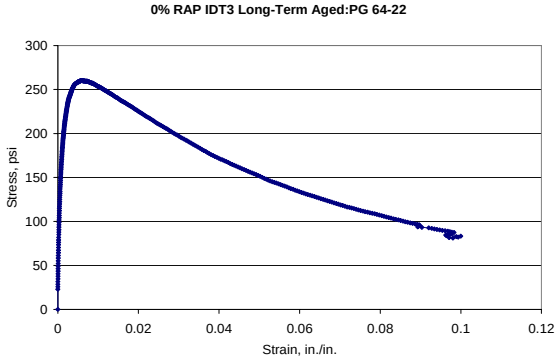

0% RAP IDT1 Short-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
300
0
0.02
0.04
0.06
0.08
0.1
0.12

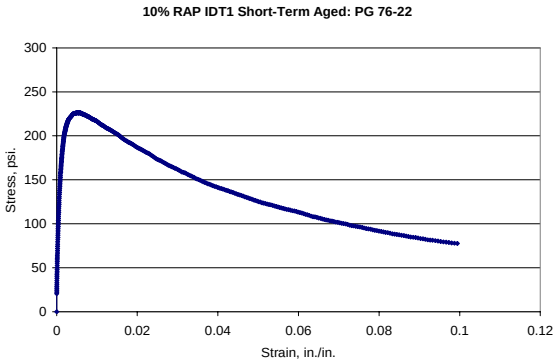

0% RAP IDT1 Long-Term Aged: PG 76-22
Stress,psi.
Strain, in./in.
0
50
100
150
200
250
300
0
0.02
0.04
0.06
0.08
0.1
0.12

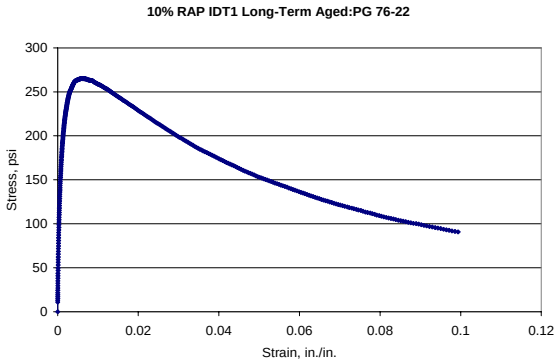

0% RAP IDT2 Short-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
300
0
0.02
0.04
0.06
0.08
0.1
0.12

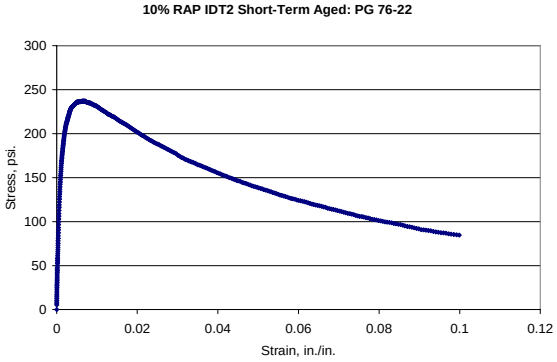

0% RAP IDT2 Long-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
300
0
0.02
0.04
0.06
0.08
0.1
0.12

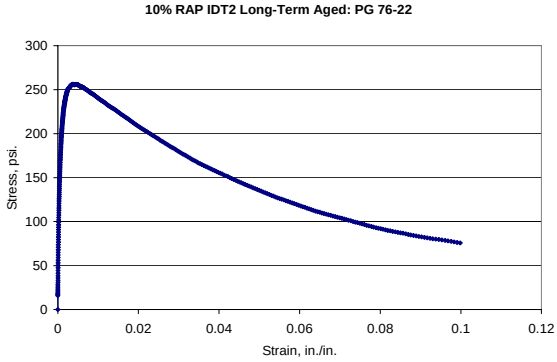

0% RAP IDT3 Short-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
300
0
0.02
0.04
0.06
0.08
0.1
0.12

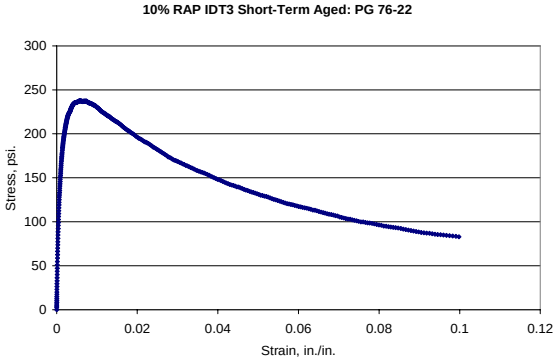

0% RAP IDT3 Long-Term Aged:PG 64-22
Stress, psi
Strain, in./in.
0
50
100
150
200
250
300
0
0.02
0.04
0.06
0.08
0.1
0.12

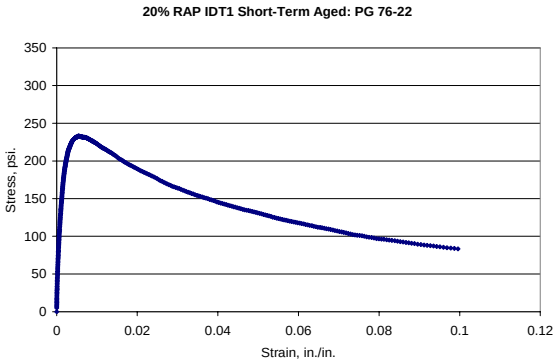

10% RAP IDT1 Short-Term Aged: PG 76-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

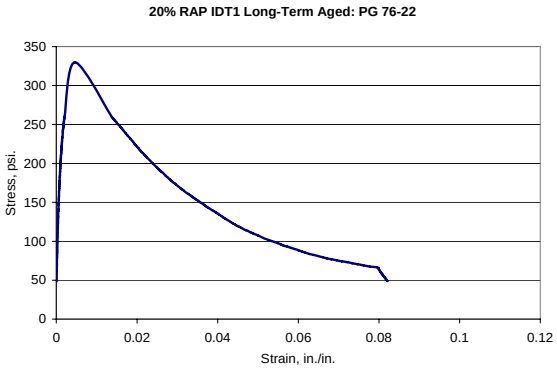

10% RAP IDT1 Long-Term Aged:PG 76-22
Stress, psi
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

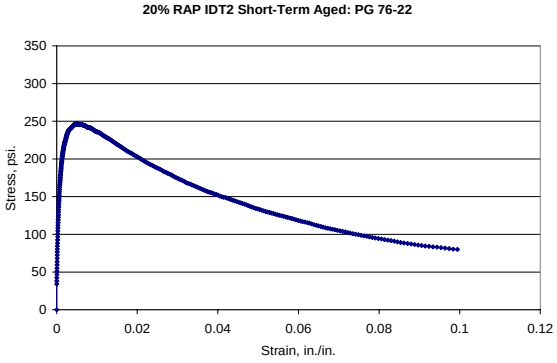

10% RAP IDT2 Short-Term Aged: PG 76-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

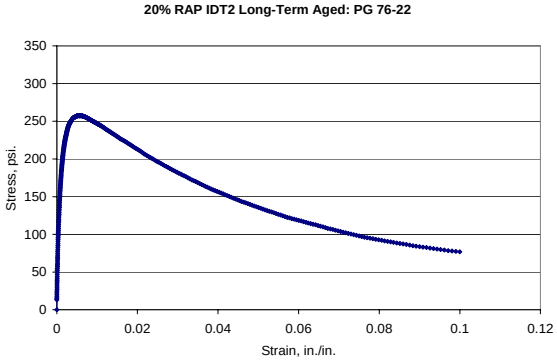

10% RAP IDT2 Long-Term Aged: PG 76-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

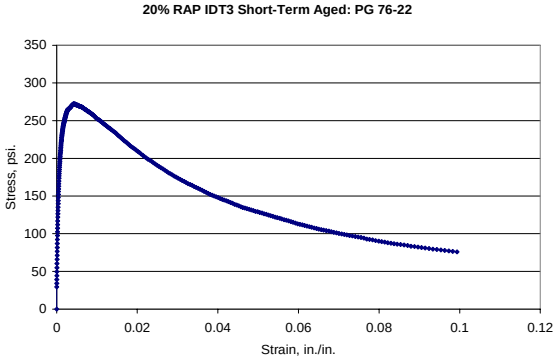

10% RAP IDT3 Short-Term Aged: PG 76-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

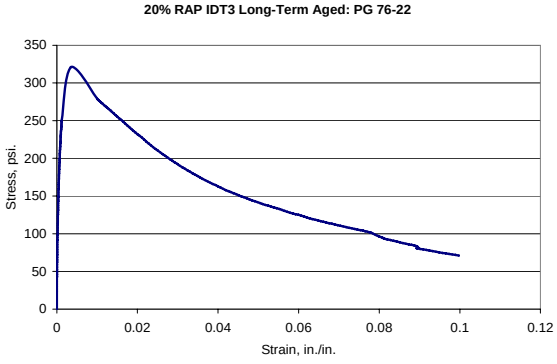

20% RAP IDT1 Short-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
300
350
0
0.02
0.04
0.06
0.08
0.1
0.12

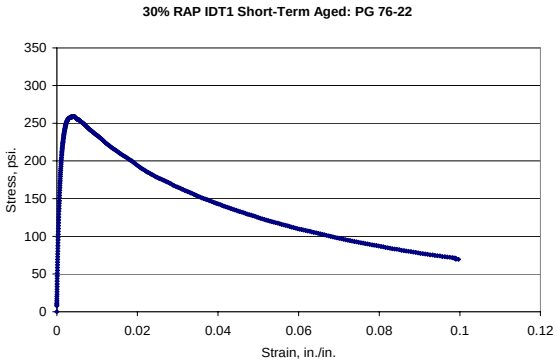

20% RAP IDT1 Long-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
300
350
0
0.02
0.04
0.06
0.08
0.1
0.12

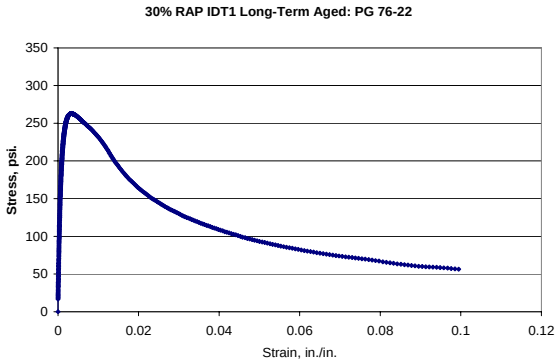

20% RAP IDT2 Short-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
300
350
0
0.02
0.04
0.06
0.08
0.1
0.12

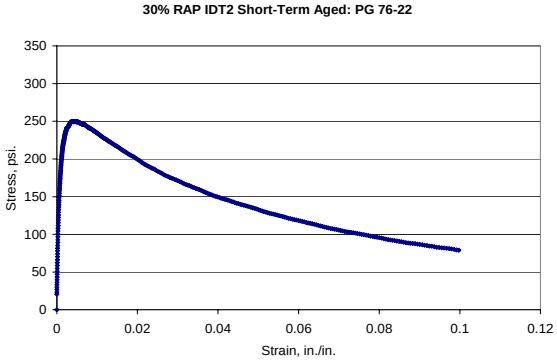

20% RAP IDT2 Long-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
300
350
0
0.02
0.04
0.06
0.08
0.1
0.12

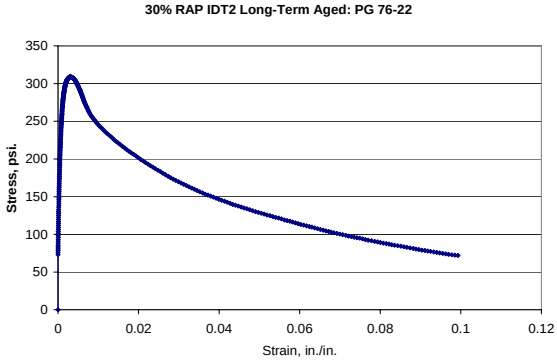

20% RAP IDT3 Short-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
300
350
0
0.02
0.04
0.06
0.08
0.1
0.12

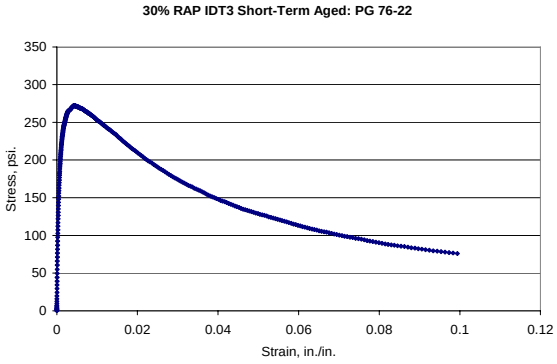

20% RAP IDT3 Long-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
300
350
0
0.02
0.04
0.06
0.08
0.1
0.12

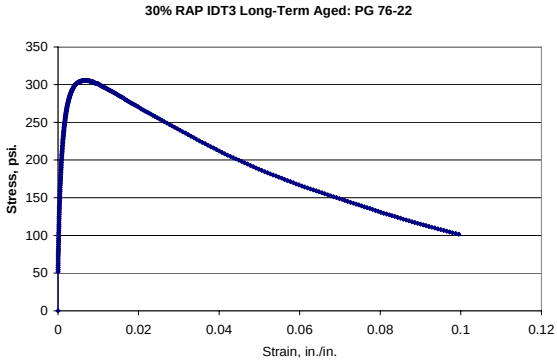

30% RAP IDT1 Short-Term Aged: PG 76-22
Stress, psi.
350
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.


30% RAP IDT1 Long-Term Aged: PG 76-22
Stress, psi.
350
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.


30% RAP IDT2 Short-Term Aged: PG 76-22
Stress, psi.
350
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.


30% RAP IDT2 Long-Term Aged: PG 76-22
Stress, psi.
350
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.


30% RAP IDT3 Short-Term Aged: PG 76-22
Stress, psi.
350
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

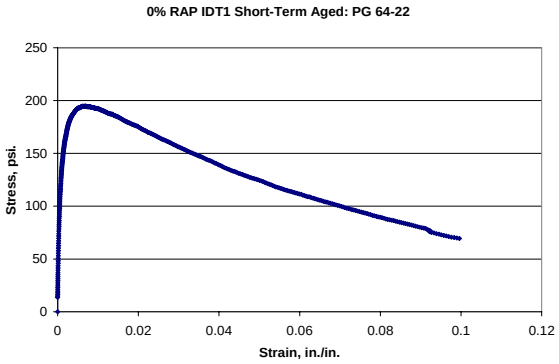

30% RAP IDT3 Long-Term Aged: PG 76-22
Stress, psi.
350
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

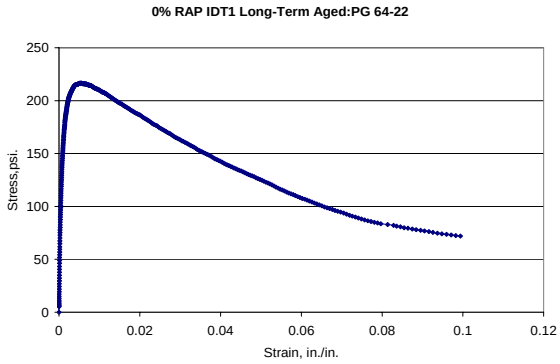
Gravel Mixtures

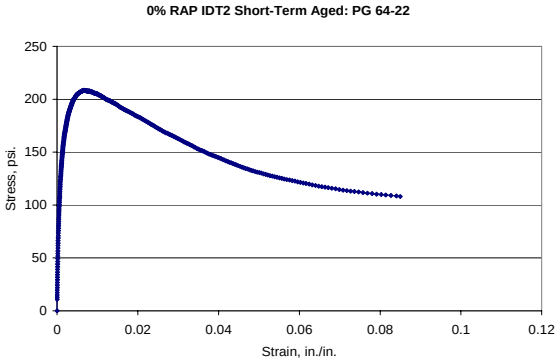
6 in. IDT: PG 64-22				Stress			Strain				TI		
Virgin	Stress, psi.	Strain in./in.	TI	avg	std	COV	avg	std	Diam. Strain,%	COV	avg	std.	COV
U-1	194.7	0.006904	0.64										
U-2	208.5	0.006622	0.62										
U-3	201.0	0.006658	0.58	201.4	6.9	3.4	0.0067	0.0002	0.673	2.3	0.616	0.030	4.9
A-1	216.5	0.005314	0.60										
A-2	206.7	0.006126	0.63										
A-3	223.7	0.006372	0.58	215.6	8.5	3.9	0.0059	0.0006	0.594	9.3	0.602	0.028	4.6
10% RAP	Stress, psi.	Strain in./in.	TI										
U-1	207.7	0.008275	0.63										
U-2	281.3	0.007583	0.59										
U-3	216.2	0.007417	0.63	211.9	6.0	2.8	0.0078	0.0006	0.785	7.7	0.632	0.000	0.0
A-1	234.0	0.008770	0.65										
A-2	227.4	0.008470	0.67										
A-3	236.7	0.006450	0.62	232.7	4.8	2.0	0.0079	0.0013	0.790	16.0	0.648	0.021	3.3
20% RAP	Stress, psi.	Strain in./in.	TI										
U-1	255.1	0.006479	0.57										
U-2	221.1	0.006596	0.63										
U-3	225.8	0.006368	0.53	234.0	18.4	7.9	0.0065	0.0001	0.648	1.8	0.577	0.047	8.1
A-1	256.2	0.005340	0.54										
A-2	249.9	0.004110	0.49										
A-3				253.0	4.4	1.8	0.0047	0.0009	0.473	18.4	0.511	0.036	7.0
30% RAP	Stress, psi.	Strain in./in.	TI										
U-1	221.2	0.005385	0.55										
U-2	251.8	0.006097	0.56										
U-3	241.7	0.006161	0.60	238.2	15.6	6.5	0.0059	0.0004	0.588	7.3	0.571	0.024	4.3
A-1	236.7	0.004950	0.55										
A-2	263.7	0.003590	0.51										
A-3	244.6	0.003840	0.52	248.3	13.8	5.6	0.0041	0.0007	0.413	17.5	0.515	0.019	3.7

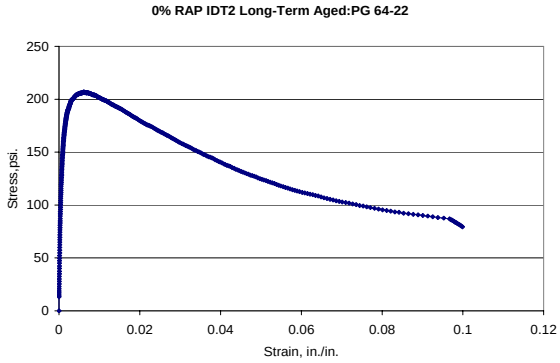
6 in. IDT: PG 70-22				Stress			Strain				TI		
Virgin	Stress, psi.	Strain, in./in.	TI	avg	std	COV	avg	std	diam strain %	COV	avg	std.	COV
U-1	220.9	0.008570	0.64										
U-2	201.0	0.007882	0.67										
U-3	213.9	0.009548	0.69	207.5	9.1	4.4	0.0087	0.0012	0.872	13.5	0.680	0.020	3.0
A-1	218.7	0.008069	0.68										
A-2	200.0	0.008336	0.63										
A-3	216.3	0.010026	0.63	211.7	10.2	4.8	0.0088	0.0011	0.881	12.0	0.647	0.032	4.9
10% RAP	Stress, psi.	Strain, in./in.	TI										
U-1	230.7	0.008146	0.62										
U-2	222.0	0.009429	0.64										
U-3	219.5	0.007528	0.65	224.1	5.9	2.6	0.0084	0.0010	0.837	11.6	0.637	0.015	2.4
A-1	243.5	0.006745	0.60										
A-2	241.3	0.005705	0.64										
A-3	205.2	0.008717	0.66	230.0	21.5	9.4	0.0071	0.0015	0.706	21.7	0.635	0.029	4.5
20% RAP	Stress, psi.	Strain, in./in.	TI										
U-1	241.4	0.006692	0.61										
U-2	239.1	0.006528	0.60										
U-3	238.2	0.006411	0.57	239.5	1.7	0.7	0.0065	0.0001	0.654	2.2	0.594	0.021	3.5
A-1	221.0	0.007806	0.61										
A-2	234.5	0.006494	0.59										
A-3	227.5	0.007582	0.53	231.0	5.0	2.2	0.0070	0.0008	0.704	10.9	0.560	0.036	6.4
30% RAP	Stress, psi.	Strain, in./in.	TI										
U-1	241.1	0.005597	0.56										
U-2	257.0	0.004961	0.57										
U-3	261.4	0.005299	0.56	253.1	10.7	4.2	0.0053	0.0003	0.529	6.0	0.564	0.006	1.0
A-1	263.5	0.003595	0.51										
A-2	263.4	0.005212	0.52										
A-3	273.9	0.004659	0.53	266.9	6.0	2.3	0.0045	0.0008	0.449	18.3	0.518	0.008	1.5

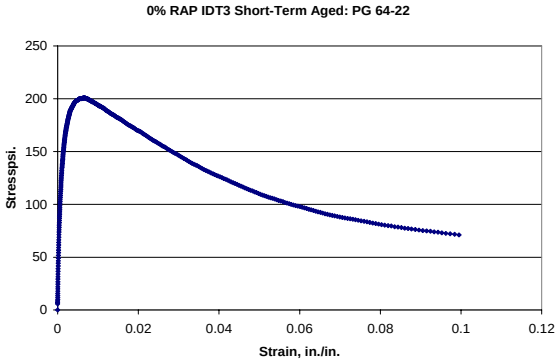
Bad Specimen

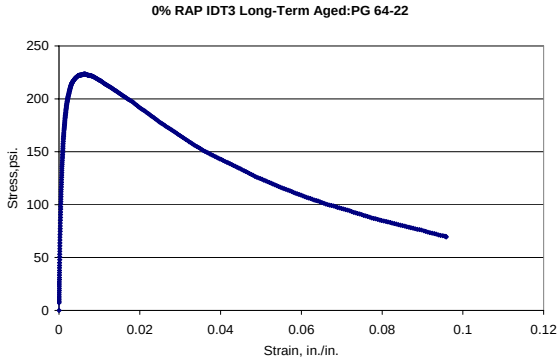

0% RAP IDT1 Short-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
0.02
0.04
0.06
0.08
0.1
0.12

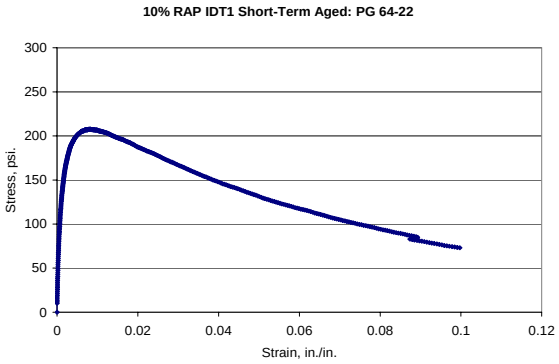

0% RAP IDT1 Long-Term Aged:PG 64-22
Stress,psi.
Strain, in./in.
0
50
100
150
200
250
0.02
0.04
0.06
0.08
0.1
0.12

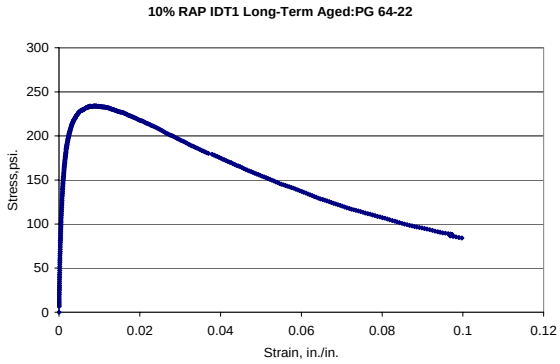

0% RAP IDT2 Short-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
0.02
0.04
0.06
0.08
0.1
0.12

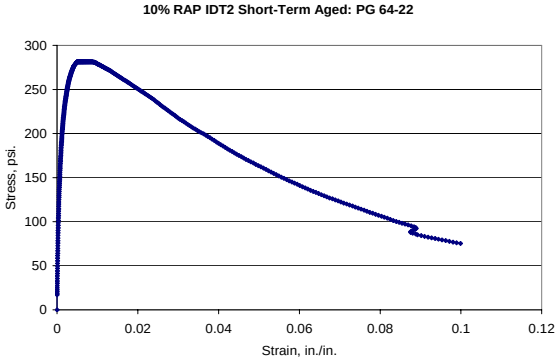

0% RAP IDT2 Long-Term Aged:PG 64-22
Stress,psi.
Strain, in./in.
0
50
100
150
200
250
0.02
0.04
0.06
0.08
0.1
0.12

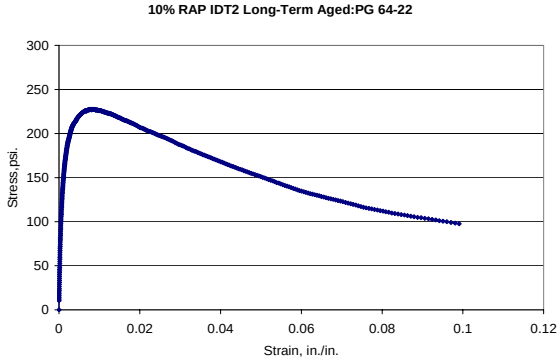

0% RAP IDT3 Short-Term Aged: PG 64-22
Stresspsi.
Strain, in./in.
0
50
100
150
200
250
0.02
0.04
0.06
0.08
0.1
0.12

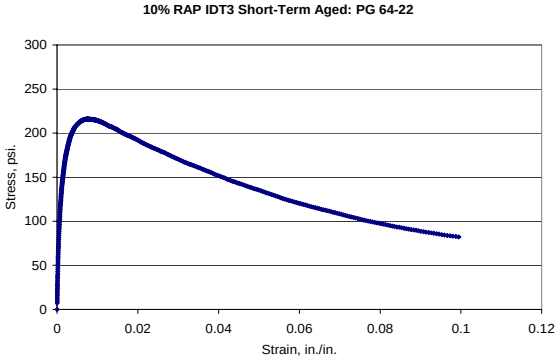

0% RAP IDT3 Long-Term Aged:PG 64-22
Stress,psi.
Strain, in./in.
0
50
100
150
200
250
0.02
0.04
0.06
0.08
0.1
0.12

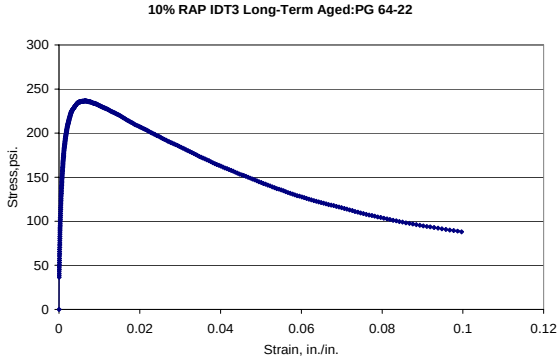

10% RAP IDT1 Short-Term Aged: PG 64-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

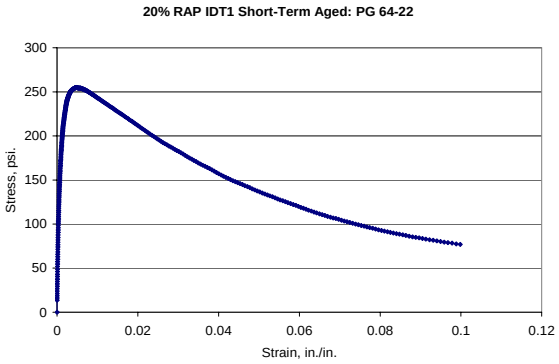

10% RAP IDT1 Long-Term Aged:PG 64-22
Stress,psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

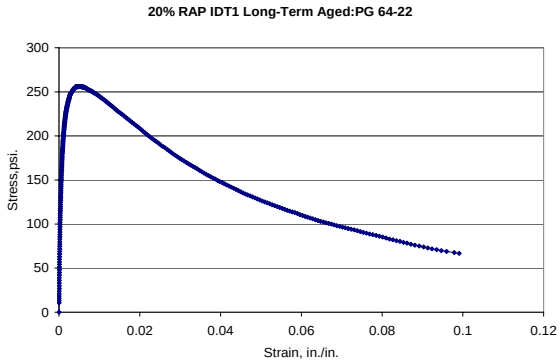

10% RAP IDT2 Short-Term Aged: PG 64-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

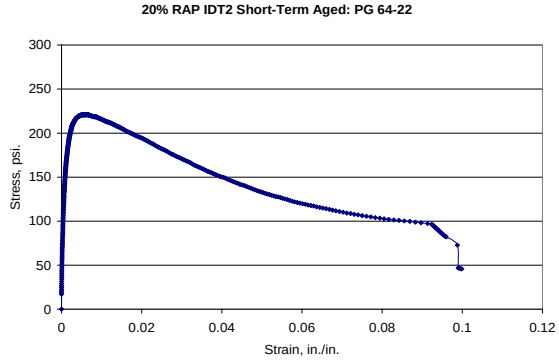

10% RAP IDT2 Long-Term Aged:PG 64-22
Stress,psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

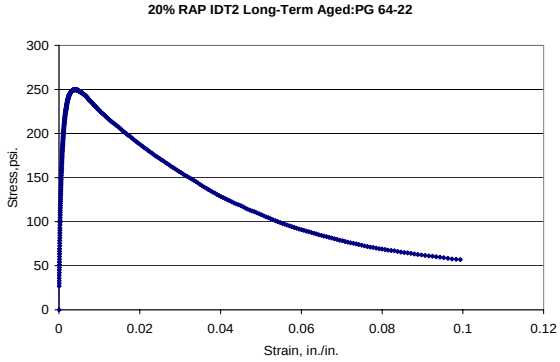

10% RAP IDT3 Short-Term Aged: PG 64-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

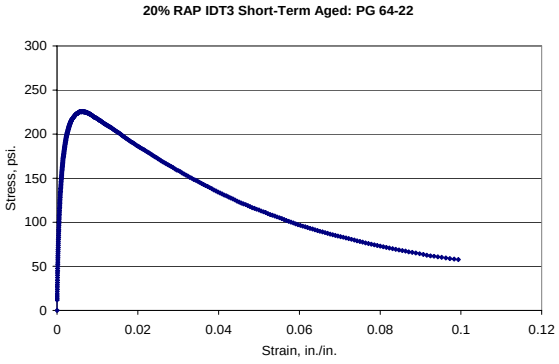

10% RAP IDT3 Long-Term Aged:PG 64-22
Stress,psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

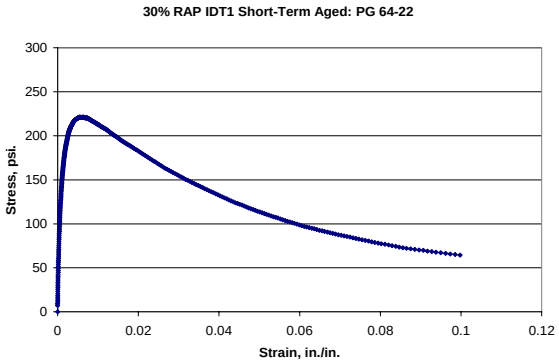

20% RAP IDT1 Short-Term Aged: PG 64-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

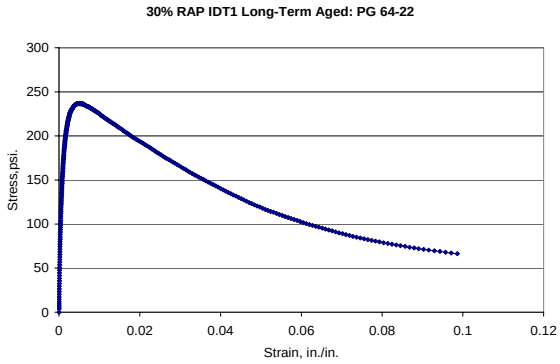

20% RAP IDT1 Long-Term Aged:PG 64-22
Stress,psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

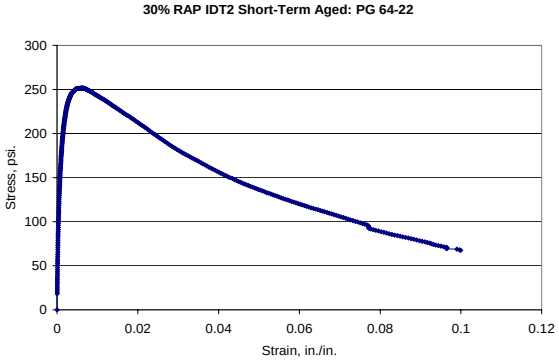

20% RAP IDT2 Short-Term Aged: PG 64-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

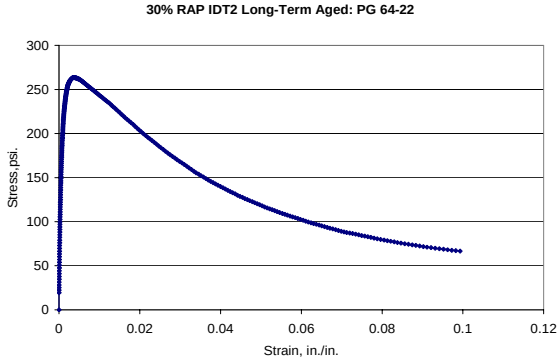

20% RAP IDT2 Long-Term Aged:PG 64-22
Stress,psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

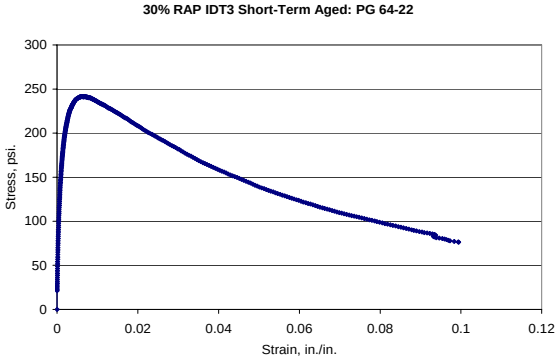

20% RAP IDT3 Short-Term Aged: PG 64-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

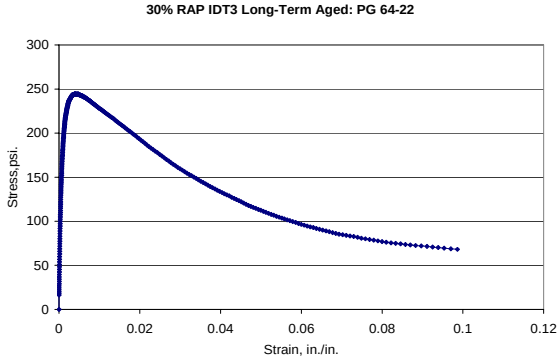

30% RAP IDT1 Short-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
300
0
0.02
0.04
0.06
0.08
0.1
0.12

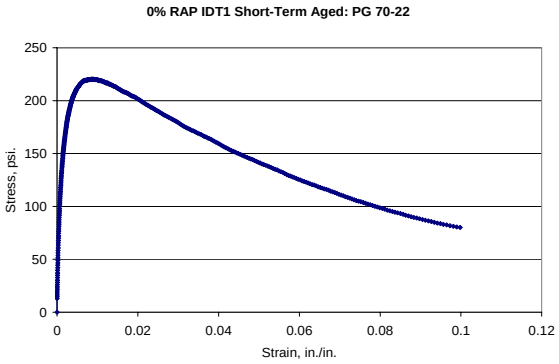

30% RAP IDT1 Long-Term Aged: PG 64-22
Stress,psi.
Strain, in./in.
0
50
100
150
200
250
300
0
0.02
0.04
0.06
0.08
0.1
0.12

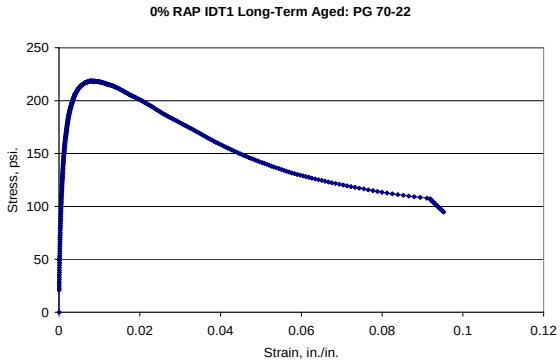

30% RAP IDT2 Short-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
300
0
0.02
0.04
0.06
0.08
0.1
0.12

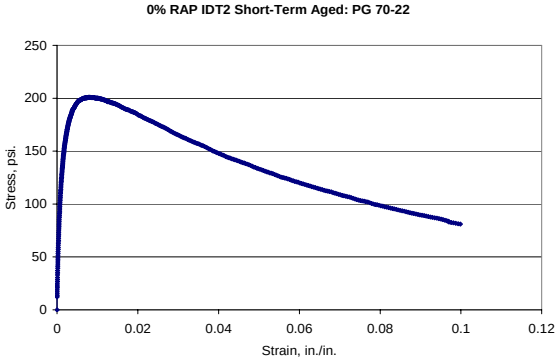

30% RAP IDT2 Long-Term Aged: PG 64-22
Stress,psi.
Strain, in./in.
0
50
100
150
200
250
300
0
0.02
0.04
0.06
0.08
0.1
0.12

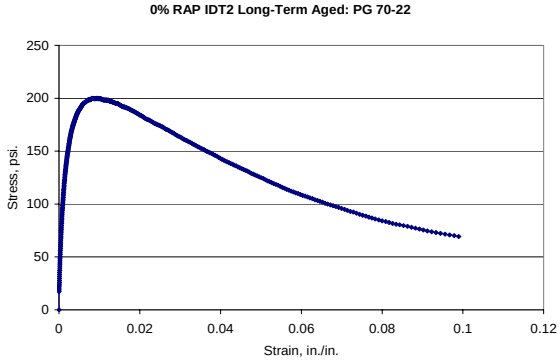

30% RAP IDT3 Short-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
50
100
150
200
250
300
0
0.02
0.04
0.06
0.08
0.1
0.12

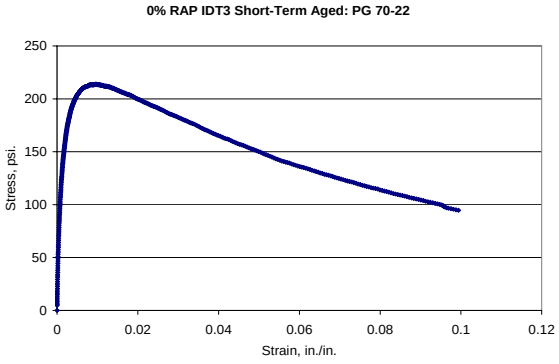

30% RAP IDT3 Long-Term Aged: PG 64-22
Stress,psi.
Strain, in./in.
0
50
100
150
200
250
300
0
0.02
0.04
0.06
0.08
0.1
0.12

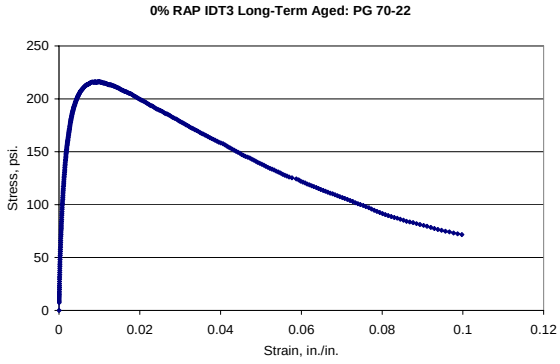

0% RAP IDT1 Short-Term Aged: PG 70-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

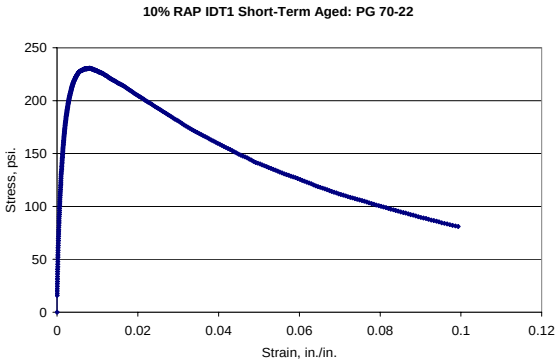

0% RAP IDT1 Long-Term Aged: PG 70-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

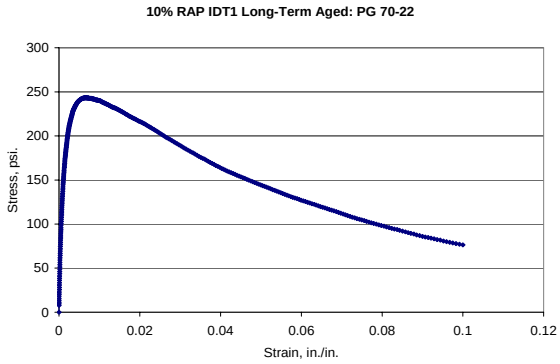

0% RAP IDT2 Short-Term Aged: PG 70-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

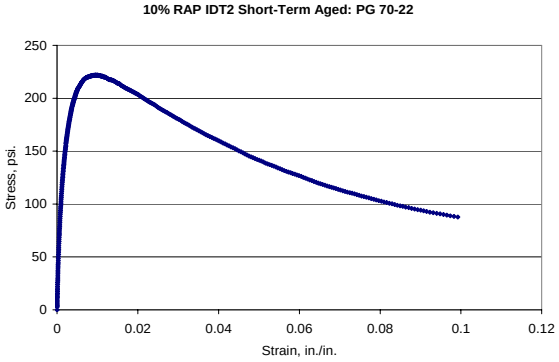

0% RAP IDT2 Long-Term Aged: PG 70-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

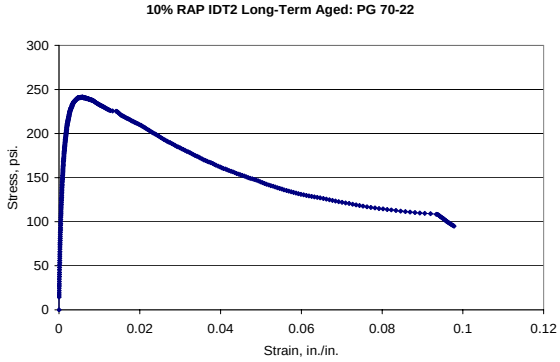

0% RAP IDT3 Short-Term Aged: PG 70-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

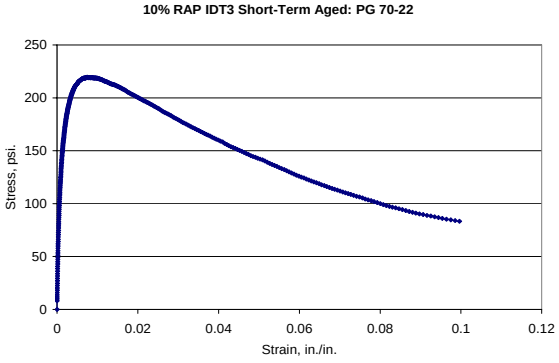

0% RAP IDT3 Long-Term Aged: PG 70-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

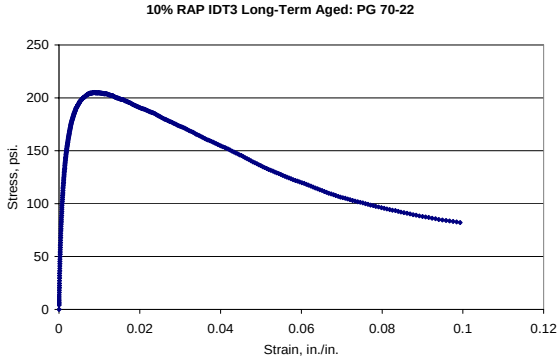

10% RAP IDT1 Short-Term Aged: PG 70-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

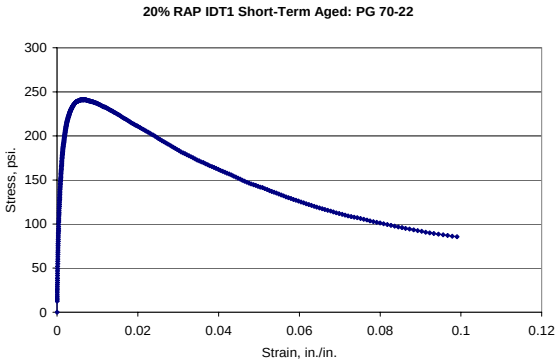

10% RAP IDT1 Long-Term Aged: PG 70-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

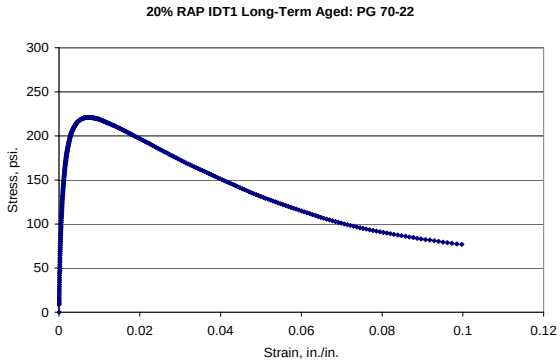

10% RAP IDT2 Short-Term Aged: PG 70-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

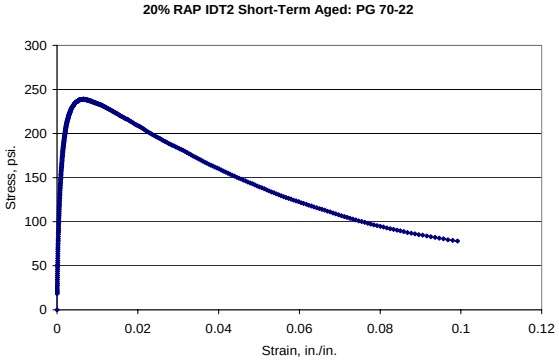

10% RAP IDT2 Long-Term Aged: PG 70-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

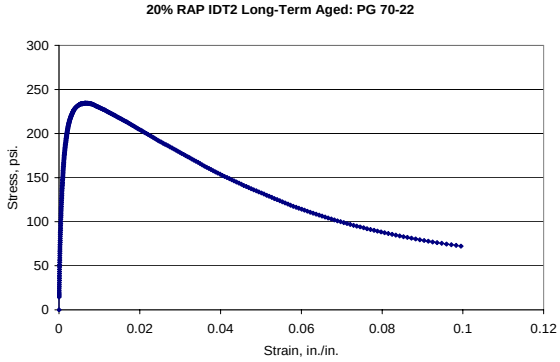

10% RAP IDT3 Short-Term Aged: PG 70-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

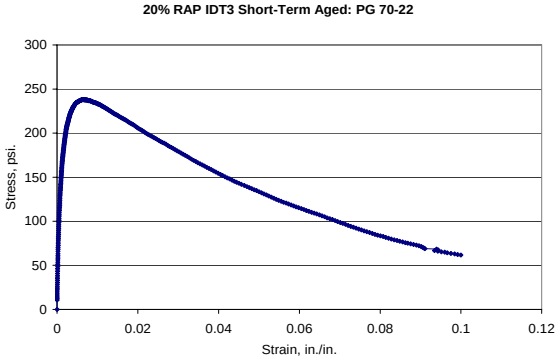

10% RAP IDT3 Long-Term Aged: PG 70-22
Stress, psi.
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

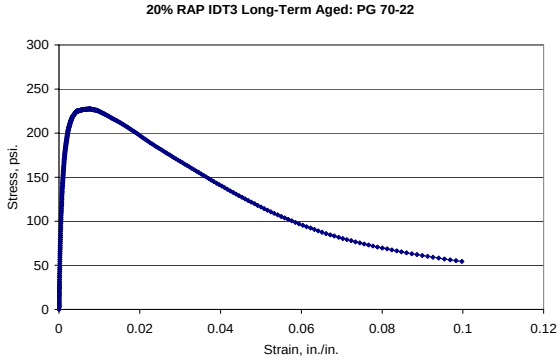

20% RAP IDT1 Short-Term Aged: PG 70-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

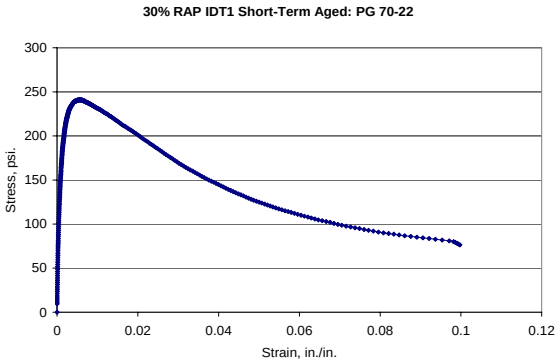

20% RAP IDT1 Long-Term Aged: PG 70-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

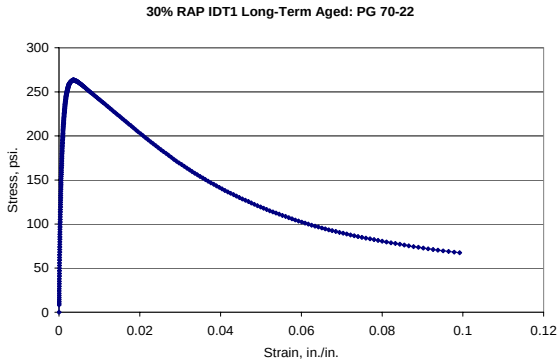

20% RAP IDT2 Short-Term Aged: PG 70-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

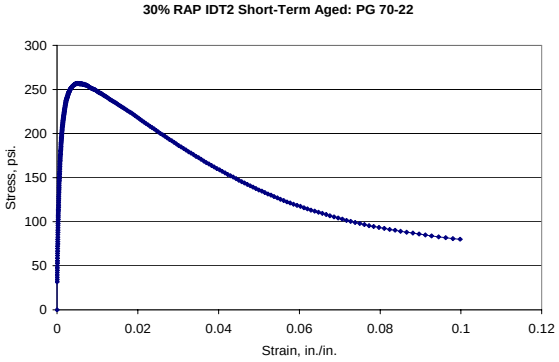

20% RAP IDT2 Long-Term Aged: PG 70-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

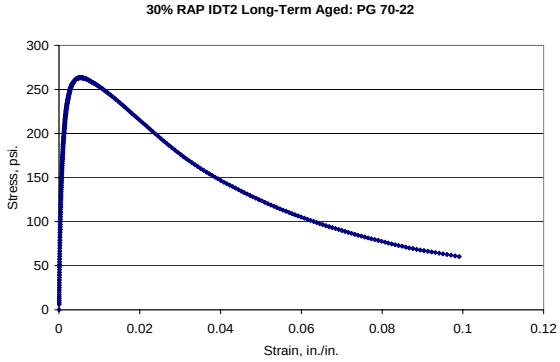

20% RAP IDT3 Short-Term Aged: PG 70-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

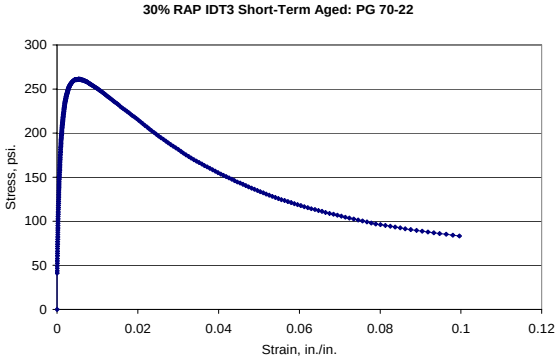

20% RAP IDT3 Long-Term Aged: PG 70-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

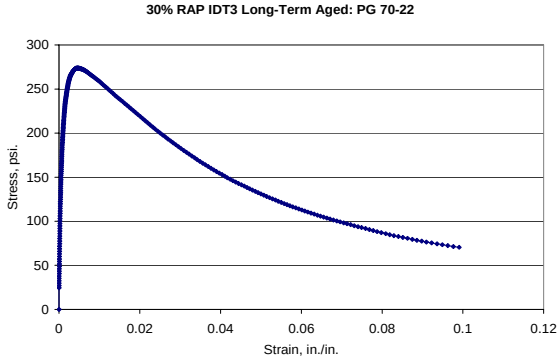

30% RAP IDT1 Short-Term Aged: PG 70-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.


30% RAP IDT1 Long-Term Aged: PG 70-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.


30% RAP IDT2 Short-Term Aged: PG 70-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.


30% RAP IDT2 Long-Term Aged: PG 70-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.


30% RAP IDT3 Short-Term Aged: PG 70-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.


30% RAP IDT3 Long-Term Aged: PG 70-22
Stress, psi.
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

APPENDIX C: INDIRECT TENSILE STRENGTH TEST DATA (ROQUE METHOD)

Limestone Mixtures

6 in. IDT: PG 64-22				Mr, psi.			FE (psi)			DSCEf (psi)		
Virgin	Mr, psi.	FE (psi.)	DSCEf (psi.)	avg	std	COV	avg	std	COV	avg	std.	COV
U-1	319297	2.67957	2.6365									
U-2	302122	2.25215	2.2014									
U-3	764688	2.087293	2.0588	310709.5	12144.6	3.9	2.4659	0.3022	12.3	2.419	0.308	12.7
A-1	327959	2.381350	2.3247									
A-2	373349	2.480486	2.4322									
A-3	468467	2.622982	2.5807	389925.0	71705.6	18.4	2.4949	0.1215	4.9	2.446	0.129	5.3
10% RAP	Mr, psi.	FE (psi.)	DSCEf (psi.)									
U-1	346430	2.02651	1.9761									
U-2	332645	2.18966	2.1432									
U-3	362863	2.145076	2.0946	347312.7	15128.3	4.4	2.1204	0.0843	4.0	2.071	0.086	4.1
A-1	393467	2.327025	2.2758									
A-2	455433	2.100641	2.0482									
A-3	398449	2.545640	2.4882	415783.0	34428.1	8.3	2.3244	0.2225	9.6	2.271	0.220	9.7
20% RAP	Mr, psi.	FE (psi.)	DSCEf (psi.)									
U-1	374785	2.599328	2.5525									
U-2	384349	1.354149	1.3088									
U-3	459724	1.385207	1.3439	406286.0	46525.1	11.5	1.7796	0.7101	39.9	1.735	0.708	40.8
A-1	519981	1.393006	1.3503									
A-2	502014	1.454265	1.4115									
A-3	432437	1.398866	1.3493	484810.7	46238.0	9.5	1.4154	0.0338	2.4	1.370	0.036	2.6
30% RAP	Mr, psi.	FE (psi.)	DSCEf (psi.)									
U-1	466360	1.120607	1.0737									
U-2	422486	1.682386	1.6377									
U-3	452013	1.414639	1.3703	446953.0	22370.4	5.0	1.4059	0.2810	20.0	1.361	0.282	20.7
A-1	595665	1.292230	1.2538									
A-2	889026	1.350272	1.3259									
A-3	475157	1.465890	1.4126	653282.7	212865.5	32.6	1.3695	0.0884	6.5	1.331	0.080	6.0

6 in. IDT: PG 76-22				Mr, psi.			FE (psi)			DSCEf (psi)		
Virgin	Mr, psi.	FE (psi.)	DSCEf (psi.)	avg	std	COV	avg	std	COV	avg	std.	COV
U-1	575747	0.978700	0.9364									
U-2	563505	1.293900	1.2471									
U-3	386559	1.560000	1.4237	508603.7	105870.9	20.8	1.2775	0.2910	22.8	1.202	0.247	20.5
A-1	578458	1.466400	1.4052									
A-2	754850	1.440700	1.3992									
A-3	743490	1.260800	1.2186	692266.0	98724.2	14.3	1.3893	0.1120	8.1	1.341	0.106	7.9
10% RAP	Mr, psi.	FE (psi.)	DSCEf (psi.)									
U-1	484404	1.024900	0.9828									
U-2	658219	0.982900	0.9515									
U-3	595411	1.478600	1.4467	579344.7	88014.3	15.2	1.1621	0.2749	23.7	1.127	0.277	24.6
A-1	794836	1.299500	1.2576									
A-2	656281	0.757200	0.7572									
A-3				725558.5	97973.2	13.5	1.0284	0.3835	37.3	1.007	0.354	35.1
20% RAP	Mr, psi.	FE (psi.)	DSCEf (psi.)									
U-1	580328	0.954000	0.9106									
U-2	693783	1.059100	1.0191									
U-3	700712	0.922100	0.8738	658274.3	67592.4	10.3	0.9784	0.0717	7.3	0.935	0.076	8.1
A-1	841828	0.358000	0.3214									
A-2	711666	1.311000	1.2658									
A-3	891984	1.895700	1.8546	815159.3	93070.2	11.4	1.1882	0.7762	65.3	1.147	0.773	67.4
30% RAP	Mr, psi.	FE (psi.)	DSCEf (psi.)									
U-1	642722	0.890500	0.8397									
U-2	694247	0.809100	0.7666									
U-3	703752	0.946400	0.8943	680240.3	32837.6	4.8	0.8820	0.0690	7.8	0.803	0.064	8.0
A-1	713857	0.702600	0.6584									
A-2	798353	0.749400	0.6929									
A-3	730862	1.755500	1.6960	747690.7	44691.1	6.0	1.2291	0.7445	60.6	1.016	0.589	58.0

Bad Specimen

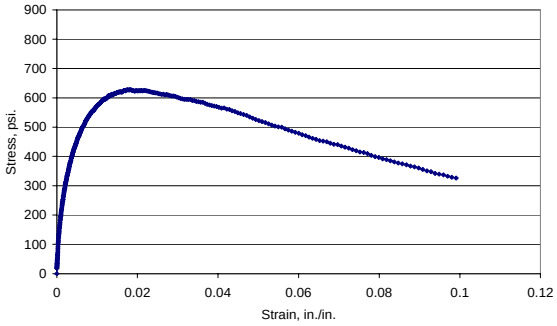
APPENDIX D: SEMI-CIRCULAR BENDING TEST DATA

Limestone Mixtures

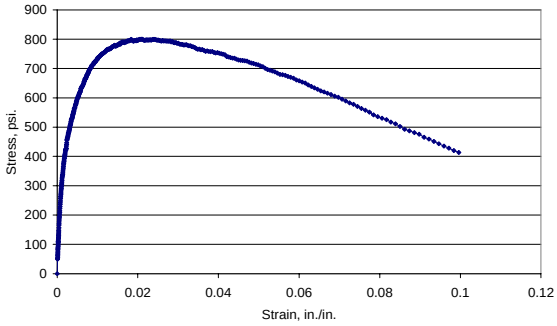
6 in. IDT: PG 64-22				Stress			Strain				TI		
Virgin	Stress, psi.	Strain in./in.	TI	avg	std	COV	avg	std	Diam. Strain,%	COV	avg	std.	COV
U-1	628.0	0.018253	0.77										
U-2	679.2	0.034142	0.92										
U-3				653.6	36.2	5.5	0.0262	0.0112	2.620	42.9	0.846	0.104	12.3
A-1	799.9	0.020986	0.80										
A-2	807.3	0.024906	0.80										
A-3	763.9	0.023722	0.65	790.4	23.2	2.9	0.0232	0.0020	2.320	8.7	0.749	0.088	11.8
10% RAP	Stress, psi.	Strain in./in.	TI										
U-1	743.9	0.022103	0.74										
U-2	651.8	0.018253	0.77										
U-3				697.8	65.1	9.3	0.0202	0.0027	2.018	13.5	0.755	0.019	2.5
A-1	713.6	0.018554	0.67										
A-2	774.2	0.021208	0.71										
A-3	635.4	0.023714	0.77	707.7	69.6	9.8	0.0212	0.0026	2.116	12.2	0.715	0.047	6.6
20% RAP	Stress, psi.	Strain in./in.	TI										
U-1	766.0	0.025342	0.82										
U-2	665.7	0.023109	0.77										
U-3	700.9	0.020590	0.70	710.9	50.9	7.2	0.0230	0.0024	2.301	10.3	0.762	0.060	7.9
A-1	788.1	0.017727	0.61										
A-2	680.8	0.022749	0.62										
A-3				734.5	75.8	10.3	0.0202	0.0036	2.024	17.5	0.614	0.005	0.8
30% RAP	Stress, psi.	Strain in./in.	TI										
U-1	743.9	0.018255	0.75										
U-2	734.5	0.023773	0.86										
U-3				739.2	6.7	0.9	0.0210	0.0039	2.101	18.6	0.804	0.074	9.2
A-1	774.6	0.015103	0.70										
A-2	779.1	0.015519	0.57										
A-3	700.5	0.016351	0.73	751.4	44.1	5.9	0.0157	0.0006	1.566	4.1	0.666	0.086	13.0

6 in. IDT: PG 76-22				Stress			Strain				TI		
Virgin	Stress, psi.	Strain, in./in.	TI	avg	std	COV	avg	std	diam strain %	COV	avg	std.	COV
U-1	757.4	0.015836	0.71										
U-2	698.4	0.017592	0.69										
U-3	699.7	0.017695	0.66	718.5	33.7	4.7	0.0170	0.0010	1.704	6.1	0.690	0.027	3.8
A-1	786.4	0.017941	0.80										
A-2	803.2	0.014238	0.46										
A-3	860.9	0.009351	0.53	816.9	39.1	4.8	0.0138	0.0043	1.384	31.1	0.596	0.180	30.3
10% RAP	Stress, psi.	Strain, in./in.	TI										
U-1	734.9	0.016553	0.65										
U-2	748.4	0.016652	0.76										
U-3	807.7	0.014365	0.61	763.7	38.8	5.1	0.0159	0.0013	1.586	8.2	0.674	0.078	11.5
A-1													
A-2	740.6	0.014368	0.69										
A-3	885.9	0.013855	0.50	813.3	102.8	12.6	0.0141	0.0004	1.411	2.6	0.595	0.131	22.0
20% RAP	Stress, psi.	Strain, in./in.	TI										
U-1	753.3	0.016912	0.73										
U-2	784.8	0.016050	0.76										
U-3	782.8	0.020337	0.78	773.6	17.6	2.3	0.0178	0.0023	1.777	12.8	0.756	0.026	3.5
A-1	921.9	0.011507	0.61										
A-2	934.2	0.012434	0.63										
A-3	921.5	0.013710	0.49	925.9	7.2	0.8	0.0126	0.0011	1.255	8.8	0.573	0.075	13.0
30% RAP	Stress, psi.	Strain, in./in.	TI										
U-1	843.3	0.015126	0.72										
U-2	840.5	0.011479	0.58										
U-3	856.4	0.013544	0.78	846.7	8.5	1.0	0.0134	0.0018	1.338	13.7	0.693	0.104	15.0
A-1	912.9	0.014521	0.68										
A-2	790.5	0.010571	0.34										
A-3	919.1	0.010737	0.55	874.2	72.5	8.3	0.0119	0.0022	1.194	18.7	0.522	0.174	33.3

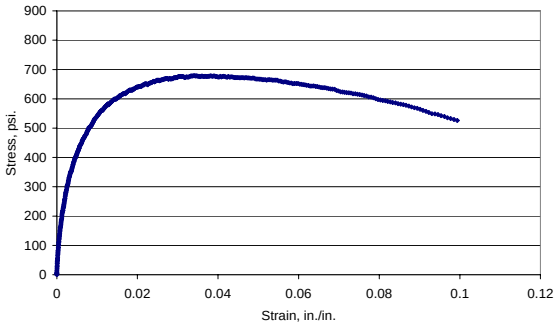
0% RAP SCB IDT1 Short-Term Aged: PG 64-22



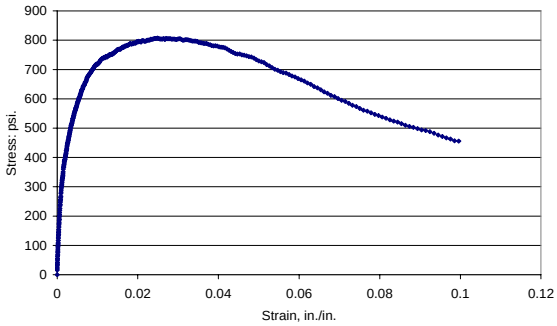
0% RAP SCB IDT1 Long-Term Aged: PG 64-22



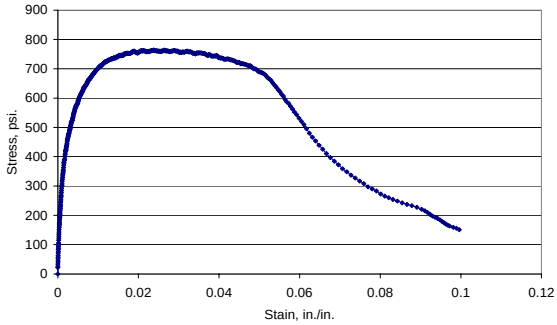
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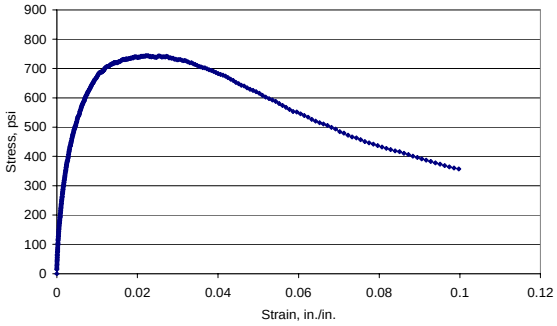
0% RAP SCB IDT2 Long-Term Aged: PG 64-22



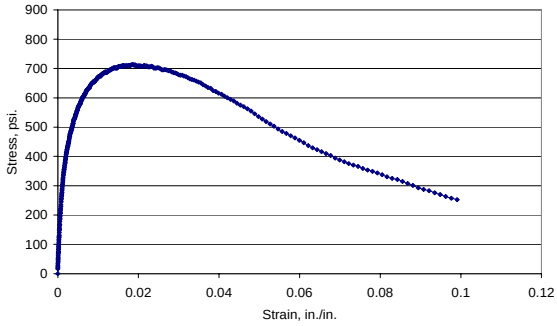
0% RAP SCB IDT3 Long-Term Aged: PG 64-22



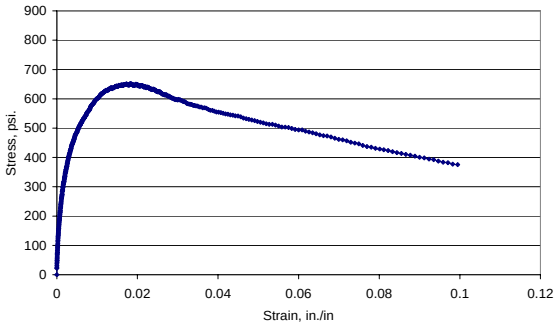
10% RAP SCB IDT1 Short-Term Aged: PG 64-22



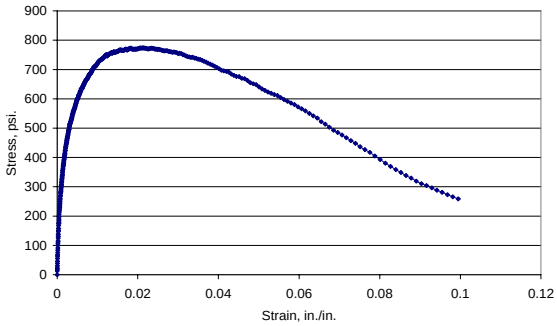
10% RAP SCB IDT1 Long-Term Aged: PG 64-22



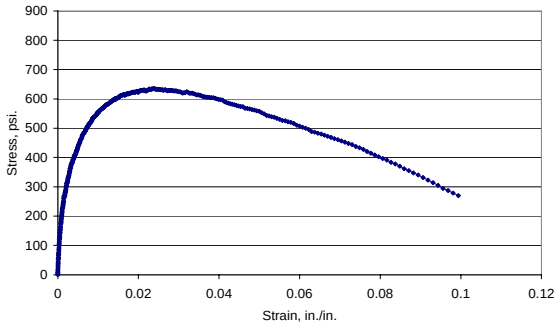
10% RAP SCB IDT2 Short-Term Aged: PG 64-22



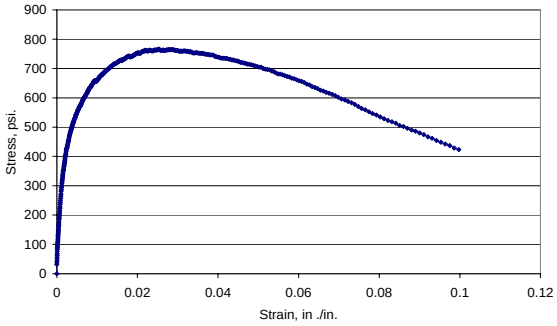
10% RAP SCB IDT2 Long-Term Aged: PG 64-22



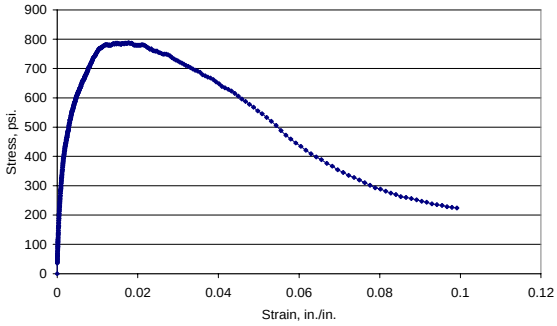
10% RAP SCB IDT3 Long-Term Aged: PG 64-22



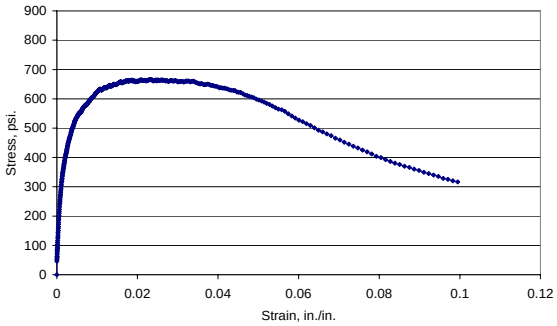
20% RAP SCB IDT1 Short-Term Aged: PG 64-22



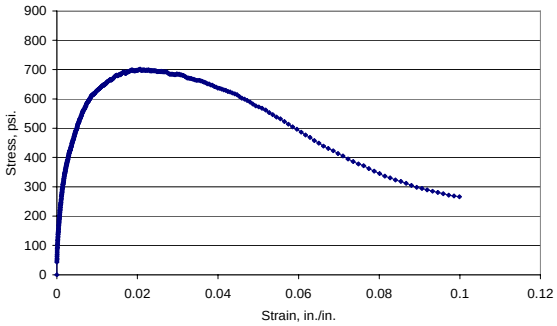
20% RAP SCB IDT1 Long-Term Aged: PG 64-22



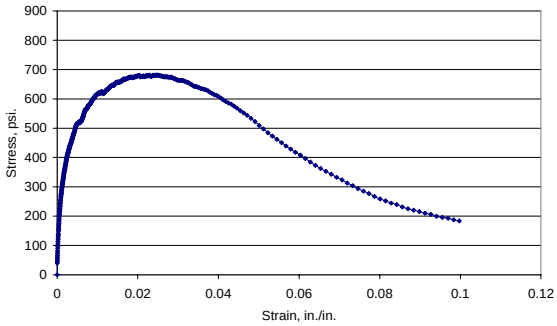
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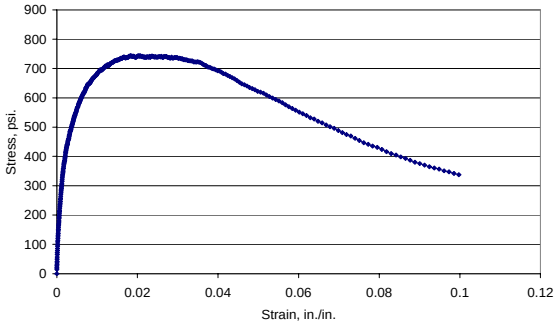
20% RAP SCB IDT3 Short-Term Aged: PG 64-22



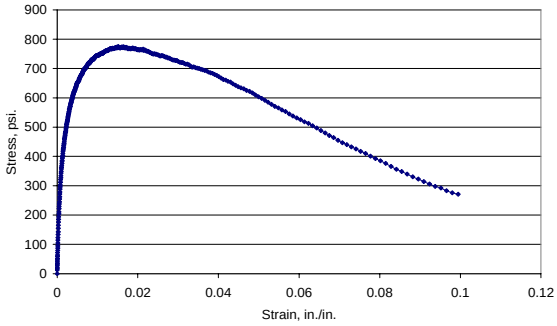
20% RAP SCB IDT3 Long-Term Aged: PG 64-22



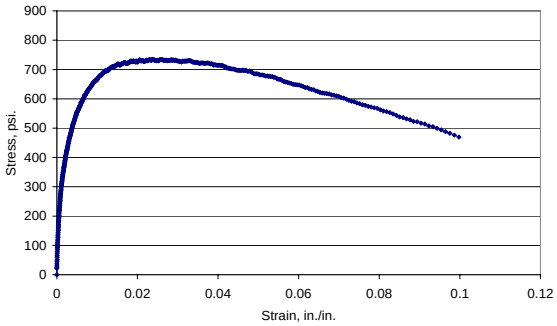
30% RAP SCB IDT1 Short-Term Aged: PG 64-22



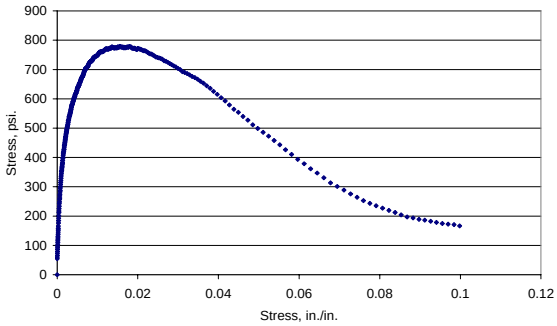
30% RAP SCB IDT1 Long-Term Aged: PG 64-22



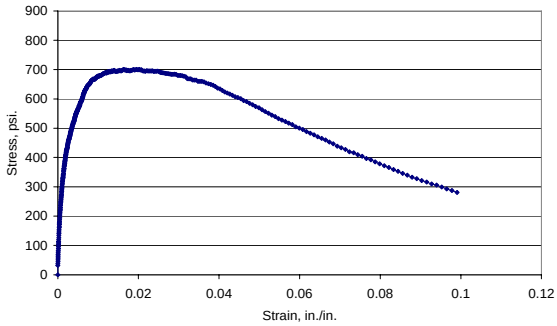
30% RAP SCB IDT2 Short-Term Aged: PG 64-22

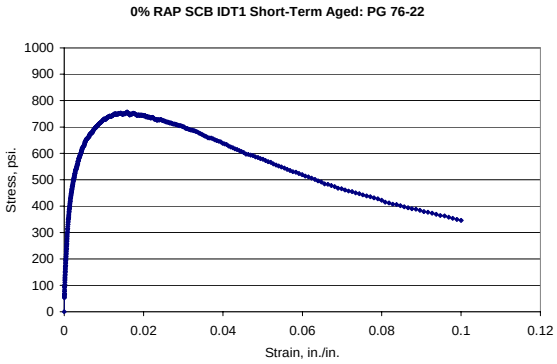


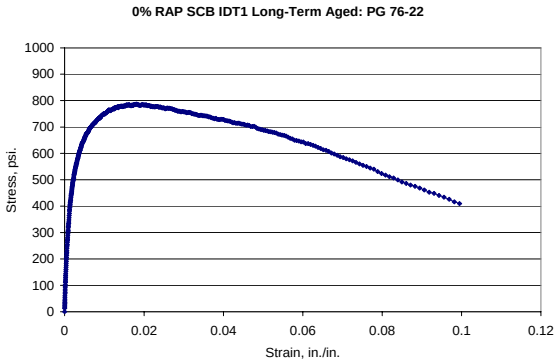
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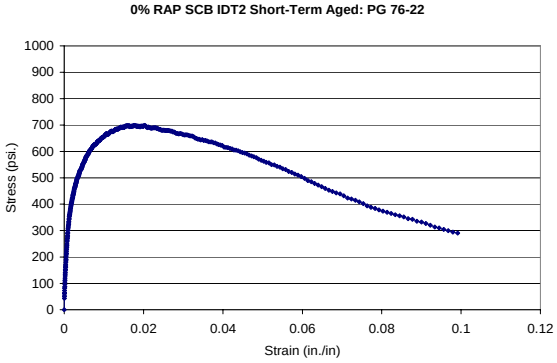


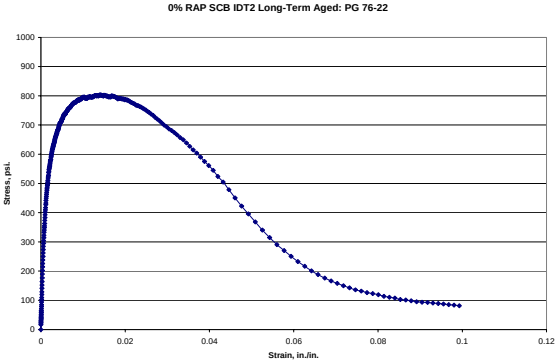
30% RAP SCB IDT3 Long-Term Aged: PG 64-22

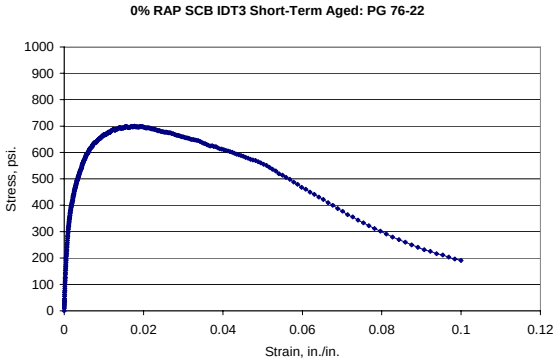


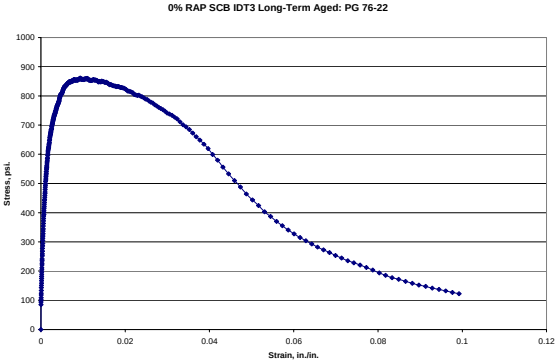

0% RAP SCB IDT1 Short-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.


0% RAP SCB IDT1 Long-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.

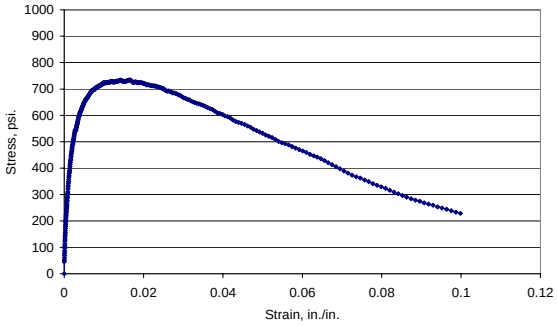

0% RAP SCB IDT2 Short-Term Aged: PG 76-22
Stress (psi.)
Strain (in./in)


0% RAP SCB IDT2 Long-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.

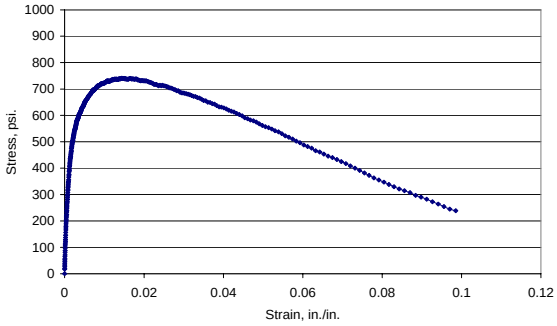

0% RAP SCB IDT3 Short-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.


0% RAP SCB IDT3 Long-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.

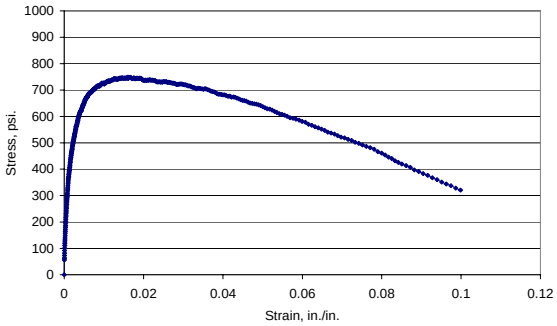
10% RAP SCB IDT1 Short-Term Aged: PG 76-22



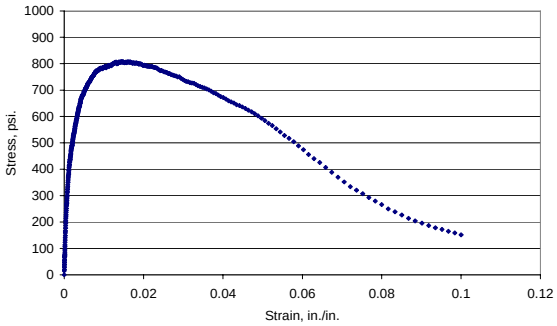
20% RAP SCB IDT1 Long-Term Aged: PG 76-22



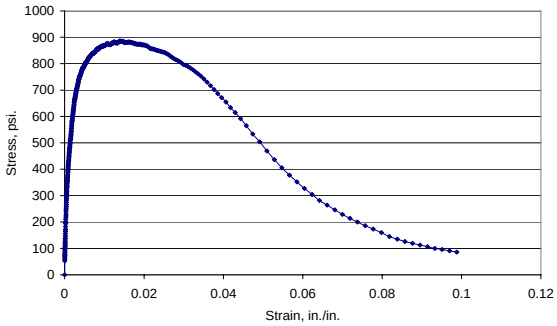
10% RAP SCB IDT2 Short-Term Aged: PG 76-22

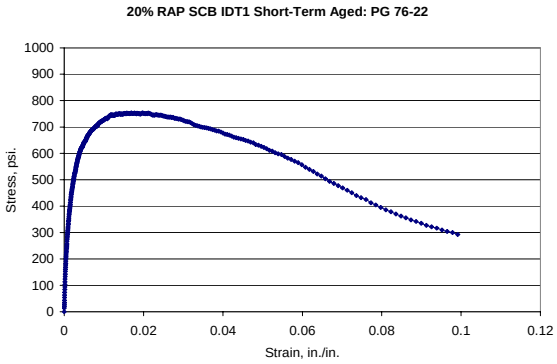


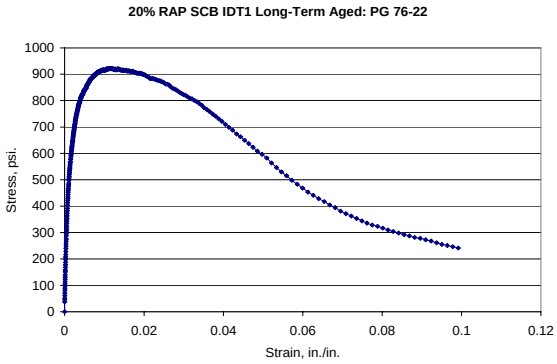
10% RAP SCB IDT3 Short-Term Aged: PG 76-22

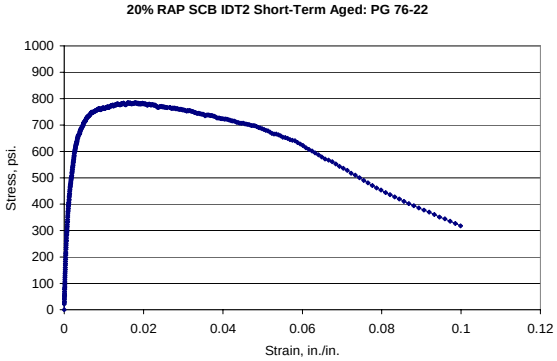


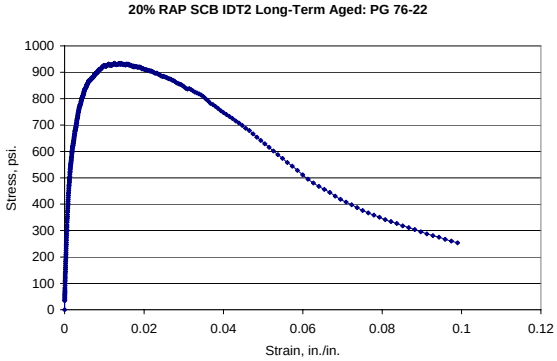
10% RAP SCB IDT3 Long-Term Aged: PG 76-22

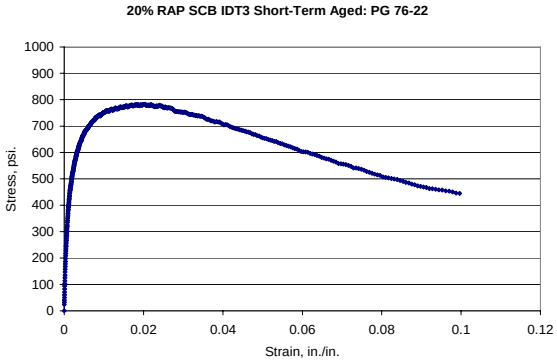


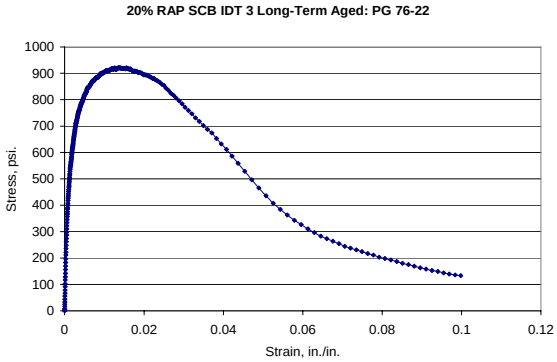

20% RAP SCB IDT1 Short-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.

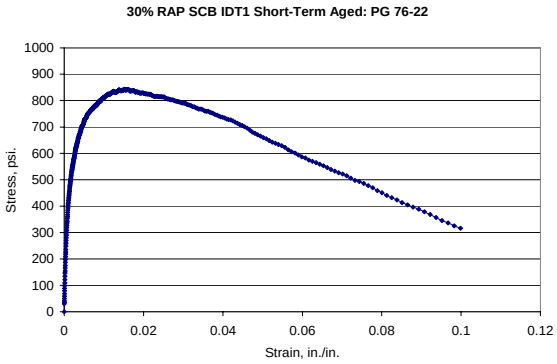

20% RAP SCB IDT1 Long-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.

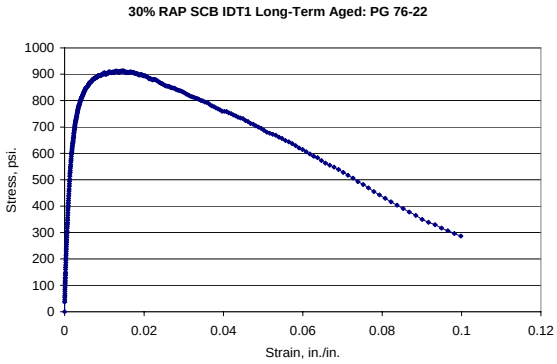

20% RAP SCB IDT2 Short-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.

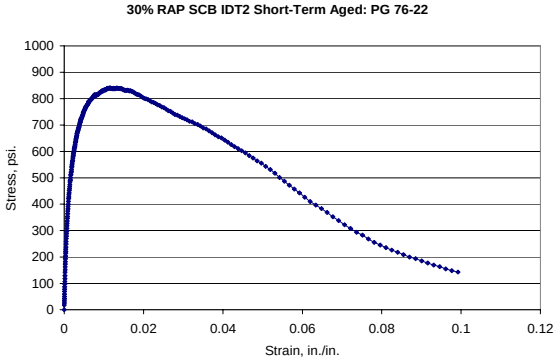

20% RAP SCB IDT2 Long-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.

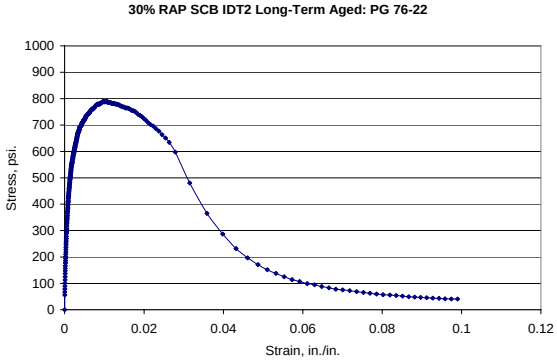

20% RAP SCB IDT3 Short-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.

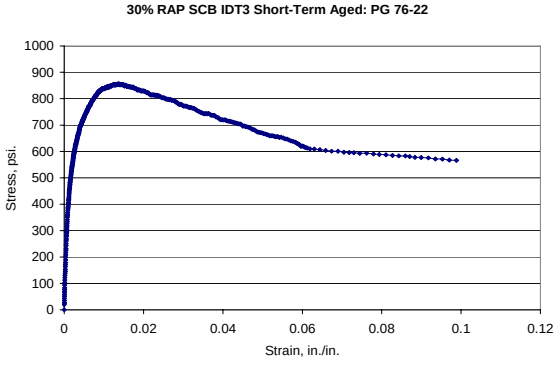

20% RAP SCB IDT 3 Long-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.

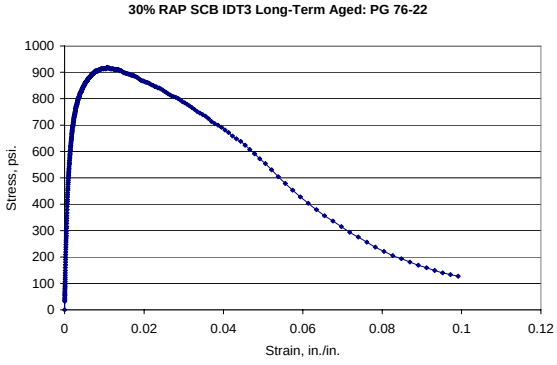

30% RAP SCB IDT1 Short-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.


30% RAP SCB IDT1 Long-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.


30% RAP SCB IDT2 Short-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.


30% RAP SCB IDT2 Long-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.


30% RAP SCB IDT3 Short-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.

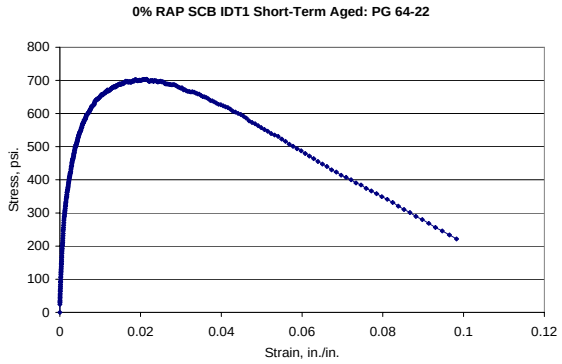

30% RAP SCB IDT3 Long-Term Aged: PG 76-22
Stress, psi.
Strain, in./in.

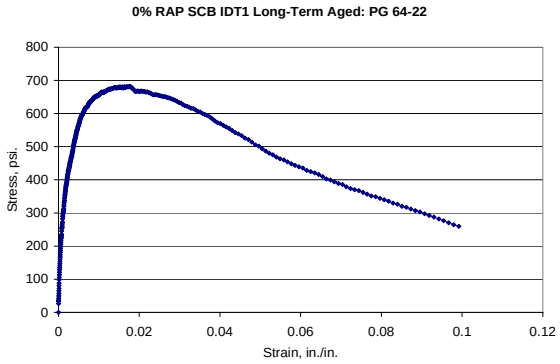
Gravel Mixtures

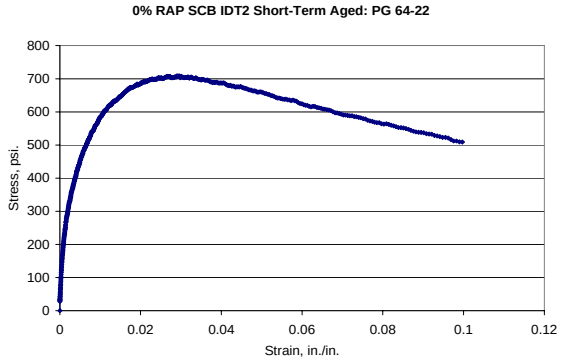
6 in. IDT: PG 64-22				Stress			Strain				TI		
Virgin	Stress, psi.	Strain in./in.	TI	avg	std	COV	avg	std	Diam. Strain,%	COV	avg	std.	COV
U-1	703.3	0.02148	0.69										
U-2	709.1	0.02953	0.86										
U-3	634.6	0.02478	0.75	671.8	52.7	7.8	0.0272	0.0034	2.715	12.4	0.805	0.081	10.1
A-1	682.1	0.01767	0.68										
A-2	706.2	0.02307	0.81										
A-3	651.4	0.02054	0.82	679.9	27.5	4.0	0.0204	0.0027	2.043	13.2	0.768	0.078	10.2
10% RAP	Stress, psi.	Strain in./in.	TI										
U-1	716.0	0.02230	0.81										
U-2	687.4	0.02241	0.74										
U-3	617.8	0.01882	0.72	673.7	50.5	7.5	0.0212	0.0020	2.118	9.7	0.756	0.046	6.1
A-1	739.8	0.01876	0.58										
A-2	763.5	0.01031	0.53										
A-3	701.7	0.01670	0.72	735.0	31.2	4.2	0.0153	0.0044	1.525	28.9	0.611	0.101	16.6
20% RAP	Stress, psi.	Strain in./in.	TI										
U-1	743.9	0.01175	0.62										
U-2	784.0	0.01459	0.46										
U-3	645.2	0.01249	0.58	724.4	71.4	9.9	0.0129	0.0015	1.294	11.4	0.551	0.081	14.7
A-1	864.2	0.00876	0.55										
A-2	888.8	0.01498	0.48										
A-3				876.5	17.4	2.0	0.0119	0.0044	1.187	37.1	0.515	0.043	8.3
30% RAP	Stress, psi.	Strain in./in.	TI										
U-1	954.7	0.01120	0.48										
U-2	861.8	0.00998	0.41										
U-3	802.8	0.01105	0.37	908.2	65.7	7.2	0.0106	0.0009	1.059	8.1	0.444	0.050	11.2
A-1	886.7	0.00682	0.30										
A-2	775.4	0.00729	0.33										
A-3	784.0	0.00866	0.23	815.4	61.9	7.6	0.0076	0.0010	0.759	12.6	0.287	0.053	18.6

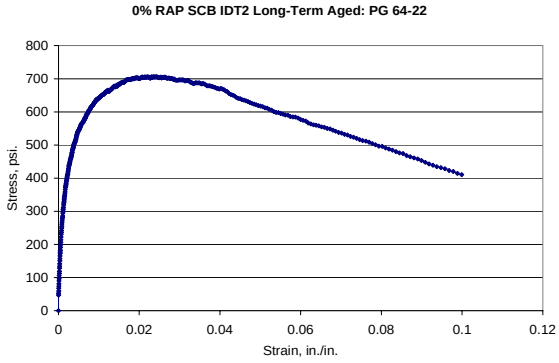
6 in. IDT: PG 70-22				Stress			Strain				TI		
Virgin	Stress, psi.	Strain, in./in.	TI	avg	std	COV	avg	std	diam strain %	COV	avg	std.	COV
U-1	634.6	0.016390	0.87										
U-2	655.0	0.020812	0.87										
U-3				644.8	14.5	2.2	0.0186	0.0031	1.860	16.8	0.869	0.005	0.6
A-1	698.8	0.004504	0.60										
A-2	719.3	0.015249	0.56										
A-3	758.6	0.020685	0.72	725.6	30.4	4.2	0.0135	0.0082	1.348	61.1	0.626	0.081	13.0
10% RAP	Stress, psi.	Strain, in./in.	TI										
U-1	845.4	0.018199	0.80										
U-2	770.9	0.021139	0.70										
U-3	679.2	0.015221	0.66	765.2	83.2	10.9	0.0182	0.0030	1.819	16.3	0.719	0.076	10.5
A-1	865.4	0.010185	0.31										
A-2	725.5	0.013837	0.44										
A-3				795.4	99.0	12.4	0.0120	0.0026	1.201	21.5	0.375	0.097	25.9
20% RAP	Stress, psi.	Strain, in./in.	TI										
U-1	786.0	0.013927	0.67										
U-2	764.7	0.016925	0.67										
U-3				775.4	15.1	1.7	0.0154	0.0021	1.543	13.7	0.667	0.003	0.7
A-1	947.7	0.010293	0.63										
A-2	883.0	0.008264	0.33										
A-3				915.4	45.7	5.0	0.0093	0.0014	0.928	15.5	0.479	0.213	44.5
30% RAP	Stress, psi.	Strain, in./in.	TI										
U-1	854.8	0.014511	0.39										
U-2	879.8	0.012707	0.53										
U-3				867.3	17.7	2.3	0.0136	0.0013	1.361	9.4	0.459	0.102	15.3
A-1	961.2	0.008361	0.51										
A-2	957.9	0.009823	0.28										
A-3	790.1	0.009450	0.31	903.1	97.9	10.8	0.0092	0.0008	0.921	8.2	0.369	0.123	33.4

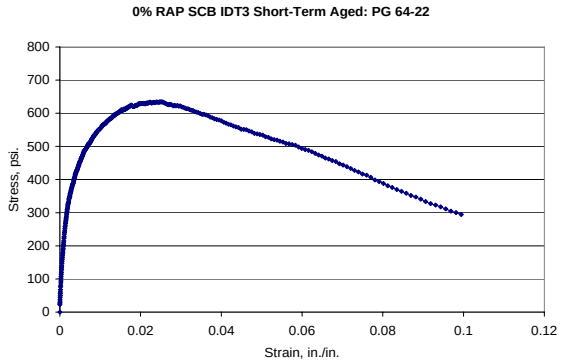
Bad Specimen

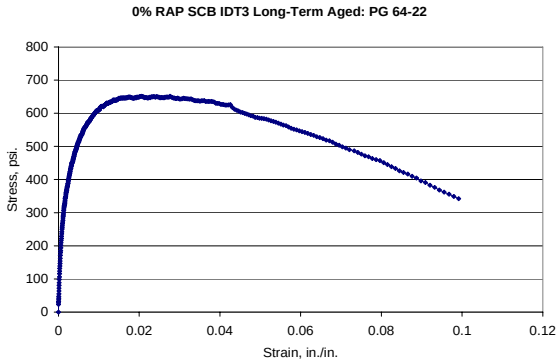

0% RAP SCB IDT1 Short-Term Aged: PG 64-22
Stress, psi.
800
700
600
500
400
300
200
100
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

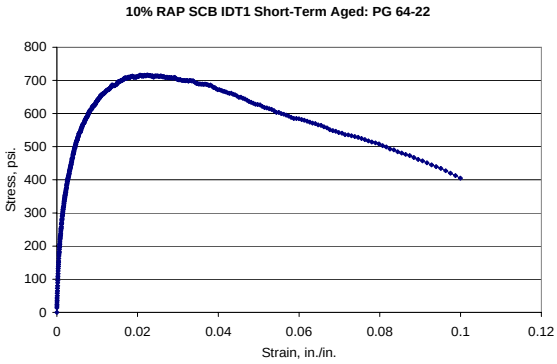

0% RAP SCB IDT1 Long-Term Aged: PG 64-22
Stress, psi.
800
700
600
500
400
300
200
100
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

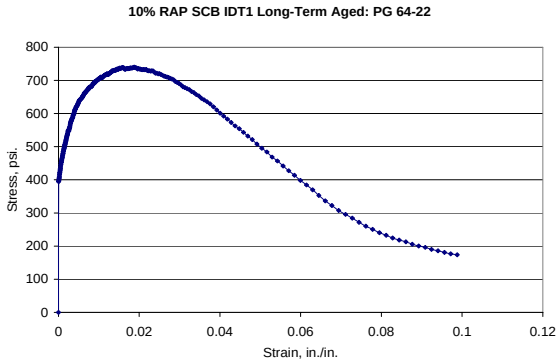

0% RAP SCB IDT2 Short-Term Aged: PG 64-22
Stress, psi.
800
700
600
500
400
300
200
100
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

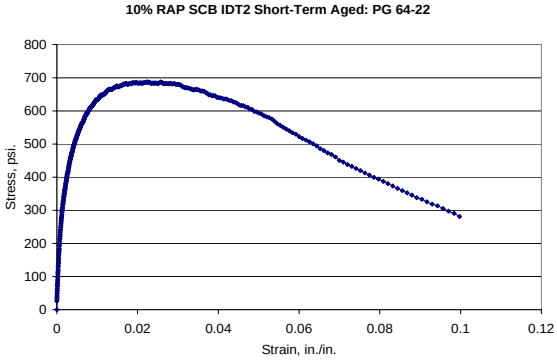

0% RAP SCB IDT2 Long-Term Aged: PG 64-22
Stress, psi.
800
700
600
500
400
300
200
100
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

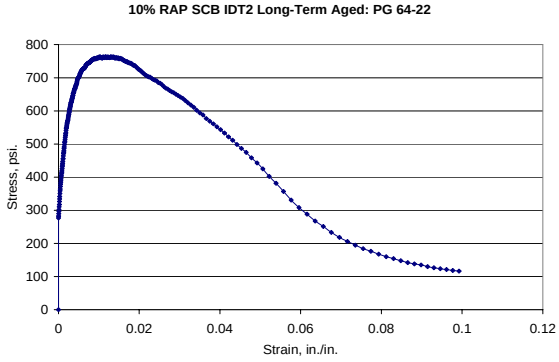

0% RAP SCB IDT3 Short-Term Aged: PG 64-22
Stress, psi.
800
700
600
500
400
300
200
100
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

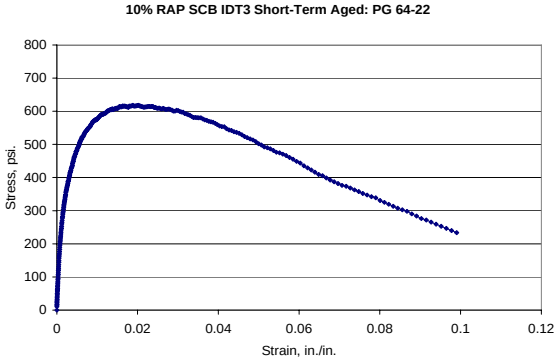

0% RAP SCB IDT3 Long-Term Aged: PG 64-22
Stress, psi.
800
700
600
500
400
300
200
100
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

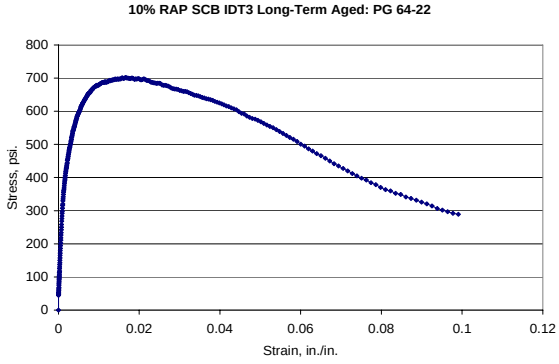

10% RAP SCB IDT1 Short-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
100
200
300
400
500
600
700
800
0
0.02
0.04
0.06
0.08
0.1
0.12


10% RAP SCB IDT1 Long-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
100
200
300
400
500
600
700
800
0
0.02
0.04
0.06
0.08
0.1
0.12

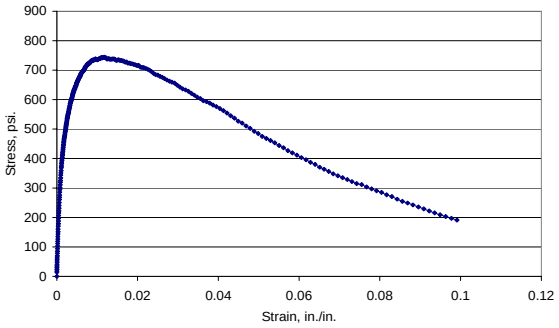

10% RAP SCB IDT2 Short-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
100
200
300
400
500
600
700
800
0
0.02
0.04
0.06
0.08
0.1
0.12


10% RAP SCB IDT2 Long-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
100
200
300
400
500
600
700
800
0
0.02
0.04
0.06
0.08
0.1
0.12

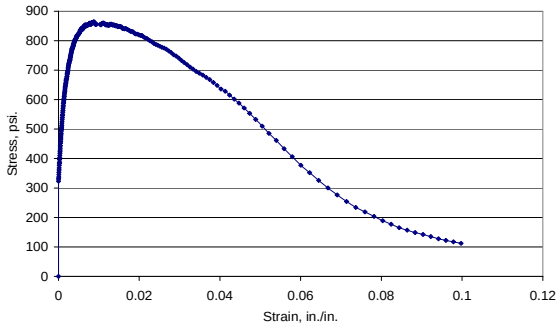

10% RAP SCB IDT3 Short-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
100
200
300
400
500
600
700
800
0
0.02
0.04
0.06
0.08
0.1
0.12


10% RAP SCB IDT3 Long-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
100
200
300
400
500
600
700
800
0
0.02
0.04
0.06
0.08
0.1
0.12

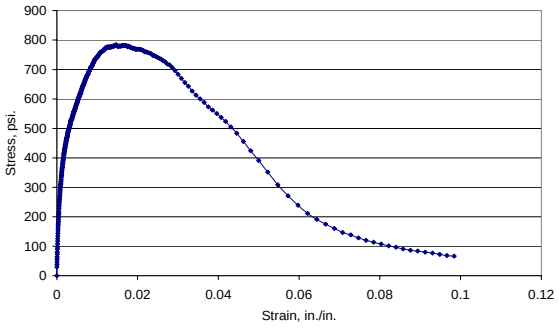
20% RAP SCB IDT1 Short-Term Aged: PG 64-22



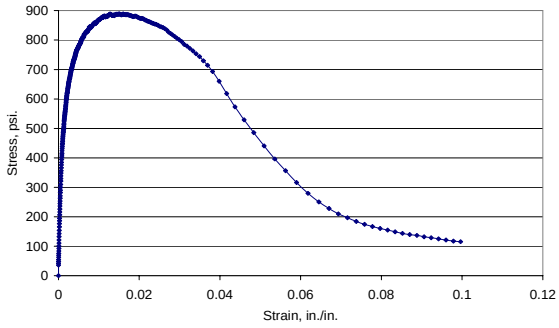
20% RAP SCB IDT1 Long-Term Aged: PG 64-22



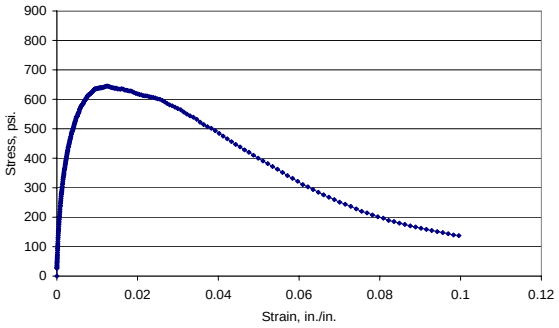
20% RAP SCB IDT2 Short-Term Aged: PG 64-22

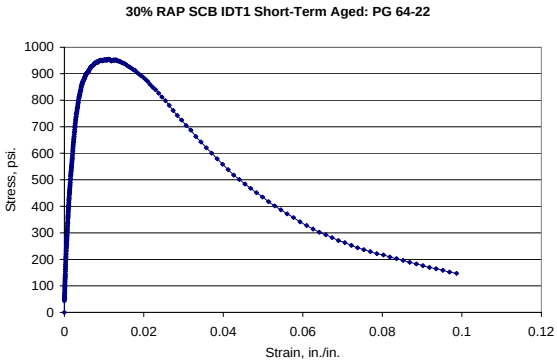


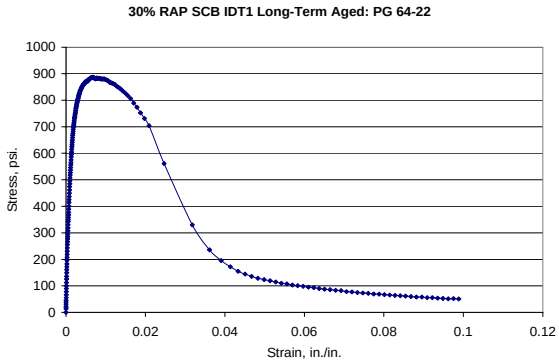
20% RAP SCB IDT2 Long-Term Aged: PG 64-22

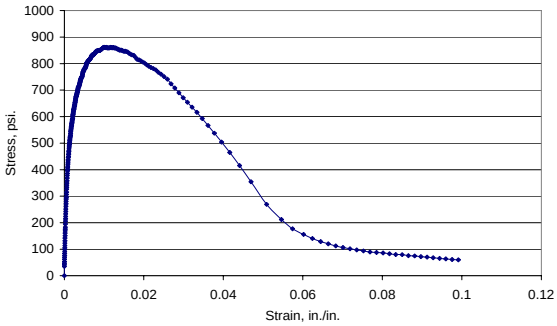


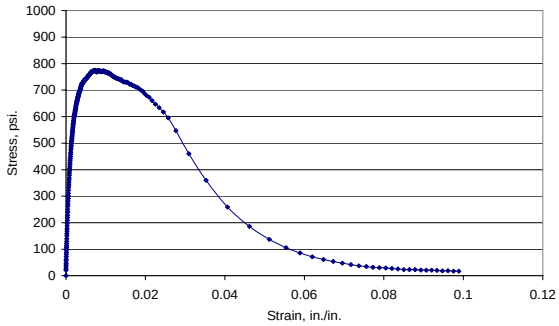
20% RAP SCB IDT3 Short-Term Aged: PG 64-22

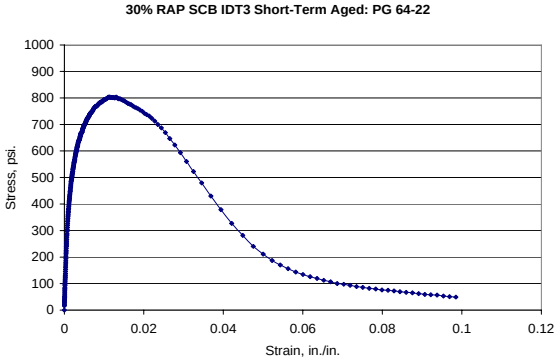


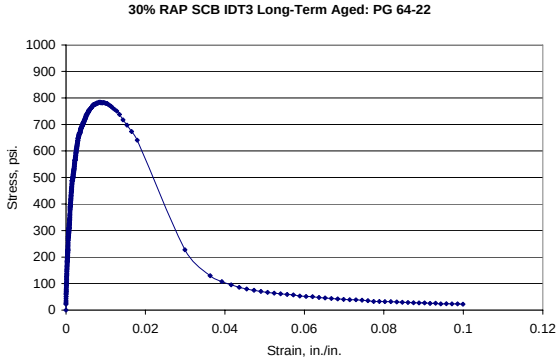

30% RAP SCB IDT1 Short-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
100
200
300
400
500
600
700
800
900
1000
0
0.02
0.04
0.06
0.08
0.1
0.12

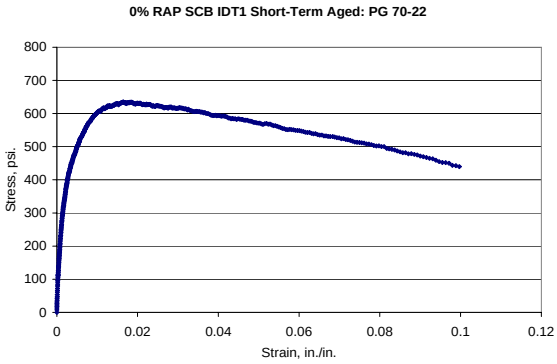

30% RAP SCB IDT1 Long-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
100
200
300
400
500
600
700
800
900
1000
0
0.02
0.04
0.06
0.08
0.1
0.12

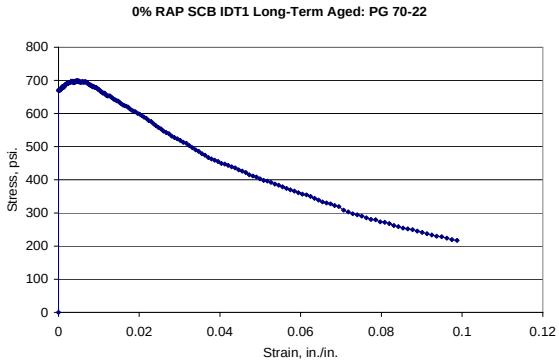

30% RAP SCB IDT2 Short-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
100
200
300
400
500
600
700
800
900
1000
0
0.02
0.04
0.06
0.08
0.1
0.12

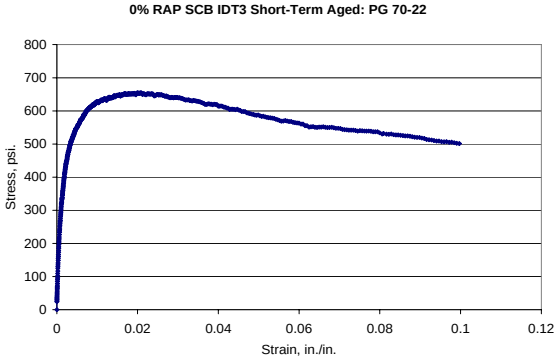

30% RAP SCB IDT2 Long-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
100
200
300
400
500
600
700
800
900
1000
0
0.02
0.04
0.06
0.08
0.1
0.12

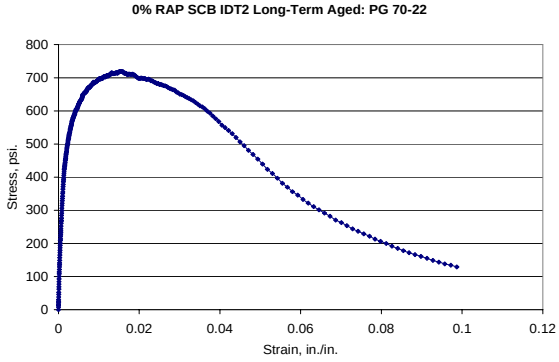

30% RAP SCB IDT3 Short-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
100
200
300
400
500
600
700
800
900
1000
0
0.02
0.04
0.06
0.08
0.1
0.12

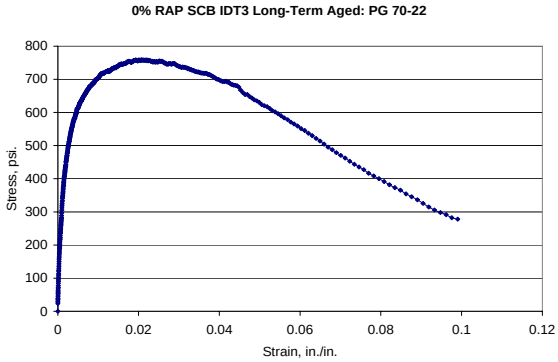

30% RAP SCB IDT3 Long-Term Aged: PG 64-22
Stress, psi.
Strain, in./in.
0
100
200
300
400
500
600
700
800
900
1000
0
0.02
0.04
0.06
0.08
0.1
0.12


0% RAP SCB IDT1 Short-Term Aged: PG 70-22
Stress, psi.
800
700
600
500
400
300
200
100
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

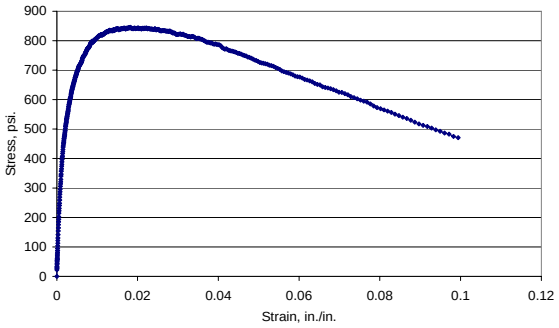

0% RAP SCB IDT1 Long-Term Aged: PG 70-22
Stress, psi.
800
700
600
500
400
300
200
100
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.


0% RAP SCB IDT3 Short-Term Aged: PG 70-22
Stress, psi.
800
700
600
500
400
300
200
100
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

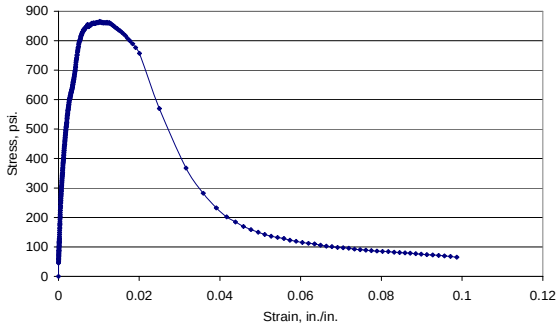

0% RAP SCB IDT2 Long-Term Aged: PG 70-22
Stress, psi.
800
700
600
500
400
300
200
100
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.


0% RAP SCB IDT3 Long-Term Aged: PG 70-22
Stress, psi.
800
700
600
500
400
300
200
100
0
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain, in./in.

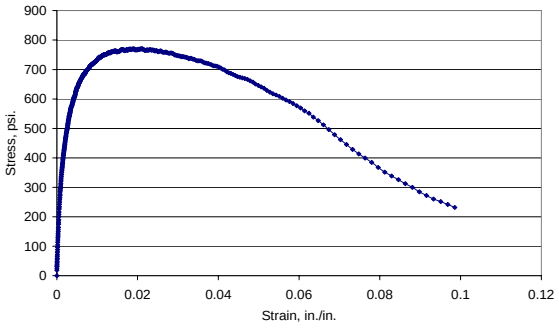
10% RAP SCB IDT1 Short-Term Aged: PG 70-22



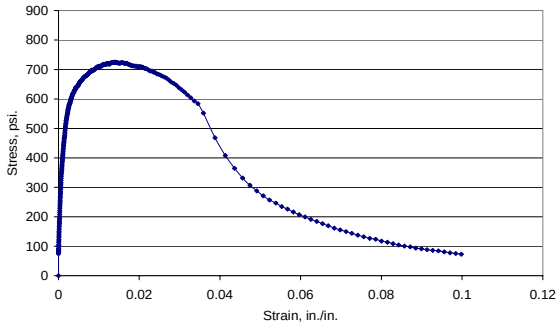
10% RAP SCB IDT1 Long-Term Aged: PG 70-22



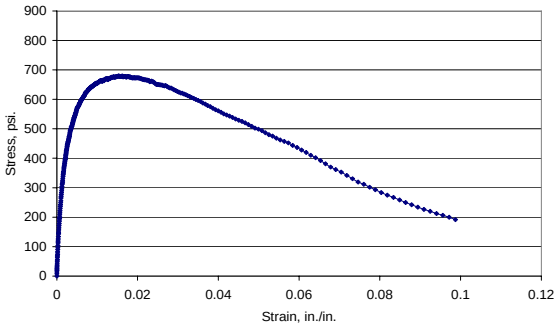
10% RAP SCB IDT2 Short-Term Aged: PG 70-22

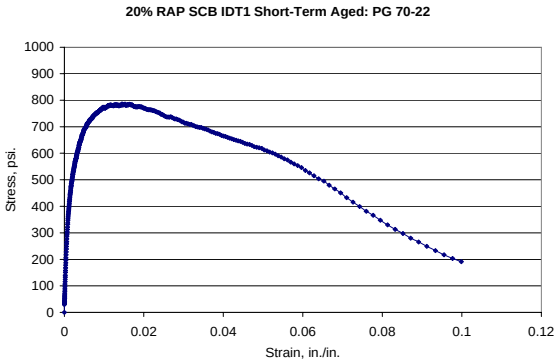


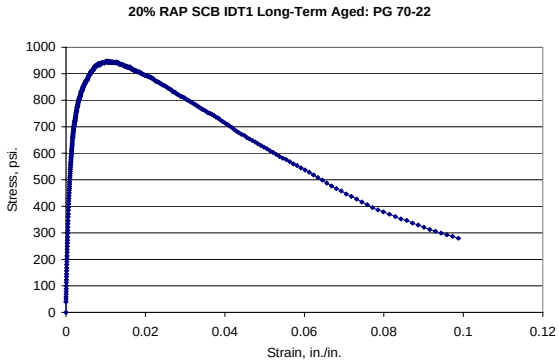
10% RAP SCB IDT2 Long-Term Aged: PG 70-22

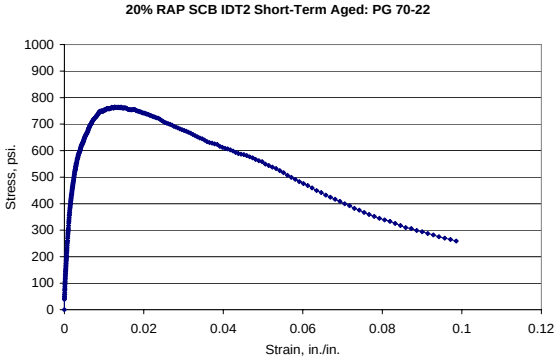


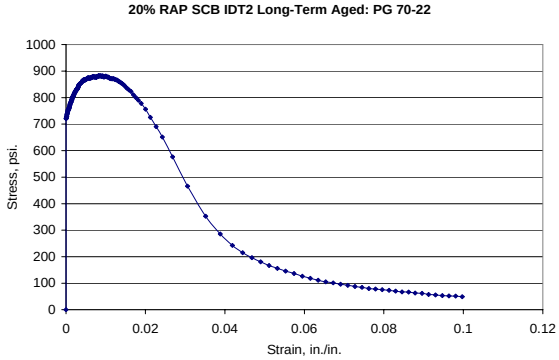
10% RAP SCB IDT3 Short-Term Aged: PG 70-22



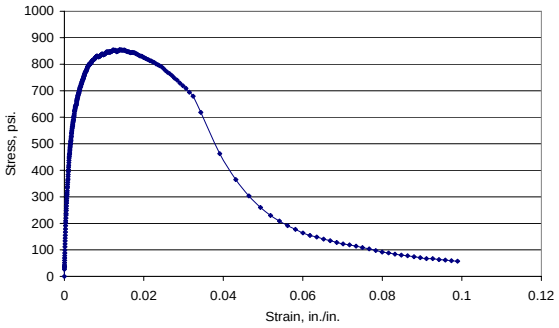

20% RAP SCB IDT1 Short-Term Aged: PG 70-22
Stress, psi.
Strain, in./in.


20% RAP SCB IDT1 Long-Term Aged: PG 70-22
Stress, psi.
Strain, in./in.

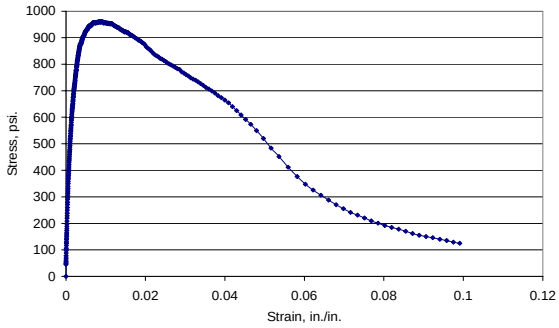

20% RAP SCB IDT2 Short-Term Aged: PG 70-22
Stress, psi.
Strain, in./in.


20% RAP SCB IDT2 Long-Term Aged: PG 70-22
Stress, psi.
Strain, in./in.

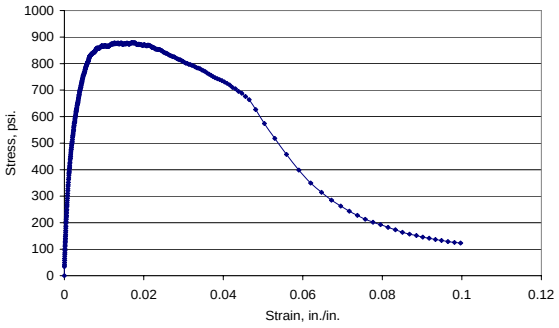
30% RAP SCB IDT1 Short-Term Aged: PG 70-22



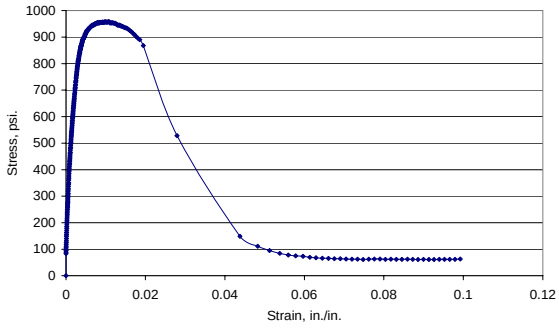
30% RAP SCB IDT1 Long-Term Aged: PG 70-22



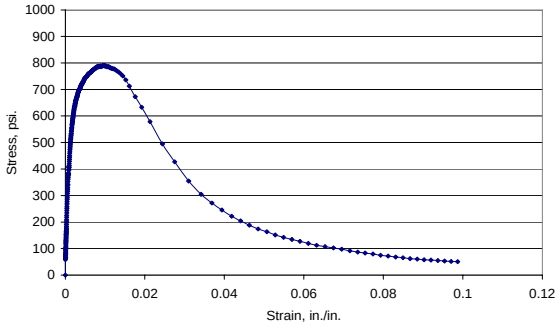
30% RAP SCB IDT2 Short-Term Aged: PG 70-22



30% RAP SCB IDT2 Long-Term Aged: PG 70-22



30% RAP SCB IDT3 Long-Term Aged: PG 70-22



APPENDIX E: SEMI-CIRCULAR BENDING J-INTEGRAL TEST DATA

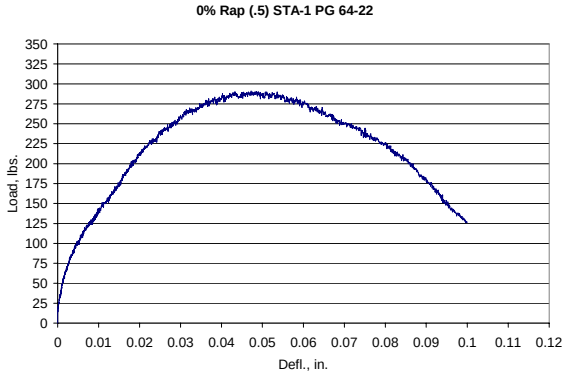
SCB Notched IDT

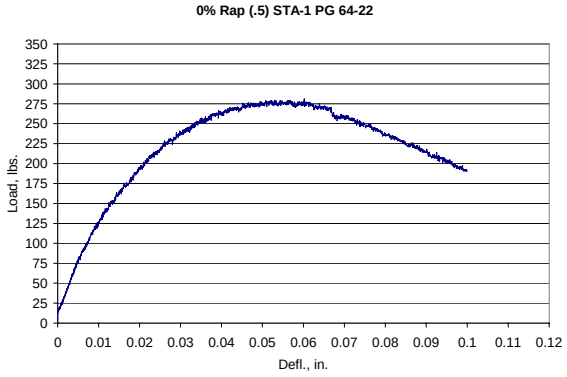
Limestone PG 64-22

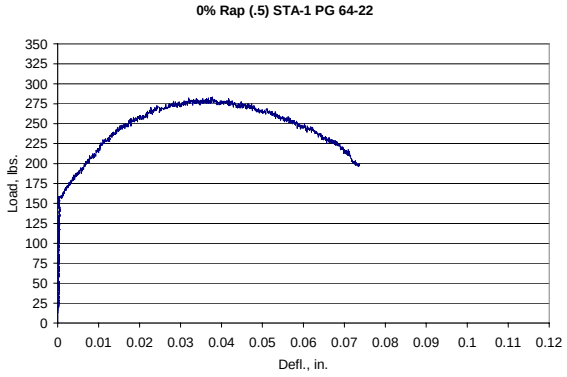
	.5" Notched Samples									Peak Load Area Calculations			
										Origin	Origin	Origin	Origin
	ID	Notch		Width		Peak		Defl.		Area	Area	Strain Energy	Strain Energy
		in.	mm	in.	m	lbs.	newtons	in.	mm	lb-in.	N-m	lbs/in.^2	J/m
0%		0.5	12.7	1.080	0.027	347.51	1545.80	0.051	1.288	12.3876	1.39961036	11.470	51.021
		0.5	12.7	1.080	0.027	344.07	1530.50	0.040	1.013	9.6015	1.084823442	8.890	39.546
		0.5	12.7	1.070	0.027	331.66	1475.30	0.033	0.843	7.7103	0.871146611	7.206	32.053
	Average	**0.5**	**12.7**	**1.0766667**	**0.0273473**	**341.08**	**1517.198878**	**0.0412667**	**1.0481733**	**9.8998**	**1.118526804**	**9.188721876**	**40.87345642**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**8.34**	**37.09**	**0.01**	**0.22**	**2.35**	**0.27**	**2.15**	**9.55**
	COV	**0.0**	**0.0**	**0.5**	**0.5**	**2.4**	**2.4**	**21.4**	**21.4**	**23.8**	**23.8**	**23.4**	**23.4**
		0.5	12.7	1.080	0.027	291.00	1294.43	0.047	1.199	9.8378	1.111521747	9.109	40.519
		0.5	12.7	1.070	0.027	281.36	1251.55	0.060	1.529	12.5704	1.420263979	11.748	52.258
		0.5	12.7	1.080	0.027	283.42	1260.71	0.038	0.960	9.0709	1.024873713	8.399	37.361
	Average	**0.5**	**12.7**	**1.0766667**	**0.0273473**	**285.26**	**1268.899237**	**0.0484**	**1.22936**	**10.49303333**	**1.185553147**	**9.75203098**	**43.37917924**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**5.08**	**22.58**	**0.01**	**0.29**	**1.84**	**0.21**	**1.76**	**7.85**
	COV	**0.0**	**0.0**	**0.5**	**0.5**	**1.8**	**1.8**	**23.2**	**23.2**	**17.5**	**17.5**	**18.1**	**18.1**
10%		0.5	12.7	1.060	0.027	315.12	1401.72	0.054	1.367	12.2077	1.379284396	11.517	51.229
		0.5	12.7	1.050	0.027	336.48	1496.74	0.049	1.250	11.5291	1.302612919	10.980	48.842
		0.5	12.7	1.050	0.027	328.90	1463.02	0.048	1.229	10.4711	1.183075014	9.972	44.360
	Average	**0.5**	**12.7**	**1.0533333**	**0.0267547**	**326.83333**	**1453.82657**	**0.0504667**	**1.2818533**	**11.40263333**	**1.28832411**	**10.82308985**	**48.14348472**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**10.83**	**48.17**	**0.00**	**0.07**	**0.88**	**0.10**	**0.78**	**3.49**
	COV	**0.0**	**0.0**	**0.5**	**0.5**	**3.3**	**3.3**	**5.8**	**5.8**	**7.7**	**7.7**	**7.2**	**7.2**
		0.5	12.7	1.040	0.026	287.05	1276.86	0.055	1.400	10.7125	1.210349541	10.300	45.819
		0.5	12.7	1.050	0.027	328.22	1459.99	0.057	1.455	13.3699	1.510595317	12.733	56.640
		0.5	12.7	1.050	0.027	310.29	1380.24	0.045	1.140	12.4951	1.411756225	11.900	52.934
	Average	**0.5**	**12.7**	**1.0466667**	**0.0265853**	**308.52**	**1372.364834**	**0.0524333**	**1.3318067**	**12.1925**	**1.377567028**	**11.6446047**	**51.79776352**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**20.64**	**91.82**	**0.01**	**0.17**	**1.35**	**0.15**	**1.24**	**5.50**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**6.7**	**6.7**	**12.6**	**12.6**	**11.1**	**11.1**	**10.6**	**10.6**
20%		0.5	12.7	1.050	0.027	380.59	1692.95	0.025	0.627	10.3251	1.166579235	9.833	43.741
		0.5	12.7	1.060	0.027	377.14	1677.60	0.047	1.186	12.3699	1.397610529	11.670	51.909
		0.5	12.7	1.050	0.027	410.22	1824.75	0.041	1.039	12.4951	1.411756225	11.900	52.934
	Average	**0.5**	**12.7**	**1.0533333**	**0.0267547**	**389.31667**	**1731.766183**	**0.0374333**	**0.9508067**	**11.73003333**	**1.325315329**	**11.1344136**	**49.52832125**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**18.18**	**80.89**	**0.01**	**0.29**	**1.22**	**0.14**	**1.13**	**5.04**
	COV	**0.0**	**0.0**	**0.5**	**0.5**	**4.7**	**4.7**	**30.5**	**30.5**	**10.4**	**10.4**	**10.2**	**10.2**
		0.5	12.7	1.050	0.027	317.19	1410.93	0.047	1.189	12.1198	1.369353034	11.543	51.344
		0.5	12.7	1.060	0.027	358.54	1594.86	0.057	1.440	14.4871	1.636821922	13.667	60.794
		0.5	12.7	1.060	0.027	374.39	1665.37	0.043	1.095	11.1945	1.264808209	10.561	46.977
	Average	**0.5**	**12.7**	**1.0566667**	**0.0268393**	**350.04**	**1557.054929**	**0.0488667**	**1.2412133**	**12.60046667**	**1.423661055**	**11.9235304**	**53.03848639**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**29.53**	**131.37**	**0.01**	**0.18**	**1.70**	**0.19**	**1.59**	**7.06**
	COV	**0.0**	**0.0**	**0.5**	**0.5**	**8.4**	**8.4**	**14.4**	**14.4**	**13.5**	**13.5**	**13.3**	**13.3**
30%		0.5	12.7	1.090	0.028	449.50	1999.47	0.027	0.693	8.9589	1.012219417	8.219	36.561
		0.5	12.7	1.020	0.026	438.47	1950.41	0.029	0.734	8.6504	0.97736361	8.481	37.724
		0.5	12.7	1.020	0.026	348.20	1548.87	0.026	0.650	6.6564	0.752071943	6.526	29.029
	Average	**0.5**	**12.7**	**1.0433333**	**0.0265007**	**412.05667**	**1832.918706**	**0.0272667**	**0.6925733**	**8.088566667**	**0.91388499**	**7.741946993**	**34.43788345**
	STD Dev.	**0.00**	**0.00**	**0.04**	**0.00**	**55.58**	**247.21**	**0.00**	**0.04**	**1.25**	**0.14**	**1.06**	**4.72**
	COV	**0.0**	**0.0**	**3.9**	**3.9**	**13.5**	**13.5**	**6.1**	**6.1**	**15.5**	**15.5**	**13.7**	**13.7**
		0.5	12.7	1.050	0.027	273.09	1214.76	0.041	1.039	8.5382	0.964686717	8.132	36.171
		0.5	12.7	1.040	0.026	337.17	1499.81	0.040	1.003	9.3348	1.054690399	8.976	39.926
		0.5	12.7	1.020	0.026	369.56	1643.89	0.037	0.927	9.5686	1.081106242	9.381	41.729
	Average	**0.5**	**12.7**	**1.0366667**	**0.0263313**	**326.61**	**1452.82**	**0.04**	**0.99**	**9.15**	**1.03**	**8.83**	**39.28**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**49.10**	**218.39**	**0.00**	**0.06**	**0.54**	**0.06**	**0.64**	**2.84**
	COV	**0.0**	**0.0**	**1.5**	**1.5**	**15.0**	**15.0**	**5.8**	**5.8**	**5.9**	**5.9**	**7.2**	**7.2**

Limestone 64-22 0.5” 0%

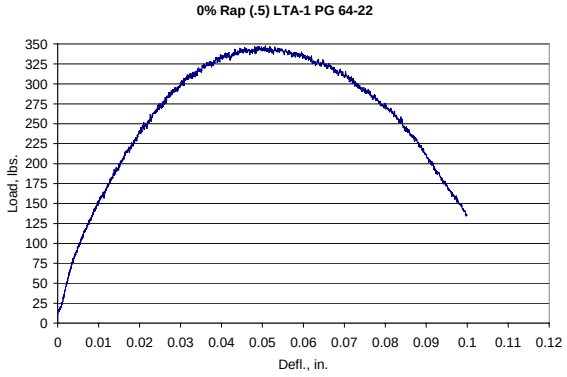
Short term age

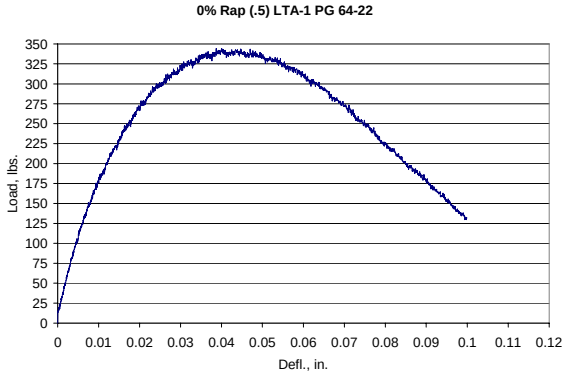


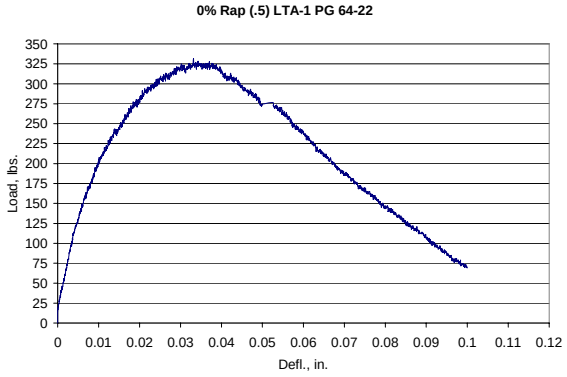




Long term age

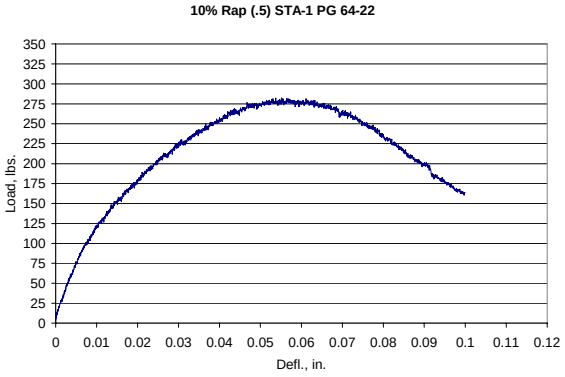


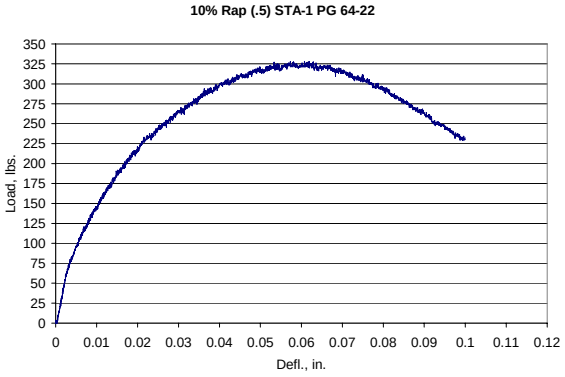


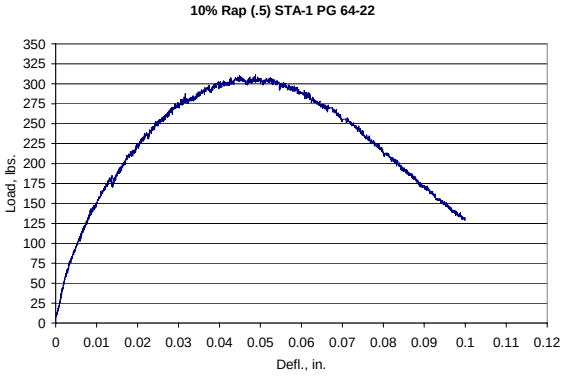


Limestone 64-22 0.5” 10%

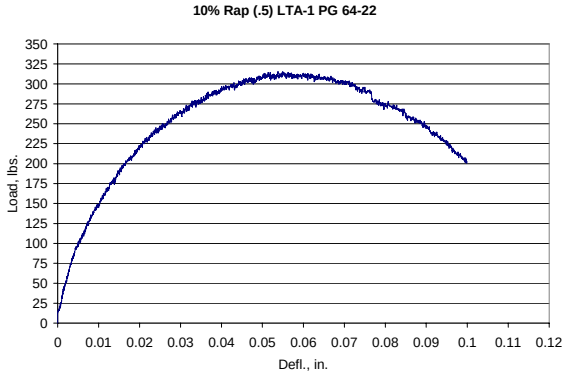
Short term age

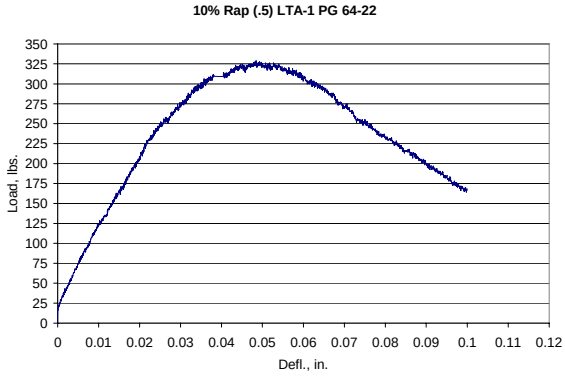


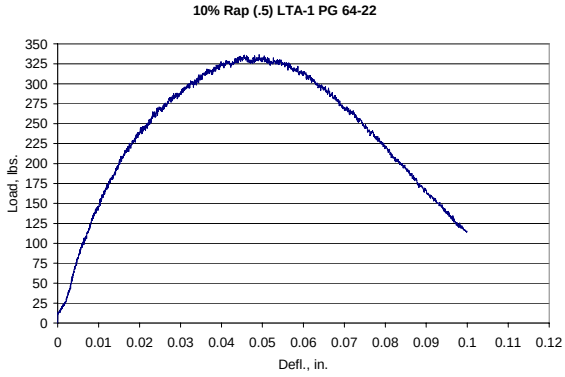




Long term age

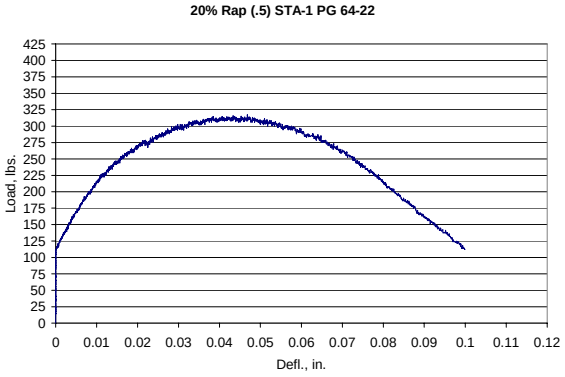


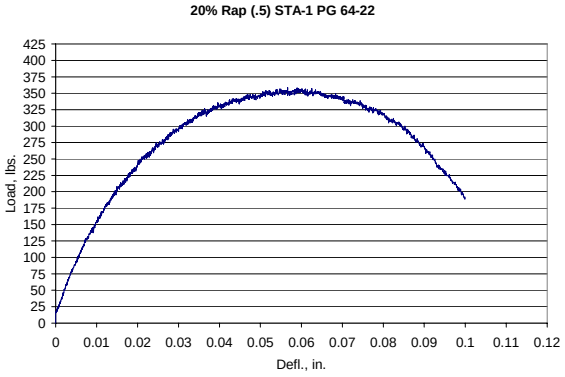


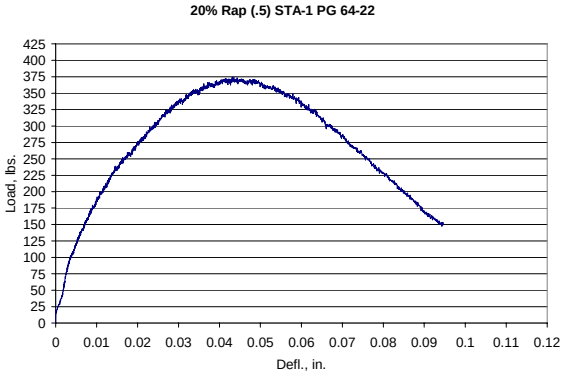


Limestone 64-22 0.5” 20%

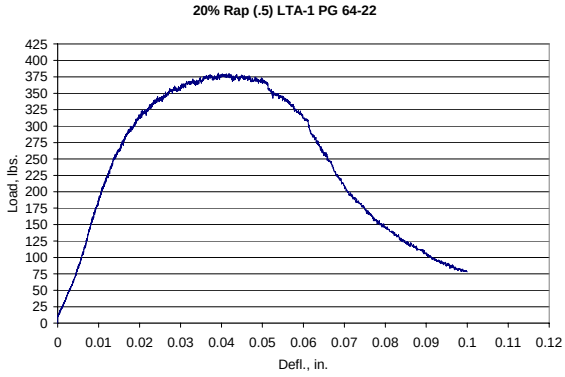
Short term age

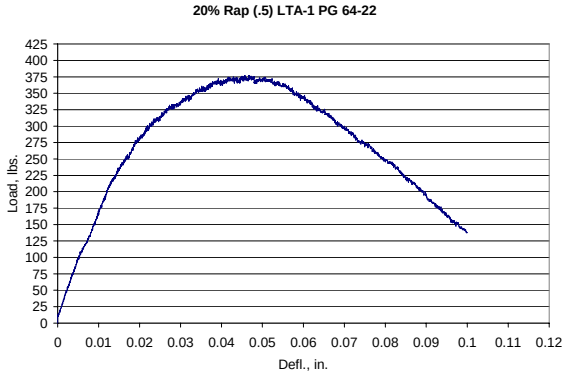


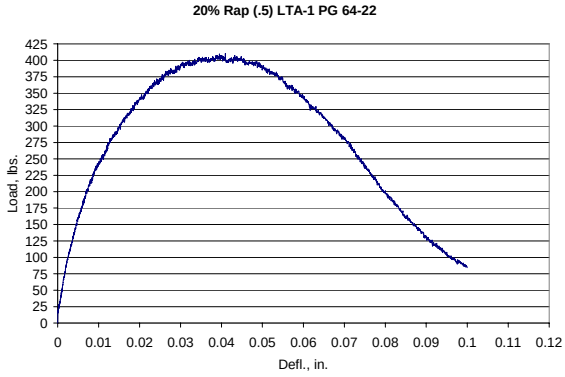




Long term age

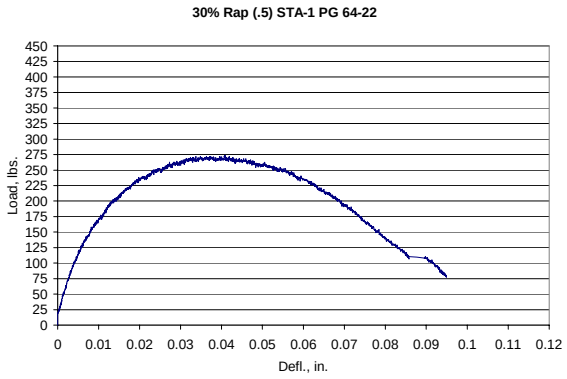


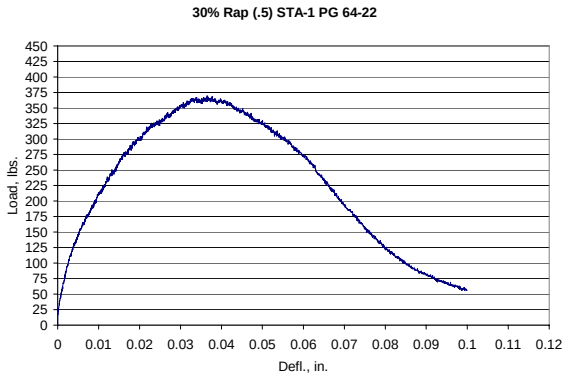


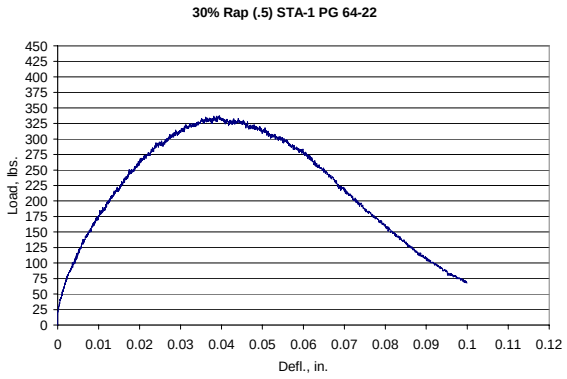


Limestone 64-22 0.5” 30%

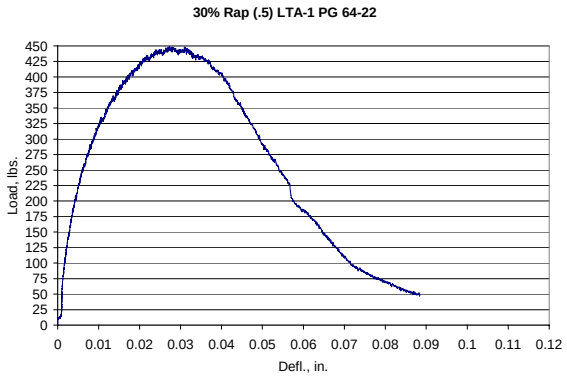
Short term age

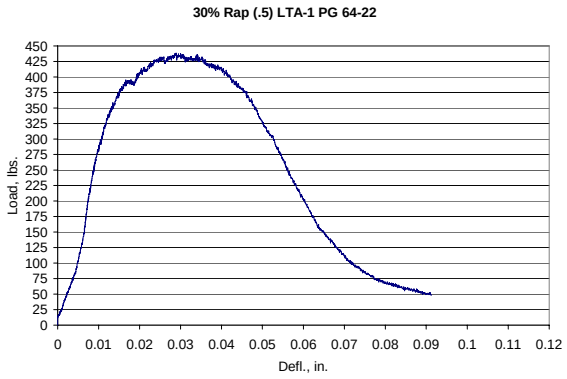


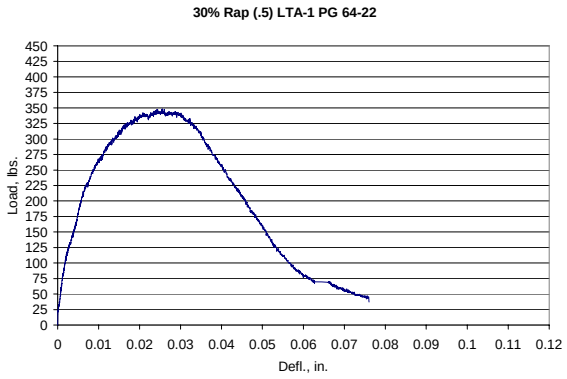




Long term age





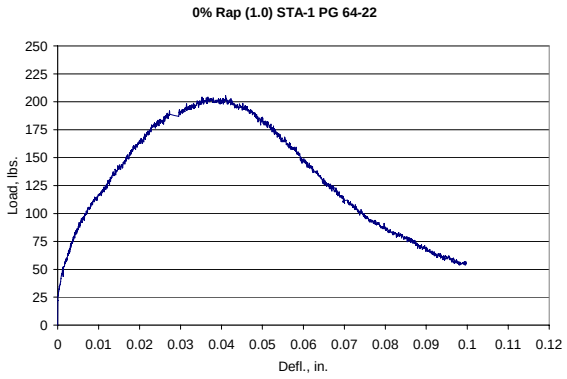


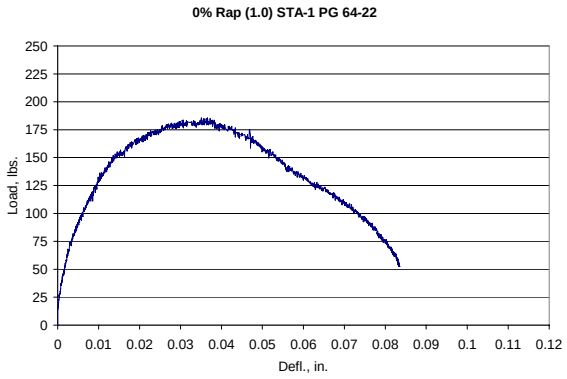
		1" Notched Samples								Peak Load Area Calculations			
										Origin	Origin	Origin	Origin
	ID	Notch		Width		Peak		Defl.		Area	Area	Strain Energy	Strain Energy
		in.	mm	in.	m	lbs.	newtons	in.	mm	lb-in.	N-m	lbs/in.^2	J/m
0%		1	25.4	1.000	0.025	186.95	831.59	0.031	0.795	4.1766	0.471892266	4.177	18.578
		1	25.4	1.000	0.025	224.16	997.11	0.042	1.072	6.8254	0.771166372	6.825	30.361
		1	25.4	1.000	0.025	204.18	908.24	0.033	0.833	4.8952	0.553083134	4.895	21.775
	Average	**1**	**25.4**	**1.000**	**0.0254**	**205.09667**	**912.3150946**	**0.0354333**	**0.9000067**	**5.299066667**	**0.598713924**	**5.299066667**	**23.57141433**
	STD Dev.	**0.00**	**0.00**	**0.00**	**0.00**	**18.62**	**82.83**	**0.01**	**0.15**	**1.37**	**0.15**	**1.37**	**6.09**
	COV	**0.0**	**0.0**	**0.0**	**0.0**	**9.1**	**9.1**	**16.7**	**16.7**	**25.8**	**25.8**	**25.8**	**25.8**
		1	25.4	1.000	0.025	205.55	914.33	0.041	1.041	6.2151	0.702211756	6.215	27.646
		1	25.4	1.000	0.025	185.57	825.46	0.035	0.892	5.0262	0.567884141	5.026	22.358
		1	25.4	1.000	0.025	187.64	834.66	0.050	1.257	6.5082	0.735327597	6.508	28.950
	Average	**1**	**25.4**	**1**	**0.0254**	**192.92**	**858.1506024**	**0.0418667**	**1.0634133**	**5.9165**	**0.668474498**	**5.9165**	**26.31789363**
	STD Dev.	**0.00**	**0.00**	**0.00**	**0.00**	**10.99**	**48.87**	**0.01**	**0.18**	**0.78**	**0.09**	**0.78**	**3.49**
	COV	**0.0**	**0.0**	**0.0**	**0.0**	**5.7**	**5.7**	**17.3**	**17.3**	**13.3**	**13.3**	**13.3**	**13.3**
10%		1	25.4	1.040	0.026	214.51	954.19	0.038	0.968	5.5862	0.631155623	5.371	23.893
		1	25.4	1.040	0.026	262.75	1168.77	0.008	0.203	0.091699	0.010360592	0.088	0.392
		1	25.4	1.050	0.027	261.37	1162.63	0.037	0.930	7.3831	0.834177988	7.032	31.278
	Average	**1**	**25.4**	**1.045**	**0.027**	**237.940**	**1058.409**	**0.037**	**0.949**	**6.485**	**0.733**	**6.201**	**27.585**
	STD Dev.	**0.00**	**0.0**	**0.01**	**0.00**	**33.14**	**147.39**	**0.00**	**0.03**	**1.27**	**0.14**	**1.17**	**5.22**
	COV	**0.0**	**0.0**	**0.7**	**0.7**	**13.9**	**13.9**	**2.8**	**2.8**	**19.6**	**19.6**	**18.9**	**18.9**
		1	25.4	1.030	0.026	235.19	1046.18	0.040	1.003	6.9177	0.781594868	6.716	29.875
		1	25.4	1.040	0.026	224.16	997.11	0.047	1.196	7.4093	0.83713819	7.124	31.691
		1	25.4	1.030	0.026	203.49	905.17	0.032	0.810	5.0782	0.57375935	4.930	21.931
	Average	**1**	**25.4**	**1.0333333**	**0.0262467**	**220.94667**	**982.8193816**	**0.0395**	**1.0033**	**6.4684**	**0.730830803**	**6.256943926**	**27.83226311**
	STD Dev.	**0.00**	**0.0**	**0.01**	**0.00**	**16.09**	**71.58**	**0.01**	**0.19**	**1.23**	**0.14**	**1.17**	**5.19**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**7.3**	**7.3**	**19.2**	**19.2**	**19.0**	**19.0**	**18.6**	**18.6**
20%		1	25.4	1.040	0.026	308.92	1374.14	0.005	0.117	0.3058	0.034550748	0.294	1.308
		1	25.4	1.040	0.026	315.81	1404.79	0.029	0.729	6.5963	0.745281557	6.343	28.213
		1	25.4	1.050	0.027	258.62	1150.40	0.024	0.605	4.378005	0.494647967	4.170	18.547
	Average	**1**	**25.4**	**1.045**	**0.027**	**287.215**	**1277.596**	**0.026**	**0.667**	**5.487**	**0.620**	**5.256**	**23.380**
	STD Dev.	**0.00**	**0.0**	**0.01**	**0.00**	**40.44**	**179.88**	**0.00**	**0.09**	**1.57**	**0.18**	**1.54**	**6.84**
	COV	**0.0**	**0.0**	**0.7**	**0.7**	**14.1**	**14.1**	**13.2**	**13.2**	**28.6**	**28.6**	**29.2**	**29.2**
		1	25.4	1.030	0.026	272.39	1211.65	0.035	0.899	6.8899	0.778453891	6.689	29.755
		1	25.4	1.040	0.026	344.06	1530.45	0.048	1.212	11.6187	1.312736356	11.172	49.695
		1	25.4	1.040	0.026	226.92	1009.39	0.004	0.100	6.4945	0.733779706	6.245	27.778
	Average	**1**	**25.4**	**1.0366667**	**0.0263313**	**281.12333**	**1250.498434**	**0.0290067**	**0.7367693**	**8.334366667**	**0.941656651**	**8.035253921**	**35.7425772**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**59.06**	**262.70**	**0.02**	**0.57**	**2.85**	**0.32**	**2.73**	**12.12**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**21.0**	**21.0**	**77.8**	**77.8**	**34.2**	**34.2**	**33.9**	**33.9**
30%		1	25.4	1.040	0.026	327.53	1456.93	0.031	0.775	7.2561	0.81982892	6.977	31.035
		1	0	1.050	0.027	264.82	1177.98	0.020	0.503	3.8617	0.436313356	3.678	16.360
		1	25.4	1.040	0.026	272.40	1211.70	0.021	0.544	5.1164	0.578075369	4.920	21.884
	Average	**1**	**16.93333333**	**1.0433333**	**0.0265007**	**288.25**	**1282.199415**	**0.0239**	**0.60706**	**5.4114**	**0.611405882**	**5.19148138**	**23.0928513**
	STD Dev.	**0.00**	**14.66**	**0.01**	**0.00**	**34.23**	**152.25**	**0.01**	**0.15**	**1.72**	**0.19**	**1.67**	**7.41**
	COV	**0.0**	**86.6**	**0.6**	**0.6**	**11.9**	**11.9**	**24.1**	**24.1**	**31.7**	**31.7**	**32.1**	**32.1**
		1	25.4	1.030	0.026	284.80	1266.85	0.034	0.866	6.6788	0.754602802	6.484	28.843
		1	25.4	1.040	0.026	284.11	1263.78	0.039	0.986	7.6473	0.864028569	7.353	32.709
		1	25.4	1.040	0.026	237.94	1058.41	0.030	0.762	5.3776	0.607586996	5.171	23.001
	Average	**1**	**25.4**	**1.0366667**	**0.0263313**	**268.95**	**1196.348769**	**0.0343**	**0.87122**	**6.5679**	**0.742072789**	**6.336071384**	**28.18423945**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**26.86**	**119.47**	**0.00**	**0.11**	**1.14**	**0.13**	**1.10**	**4.89**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**10.0**	**10.0**	**12.8**	**12.8**	**17.3**	**17.3**	**17.3**	**17.3**

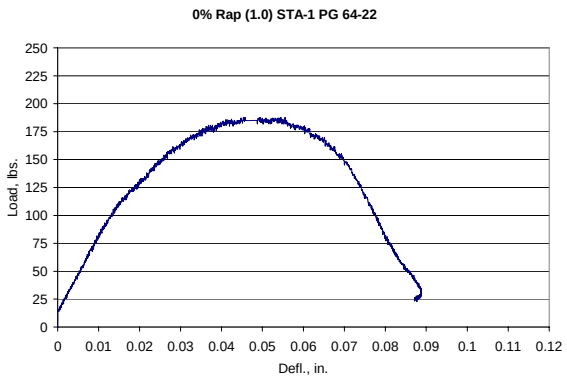
Bad Specimen

Limestone 64-22 1.0” 0%

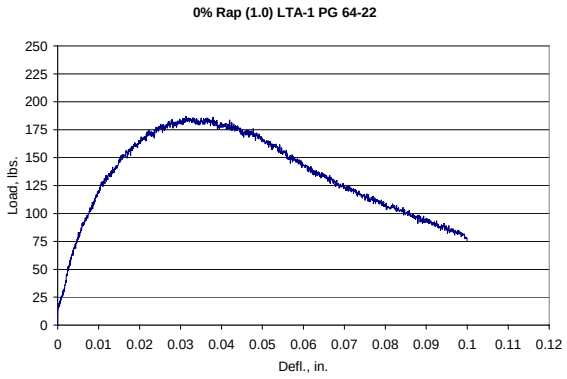
Short term age

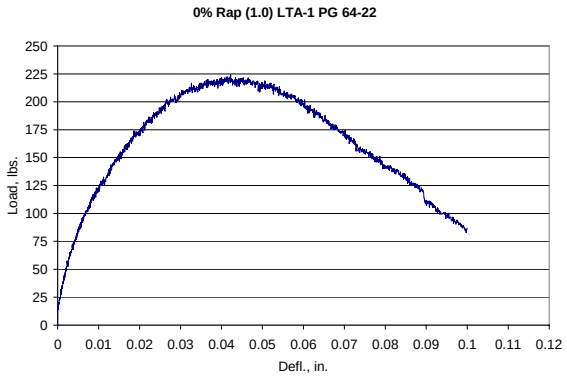


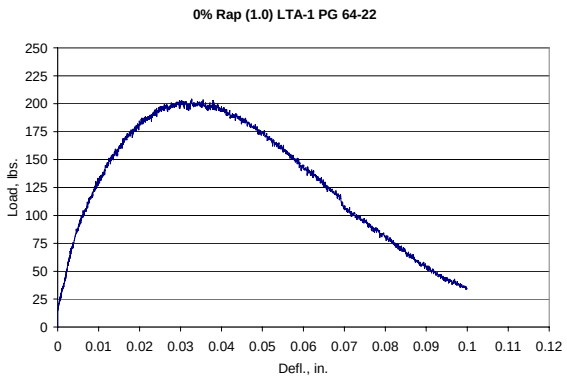




Long term age

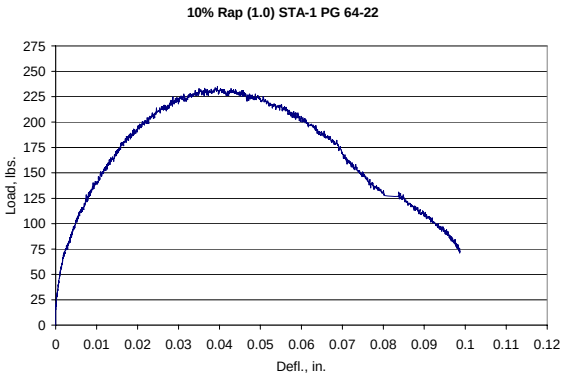


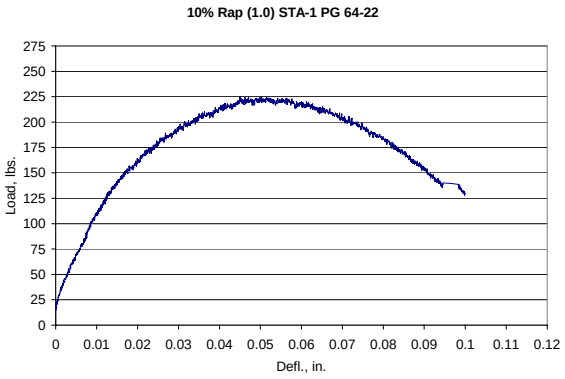


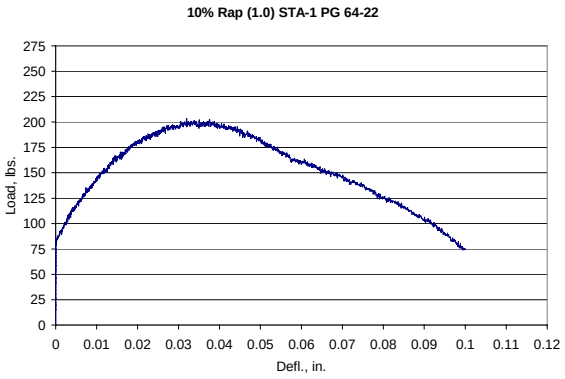


Limestone 64-22 1.0” 10%

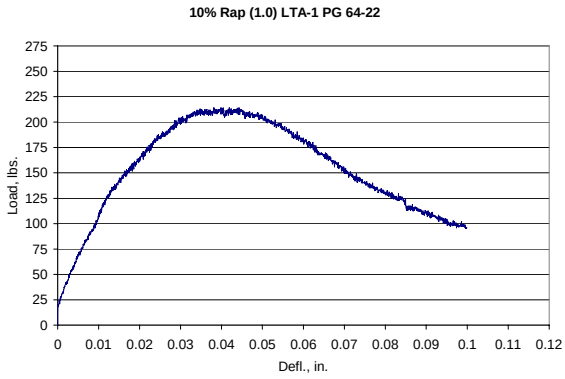
Short term age

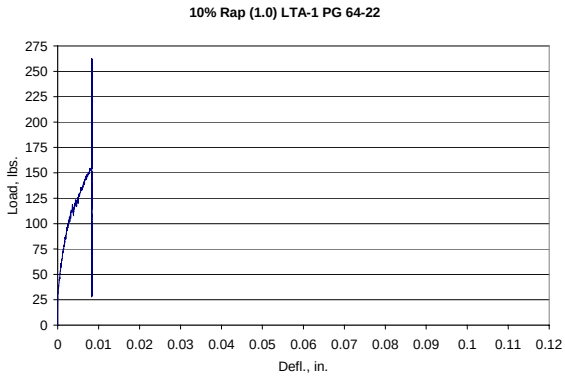


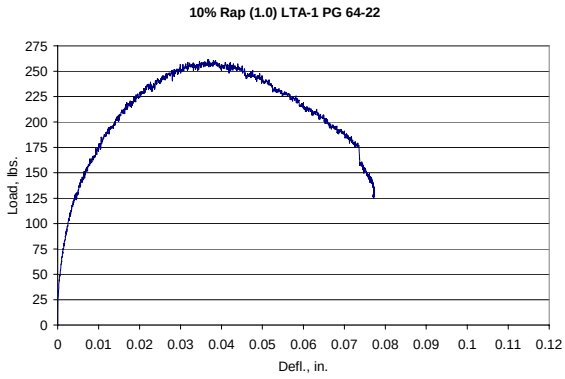




Long term age

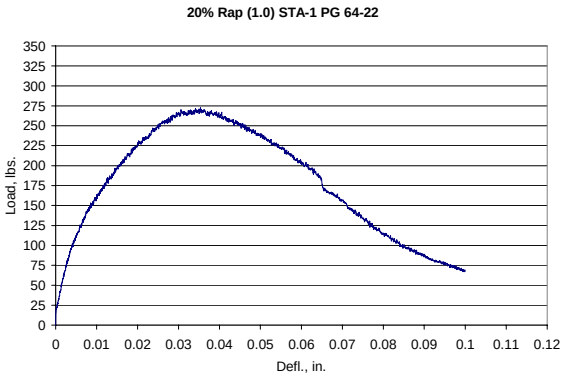


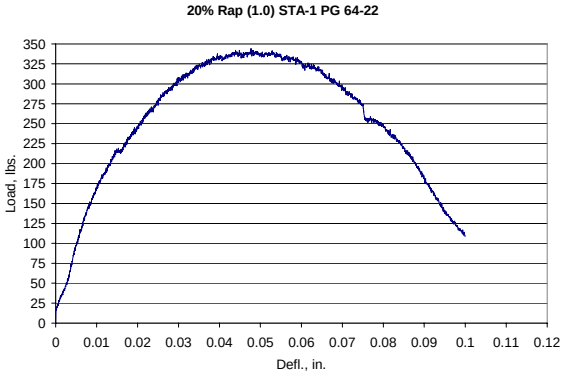


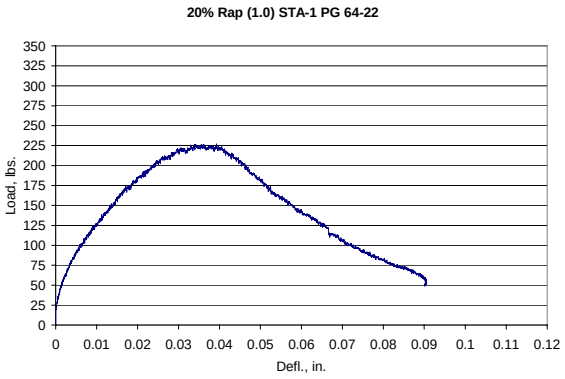


Limestone 64-22 1.0” 20%

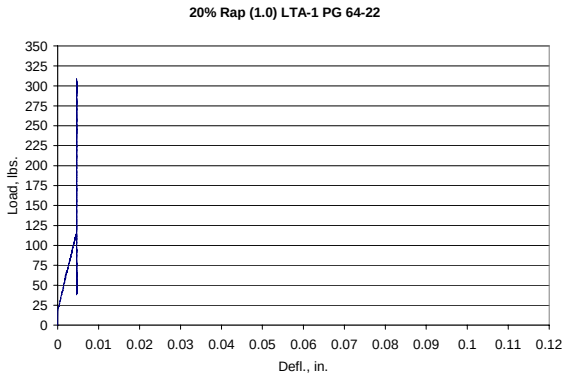
Short term age

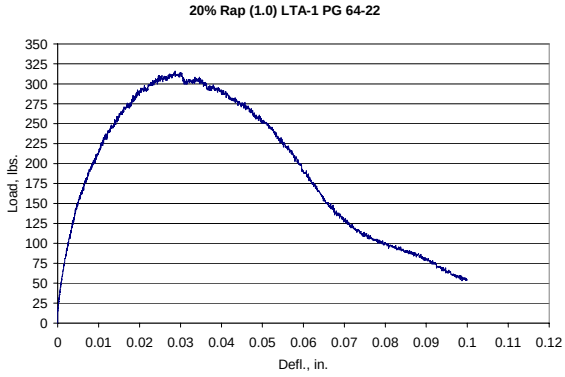


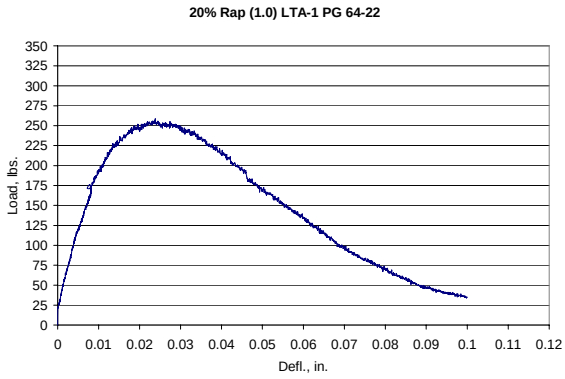




Long term age

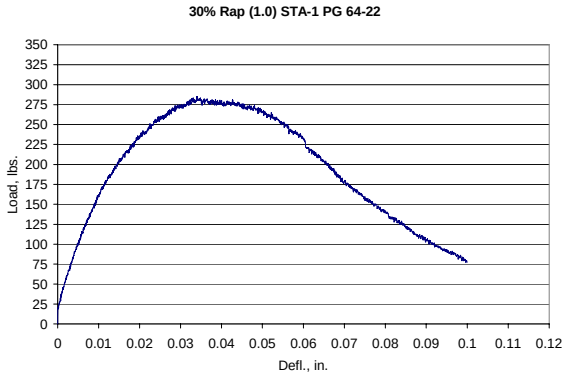


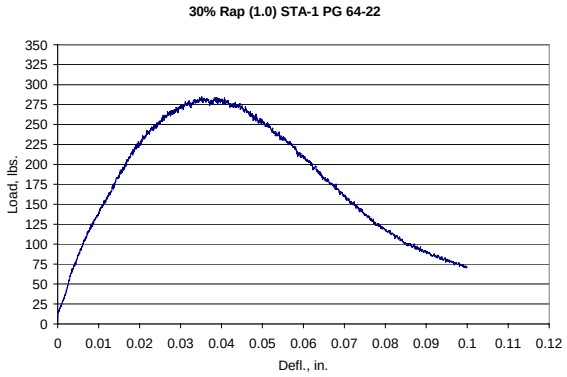


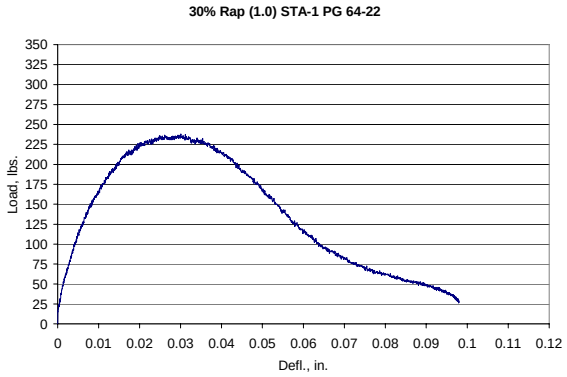


Limestone 64-22 1.0” 30%

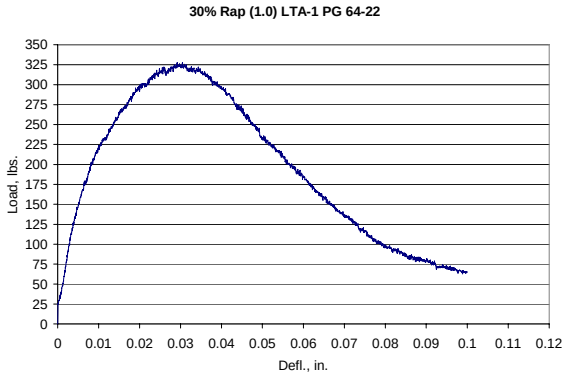
Short term age

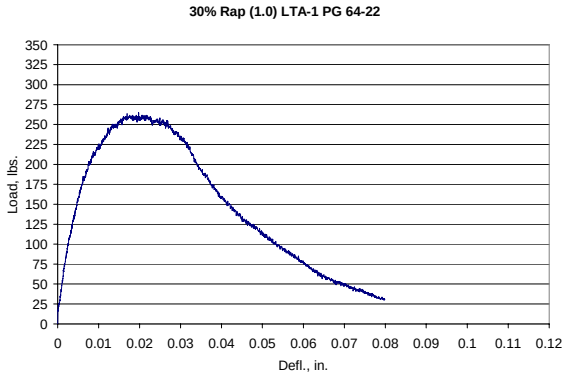


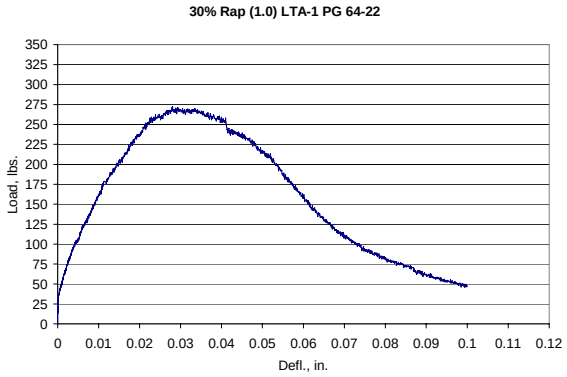




Long term age



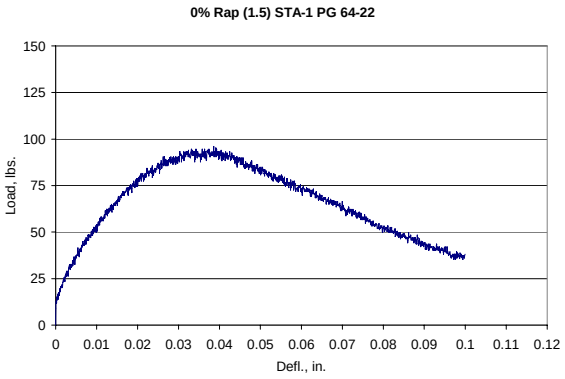


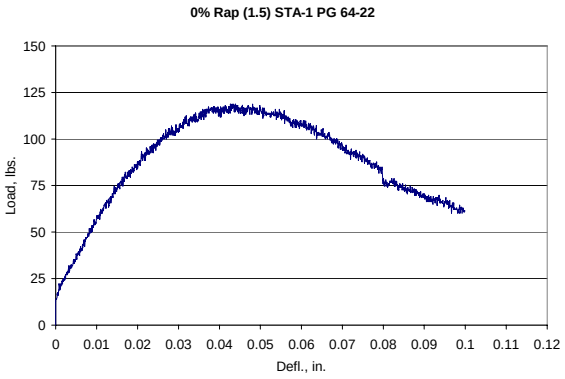


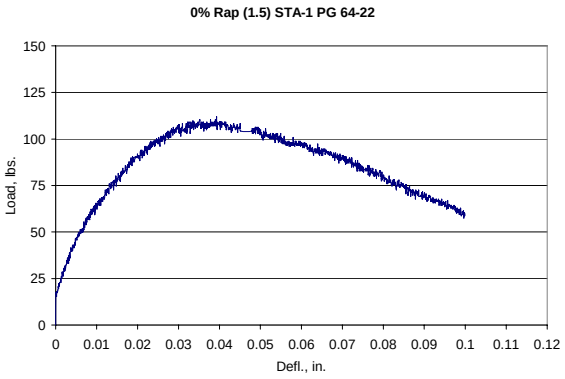
		1.5" Notched Samples								Peak Load Area Calculations			
										Origin	Origin	Origin	Origin
	ID	Notch		Width		Peak		Defl.		Area	Area	Strain Energy	Strain Energy
		in.	mm	in.	m	lbs.	newtons	in.	mm	lb-in.	N-m	lbs/in.^2	J/m
0%		1.5	38.1	1.050	0.027	122.17	543.44	0.022	0.564	1.9639	0.221890825	1.870	8.320
		1.5	38.1	1.070	0.027	129.06	574.09	0.037	0.947	3.4367	0.388294821	3.212	14.287
		1.5	38.1	1.050	0.027	150.43	669.15	0.036	0.912	4.1089	0.464243195	3.913	17.407
	Average	**1.5**	**38.1**	**1.0566667**	**0.0268393**	**133.88667**	**595.5573484**	**0.0318**	**0.80772**	**3.169833333**	**0.358142947**	**2.998496069**	**13.33797018**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**14.74**	**65.55**	**0.01**	**0.21**	**1.10**	**0.12**	**1.04**	**4.62**
	COV	**0.0**	**0.0**	**1.1**	**1.1**	**11.0**	**11.0**	**26.2**	**26.2**	**34.6**	**34.6**	**34.6**	**34.6**
		1.5	38.1	1.060	0.027	95.99	426.98	0.039	0.980	2.6477	0.299149823	2.498	11.111
		1.5	38.1	1.050	0.027	118.73	528.14	0.044	1.115	3.637	0.410925674	3.464	15.408
		1.5	38.1	1.060	0.027	111.84	497.49	0.039	0.998	3.1976	0.361280158	3.017	13.419
	Average	**1.5**	**38.1**	**1.0566667**	**0.0268393**	**108.85333**	**484.2035744**	**0.0406**	**1.03124**	**3.160766667**	**0.357118552**	**2.992747829**	**13.31240075**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**11.66**	**51.87**	**0.00**	**0.07**	**0.50**	**0.06**	**0.48**	**2.15**
	COV	**0.0**	**0.0**	**0.5**	**0.5**	**10.7**	**10.7**	**7.1**	**7.1**	**15.7**	**15.7**	**16.2**	**16.2**
10%		1.5	38.1	1.060	0.027	140.09	623.15	0.029	0.747	3.0081	0.339869541	2.838	12.623
		1.5	38.1	1.040	0.026	118.04	525.07	0.023	0.584	2.0339	0.22979976	1.956	8.699
		1.5	38.1	1.060	0.027	118.04	525.07	0.027	0.696	2.661	0.300652521	2.510	11.167
	Average	**1.5**	**38.1**	**1.0533333**	**0.0267547**	**125.39**	**557.7623058**	**0.0266**	**0.67564**	**2.567666667**	**0.290107274**	**2.434626875**	**10.82975596**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**12.73**	**56.63**	**0.00**	**0.08**	**0.49**	**0.06**	**0.45**	**1.98**
	COV	**0.0**	**0.0**	**1.1**	**1.1**	**10.2**	**10.2**	**12.3**	**12.3**	**19.2**	**19.2**	**18.3**	**18.3**
		1.5	38.1	1.050	0.027	118.73	528.14	0.041	1.039	3.5495	0.401039505	3.380	15.037
		1.5	38.1	1.060	0.027	148.36	659.94	0.046	1.176	4.8372	0.546530017	4.563	20.299
		1.5	38.1	1.060	0.027	115.28	512.79	0.040	1.006	3.1644	0.357529063	2.985	13.279
	Average	**1.5**	**38.1**	**1.0566667**	**0.0268393**	**127.45667**	**566.9552938**	**0.0422667**	**1.0735733**	**3.850366667**	**0.435032862**	**3.643051812**	**16.20509593**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**18.18**	**80.89**	**0.00**	**0.09**	**0.88**	**0.10**	**0.82**	**3.65**
	COV	**0.0**	**0.0**	**0.5**	**0.5**	**14.3**	**14.3**	**8.4**	**8.4**	**22.8**	**22.8**	**22.5**	**22.5**
20%		1.5	38.1	1.050	0.027	182.14	810.20	0.024	0.610	3.1518	0.356105455	3.002	13.352
		1.5	38.1	1.070	0.027	193.84	862.24	0.036	0.904	5.3109	0.600050911	4.963	22.079
		1.5	38.1	1.070	0.027	186.26	828.53	0.029	0.724	4.0027	0.452244211	3.741	16.640
	Average	**1.5**	**38.1**	**1.0633333**	**0.0270087**	**187.41367**	**833.6572203**	**0.0293667**	**0.7459133**	**4.155133333**	**0.469466859**	**3.90200445**	**17.35697424**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**5.93**	**26.40**	**0.01**	**0.15**	**1.09**	**0.12**	**0.99**	**4.41**
	COV	**0.0**	**0.0**	**1.1**	**1.1**	**3.2**	**3.2**	**19.9**	**19.9**	**26.2**	**26.2**	**25.4**	**25.4**
		1.5	38.1	1.040	0.026	162.83	724.30	0.032	0.810	3.6986	0.417885537	3.556	15.819
		1.5	38.1	1.030	0.026	160.76	715.10	0.015	0.378	2.1947	0.247967714	2.131	9.478
		1.5	38.1	1.040	0.026	157.32	699.79	0.030	0.759	3.5513	0.401242878	3.415	15.189
	Average	**1.5**	**38.1**	**1.0366667**	**0.0263313**	**160.30333**	**713.0644934**	**0.0255667**	**0.6493933**	**3.1482**	**0.35569871**	**3.033944797**	**13.49565393**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**2.78**	**12.38**	**0.01**	**0.24**	**0.83**	**0.09**	**0.79**	**3.49**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**1.7**	**1.7**	**36.3**	**36.3**	**26.3**	**26.3**	**25.9**	**25.9**
30%		1.5	38.1	1.040	0.026	187.64	834.66	0.027	0.693	3.2214	0.363969196	3.098	13.778
		1.5	38.1	1.020	0.026	198.66	883.68	0.025	0.640	3.0821	0.348230415	3.022	13.441
		1.5	38.1	1.040	0.026	219.34	975.67	0.023	0.574	3.4037	0.384566323	3.273	14.558
	Average	**1.5**	**38.1**	**1.0333333**	**0.0262467**	**201.88**	**898.0066536**	**0.0250333**	**0.6358467**	**3.235733333**	**0.365588645**	**3.130651709**	**13.92582755**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**16.09**	**71.59**	**0.00**	**0.06**	**0.16**	**0.02**	**0.13**	**0.57**
	COV	**0.0**	**0.0**	**1.1**	**1.1**	**8.0**	**8.0**	**9.4**	**9.4**	**5.0**	**5.0**	**4.1**	**4.1**
		1.5	38.1	1.050	0.027	169.72	754.95	0.029	0.747	3.6153	0.408473904	3.443	15.316
		1.5	38.1	1.070	0.027	135.27	601.71	0.027	0.688	2.8229	0.318944758	2.638	11.735
		1.5	38.1	1.050	0.027	152.49	678.31	0.032	0.803	3.6331	0.410485033	3.460	15.391
	Average	**1.5**	**38.1**	**1.0566667**	**0.0268393**	**152.49333**	**678.3238952**	**0.0293667**	**0.7459133**	**3.3571**	**0.379301232**	**3.180487465**	**14.14750795**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**17.23**	**76.62**	**0.00**	**0.06**	**0.46**	**0.05**	**0.47**	**2.09**
	COV	**0.0**	**0.0**	**1.1**	**1.1**	**11.3**	**11.3**	**7.7**	**7.7**	**13.8**	**13.8**	**14.8**	**14.8**

Limestone 64-22 1.5” 0%

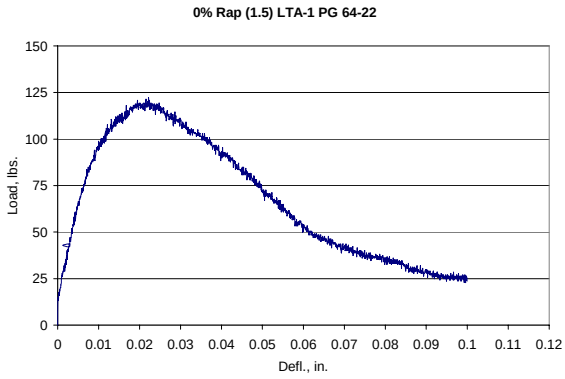
Short term age

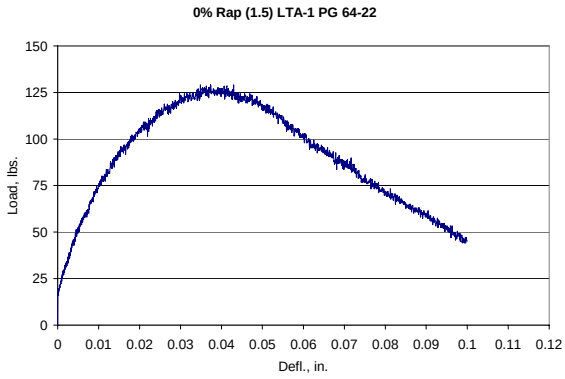


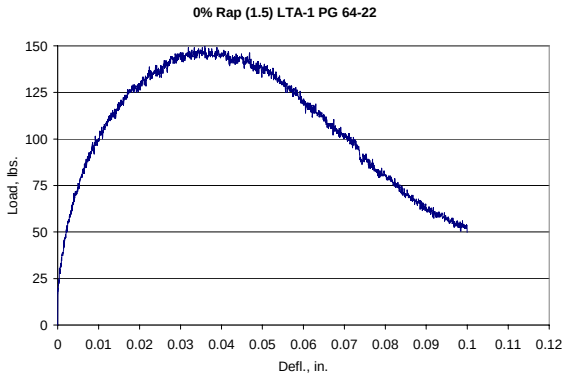




Long term age

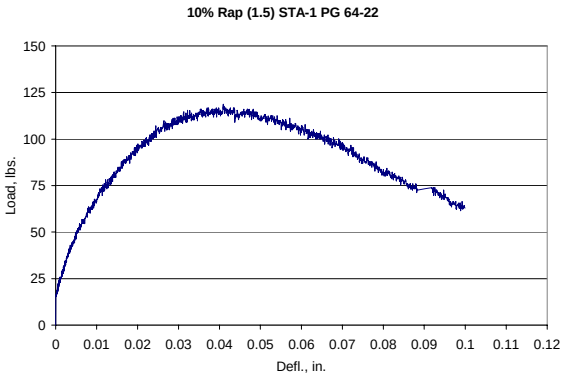


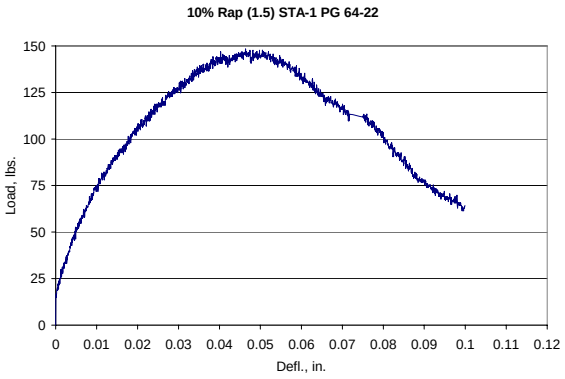


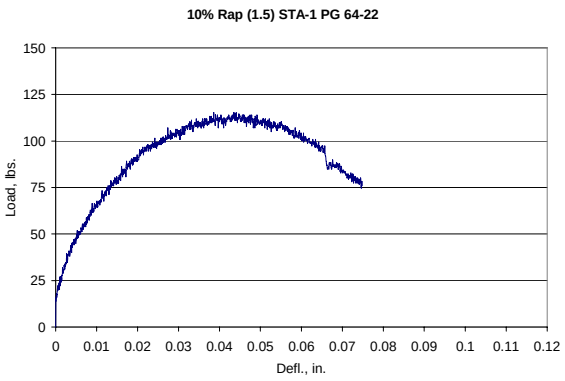


Limestone 64-22 1.5” 10%

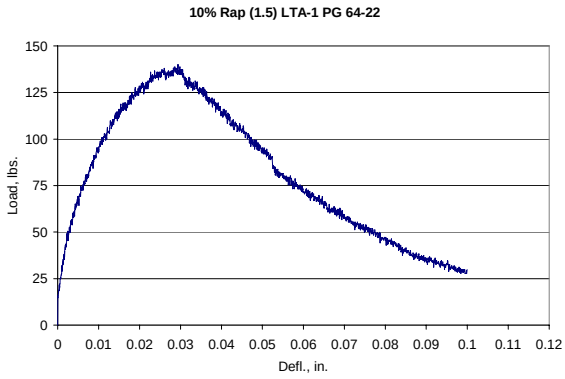
Short term age

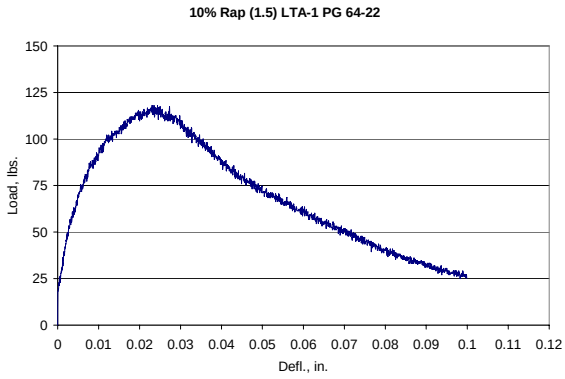


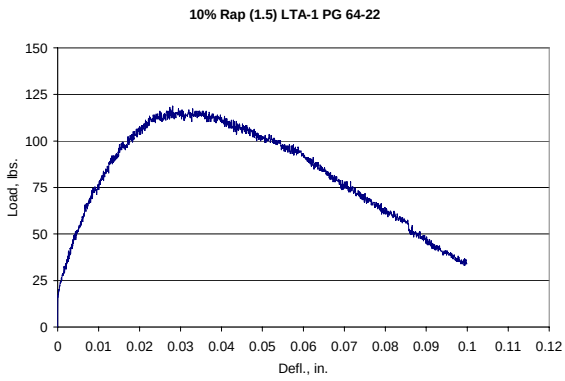




Long term age

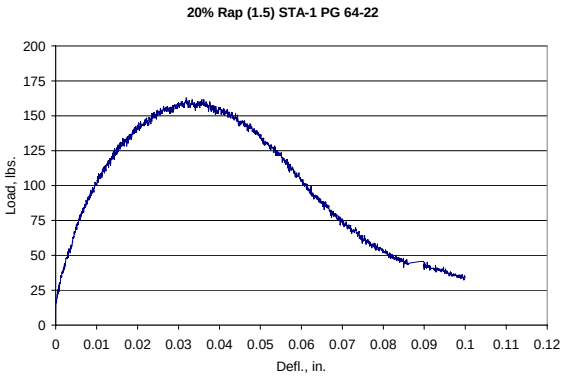


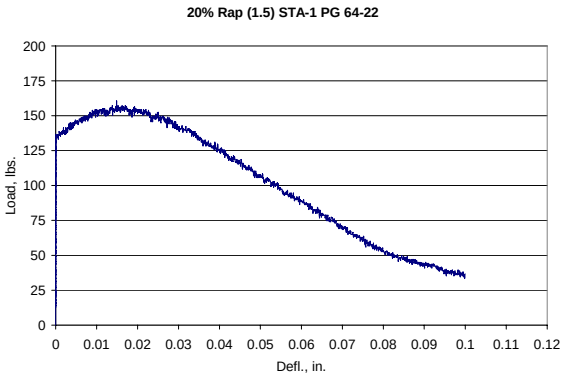


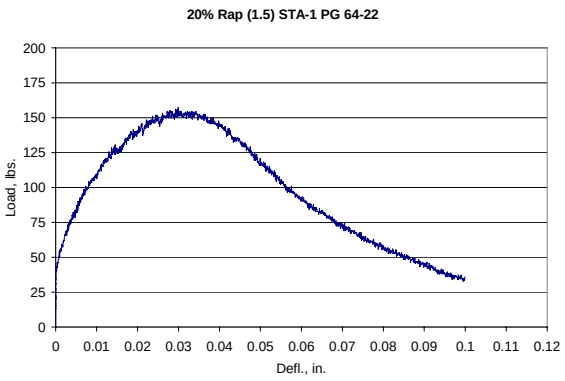


Limestone 64-22 1.5” 20%

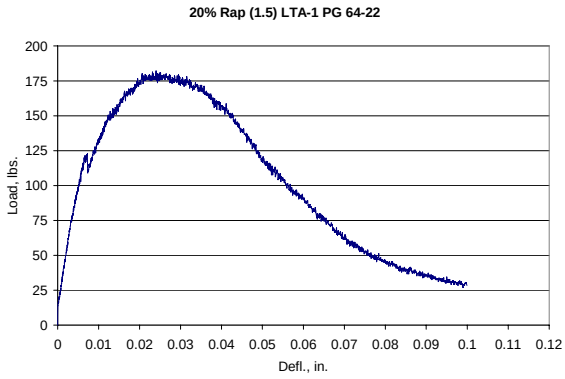
Short term age

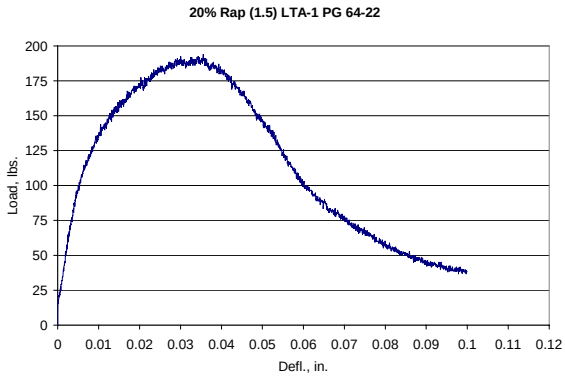


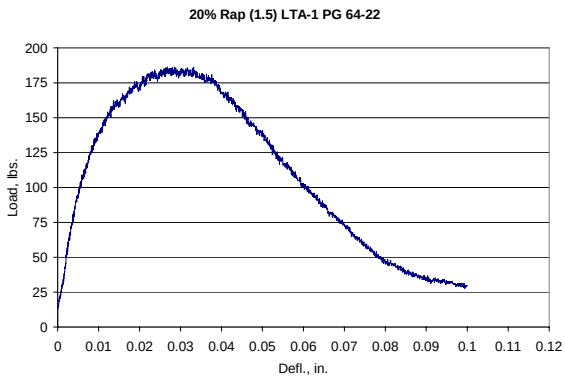




Long term age

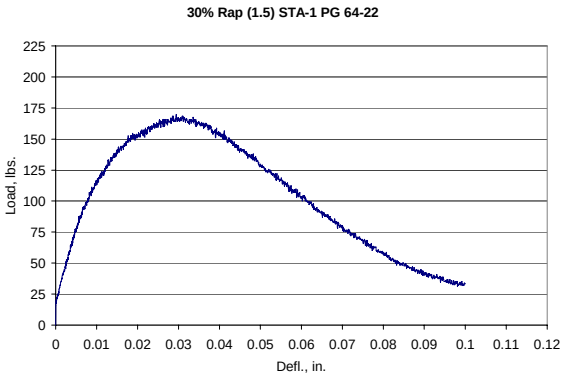


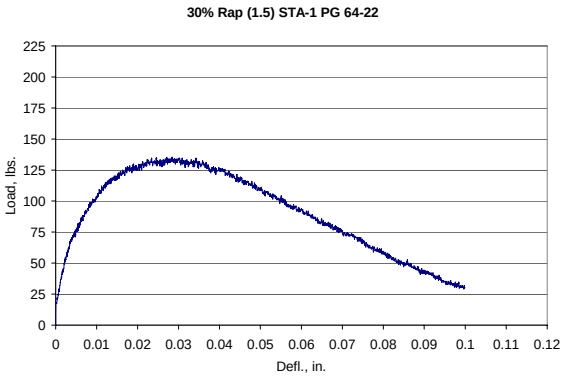


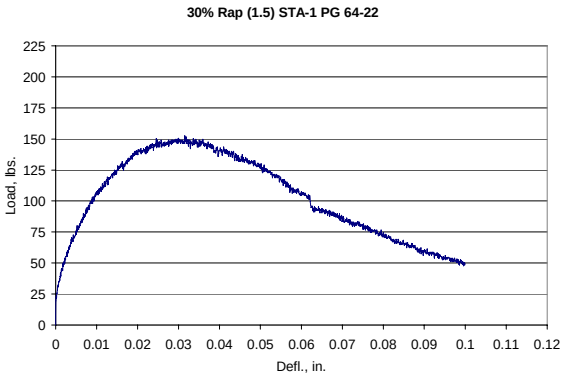


Limestone 64-22 1.5” 30%

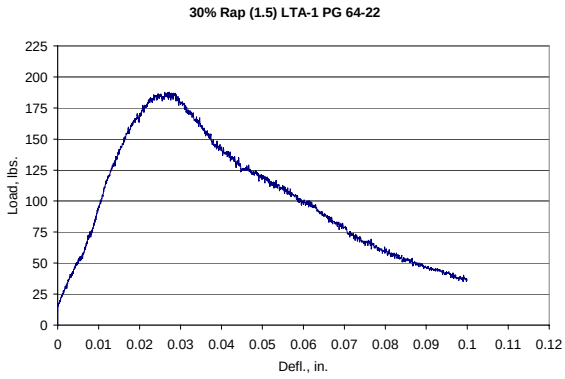
Short term age

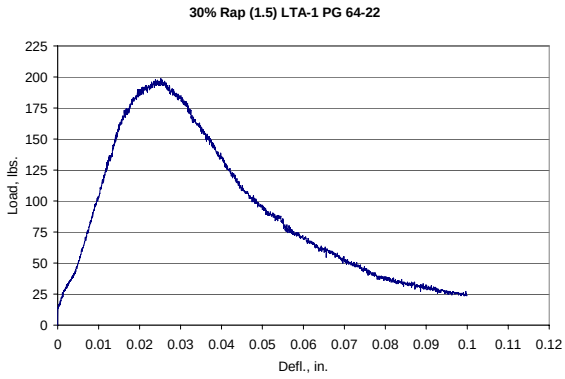


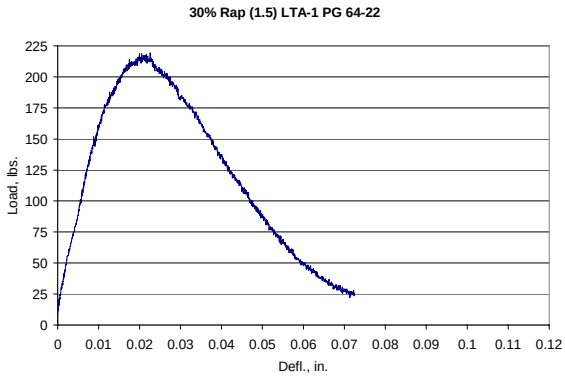




Long term age





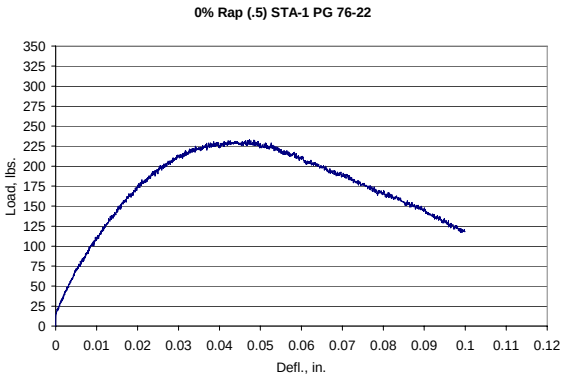


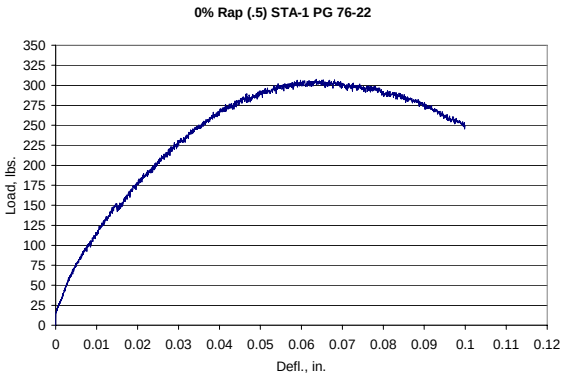
Limestone PG 76-22

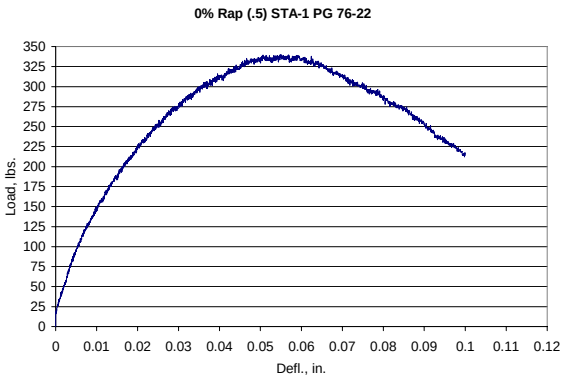
	.5" Notched Samples								Peak Load			
									Origin	Origin	Origin	Origin
	ID	Notch		Width		Peak		Defl.		Area	Area	Strain Energy	Strain Energy
		in.	mm	in.	m	lbs.	newtons	in.	mm	lb-in.	N-m	lbs/in.^2	J/m
0%		0.5	12.7	1.090	0.028	301.34	1340.43	0.053	1.344	11.4576	1.294534507	10.512	46.758
		0.5	12.7	1.090	0.028	341.31	1518.22	0.036	0.907	8.6759	0.980244722	7.960	35.406
		0.5	12.7	1.110	0.028	335.79	1493.67	0.059	1.486	13.6322	1.540231227	12.281	54.630
	Average	**0.5**	**12.7**	**1.0966667**	**0.0278553**	**326.14667**	**1450.772126**	**0.0490333**	**1.2454467**	**11.25523333**	**1.271670152**	**10.25078739**	**45.5977575**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**21.66**	**96.35**	**0.01**	**0.30**	**2.48**	**0.28**	**2.17**	**9.66**
	COV	**0.0**	**0.0**	**1.1**	**1.1**	**6.6**	**6.6**	**24.2**	**24.2**	**22.1**	**22.1**	**21.2**	**21.2**
		0.5	12.7	1.090	0.028	233.12	1036.97	0.047	1.201	7.9223	0.895099386	7.268	32.330
		0.5	12.7	1.100	0.028	307.54	1368.01	0.064	1.618	13.5507	1.531022967	12.319	54.797
		0.5	12.7	1.110	0.028	339.24	1509.01	0.051	1.285	11.7123	1.323311732	10.552	46.936
	Average	**0.5**	**12.7**	**1.1**	**0.02794**	**293.3**	**1304.662926**	**0.0538667**	**1.3682133**	**11.06176667**	**1.249811362**	**10.04620165**	**44.68771509**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**54.47**	**242.31**	**0.01**	**0.22**	**2.87**	**0.32**	**2.56**	**11.40**
	COV	**0.0**	**0.0**	**0.9**	**0.9**	**18.6**	**18.6**	**16.1**	**16.1**	**25.9**	**25.9**	**25.5**	**25.5**
10%		0.5	12.7	1.070	0.027	303.41	1349.63	0.046	1.166	9.2783	1.048306759	8.671	38.572
		0.5	12.7	1.060	0.027	307.54	1368.01	0.041	1.034	9.4816	1.071276566	8.945	39.789
		0.5	12.7	1.060	0.027	315.81	1404.79	0.048	1.217	9.8359	1.111307076	9.279	41.276
	Average	**0.5**	**12.7**	**1.0633333**	**0.0270087**	**308.92**	**1374.144122**	**0.0448333**	**1.1387667**	**9.531933333**	**1.076963467**	**8.965121672**	**39.87883352**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**6.31**	**28.09**	**0.00**	**0.09**	**0.28**	**0.03**	**0.30**	**1.35**
	COV	**0.0**	**0.0**	**0.5**	**0.5**	**2.0**	**2.0**	**8.3**	**8.3**	**3.0**	**3.0**	**3.4**	**3.4**
		0.5	12.7	1.090	0.028	254.48	1131.98	0.057	1.438	10.0343	1.133723258	9.206	40.949
		0.5	12.7	1.100	0.028	299.27	1331.22	0.054	1.361	11.3797	1.285732992	10.345	46.018
		0.5	12.7	1.080	0.027	274.47	1220.90	0.054	1.382	10.4715	1.183120208	9.696	43.129
	Average	**0.5**	**12.7**	**1.09**	**0.027686**	**276.07333**	**1228.034923**	**0.0548667**	**1.3936133**	**10.6285**	**1.200858819**	**9.748931656**	**43.36539277**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**22.44**	**99.81**	**0.00**	**0.04**	**0.69**	**0.08**	**0.57**	**2.54**
	COV	**0.0**	**0.0**	**0.9**	**0.9**	**8.1**	**8.1**	**2.8**	**2.8**	**6.5**	**6.5**	**5.9**	**5.9**
20%		0.5	12.7	1.001	0.025	348.19	1548.83	0.056	1.417	12.8356	1.450227545	12.823	57.039
		0.5	12.7	1.050	0.027	397.13	1766.52	0.039	0.980	11.0679	1.250504335	10.541	46.888
		0.5	12.7	1.040	0.026	315.12	1401.72	0.066	1.669	13.7613	1.554817563	13.232	58.859
	Average	**0.5**	**12.7**	**1.0303333**	**0.0261705**	**353.48**	**1572.356806**	**0.0533667**	**1.3555133**	**12.55493333**	**1.418516481**	**12.1985512**	**54.26183941**
	STD Dev.	**0.00**	**0.00**	**0.03**	**0.00**	**41.26**	**183.53**	**0.01**	**0.35**	**1.37**	**0.15**	**1.45**	**6.45**
	COV	**0.0**	**0.0**	**2.5**	**2.5**	**11.7**	**11.7**	**25.7**	**25.7**	**10.9**	**10.9**	**11.9**	**11.9**
		0.5	12.7	1.060	0.027	273.78	1217.83	0.046	1.158	8.5242	0.96310493	8.042	35.771
		0.5	12.7	1.050	0.027	286.87	1276.06	0.052	1.311	10.1625	1.148207908	9.679	43.052
		0.5	12.7	1.070	0.027	311.68	1386.42	0.069	1.753	14.6241	1.652300838	13.667	60.796
	Average	**0.5**	**12.7**	**1.06**	**0.026924**	**290.77667**	**1293.438584**	**0.0554**	**1.40716**	**11.1036**	**1.254537892**	**10.46255091**	**46.53972819**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**19.25**	**85.63**	**0.01**	**0.31**	**3.16**	**0.36**	**2.89**	**12.87**
	COV	**0.0**	**0.0**	**0.9**	**0.9**	**6.6**	**6.6**	**21.9**	**21.9**	**28.4**	**28.4**	**27.7**	**27.7**
30%		0.5	12.7	1.100	0.028	356.47	1585.66	0.041	1.044	10.1106	1.142343998	9.191	40.886
		0.5	12.7	1.120	0.028	445.36	1981.06	0.041	1.044	12.0887	1.365839207	10.793	48.012
		0.5	12.7	1.140	0.029	421.93	1876.84	0.035	0.879	10.8685	1.227975168	9.534	42.408
	Average	**0.5**	**12.7**	**1.12**	**0.028448**	**407.92**	**1814.517902**	**0.0389333**	**0.9889067**	**11.0226**	**1.245386124**	**9.839569539**	**43.76857002**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**46.07**	**204.94**	**0.00**	**0.10**	**1.00**	**0.11**	**0.84**	**3.75**
	COV	**0.0**	**0.0**	**1.8**	**1.8**	**11.3**	**11.3**	**9.6**	**9.6**	**9.1**	**9.1**	**8.6**	**8.6**
		0.5	12.7	1.040	0.026	253.10	1125.84	0.044	1.123	7.8461	0.886489945	7.544	33.559
		0.5	12.7	1.010	0.026	319.26	1420.14	0.051	1.293	12.1088	1.368110201	11.989	53.329
		0.5	12.7	1.040	0.026	333.04	1481.44	0.045	1.140	10.8719	1.228359317	10.454	46.501
	Average	**0.5**	**12.7**	**1.03**	**0.026162**	**301.80**	**1342.47**	**0.05**	**1.19**	**10.28**	**1.16**	**10.00**	**44.46**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**42.73**	**190.09**	**0.00**	**0.09**	**2.19**	**0.25**	**2.26**	**10.04**
	COV	**0.0**	**0.0**	**1.7**	**1.7**	**14.2**	**14.2**	**7.9**	**7.9**	**21.3**	**21.3**	**22.6**	**22.6**

Limestone 76-22 0.5” 0%

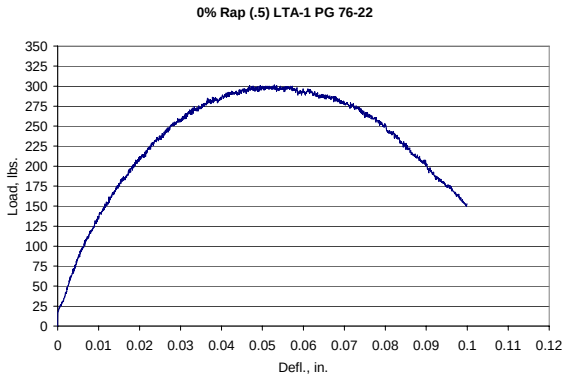
Short term age

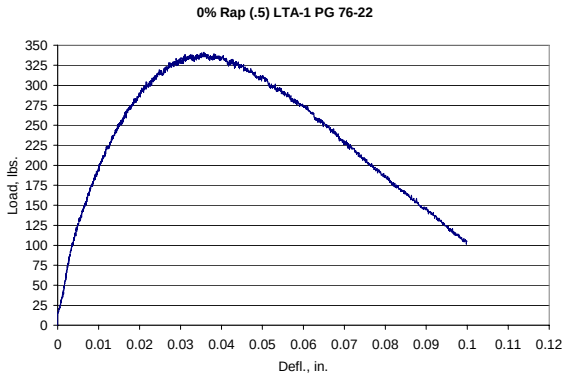


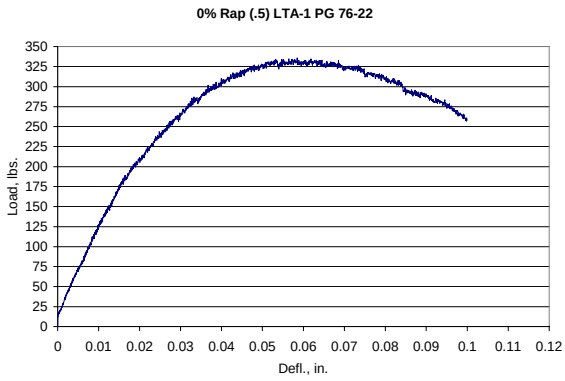




Long term age

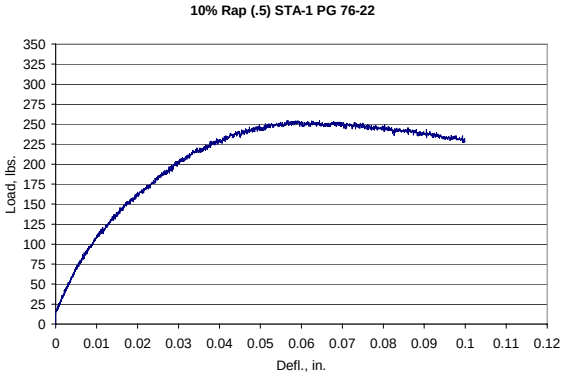


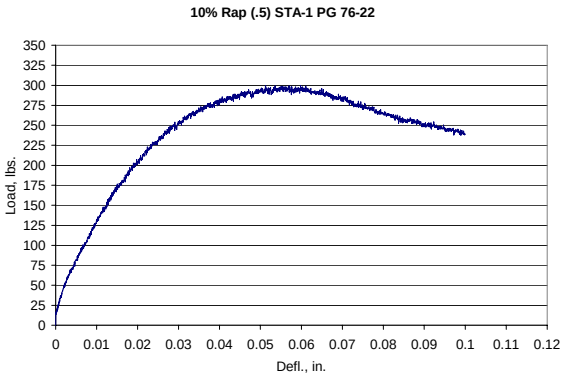


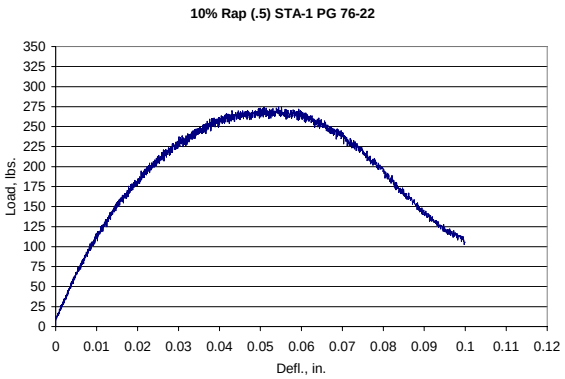


Limestone 76-22 0.5” 10%

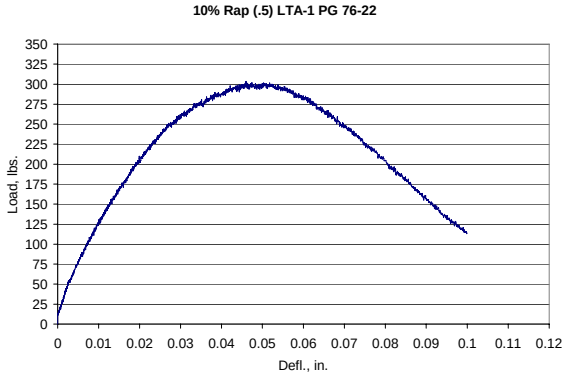
Short term age

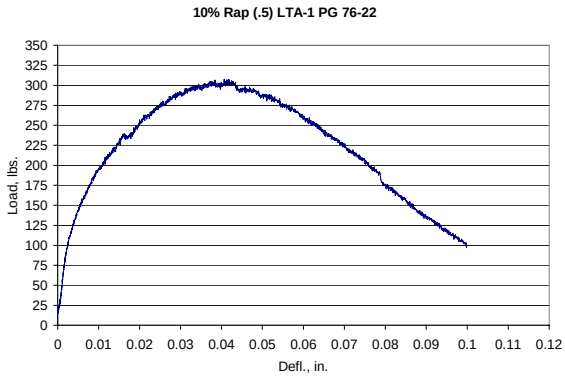


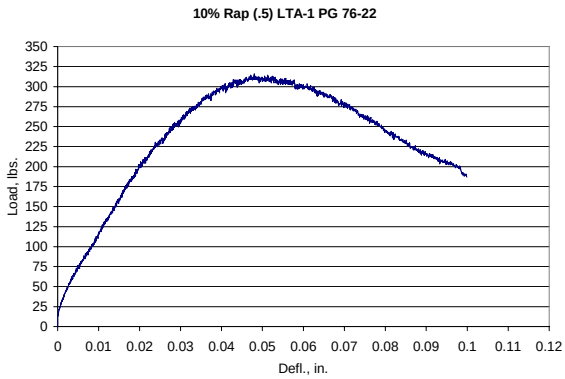




Long term age

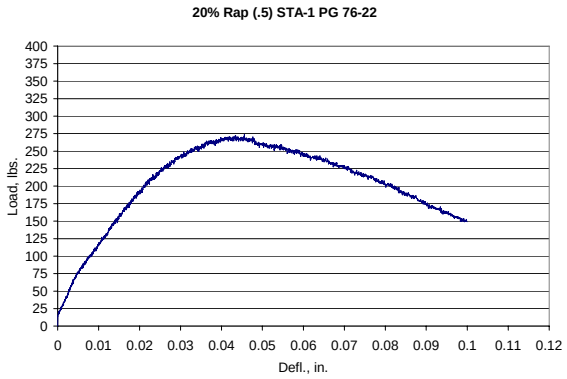


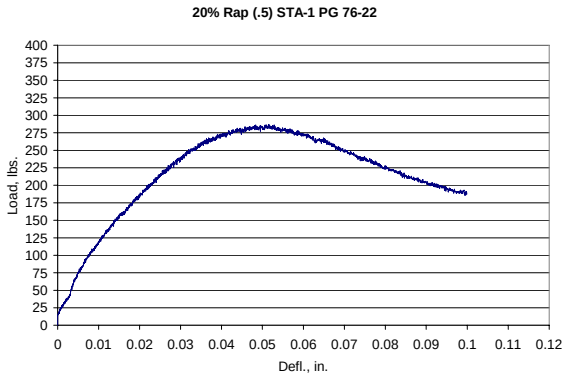


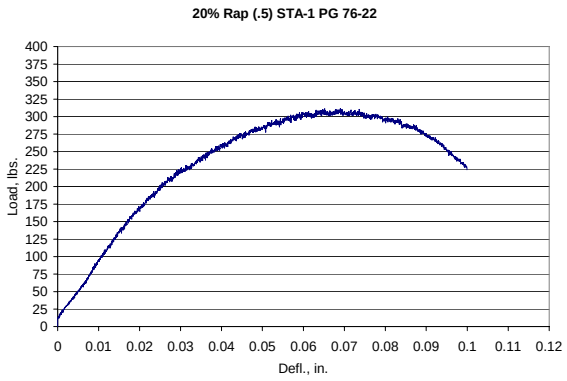


Limestone 76-22 0.5” 20%

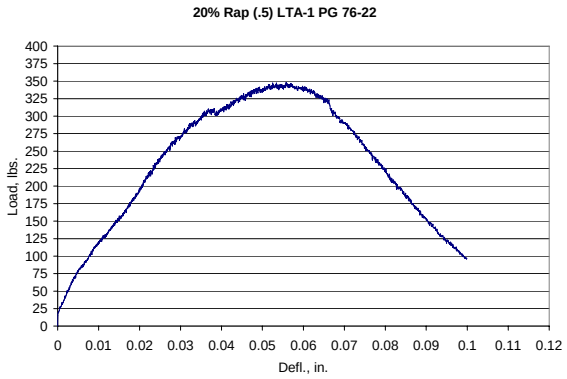
Short term age

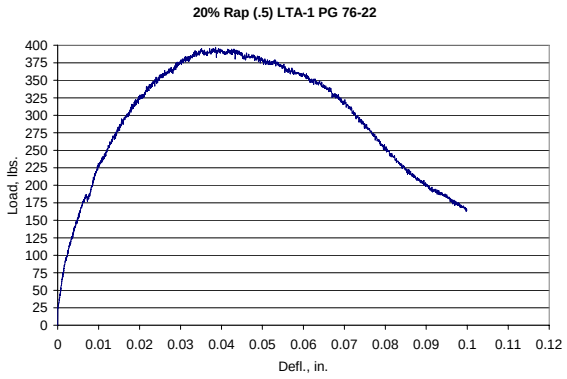


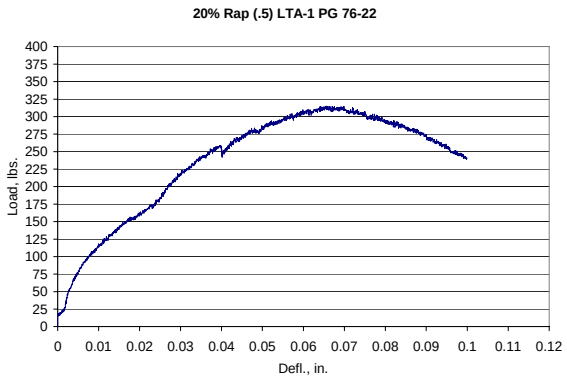




Long term age

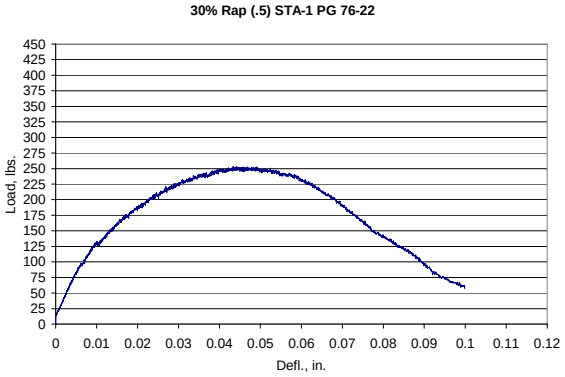


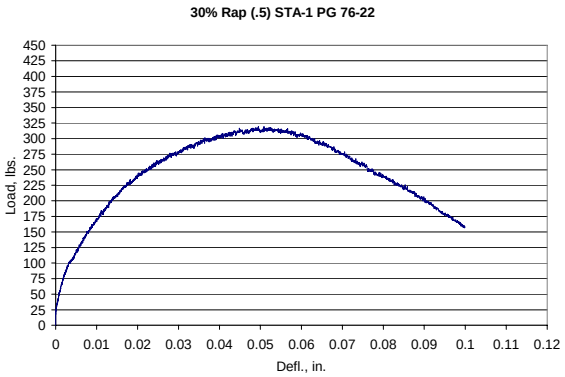


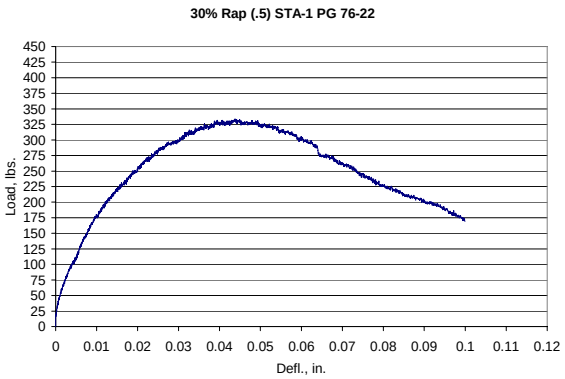


Limestone 76-22 0.5” 30%

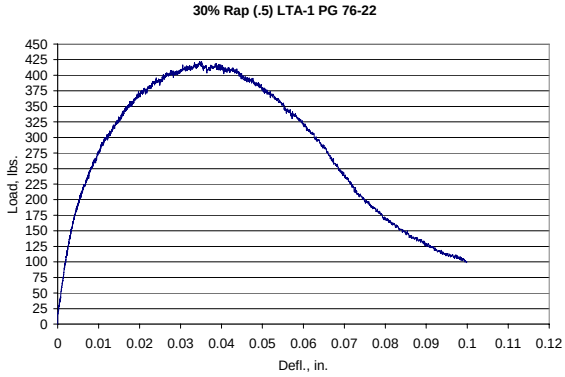
Short term age

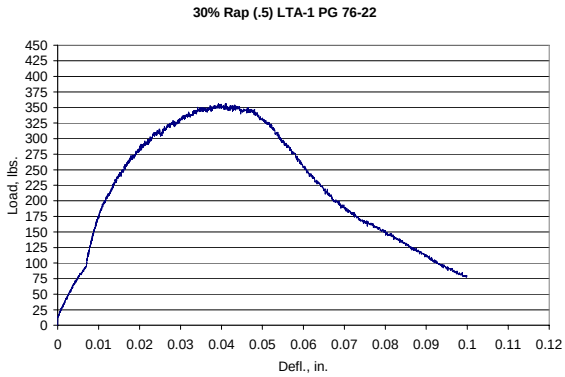


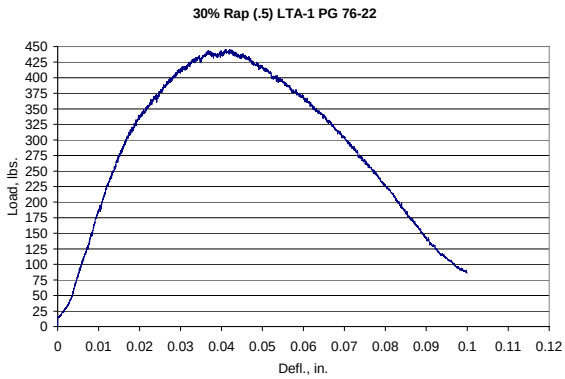




Long term age



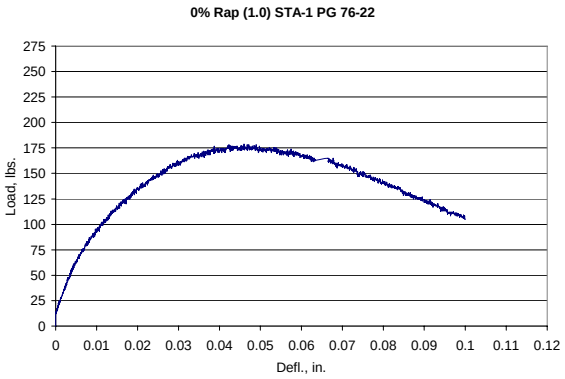


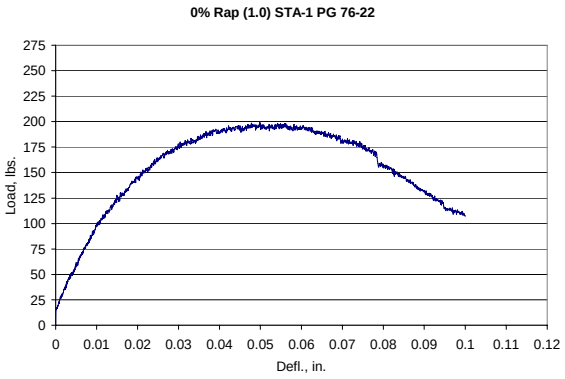


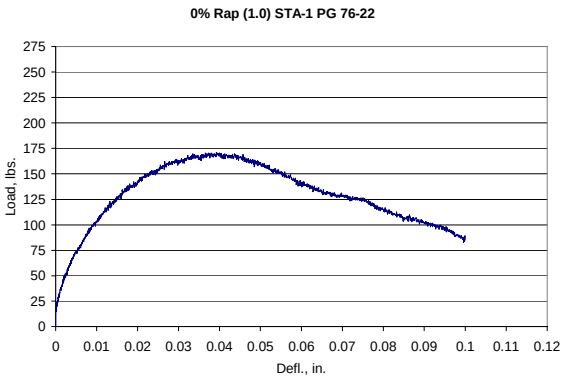
	1" Notched Samples									Peak Load			
										Origin	Origin	Origin	Origin
	ID	Notch		Width		Peak		Defl.		Area	Area	Strain Energy	Strain Energy
		in.	mm	in.	m	lbs.	newtons	in.	mm	lb-in.	N-m	lbs/in.^2	J/m
0%		1	25.4	1.130	0.029	254.48	1131.98	0.051	1.295	8.5929	0.970866985	7.604	33.826
		1	25.4	1.090	0.028	244.14	1085.99	0.037	0.940	6.3995	0.723046151	5.871	26.116
		1	25.4	1.100	0.028	228.98	1018.55	0.032	0.813	5.1968	0.587159346	4.724	21.015
	Average	**1**	**25.4**	**1.1066667**	**0.0281093**	**242.53333**	**1078.841624**	**0.04**	**1.016**	**6.729733333**	**0.760357494**	**6.066600279**	**26.98557269**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**12.83**	**57.05**	**0.01**	**0.25**	**1.72**	**0.19**	**1.45**	**6.45**
	COV	**0.0**	**0.0**	**1.9**	**1.9**	**5.3**	**5.3**	**24.6**	**24.6**	**25.6**	**25.6**	**23.9**	**23.9**
		1	25.4	1.090	0.028	178.68	794.81	0.046	1.166	5.4506	0.615834885	5.001	22.244
		1	25.4	1.090	0.028	199.35	886.75	0.050	1.265	7.1592	0.808880694	6.568	29.216
		1	25.4	1.090	0.028	171.09	761.05	0.039	0.996	5.0067	0.565680938	4.593	20.432
	Average	**1**	**25.4**	**1.09**	**0.027686**	**183.04**	**814.2021888**	**0.0449667**	**1.1421533**	**5.872166667**	**0.663465506**	**5.387308869**	**23.96393506**
	STD Dev.	**0.00**	**0.00**	**0.00**	**0.00**	**14.63**	**65.06**	**0.01**	**0.14**	**1.14**	**0.13**	**1.04**	**4.64**
	COV	**0.0**	**0.0**	**0.0**	**0.0**	**8.0**	**8.0**	**11.9**	**11.9**	**19.4**	**19.4**	**19.4**	**19.4**
10%		1	25.4	1.090	0.028	223.47	994.04	0.035	0.876	5.6118	0.634048033	5.148	22.901
		1	25.4	1.090	0.028	224.85	1000.18	0.046	1.171	7.1142	0.803796379	6.527	29.033
		1	25.4	1.060	0.027	200.04	889.82	0.049	1.237	6.9727	0.787809031	6.578	29.260
	Average	**1**	**25.4**	**1.08**	**0.027432**	**216.12**	**961.3493064**	**0.0431**	**1.09474**	**6.566233333**	**0.741884481**	**6.084416075**	**27.06482127**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**13.94**	**62.02**	**0.01**	**0.19**	**0.83**	**0.09**	**0.81**	**3.61**
	COV	**0.0**	**0.0**	**1.6**	**1.6**	**6.5**	**6.5**	**17.5**	**17.5**	**12.6**	**12.6**	**13.3**	**13.3**
		1	25.4	1.120	0.028	182.81	813.18	0.038	0.960	5.1081	0.577137596	4.561	20.287
		1	25.4	1.100	0.028	195.53	869.76	0.041	1.049	5.6484	0.638183277	5.135	22.841
		1	25.4	1.100	0.028	231.05	1027.76	0.042	1.069	6.8977	0.779335172	6.271	27.893
	Average	**1**	**25.4**	**1.1066667**	**0.0281093**	**203.13**	**903.5669286**	**0.0404**	**1.02616**	**5.884733333**	**0.664885348**	**5.322116342**	**23.67394435**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**25.00**	**111.21**	**0.00**	**0.06**	**0.92**	**0.10**	**0.87**	**3.87**
	COV	**0.0**	**0.0**	**1.0**	**1.0**	**12.3**	**12.3**	**5.7**	**5.7**	**15.6**	**15.6**	**16.3**	**16.3**
20%		1	25.4	1.050	0.027	248.97	1107.47	0.041	1.044	6.6729	0.753936192	6.355	28.269
		1	25.4	1.060	0.027	244.14	1085.99	0.031	0.787	5.4641	0.61736018	5.155	22.930
		1	25.4	1.100	0.028	269.64	1199.42	0.053	1.351	9.4954	1.072835756	8.632	38.398
	Average	**1**	**25.4**	**1.07**	**0.027178**	**254.25**	**1130.959935**	**0.0417667**	**1.0608733**	**7.2108**	**0.814710709**	**6.714045332**	**29.86555073**
	STD Dev.	**0.00**	**0.00**	**0.03**	**0.00**	**13.55**	**60.25**	**0.01**	**0.28**	**2.07**	**0.23**	**1.77**	**7.86**
	COV	**0.0**	**0.0**	**2.5**	**2.5**	**5.3**	**5.3**	**26.6**	**26.6**	**28.7**	**28.7**	**26.3**	**26.3**
		1	25.4	1.030	0.026	205.55	914.33	0.059	1.504	8.68	0.98070796	8.427	37.486
		1	25.4	1.050	0.027	246.90	1098.27	0.049	1.252	8.9822	1.014851963	8.554	38.052
		1	25.4	1.060	0.027	256.55	1141.19	0.034	0.871	6.3134	0.713318161	5.956	26.494
	Average	**1**	**25.4**	**1.0466667**	**0.0265853**	**236.33333**	**1051.26266**	**0.0476**	**1.20904**	**7.991866667**	**0.902959361**	**7.645899464**	**34.01064291**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**27.09**	**120.51**	**0.01**	**0.32**	**1.46**	**0.17**	**1.46**	**6.52**
	COV	**0.0**	**0.0**	**1.5**	**1.5**	**11.5**	**11.5**	**26.3**	**26.3**	**18.3**	**18.3**	**19.2**	**19.2**
30%		1	25.4	1.050	0.027	226.23	1006.32	0.037	0.947	5.1203	0.57851601	4.876	21.692
		1	25.4	1.030	0.026	267.57	1190.21	0.380	9.652	7.4614	0.843024697	7.244	32.223
		1	25.4	1.020	0.026	278.59	1239.23	0.031	0.785	7.9328	0.896285726	7.777	34.595
	Average	**1**	**25.4**	**1.0333333**	**0.0262467**	**257.46333**	**1145.253549**	**0.1494**	**3.79476**	**6.838166667**	**0.772608811**	**6.632602921**	**29.50327696**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**27.60**	**122.79**	**0.20**	**5.07**	**1.51**	**0.17**	**1.54**	**6.87**
	COV	**0.0**	**0.0**	**1.5**	**1.5**	**10.7**	**10.7**	**133.7**	**133.7**	**22.0**	**22.0**	**23.3**	**23.3**
		1	25.4	1.030	0.026	176.61	785.61	0.035	0.899	7.2036	0.813897219	6.994	31.110
		1	25.4	1.040	0.026	216.58	963.40	0.034	0.869	5.4126	0.611541464	5.204	23.150
		1	25.4	1.050	0.027	214.51	954.19	0.040	1.024	6.1576	0.695715131	5.864	26.086
	Average	**1**	**25.4**	**1.04**	**0.026416**	**202.56733**	**901.0640635**	**0.0366333**	**0.9304867**	**6.257933333**	**0.707051271**	**6.020863479**	**26.78212534**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**22.50**	**100.09**	**0.00**	**0.08**	**0.90**	**0.10**	**0.90**	**4.03**
	COV	**0.0**	**0.0**	**1.0**	**1.0**	**11.1**	**11.1**	**8.8**	**8.8**	**14.4**	**14.4**	**15.0**	**15.0**

Limestone 76-22 1.0” 0%

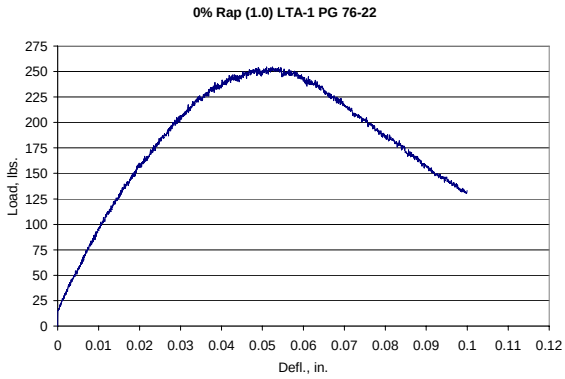
Short term age

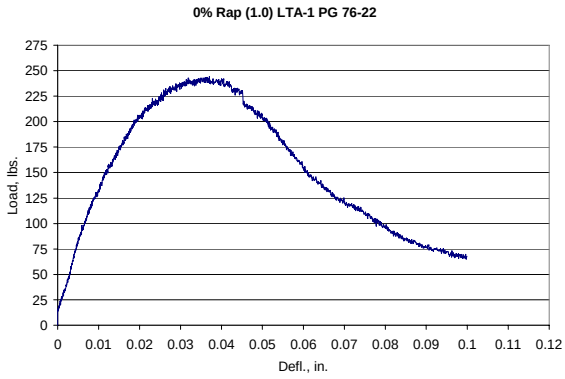


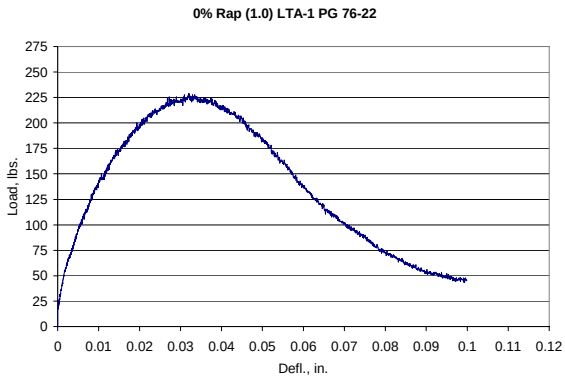




Long term age

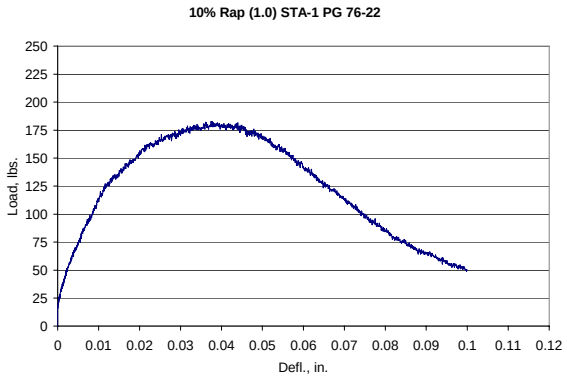


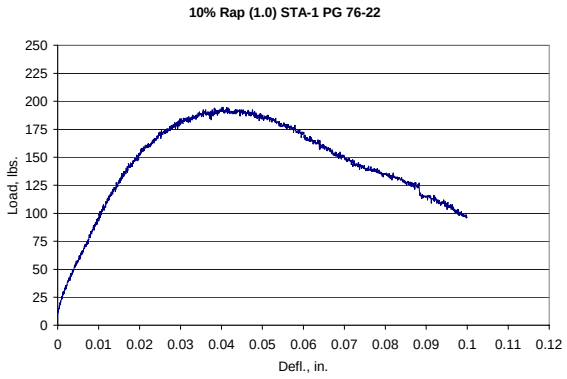


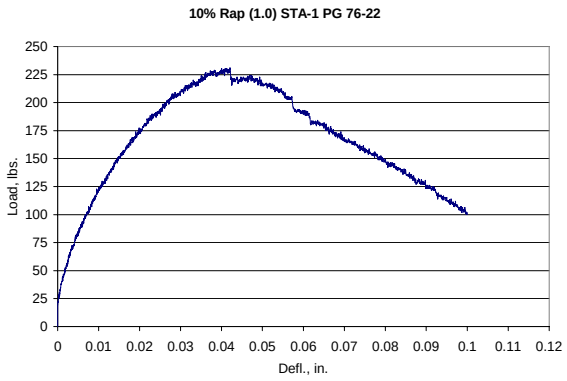


Limestone 76-22 1.0” 10%

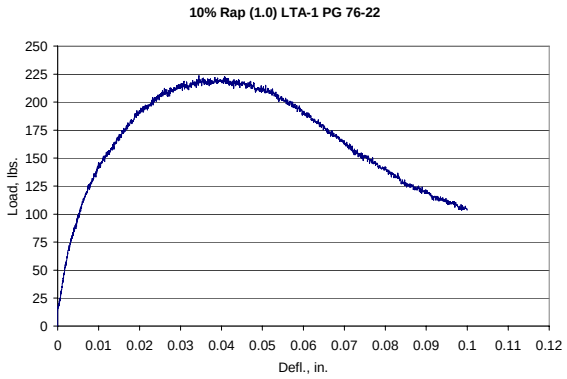
Short term age

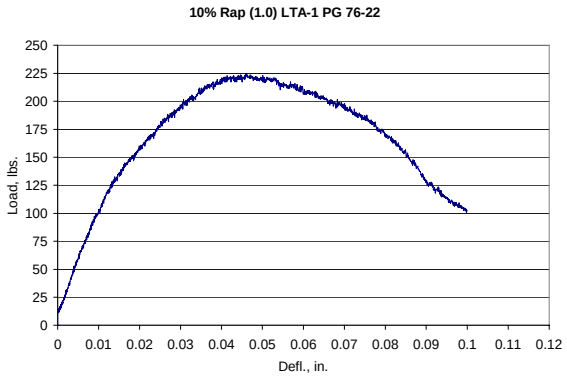


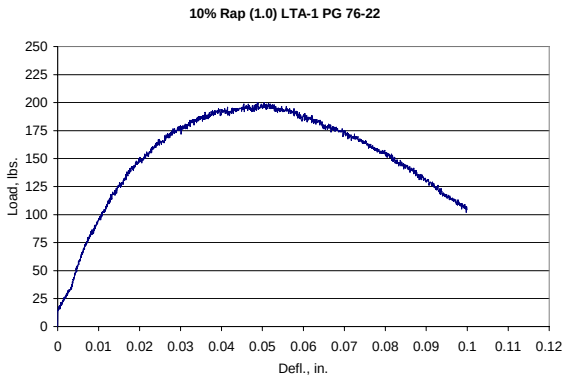




Long term age

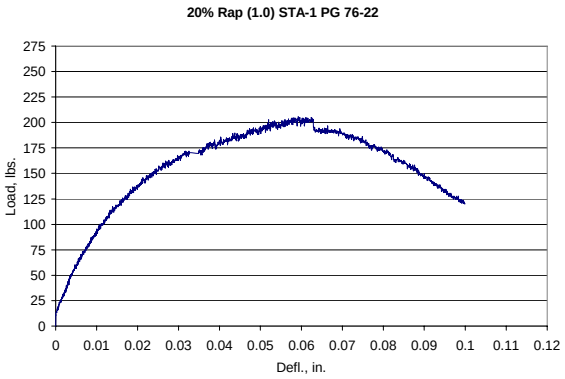


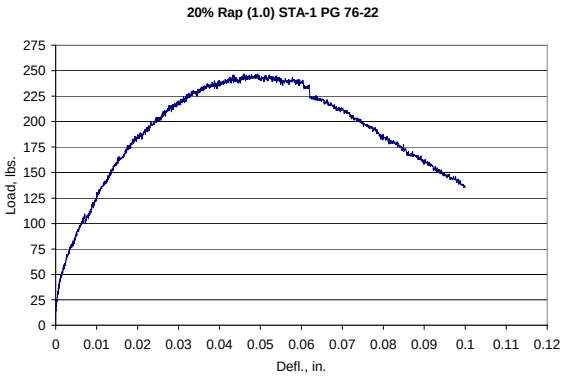


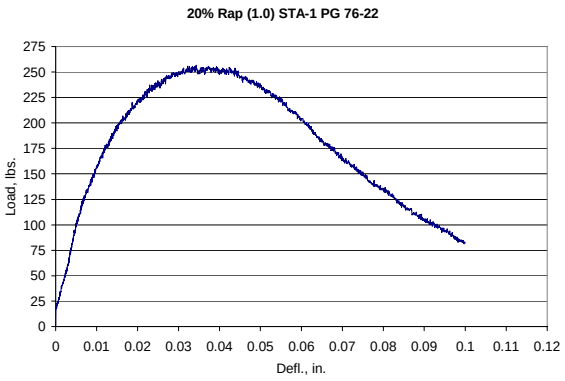


Limestone 76-22 1.0” 20%

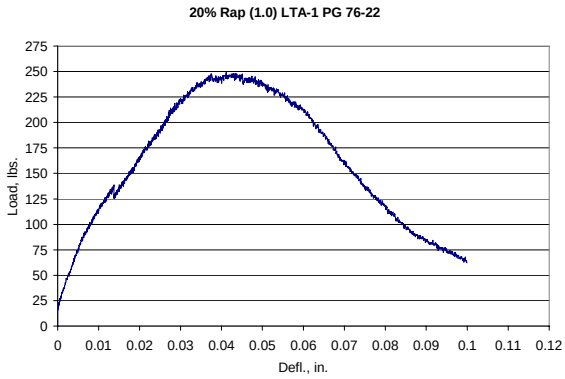
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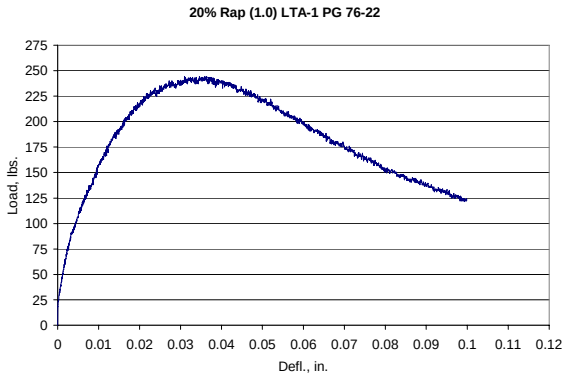


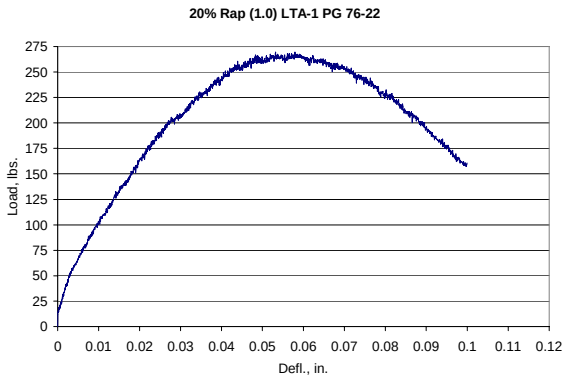




Long term age

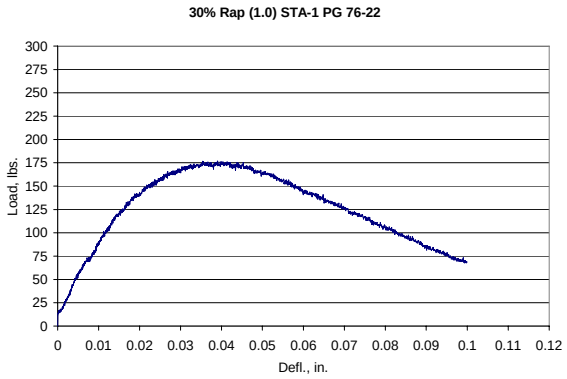


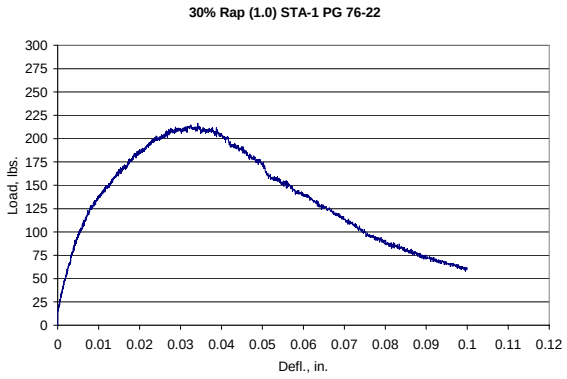


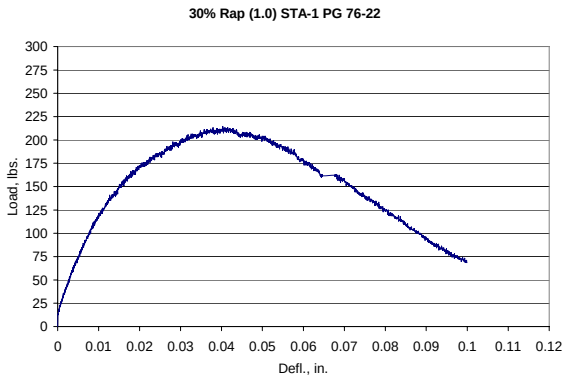


Limestone 76-22 1.0” 30%

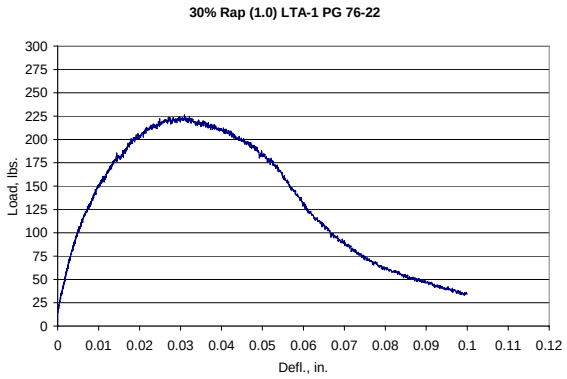
Short term age

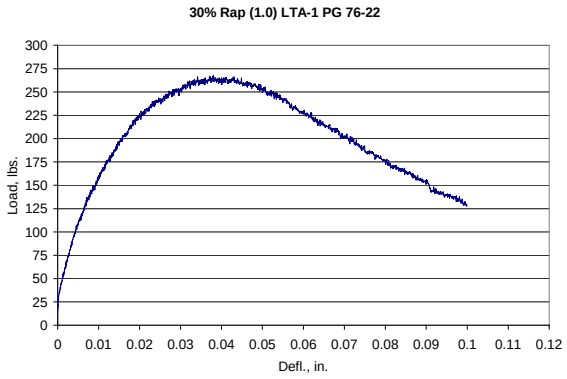


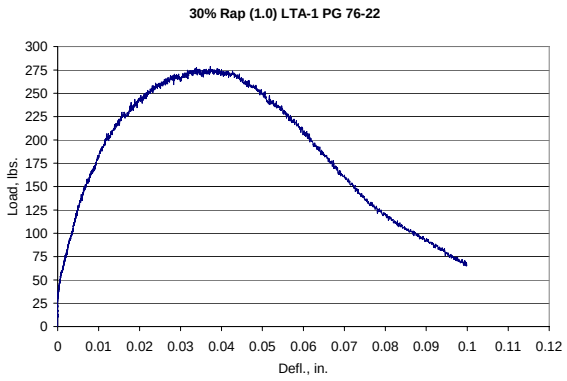




Long term age



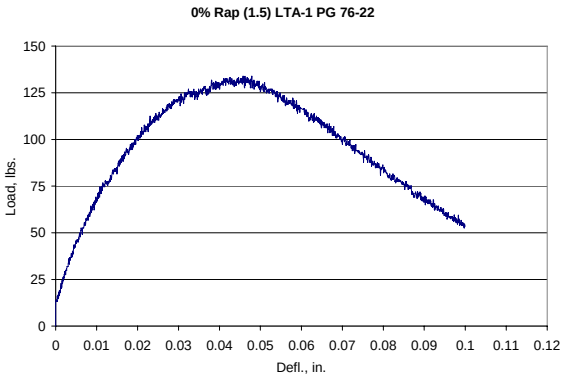


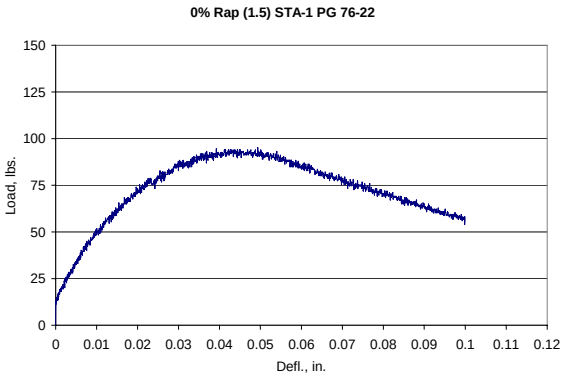


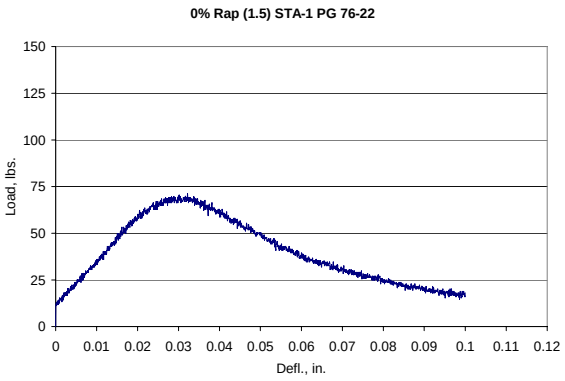
		1.5" Notched Samples								Peak Load			
										Origin	Origin	Origin	Origin
	ID	Notch		Width		Peak		Defl.		Area	Area	Strain Energy	Strain Energy
		in.	mm	in.	m	lbs.	newtons	in.	mm	lb-in.	N-m	lbs/in.^2	J/m
0%		1.5	38.1	1.110	0.028	134.58	598.64	0.035	0.881	3.4018	0.384351652	3.065	13.632
		1.5	38.1	1.090	0.028	133.19	592.46	0.045	1.133	4.2578	0.48106663	3.906	17.376
		1.5	38.1	1.090	0.028	123.55	549.58	0.042	1.077	4.0156	0.453701715	3.684	16.387
	Average	**1.5**	**38.1**	**1.0966667**	**0.0278553**	**130.44**	**580.2258168**	**0.0405667**	**1.0303933**	**3.891733333**	**0.439706666**	**3.551653305**	**15.79853526**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**6.01**	**26.72**	**0.01**	**0.13**	**0.44**	**0.05**	**0.44**	**1.94**
	COV	**0.0**	**0.0**	**1.1**	**1.1**	**4.6**	**4.6**	**12.8**	**12.8**	**11.3**	**11.3**	**12.3**	**12.3**
		1.5	38.1	1.110	0.028	112.53	500.56	0.087	2.215	7.3276	0.827907333	6.601	29.365
		1.5	38.1	1.120	0.028	95.29	423.87	0.049	1.252	3.4779	0.392949794	3.105	13.813
		1.5	38.1	1.070	0.027	710018.00	3158316.27	0.032	0.818	1.4963	0.169059138	1.398	6.220
	Average	**1.5**	**38.1**	**1.1**	**0.02794**	**236741.94**	**1053080.232**	**0.0562333**	**1.4283267**	**4.1006**	**0.463305422**	**3.701706838**	**16.46600639**
	STD Dev.	**0.00**	**0.00**	**0.03**	**0.00**	**409869.09**	**1823187.89**	**0.03**	**0.71**	**2.97**	**0.34**	**2.65**	**11.80**
	COV	**0.0**	**0.0**	**2.4**	**2.4**	**173.1**	**173.1**	**50.1**	**50.1**	**72.3**	**72.3**	**71.7**	**71.7**
10%		1.5	38.1	1.080	0.027	122.17	543.44	0.033	0.831	2.9413	0.332322157	2.723	12.114
		1.5	38.1	1.060	0.027	135.95	604.74	0.041	1.036	4.1794	0.472208623	3.943	17.539
		1.5	38.1	1.120	0.028	149.05	663.01	0.043	1.087	4.5985	0.519560548	4.106	18.264
	Average	**1.5**	**38.1**	**1.0866667**	**0.0276013**	**135.72333**	**603.7272458**	**0.0387667**	**0.9846733**	**3.9064**	**0.441363776**	**3.590686562**	**15.97216378**
	STD Dev.	**0.00**	**0.00**	**0.03**	**0.00**	**13.44**	**59.79**	**0.01**	**0.14**	**0.86**	**0.10**	**0.76**	**3.36**
	COV	**0.0**	**0.0**	**2.8**	**2.8**	**9.9**	**9.9**	**13.8**	**13.8**	**22.1**	**22.1**	**21.0**	**21.0**
		1.5	38.1	1.080	0.027	111.84	497.49	0.038	0.963	2.9598	0.334412376	2.741	12.191
		1.5	38.1	1.090	0.028	111.84	497.49	0.051	1.293	4.1386	0.467598844	3.797	16.889
		1.5	38.1	1.060	0.027	118.04	525.07	0.045	1.153	3.9177	0.442640504	3.696	16.440
	Average	**1.5**	**38.1**	**1.0766667**	**0.0273473**	**113.90667**	**506.6819128**	**0.0447333**	**1.1362267**	**3.672033333**	**0.414883908**	**3.411126562**	**15.1734414**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**3.58**	**15.92**	**0.01**	**0.17**	**0.63**	**0.07**	**0.58**	**2.59**
	COV	**0.0**	**0.0**	**1.4**	**1.4**	**3.1**	**3.1**	**14.6**	**14.6**	**17.1**	**17.1**	**17.1**	**17.1**
20%		1.5	38.1	1.040	0.026	115.28	512.79	0.039	0.986	3.2745	0.369968688	3.149	14.005
		1.5	38.1	1.060	0.027	13251.00	58943.36	0.028	0.714	2.8953	0.327124857	2.731	12.150
		1.5	38.1	1.040	0.026	152.49	678.31	0.033	0.836	3.6225	0.409287395	3.483	15.494
	Average	**1.5**	**38.1**	**1.0466667**	**0.0265853**	**4506.2567**	**20044.82103**	**0.0332667**	**0.8449733**	**3.2641**	**0.368793647**	**3.121048621**	**13.8831109**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**7573.19**	**33687.23**	**0.01**	**0.14**	**0.36**	**0.04**	**0.38**	**1.68**
	COV	**0.0**	**0.0**	**1.1**	**1.1**	**168.1**	**168.1**	**16.1**	**16.1**	**11.1**	**11.1**	**12.1**	**12.1**
		1.5	38.1	1.060	0.027	111.15	494.42	0.038	0.965	3.0271	0.342016252	2.856	12.703
		1.5	38.1	1.060	0.027	108.39	482.14	0.037	0.935	2.8803	0.325430085	2.717	12.087
		1.5	38.1	1.060	0.027	120.11	534.28	0.045	1.130	3.7238	0.420732754	3.513	15.627
	Average	**1.5**	**38.1**	**1.06**	**0.026924**	**113.21667**	**503.612641**	**0.0397667**	**1.0100733**	**3.2104**	**0.362726363**	**3.028679245**	**13.47223159**
	STD Dev.	**0.00**	**0.00**	**0.00**	**0.00**	**6.13**	**27.26**	**0.00**	**0.11**	**0.45**	**0.05**	**0.43**	**1.89**
	COV	**0.0**	**0.0**	**0.0**	**0.0**	**5.4**	**5.4**	**10.4**	**10.4**	**14.0**	**14.0**	**14.0**	**14.0**
30%		1.5	38.1	1.030	0.026	128.37	571.02	0.046	1.176	4.6783	0.528576734	4.542	20.204
		1.5	38.1	1.020	0.026	124.93	555.72	0.024	0.607	2.2431	0.253436178	2.199	9.782
		1.5	38.1	1.030	0.026	134.58	598.64	0.027	0.693	2.9353	0.331644248	2.850	12.677
	Average	**1.5**	**38.1**	**1.0266667**	**0.0260773**	**129.29333**	**575.1251912**	**0.0325**	**0.8255**	**3.285566667**	**0.371219053**	**3.196987436**	**14.22090345**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**4.89**	**21.76**	**0.01**	**0.31**	**1.25**	**0.14**	**1.21**	**5.38**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**3.8**	**3.8**	**37.1**	**37.1**	**38.2**	**38.2**	**37.8**	**37.8**
		1.5	38.1	1.040	0.026	99.43	442.29	0.034	0.853	2.3742	0.268248484	2.283	10.155
		1.5	38.1	1.050	0.027	122.17	543.44	0.037	0.937	3.1685	0.357992301	3.018	13.423
		1.5	38.1	1.030	0.026	103.57	460.70	0.026	0.650	2.1197	0.239493855	2.058	9.154
	Average	**1.5**	**38.1**	**1.04**	**0.026416**	**108.39**	**482.1425658**	**0.0320333**	**0.8136467**	**2.554133333**	**0.288578213**	**2.452821609**	**10.91069014**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**12.11**	**53.88**	**0.01**	**0.15**	**0.55**	**0.06**	**0.50**	**2.23**
	COV	**0.0**	**0.0**	**1.0**	**1.0**	**11.2**	**11.2**	**18.1**	**18.1**	**21.4**	**21.4**	**20.5**	**20.5**

Limestone 76-22 1.5” 0%

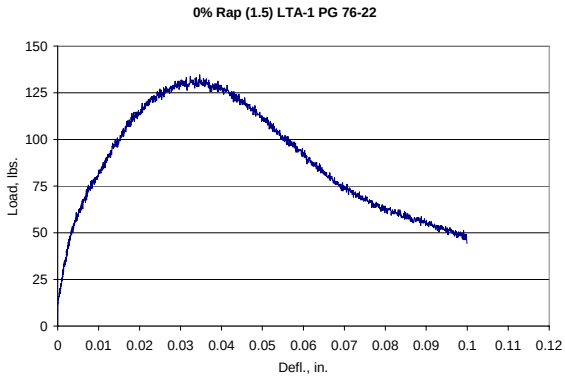
Short term age

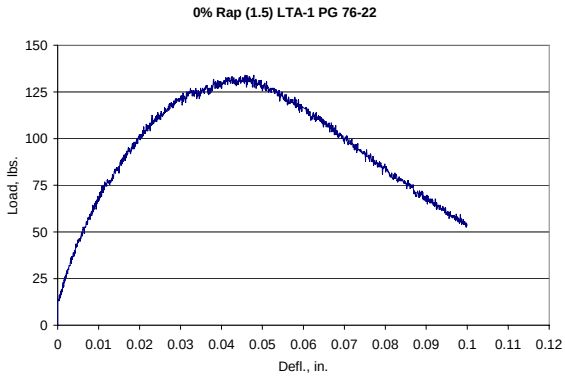


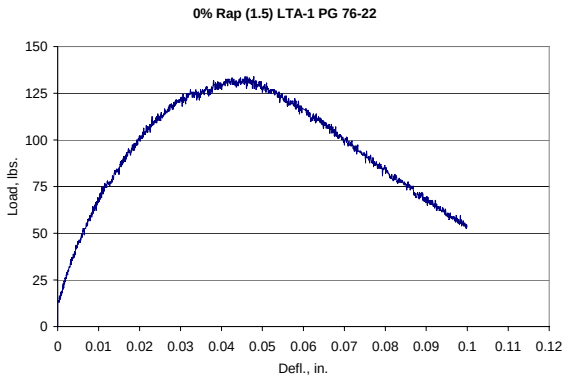




Long term age

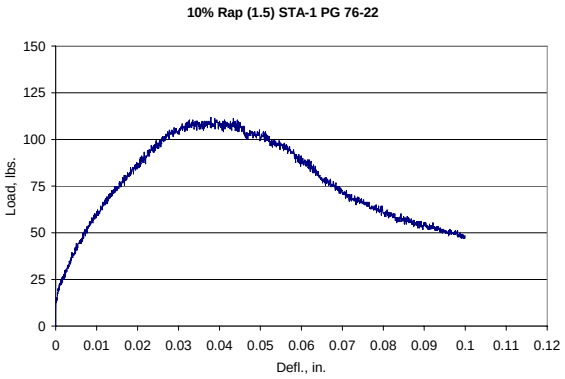


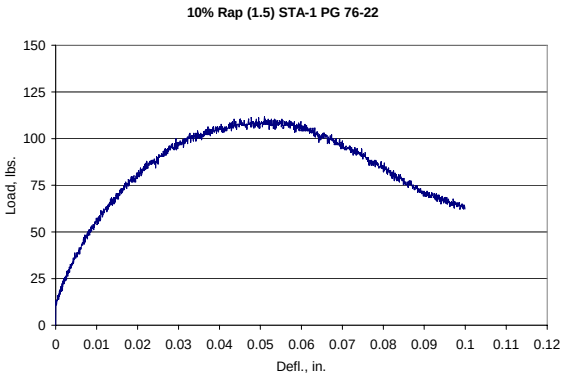


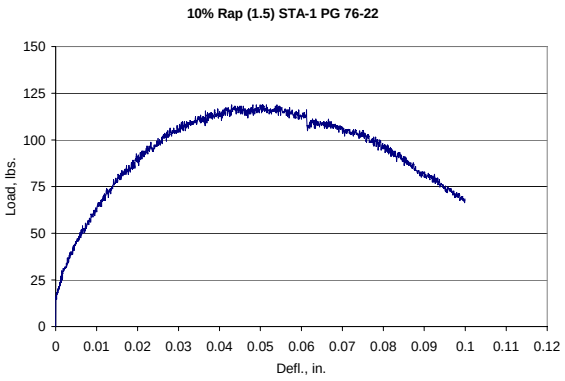


Limestone 76-22 1.5” 10%

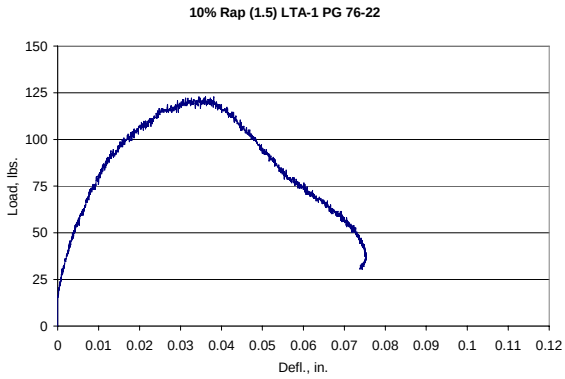
Short term age

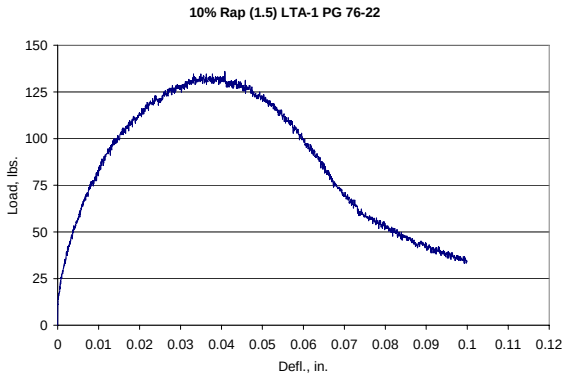


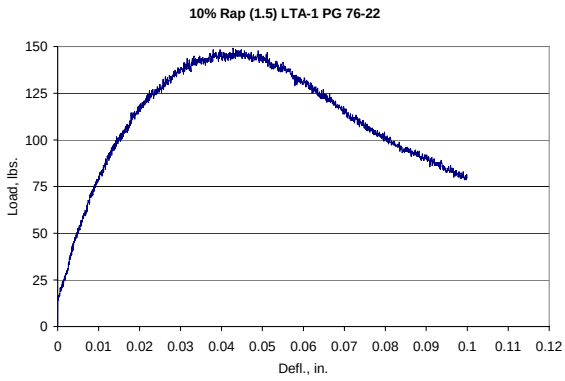




Long term age

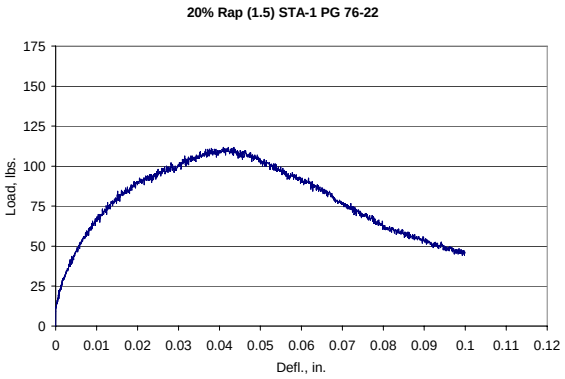


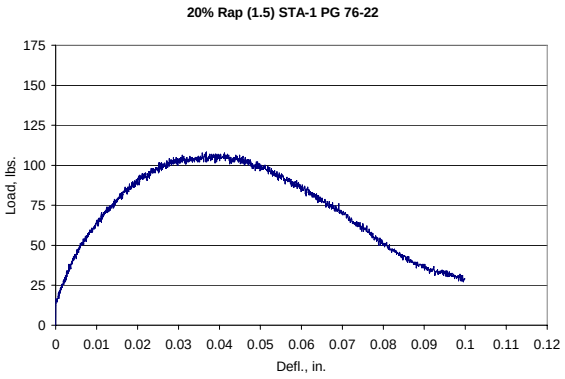


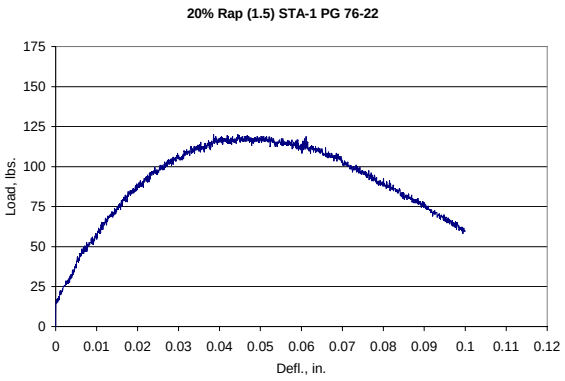


Limestone 76-22 1.5” 20%

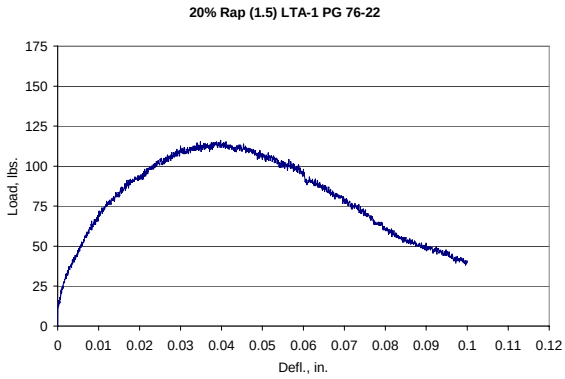
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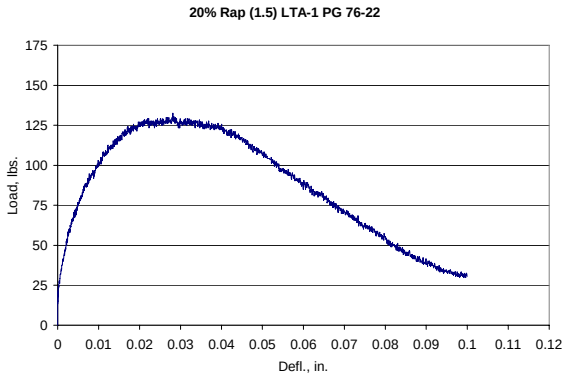


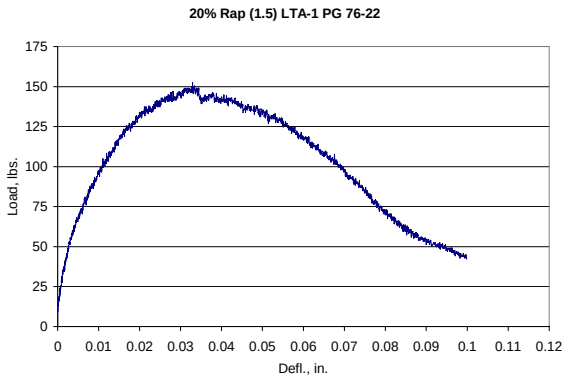




Long term age

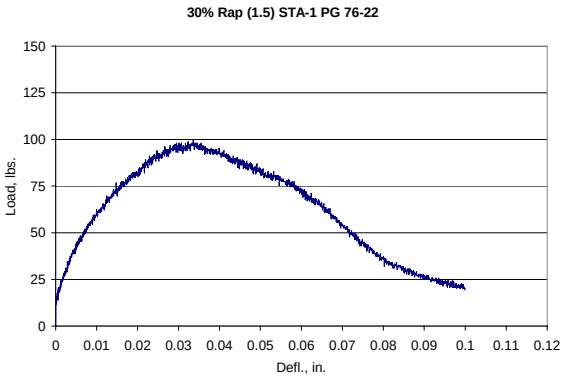


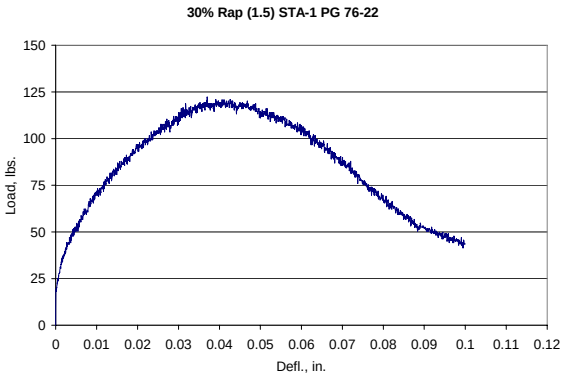


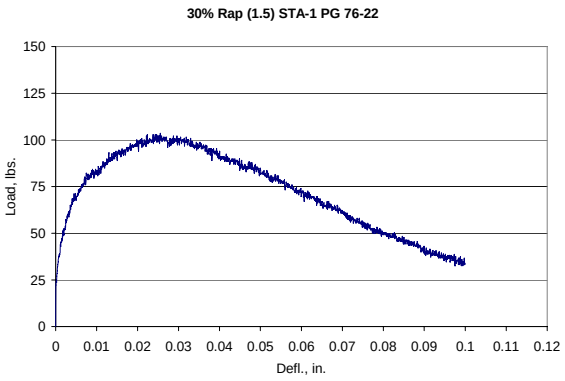


Limestone 76-22 1.5” 30%

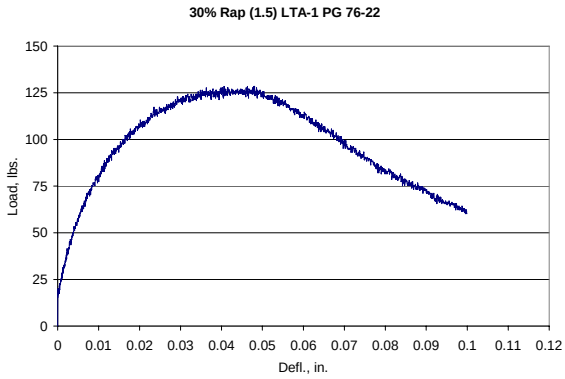
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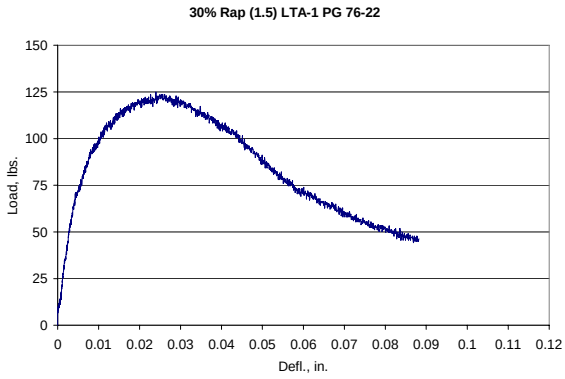


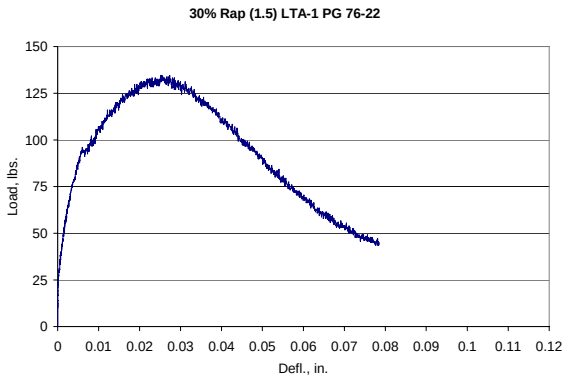




Long term age





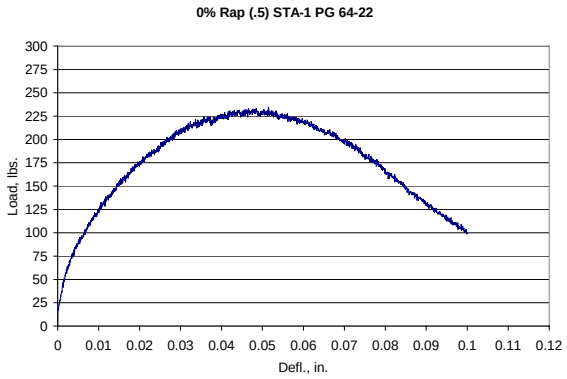


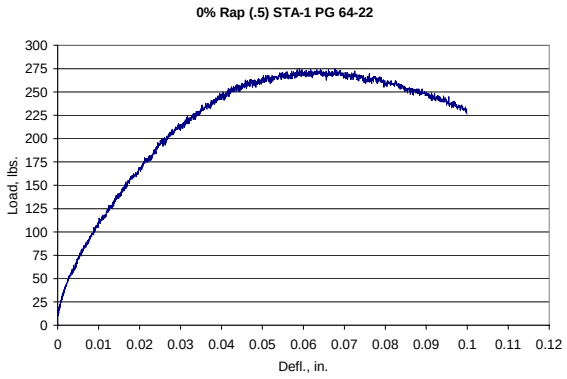
Gravel PG 64-22

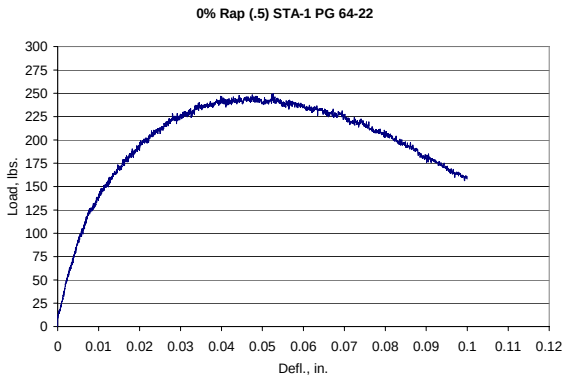
	.5" Notched Samples									Peak Load			
										Origin	Origin	Origin	Origin
	ID	Notch		Width		Peak		Defl.		Area	Area	Strain Energy	Strain Energy
		in.	mm	in.	m	lbs.	newtons	in.	mm	lb-in.	N-m	lbs/in.^2	J/m
0%		0.5	12.7	1.050	0.027	297.89	1325.08	0.045	1.147	9.6254	1.087523778	9.167	40.777
		0.5	12.7	1.060	0.027	275.15	1223.93	0.048	1.214	9.07392	1.025214928	8.560	38.078
		0.5	12.7	1.040	0.026	292.38	1300.57	0.042	1.066	8.21842	0.928556441	7.902	35.151
	Average	**0.5**	**12.7**	**1.05**	**0.02667**	**288.47333**	**1283.192851**	**0.0449667**	**1.1421533**	**8.97258**	**1.013765049**	**8.543225476**	**38.00214643**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**11.86**	**52.77**	**0.00**	**0.07**	**0.71**	**0.08**	**0.63**	**2.81**
	COV	**0.0**	**0.0**	**1.0**	**1.0**	**4.1**	**4.1**	**6.5**	**6.5**	**7.9**	**7.9**	**7.4**	**7.4**
		0.5	12.7	1.090	0.028	234.49	1043.06	0.051	1.307	9.04937	1.022441151	8.302	36.930
		0.5	12.7	1.030	0.026	275.15	1223.93	0.059	1.499	11.24514	1.270529759	10.918	48.564
		0.5	12.7	1.050	0.027	249.66	1110.54	0.053	1.336	10.04313	1.134720914	9.565	42.547
	Average	**0.5**	**12.7**	**1.0566667**	**0.0268393**	**253.1**	**1125.844482**	**0.0543567**	**1.3806593**	**10.11254667**	**1.142563941**	**9.594890559**	**42.68018408**
	STD Dev.	**0.00**	**0.00**	**0.03**	**0.00**	**20.55**	**91.40**	**0.00**	**0.10**	**1.10**	**0.12**	**1.31**	**5.82**
	COV	**0.0**	**0.0**	**2.9**	**2.9**	**8.1**	**8.1**	**7.5**	**7.5**	**10.9**	**10.9**	**13.6**	**13.6**
10%		0.5	12.7	1.060	0.027	246.21	1095.20	0.046	1.179	8.01158	0.905186668	7.558	33.620
		0.5	12.7	1.050	0.027	333.07	1481.57	0.035	0.894	8.24369	0.931411567	7.851	34.924
		0.5	12.7	1.030	0.026	286.18	1272.99	0.068	1.722	14.31908	1.617838218	13.902	61.839
	Average	**0.5**	**12.7**	**1.0466667**	**0.0265853**	**288.48667**	**1283.25216**	**0.0498033**	**1.2650047**	**10.19145**	**1.151478818**	**9.770415697**	**43.46095851**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**43.48**	**193.39**	**0.02**	**0.42**	**3.58**	**0.40**	**3.58**	**15.93**
	COV	**0.0**	**0.0**	**1.5**	**1.5**	**15.1**	**15.1**	**33.3**	**33.3**	**35.1**	**35.1**	**36.7**	**36.7**
		0.5	12.7	1.040	0.026	263.44	1171.84	0.047	1.195	9.1045	1.028670002	8.754	38.941
		0.5	12.7	1.080	0.027	289.63	1288.34	0.055	1.402	11.9747	1.352958941	11.088	49.320
		0.5	12.7	1.060	0.027	337.86	1502.88	0.059	1.499	14.0279	1.584939308	13.234	58.867
	Average	**0.5**	**12.7**	**1.06**	**0.026924**	**296.97667**	**1321.017548**	**0.0537433**	**1.3650807**	**11.70236667**	**1.322189417**	**11.02529334**	**49.04293036**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**37.75**	**167.92**	**0.01**	**0.16**	**2.47**	**0.28**	**2.24**	**9.97**
	COV	**0.0**	**0.0**	**1.9**	**1.9**	**12.7**	**12.7**	**11.4**	**11.4**	**21.1**	**21.1**	**20.3**	**20.3**
20%		0.5	12.7	1.050	0.027	400.57	1781.82	0.033	0.833	9.188	1.038104232	8.750	38.924
		0.5	12.7	1.040	0.026	406.10	1806.42	0.036	0.917	10.1511	1.146919881	9.761	43.418
		0.5	12.7	1.070	0.027	343.33	1527.21	0.027	0.688	6.7523	0.762907184	6.311	28.071
	Average	**0.5**	**12.7**	**1.0533333**	**0.0267547**	**383.33333**	**1705.151**	**0.032**	**0.8128**	**8.697133333**	**0.982643766**	**8.273903338**	**36.80414231**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**34.75**	**154.59**	**0.00**	**0.12**	**1.75**	**0.20**	**1.77**	**7.89**
	COV	**0.0**	**0.0**	**1.5**	**1.5**	**9.1**	**9.1**	**14.2**	**14.2**	**20.1**	**20.1**	**21.4**	**21.4**
		0.5	12.7	1.080	0.027	264.82	1177.98	0.035	0.879	6.9466	0.784860128	6.432	28.611
		0.5	12.7	1.060	0.027	317.19	1410.93	0.044	1.123	10.7811	1.218100298	10.171	45.242
		0.5	12.7	1.080	0.027	306.16	1361.87	0.034	0.853	7.3488	0.83030261	6.804	30.268
	Average	**0.5**	**12.7**	**1.0733333**	**0.0272627**	**296.05667**	**1316.925186**	**0.0374667**	**0.9516533**	**8.358833333**	**0.944421012**	**7.802443513**	**34.70698528**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**27.61**	**122.81**	**0.01**	**0.15**	**2.11**	**0.24**	**2.06**	**9.16**
	COV	**0.0**	**0.0**	**1.1**	**1.1**	**9.3**	**9.3**	**15.6**	**15.6**	**25.2**	**25.2**	**26.4**	**26.4**
30%		0.5	12.7	1.070	0.027	366.11	1628.54	0.022	0.566	6.4089	0.724108208	5.990	26.643
		0.5	12.7	1.060	0.027	417.11	1855.40	0.029	0.739	8.7336	0.986763944	8.239	36.650
		0.5	12.7	1.080	0.027	403.33	1794.10	0.052	1.321	13.8108	1.56041031	12.788	56.883
	Average	**0.5**	**12.7**	**1.07**	**0.027178**	**395.51667**	**1759.345147**	**0.0344667**	**0.8754533**	**9.6511**	**1.090427487**	**9.005549743**	**40.05866648**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**26.38**	**117.36**	**0.02**	**0.40**	**3.79**	**0.43**	**3.46**	**15.41**
	COV	**0.0**	**0.0**	**0.9**	**0.9**	**6.7**	**6.7**	**45.1**	**45.1**	**39.2**	**39.2**	**38.5**	**38.5**
		0.5	12.7	1.050	0.027	266.19	1184.07	0.034	0.856	6.7623	0.764037032	6.440	28.648
		0.5	12.7	1.070	0.027	352.33	1567.24	0.045	1.153	12.0478	1.361218129	11.260	50.085
		0.5	12.7	1.090	0.028	316.50	1407.86	0.033	0.836	7.3503	0.830472087	6.743	29.996
	Average	**0.5**	**12.7**	**1.07**	**0.027178**	**311.67**	**1386.39**	**0.04**	**0.95**	**8.72**	**0.99**	**8.15**	**36.24**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**43.27**	**192.48**	**0.01**	**0.18**	**2.90**	**0.33**	**2.70**	**12.01**
	COV	**0.0**	**0.0**	**1.9**	**1.9**	**13.9**	**13.9**	**18.7**	**18.7**	**33.2**	**33.2**	**33.1**	**33.1**

Gravel 64-22 0.5” 0%

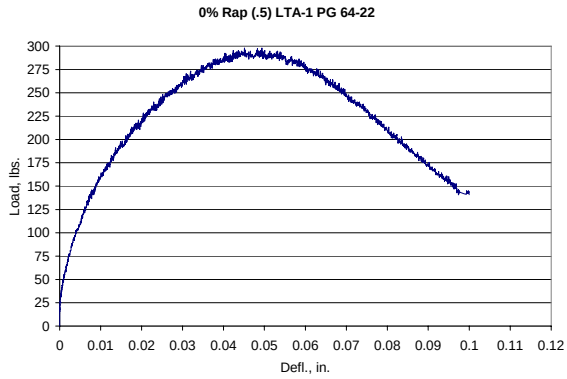
Short term age

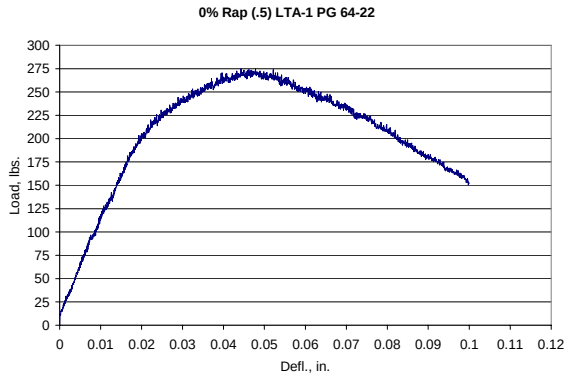


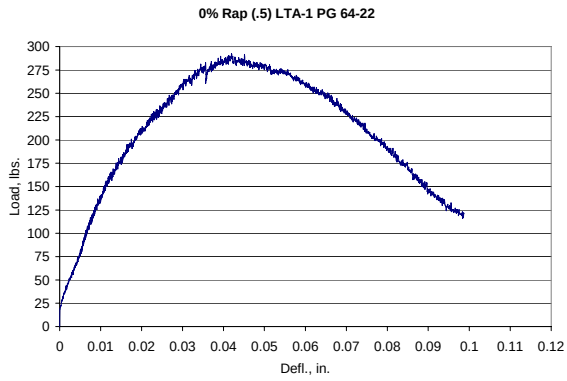




Long term age

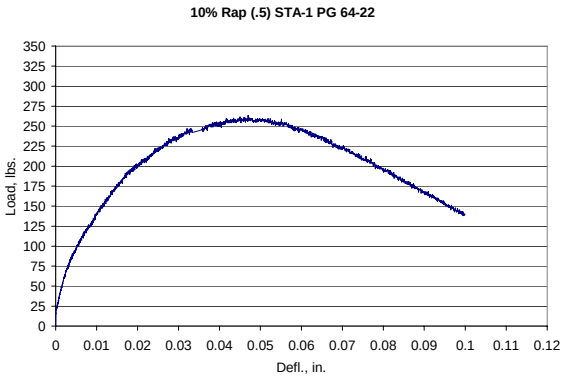


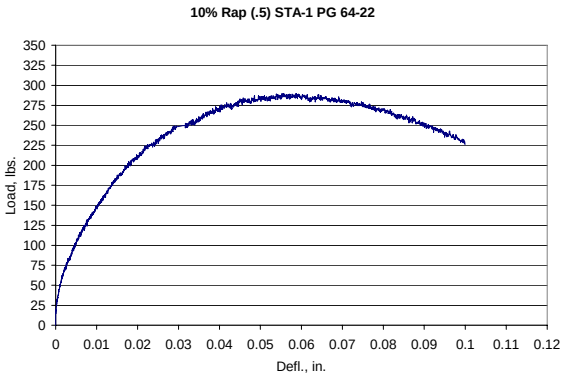


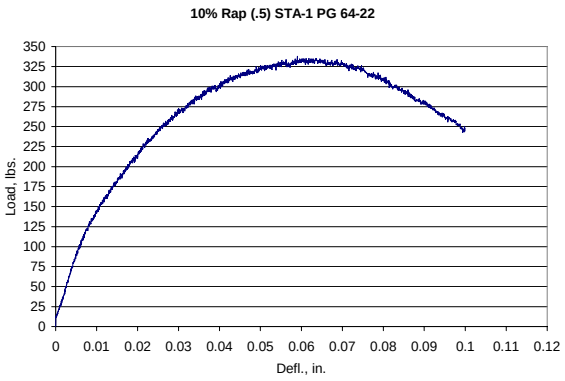


Gravel 64-22 0.5” 10%

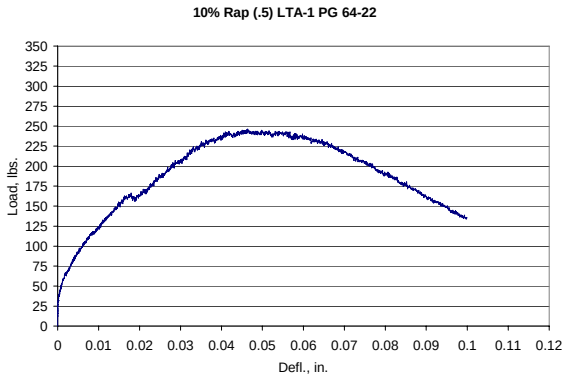
Short term age

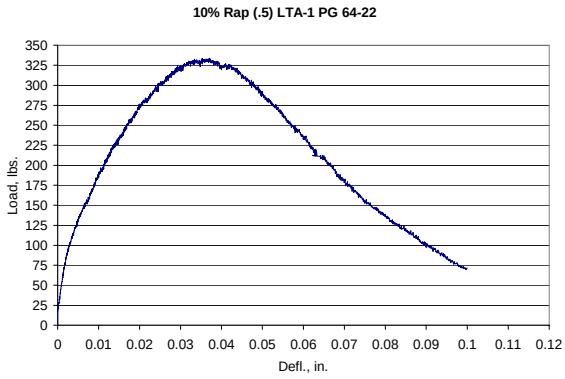


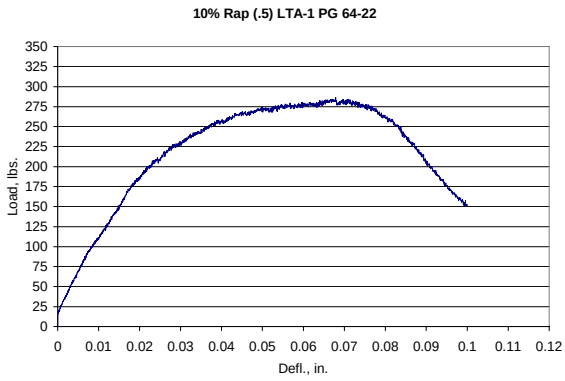




Long term age

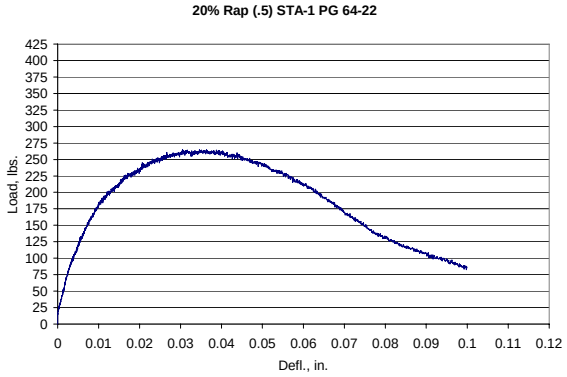


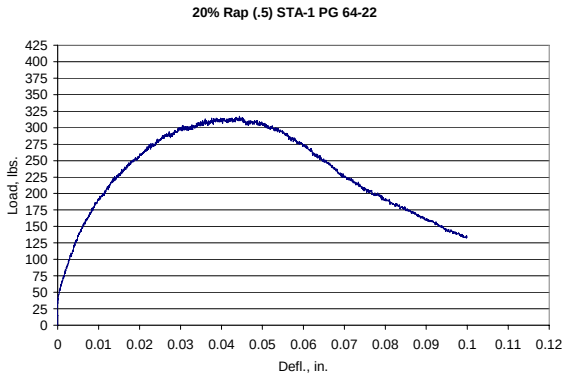


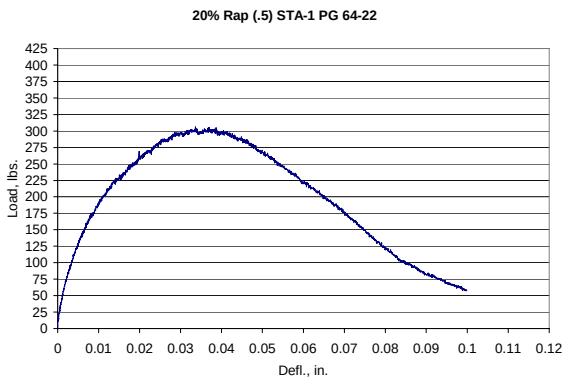


Gravel 64-22 0.5” 20%

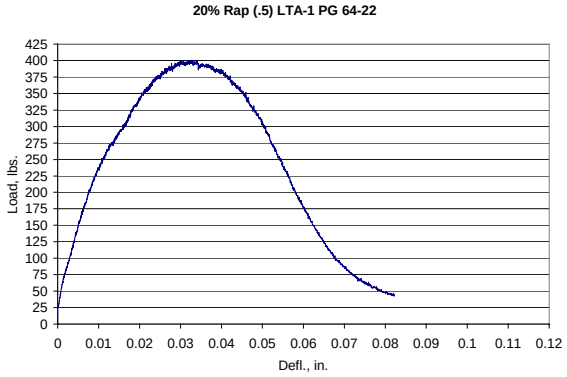
Short term age

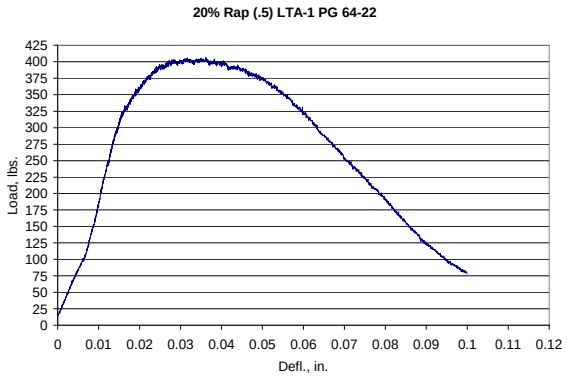


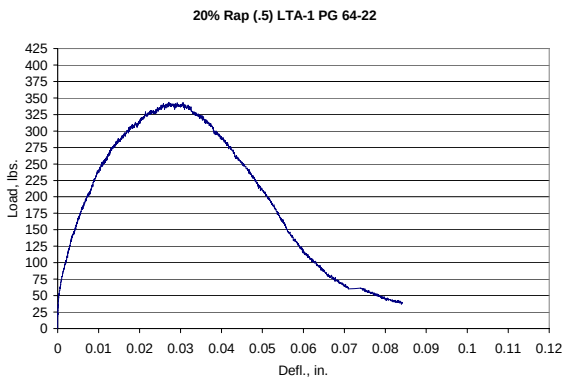




Long term age

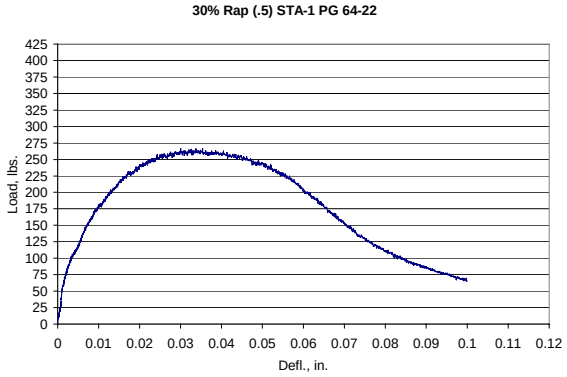


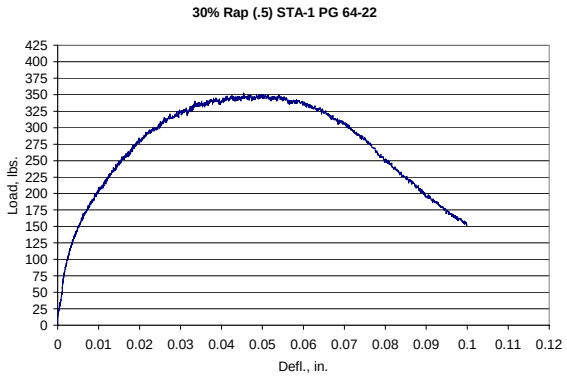


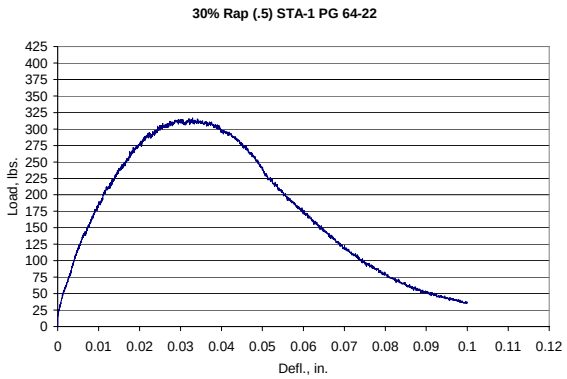


Gravel 64-22 0.5” 30%

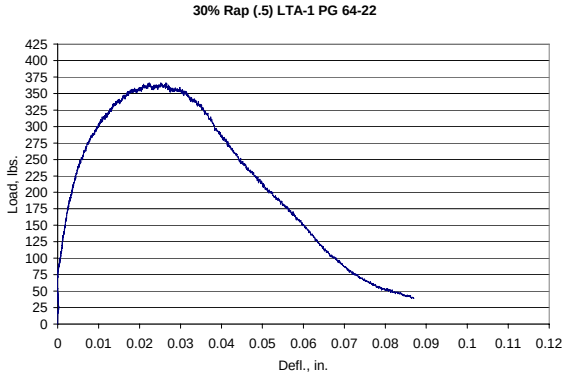
Short term age

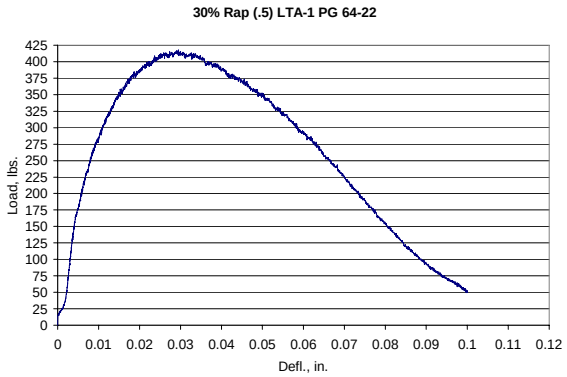


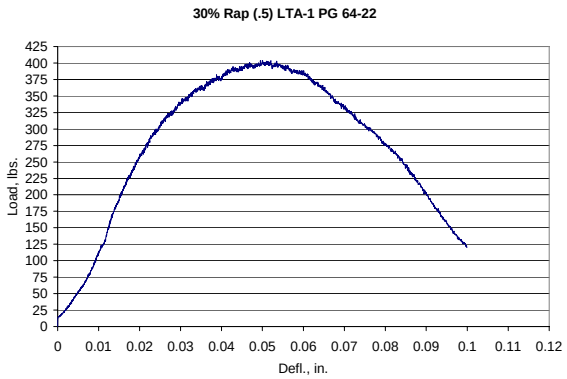




Long term age



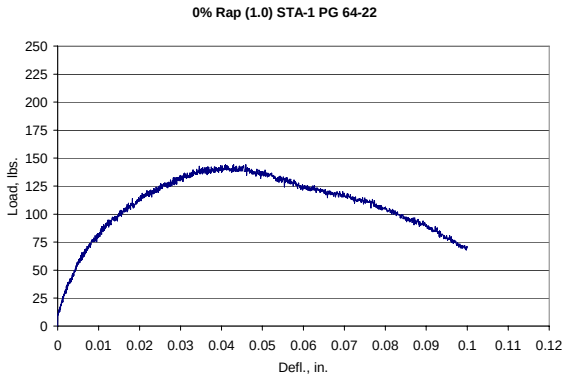


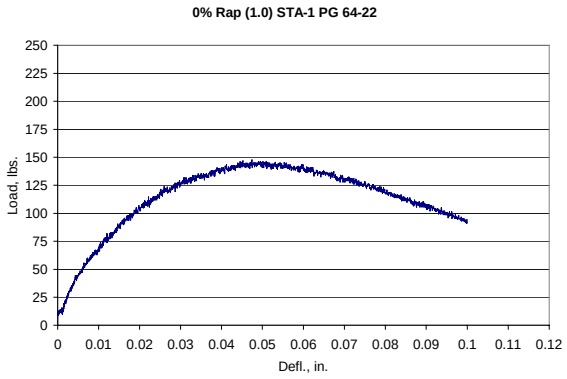


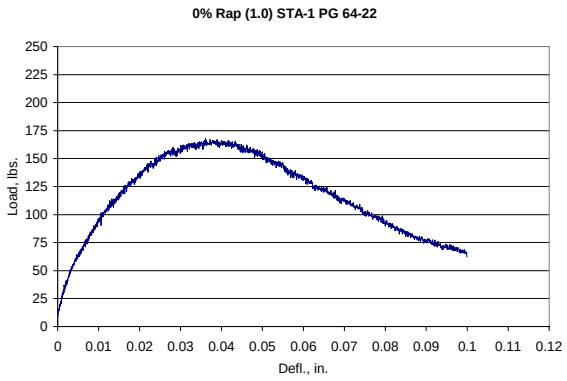
	1" Notched Samples											
									Origin	Origin	Origin	Origin
	ID	Notch		Width		Peak		Defl.		Area	Area	Strain Energy	Strain Energy
		in.	mm	in.	m	lbs.	newtons	in.	mm	lb-in.	N-m	lbs/in.^2	J/m
0%		1	25.4	1.060	0.027	193.15	859.17	0.044	1.125	6.3897	0.7219389	6.028	26.814
		1	25.4	1.060	0.027	235.19	1046.18	0.038	0.965	6.1377	0.693466733	5.790	25.756
		1	25.4	1.010	0.026	217.27	966.46	0.035	0.889	5.9215	0.669039422	5.863	26.079
	Average	**1**	**25.4**	**1.0433333**	**0.0265007**	**215.20333**	**957.2717714**	**0.0391**	**0.99314**	**6.149633333**	**0.694815018**	**5.893724391**	**26.21658271**
	STD Dev.	**0.00**	**0.00**	**0.03**	**0.00**	**21.10**	**93.84**	**0.00**	**0.12**	**0.23**	**0.03**	**0.12**	**0.54**
	COV	**0.0**	**0.0**	**2.8**	**2.8**	**9.8**	**9.8**	**12.1**	**12.1**	**3.8**	**3.8**	**2.1**	**2.1**
		1	25.4	1.050	0.027	144.22	641.52	0.041	1.041	4.2583	0.481123123	4.056	18.040
		1	25.4	1.030	0.026	147.67	656.87	0.047	1.194	4.8388	0.546710792	4.698	20.897
		1	25.4	1.070	0.027	167.65	745.74	0.036	0.914	4.2368	0.47869395	3.960	17.613
	Average	**1**	**25.4**	**1.05**	**0.02667**	**153.18**	**681.3783396**	**0.0413333**	**1.0498667**	**4.444633333**	**0.502175955**	**4.237671352**	**18.85009446**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**12.65**	**56.27**	**0.01**	**0.14**	**0.34**	**0.04**	**0.40**	**1.79**
	COV	**0.0**	**0.0**	**1.9**	**1.9**	**8.3**	**8.3**	**13.3**	**13.3**	**7.7**	**7.7**	**9.5**	**9.5**
10%		1	25.4	1.050	0.027	190.39	846.90	0.052	1.321	6.1825	0.698528452	5.888	26.192
		1	25.4	1.050	0.027	211.07	938.89	0.048	1.219	7.4855	0.845747631	7.129	31.712
		1	25.4	1.020	0.026	224.16	997.11	0.048	1.219	7.7589	0.876637672	7.607	33.837
	Average	**1**	**25.4**	**1.04**	**0.026416**	**208.54**	**927.6317988**	**0.0493333**	**1.2530667**	**7.1423**	**0.806971251**	**6.874635854**	**30.5798927**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**17.03**	**75.74**	**0.00**	**0.06**	**0.84**	**0.10**	**0.89**	**3.95**
	COV	**0.0**	**0.0**	**1.7**	**1.7**	**8.2**	**8.2**	**4.7**	**4.7**	**11.8**	**11.8**	**12.9**	**12.9**
		1	25.4	1.040	0.026	172.48	767.23	0.059	1.499	7.5641	0.854628235	7.273	32.353
		1	25.4	1.060	0.027	158.70	705.93	0.057	1.448	6.6391	0.750117306	6.263	27.861
		1	25.4	1.030	0.026	191.08	849.97	0.055	1.397	7.5408	0.851995689	7.321	32.566
	Average	**1**	**25.4**	**1.0433333**	**0.0265007**	**174.08667**	**774.3757924**	**0.057**	**1.4478**	**7.248**	**0.818913743**	**6.952546671**	**30.92645715**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**16.25**	**72.28**	**0.00**	**0.05**	**0.53**	**0.06**	**0.60**	**2.66**
	COV	**0.0**	**0.0**	**1.5**	**1.5**	**9.3**	**9.3**	**3.5**	**3.5**	**7.3**	**7.3**	**8.6**	**8.6**
20%		1	25.4	1.070	0.027	244.14	1085.99	0.021	0.526	4.0516	0.457769167	3.787	16.843
		1	25.4	1.060	0.027	291.00	1294.43	0.023	0.584	4.346	0.491031889	4.100	18.238
		1	25.4	1.090	0.028	262.06	1165.70	0.025	0.635	4.4165	0.498997316	4.052	18.023
	Average	**1**	**25.4**	**1.0733333**	**0.0272627**	**265.73333**	**1182.040328**	**0.0229**	**0.58166**	**4.271366667**	**0.482599457**	**3.979458973**	**17.70150899**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**23.64**	**105.18**	**0.00**	**0.05**	**0.19**	**0.02**	**0.17**	**0.75**
	COV	**0.0**	**0.0**	**1.4**	**1.4**	**8.9**	**8.9**	**9.4**	**9.4**	**4.5**	**4.5**	**4.2**	**4.2**
		1	25.4	1.090	0.028	189.02	840.80	0.042	1.067	5.6205	0.635031001	5.156	22.937
		1	25.4	1.060	0.027	231.74	1030.83	0.038	0.970	6.2116	0.701816309	5.860	26.067
		1	25.4	1.060	0.027	237.94	1058.41	0.026	0.668	4.732	0.534644017	4.464	19.858
	Average	**1**	**25.4**	**1.07**	**0.027178**	**219.56667**	**976.680838**	**0.0355**	**0.9017**	**5.521366667**	**0.623830442**	**5.160190987**	**22.95366475**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**26.64**	**118.48**	**0.01**	**0.21**	**0.74**	**0.08**	**0.70**	**3.10**
	COV	**0.0**	**0.0**	**1.6**	**1.6**	**12.1**	**12.1**	**23.1**	**23.1**	**13.5**	**13.5**	**13.5**	**13.5**
30%		1	25.4	1.060	0.027	270.33	1202.49	0.034	0.874	6.2845	0.7100529	5.929	26.372
		1	25.4	1.070	0.027	280.67	1248.48	0.024	0.599	4.9765	0.562268797	4.651	20.688
		1	25.4	1.050	0.027	259.99	1156.49	0.039	0.996	7.1541	0.808304472	6.813	30.308
	Average	**1**	**25.4**	**1.06**	**0.026924**	**270.33**	**1202.487313**	**0.0324**	**0.82296**	**6.138366667**	**0.693542056**	**5.797712245**	**25.78949956**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**10.34**	**45.99**	**0.01**	**0.20**	**1.10**	**0.12**	**1.09**	**4.84**
	COV	**0.0**	**0.0**	**0.9**	**0.9**	**3.8**	**3.8**	**24.7**	**24.7**	**17.9**	**17.9**	**18.8**	**18.8**
		1	25.4	1.050	0.027	213.82	951.12	0.028	0.706	4.1557	0.469530883	3.958	17.605
		1	25.4	1.050	0.027	195.91	871.45	0.030	0.765	4.5708	0.516430869	4.353	19.364
		1	25.4	1.060	0.027	224.85	1000.18	0.028	0.711	4.9237	0.556303201	4.645	20.662
	Average	**1**	**25.4**	**1.0533333**	**0.0267547**	**211.52667**	**940.9171492**	**0.0286333**	**0.7272867**	**4.550066667**	**0.514088318**	**4.318650794**	**19.21030883**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**14.61**	**64.97**	**0.00**	**0.03**	**0.38**	**0.04**	**0.34**	**1.53**
	COV	**0.0**	**0.0**	**0.5**	**0.5**	**6.9**	**6.9**	**4.4**	**4.4**	**8.4**	**8.4**	**8.0**	**8.0**

Gravel 64-22 1” 0%

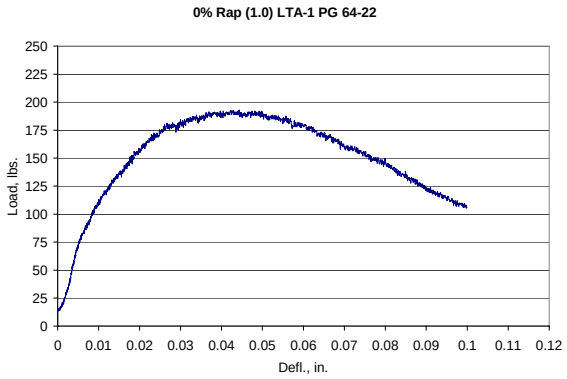
Short term age

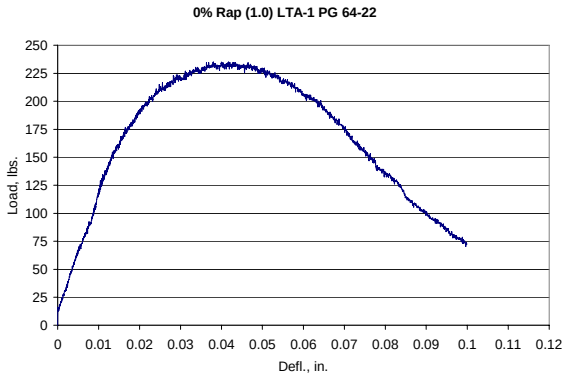


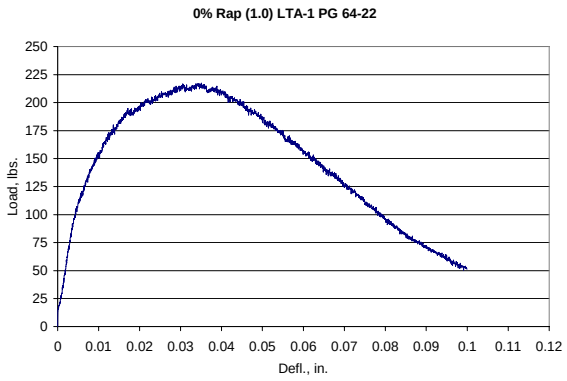




Long term age

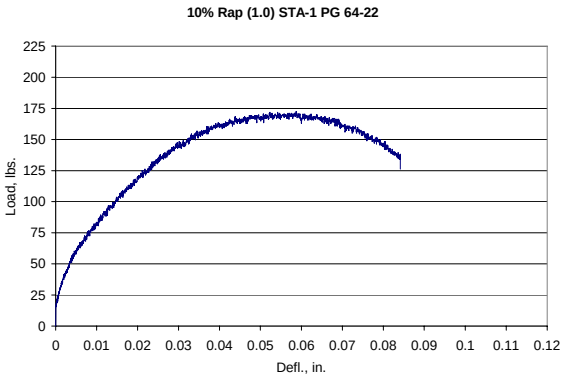


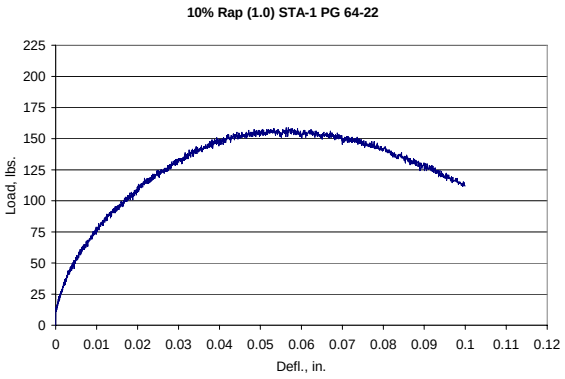


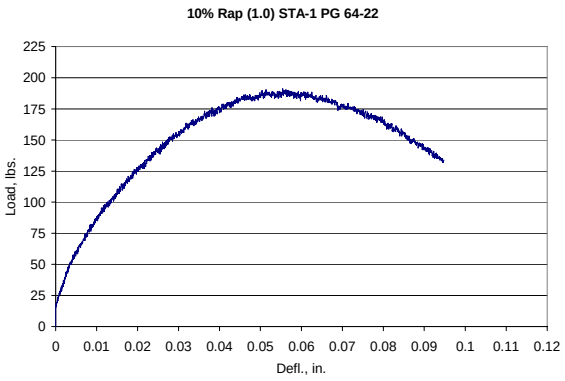


Gravel 64-22 1” 10%

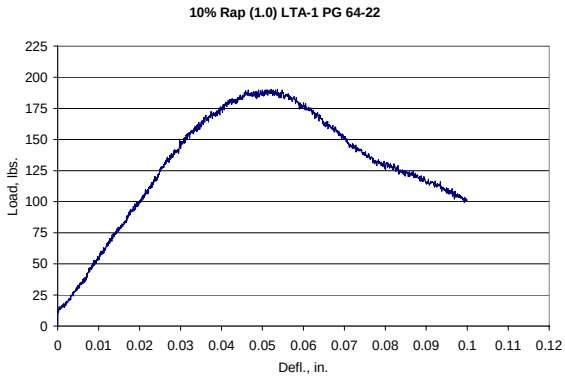
Short term age

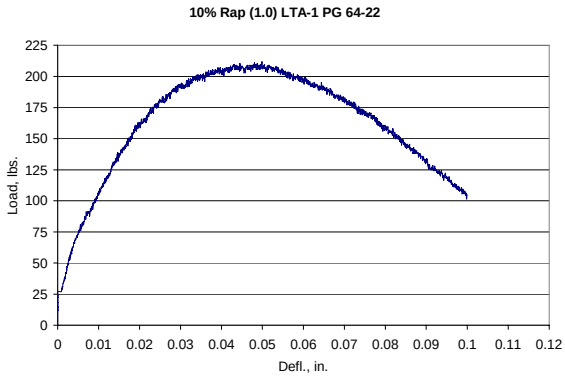


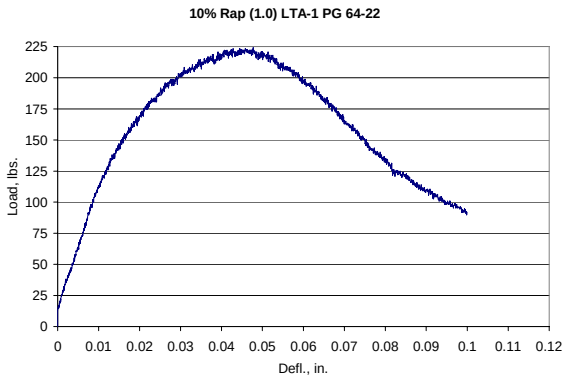




Long term age

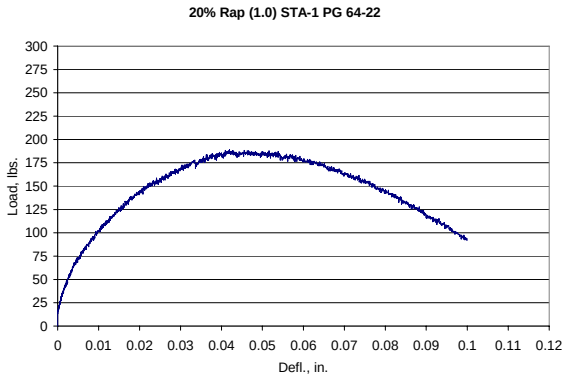


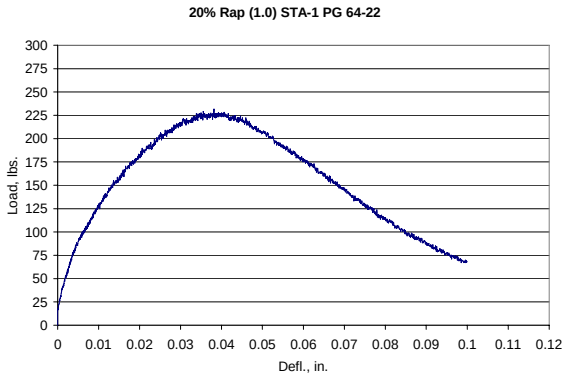


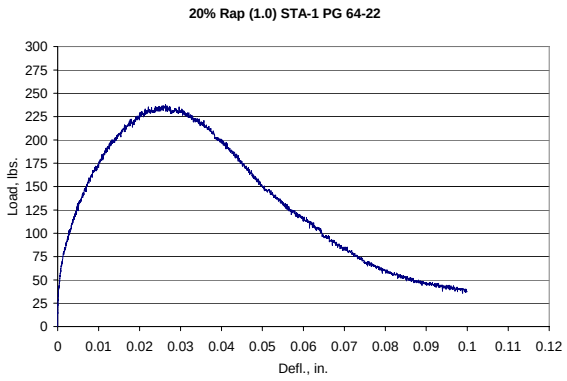


Gravel 64-22 1” 20%

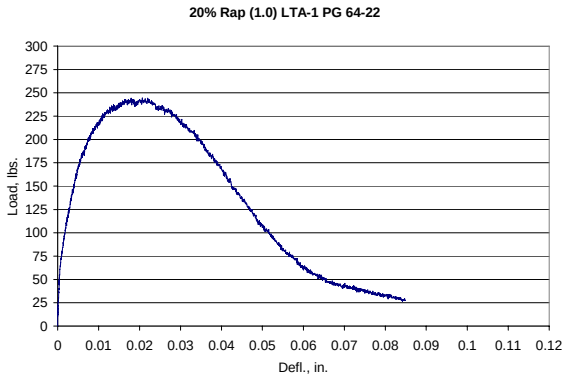
Short term age

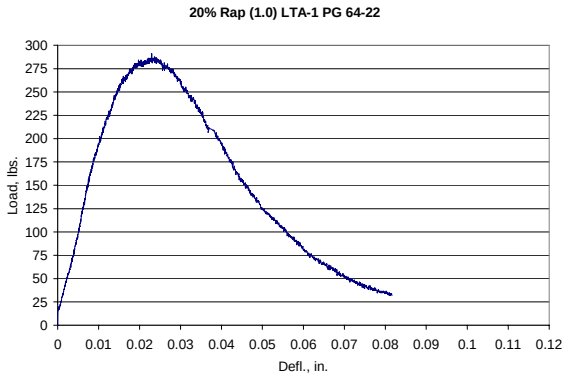


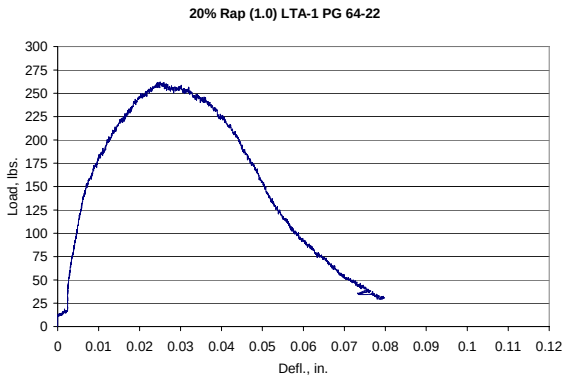




Long term age

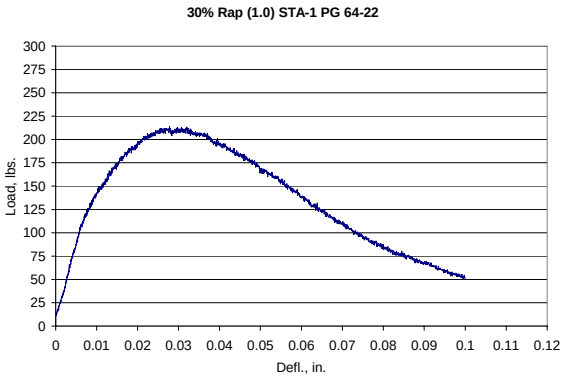


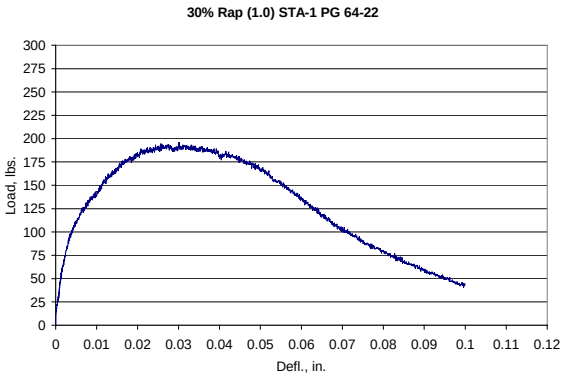


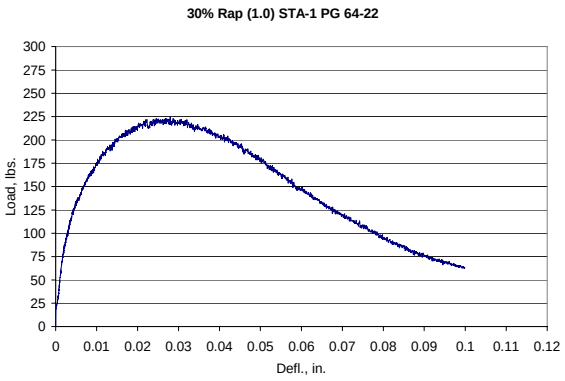


Gravel 64-22 1” 30%

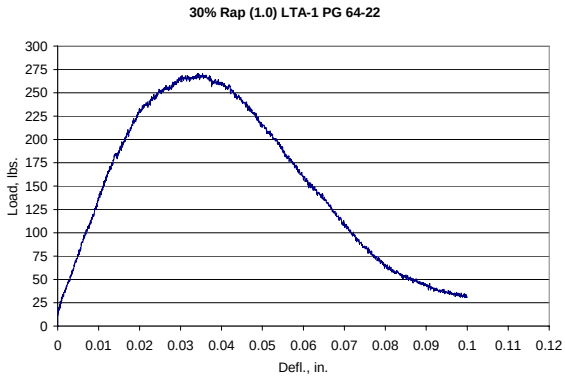
Short term age

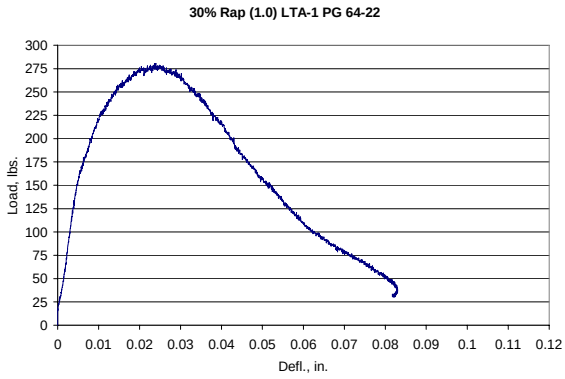


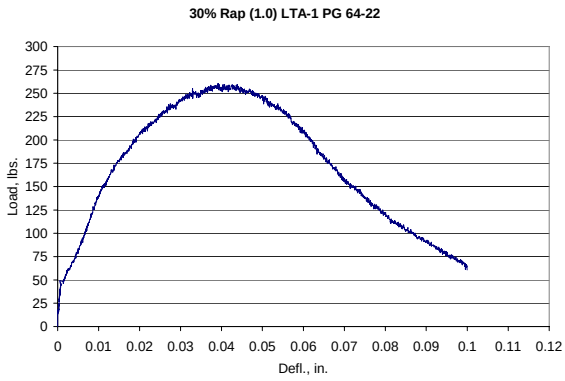




term age



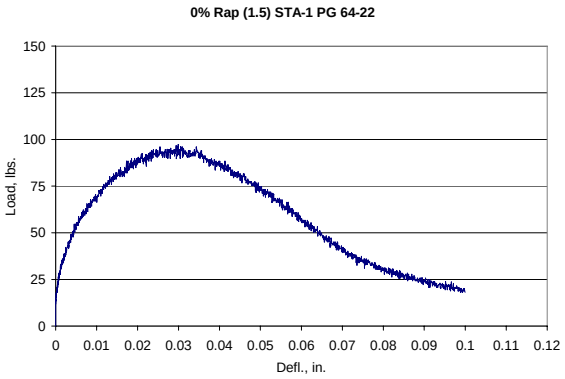


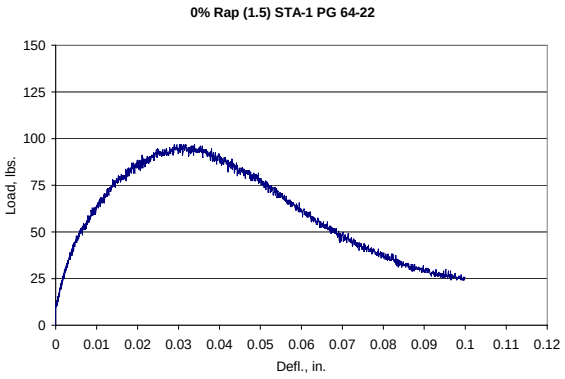


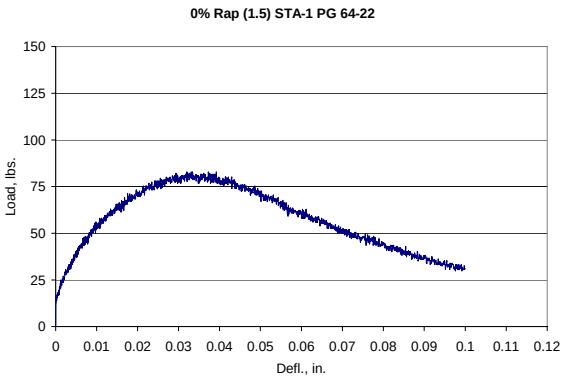
	1.5" Notched Samples											
									Origin	Origin	Origin	Origin
	ID	Notch		Width		Peak		Defl.		Area	Area	Strain Energy	Strain Energy
		in.	mm	in.	m	lbs.	newtons	in.	mm	lb-in.	N-m	lbs/in.^2	J/m
0%		1.5	38.1	1.040	0.026	113.90	506.65	0.017	0.429	1.4789	0.167093203	1.422	6.325
		1.5	38.1	1.060	0.027	126.31	561.85	0.029	0.729	2.72	0.307318623	2.566	11.414
		1.5	38.1	1.060	0.027	127.69	567.99	0.030	0.772	2.8275	0.319464488	2.667	11.865
	Average	**1.5**	**38.1**	**1.0533333**	**0.0267547**	**122.63333**	**545.500046**	**0.0253333**	**0.6434667**	**2.342133333**	**0.264625438**	**2.218503266**	**9.868390596**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**7.59**	**33.78**	**0.01**	**0.19**	**0.75**	**0.08**	**0.69**	**3.08**
	COV	**0.0**	**0.0**	**1.1**	**1.1**	**6.2**	**6.2**	**29.0**	**29.0**	**32.0**	**32.0**	**31.2**	**31.2**
		1.5	38.1	1.030	0.026	97.36	433.08	0.030	0.759	2.2125	0.249978843	2.148	9.555
		1.5	38.1	1.030	0.026	96.68	430.05	0.030	0.770	2.1146	0.238917633	2.053	9.132
		1.5	38.1	1.060	0.027	82.20	365.64	0.036	0.919	2.2541	0.254679011	2.127	9.459
	Average	**1.5**	**38.1**	**1.04**	**0.026416**	**92.08**	**409.5920976**	**0.0321333**	**0.8161867**	**2.193733333**	**0.247858496**	**2.109192465**	**9.382152107**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**8.56**	**38.09**	**0.00**	**0.09**	**0.07**	**0.01**	**0.05**	**0.22**
	COV	**0.0**	**0.0**	**1.7**	**1.7**	**9.3**	**9.3**	**11.0**	**11.0**	**3.3**	**3.3**	**2.4**	**2.4**
10%		1.5	38.1	1.050	0.027	135.27	601.71	0.047	1.186	5.0454	0.570053449	4.805	21.374
		1.5	38.1	1.050	0.027	162.83	724.30	0.032	0.813	3.6995	0.417987223	3.523	15.673
		1.5	38.1	1.070	0.027	164.90	733.51	0.026	0.663	3.2631	0.368680662	3.050	13.565
	Average	**1.5**	**38.1**	**1.0566667**	**0.0268393**	**154.33333**	**686.50862**	**0.0349333**	**0.8873067**	**4.002666667**	**0.452240445**	**3.792700786**	**16.87076749**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**16.54**	**73.58**	**0.01**	**0.27**	**0.93**	**0.10**	**0.91**	**4.04**
	COV	**0.0**	**0.0**	**1.1**	**1.1**	**10.7**	**10.7**	**30.4**	**30.4**	**23.2**	**23.2**	**23.9**	**23.9**
		1.5	38.1	1.030	0.026	98.05	436.15	0.029	0.732	2.0987	0.237121175	2.038	9.064
		1.5	38.1	1.050	0.027	115.28	512.79	0.038	0.973	3.2092	0.362590782	3.056	13.595
		1.5	38.1	1.060	0.027	107.01	476.00	0.037	0.930	3.0387	0.343326875	2.867	12.752
	Average	**1.5**	**38.1**	**1.0466667**	**0.0265853**	**106.78**	**474.9809316**	**0.0345667**	**0.8779933**	**2.7822**	**0.314346277**	**2.653550627**	**11.80357697**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**8.62**	**38.33**	**0.01**	**0.13**	**0.60**	**0.07**	**0.54**	**2.41**
	COV	**0.0**	**0.0**	**1.5**	**1.5**	**8.1**	**8.1**	**14.7**	**14.7**	**21.5**	**21.5**	**20.4**	**20.4**
20%		1.5	38.1	1.060	0.027	140.09	623.15	0.014	0.358	1.5608	0.176346657	1.472	6.550
		1.5	38.1	1.070	0.027	135.27	601.71	0.026	0.658	2.3352	0.263842077	2.182	9.708
		1.5	38.1	1.080	0.027	157.32	699.79	0.015	0.368	1.4904	0.168392528	1.380	6.139
	Average	**1.5**	**38.1**	**1.07**	**0.027178**	**144.22667**	**641.5519432**	**0.0181667**	**0.4614333**	**1.795466667**	**0.202860421**	**1.678294246**	**7.465422029**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**11.59**	**51.57**	**0.01**	**0.17**	**0.47**	**0.05**	**0.44**	**1.95**
	COV	**0.0**	**0.0**	**0.9**	**0.9**	**8.0**	**8.0**	**36.9**	**36.9**	**26.1**	**26.1**	**26.2**	**26.2**
		1.5	38.1	1.070	0.027	99.43	442.29	0.029	0.734	2.085	0.235573283	1.949	8.668
		1.5	38.1	1.050	0.027	115.28	512.79	0.028	0.701	2.3263	0.262836512	2.216	9.855
		1.5	38.1	1.090	0.028	122.86	546.51	0.034	0.859	2.9737	0.335982864	2.728	12.135
	Average	**1.5**	**38.1**	**1.07**	**0.027178**	**112.52333**	**500.5285418**	**0.0301**	**0.76454**	**2.461666667**	**0.278130886**	**2.297429026**	**10.21946974**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**11.96**	**53.18**	**0.00**	**0.08**	**0.46**	**0.05**	**0.40**	**1.76**
	COV	**0.0**	**0.0**	**1.9**	**1.9**	**10.6**	**10.6**	**10.9**	**10.9**	**18.7**	**18.7**	**17.2**	**17.2**
30%		1.5	38.1	1.070	0.027	144.22	641.52	0.025	0.640	2.3908	0.270124031	2.234	9.939
		1.5	38.1	1.080	0.027	164.21	730.44	0.019	0.472	2.2221	0.251063497	2.058	9.152
		1.5	38.1	1.060	0.027	182.12	810.11	0.023	0.589	3.1773	0.358986567	2.997	13.333
	Average	**1.5**	**38.1**	**1.07**	**0.027178**	**163.51667**	**727.358107**	**0.0223333**	**0.5672667**	**2.596733333**	**0.293391365**	**2.429781785**	**10.80820393**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**18.96**	**84.34**	**0.00**	**0.09**	**0.51**	**0.06**	**0.50**	**2.22**
	COV	**0.0**	**0.0**	**0.9**	**0.9**	**11.6**	**11.6**	**15.2**	**15.2**	**19.6**	**19.6**	**20.6**	**20.6**
		1.5	38.1	1.030	0.026	99.43	442.29	0.028	0.721	2.0071	0.226771768	1.949	8.668
		1.5	38.1	1.050	0.027	109.08	485.21	0.042	1.057	2.8101	0.317498553	2.676	11.905
		1.5	38.1	1.060	0.027	120.79	537.30	0.037	0.932	3.0596	0.345688257	2.886	12.839
	Average	**1.5**	**38.1**	**1.0466667**	**0.0265853**	**109.76667**	**488.266282**	**0.0355667**	**0.9033933**	**2.6256**	**0.296652859**	**2.503780528**	**11.13736662**
	STD Dev.	**0.00**	**0.00**	**0.02**	**0.00**	**10.70**	**47.58**	**0.01**	**0.17**	**0.55**	**0.06**	**0.49**	**2.19**
	COV	**0.0**	**0.0**	**1.5**	**1.5**	**9.7**	**9.7**	**18.8**	**18.8**	**20.9**	**20.9**	**19.7**	**19.7**

Gravel 64-22 1.5” 0%

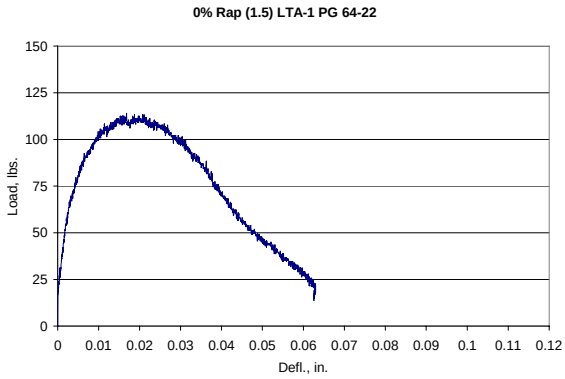
Short term age

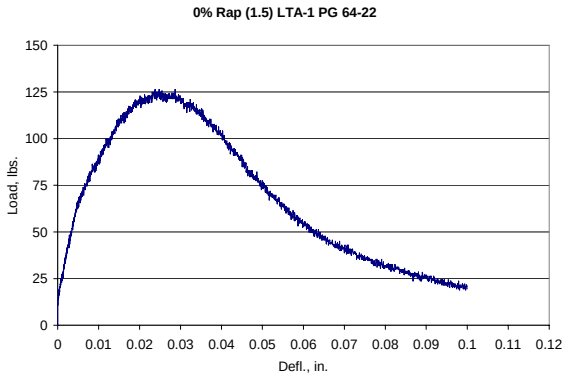


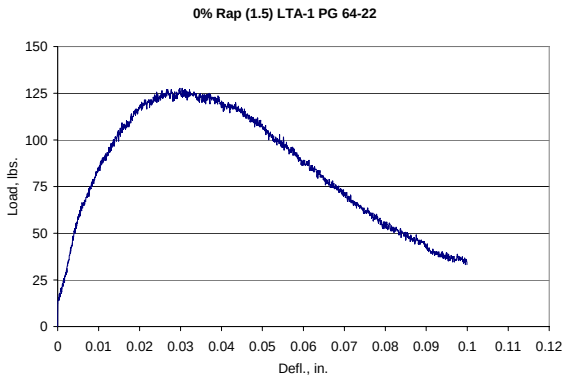




Long term age

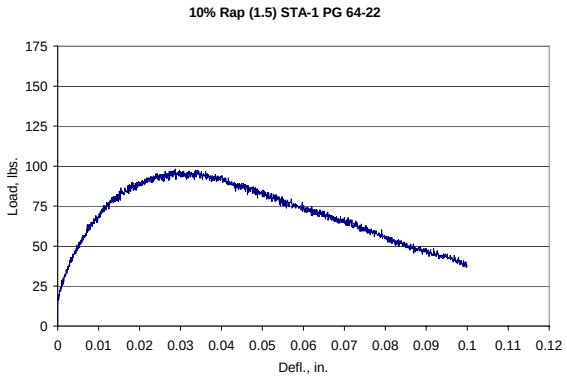


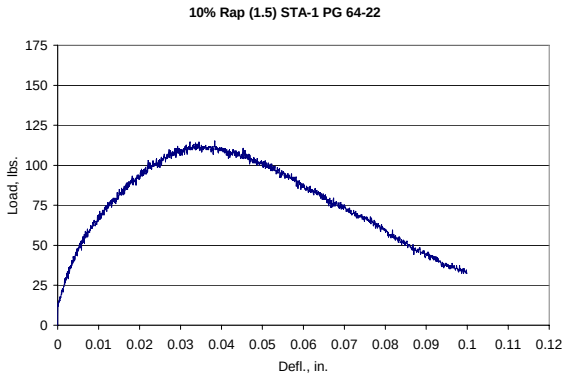


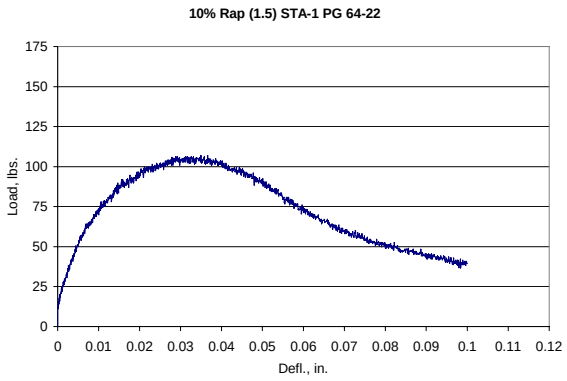


Gravel 64-22 1.5” 10%

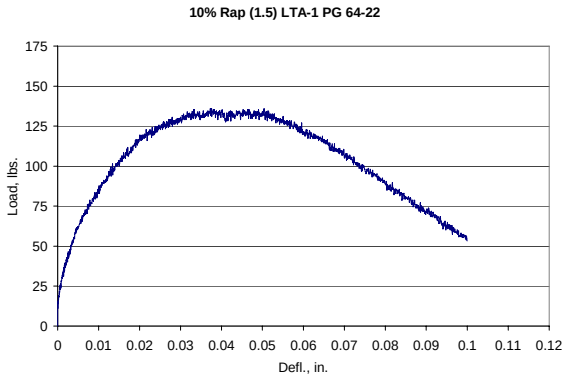
Short term age

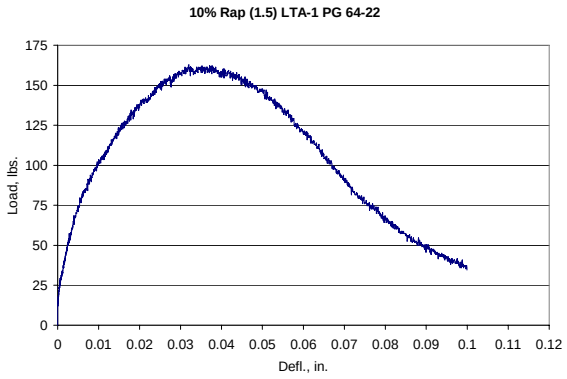


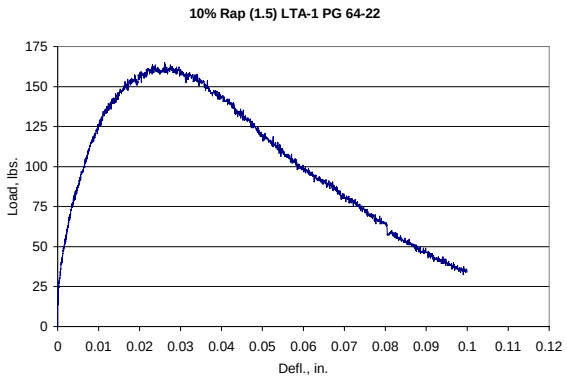




Long term age

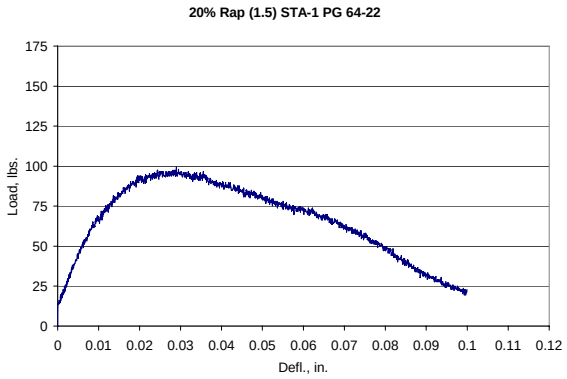


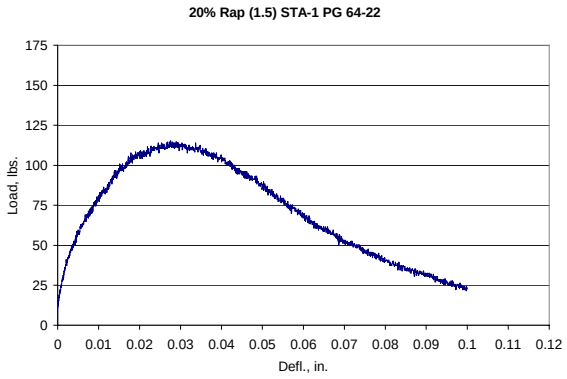


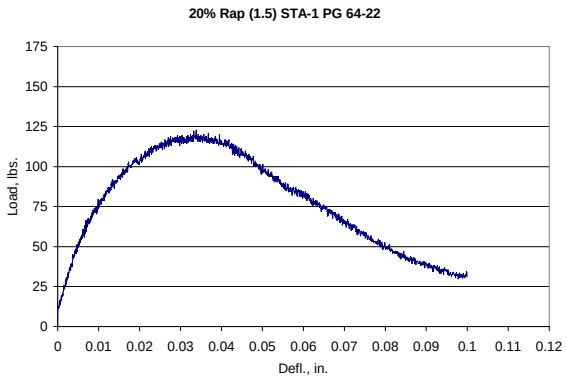


Gravel 64-221.5” 20%

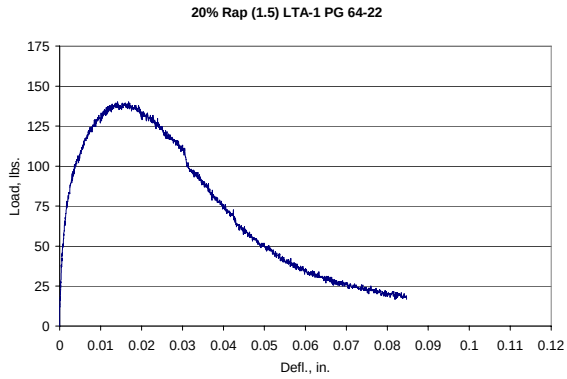
Short term age

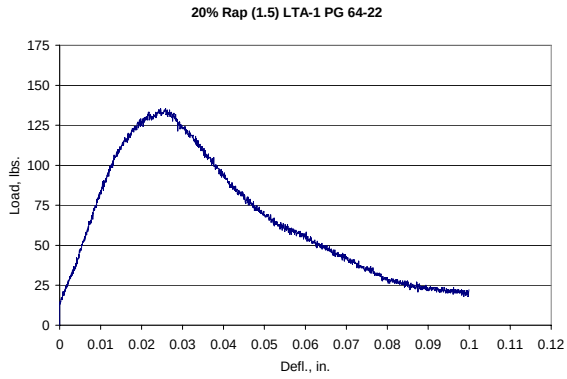


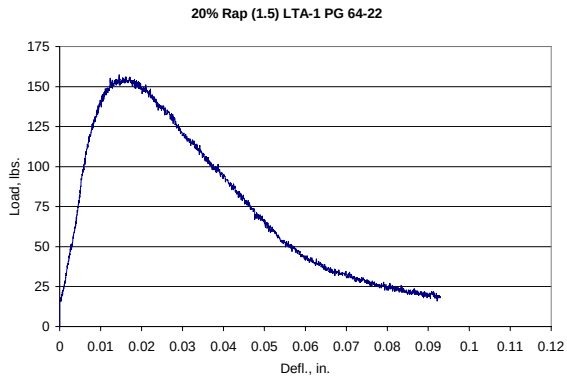




Long term age

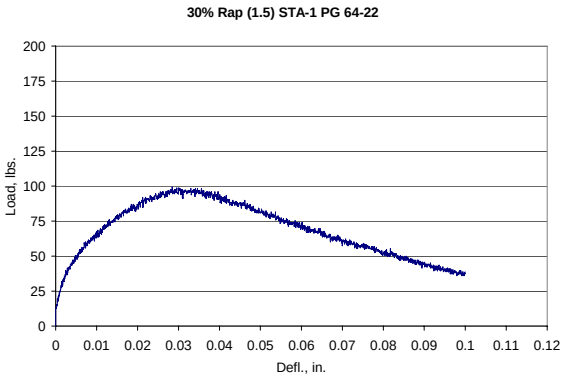


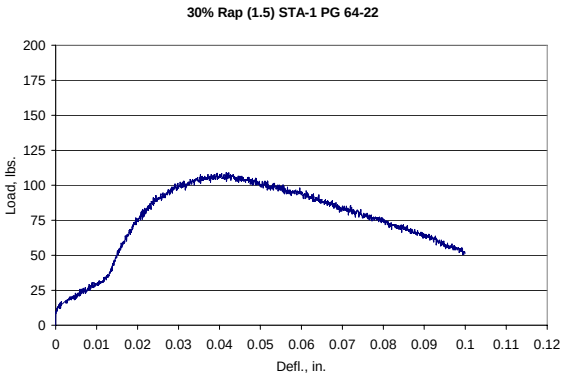


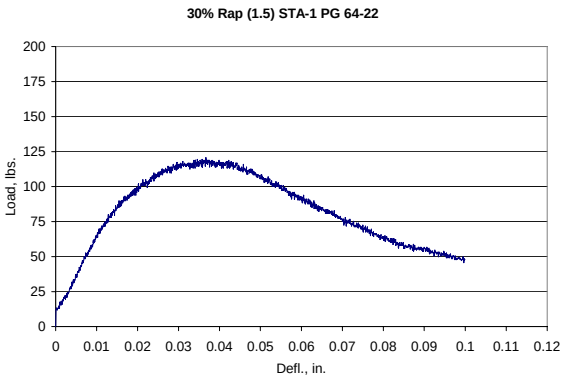


Gravel 64-22 1.5” 30%

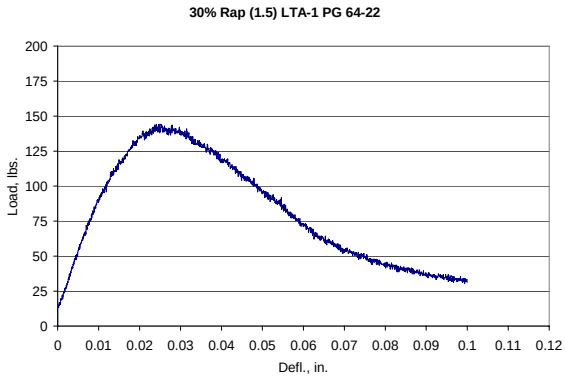
Short term age

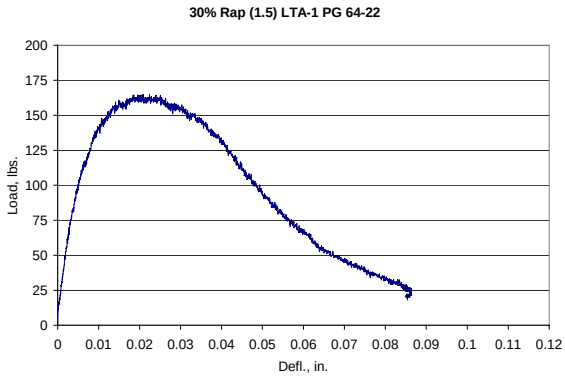


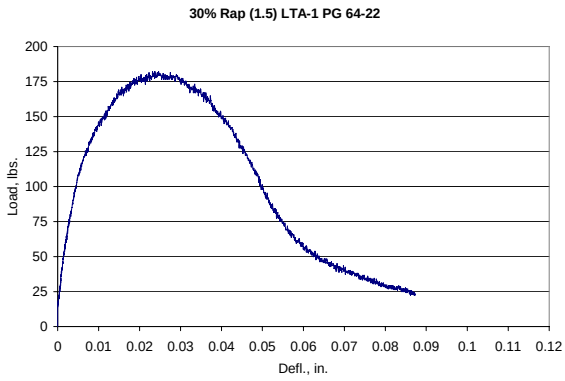




Long term age





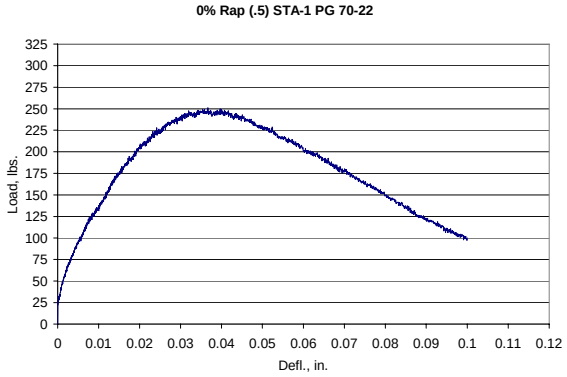


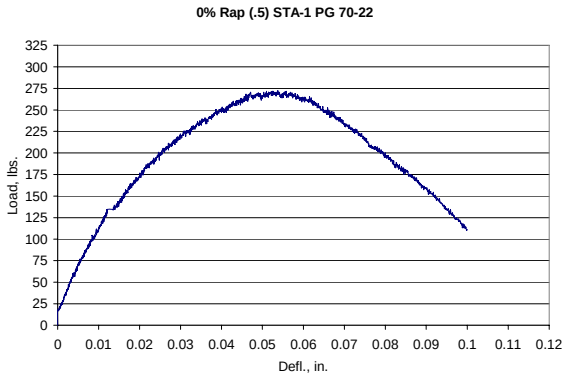
Gravel PG 70-22

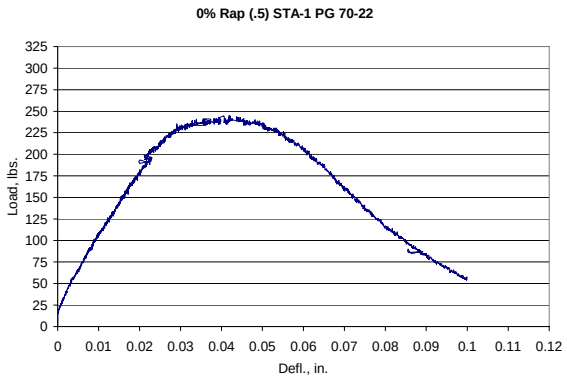
	.5" Notched Samples								Peak Load			
									Origin	Origin	Origin	Origin
	ID	Notch		Width		Peak		Defl.		Area	Strain Energy	Strain Energy
		in.	mm	in.	m	lbs.	newtons	in.	mm	lb-in.	N-m	lbs/in.^2	J/m
0%		0.5	12.7	1.010	0.026	303.41	1349.63	0.046	1.173	9.9922	1.128966599	9.893	44.007
		0.5	12.7	1.020	0.026	284.11	1263.78	0.037	0.930	7.4757	0.84464038	7.329	32.602
		0.5	12.7	1.030	0.026	260.68	1159.56	0.041	1.041	6.4147	0.72476352	6.228	27.703
	Average	**0.5**	**12.7**	**1.02**	**0.025908**	**282.73333**	**1257.660068**	**0.0412667**	**1.0481733**	**7.960866667**	**0.899456833**	**7.816749684**	**34.77062228**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**21.40**	**95.18**	**0.00**	**0.12**	**1.84**	**0.21**	**1.88**	**8.37**
	COV	**0.0**	**0.0**	**1.0**	**1.0**	**7.6**	**7.6**	**11.6**	**11.6**	**23.1**	**23.1**	**24.1**	**24.1**
		0.5	12.7	1.030	0.026	281.04	1250.13	0.037	0.932	6.5048	0.734943449	6.315	28.092
		0.5	12.7	1.030	0.026	272.40	1211.70	0.016	0.401	10.0441	1.134830509	9.752	43.377
		0.5	12.7	1.020	0.026	244.14	1085.99	0.041	1.031	6.6621	0.752715956	6.531	29.053
	Average	**0.5**	**12.7**	**1.0266667**	**0.0260773**	**265.86**	**1182.603769**	**0.0310333**	**0.7882467**	**7.737**	**0.874163305**	**7.532787931**	**33.50749793**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**19.30**	**85.85**	**0.01**	**0.34**	**2.00**	**0.23**	**1.92**	**8.56**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**7.3**	**7.3**	**43.0**	**43.0**	**25.8**	**25.8**	**25.5**	**25.5**
10%		0.5	12.7	1.030	0.026	251.04	1116.68	0.041	1.039	6.1123	0.69059692	5.934	26.397
		0.5	12.7	1.030	0.026	287.56	1279.13	0.037	0.930	7.2087	0.814473441	6.999	31.132
		0.5	12.7	1.020	0.026	295.83	1315.92	0.035	0.894	6.6919	0.756082903	6.561	29.183
	Average	**0.5**	**12.7**	**1.0266667**	**0.0260773**	**278.14333**	**1237.242738**	**0.0375667**	**0.9541933**	**6.670966667**	**0.753717755**	**6.497898661**	**28.90408278**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**23.83**	**106.02**	**0.00**	**0.08**	**0.55**	**0.06**	**0.54**	**2.38**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**8.6**	**8.6**	**7.9**	**7.9**	**8.2**	**8.2**	**8.2**	**8.2**
		0.5	12.7	1.010	0.026	257.24	1144.26	0.053	1.334	9.1542	1.034285346	9.064	40.317
		0.5	12.7	1.010	0.026	284.11	1263.78	0.049	1.247	9.5914	1.083682296	9.496	42.242
		0.5	12.7	1.010	0.026	263.44	1171.84	0.042	1.067	7.9832	0.90198016	7.904	35.159
	Average	**0.5**	**12.7**	**1.01**	**0.025654**	**268.26333**	**1193.294325**	**0.0478667**	**1.2158133**	**8.9096**	**1.006649267**	**8.821386139**	**39.23946625**
	STD Dev.	**0.00**	**0.00**	**0.00**	**0.00**	**14.07**	**62.58**	**0.01**	**0.14**	**0.83**	**0.09**	**0.82**	**3.66**
	COV	**0.0**	**0.0**	**0.0**	**0.0**	**5.2**	**5.2**	**11.2**	**11.2**	**9.3**	**9.3**	**9.3**	**9.3**
20%		0.5	12.7	1.020	0.026	260.60	1159.21	0.028	0.704	6.7421	0.761754739	6.610	29.402
		0.5	12.7	1.030	0.026	390.92	1738.90	0.028	0.701	7.8946	0.891969707	7.665	34.094
		0.5	12.7	1.020	0.026	392.30	1745.04	0.024	0.610	6.5286	0.737632487	6.401	28.471
	Average	**0.5**	**12.7**	**1.0233333**	**0.0259927**	**347.94**	**1547.713667**	**0.0264333**	**0.6714067**	**7.0551**	**0.797118978**	**6.891716797**	**30.65587249**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**75.64**	**336.47**	**0.00**	**0.05**	**0.73**	**0.08**	**0.68**	**3.01**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**21.7**	**21.7**	**8.0**	**8.0**	**10.4**	**10.4**	**9.8**	**9.8**
		0.5	12.7	1.020	0.026	304.09	1352.66	0.039	0.980	8.433	0.952800717	8.268	36.776
		0.5	12.7	1.020	0.026	417.80	1858.47	0.039	0.988	11.3705	1.284693532	11.148	49.587
		0.5	12.7	1.030	0.026	388.06	1726.18	0.031	0.782	7.9612	0.899494494	7.729	34.382
	Average	**0.5**	**12.7**	**1.0233333**	**0.0259927**	**369.98333**	**1645.767263**	**0.0361**	**0.91694**	**9.2549**	**1.045662914**	**9.048172156**	**40.24826035**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**58.97**	**262.32**	**0.00**	**0.12**	**1.85**	**0.21**	**1.84**	**8.18**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**15.9**	**15.9**	**12.7**	**12.7**	**20.0**	**20.0**	**20.3**	**20.3**
30%		0.5	12.7	1.020	0.026	355.09	1579.52	0.015	0.378	3.5847	0.40501657	3.514	15.633
		0.5	12.7	1.030	0.026	429.51	1910.55	0.025	0.645	8.1974	0.926181501	7.959	35.402
		0.5	12.7	1.020	0.026	429.51	1910.55	0.027	0.678	8.3919	0.948157042	8.227	36.597
	Average	**0.5**	**12.7**	**1.0233333**	**0.0259927**	**404.70333**	**1800.209461**	**0.0223333**	**0.5672667**	**6.724666667**	**0.759785038**	**6.566801828**	**29.21057923**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**42.97**	**191.12**	**0.01**	**0.16**	**2.72**	**0.31**	**2.65**	**11.77**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**10.6**	**10.6**	**29.0**	**29.0**	**40.5**	**40.5**	**40.3**	**40.3**
		0.5	12.7	1.020	0.026	328.22	1459.99	0.031	0.798	6.5576	0.740909046	6.429	28.598
		0.5	12.7	1.030	0.026	364.05	1619.37	0.043	1.082	10.5605	1.193175854	10.253	45.607
		0.5	12.7	1.030	0.026	426.76	1898.32	0.036	0.912	10.5841	1.195842295	10.276	45.709
	Average	**0.5**	**12.7**	**1.0266667**	**0.0260773**	**373.01**	**1659.23**	**0.04**	**0.93**	**9.23**	**1.04**	**8.99**	**39.97**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**49.88**	**221.87**	**0.01**	**0.14**	**2.32**	**0.26**	**2.21**	**9.85**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**13.4**	**13.4**	**15.4**	**15.4**	**25.1**	**25.1**	**24.6**	**24.6**

Gravel 70-22 0.5” 0%

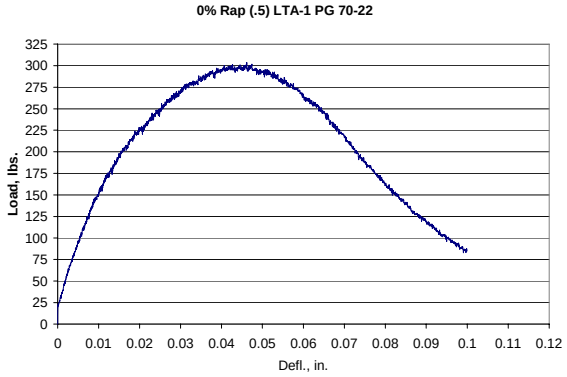
Short term age

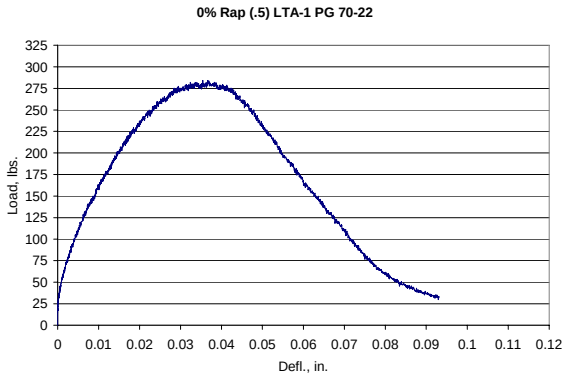


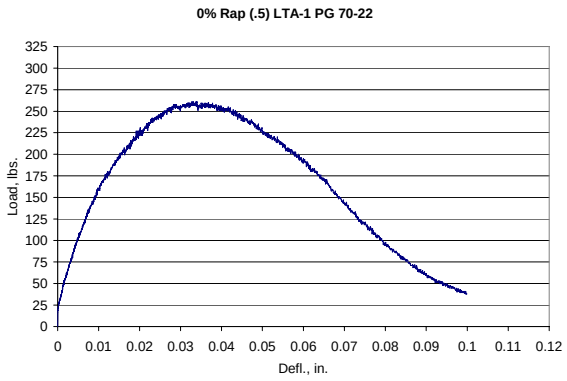




Long term age

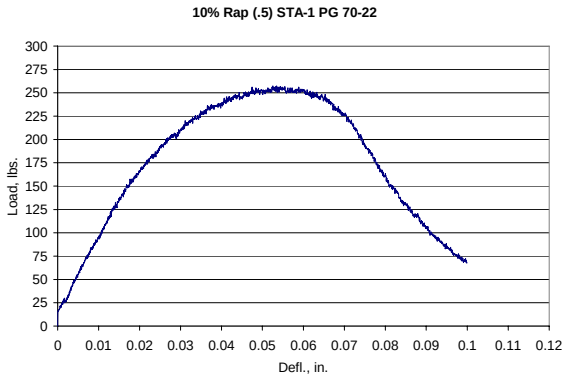


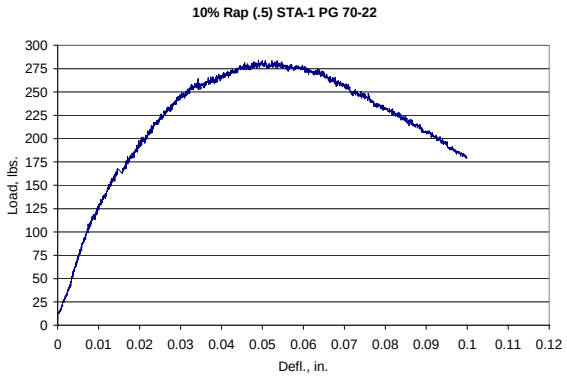


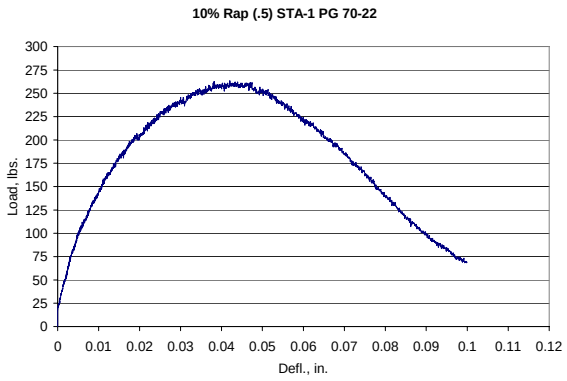


Gravel 70-22 0.5” 10%

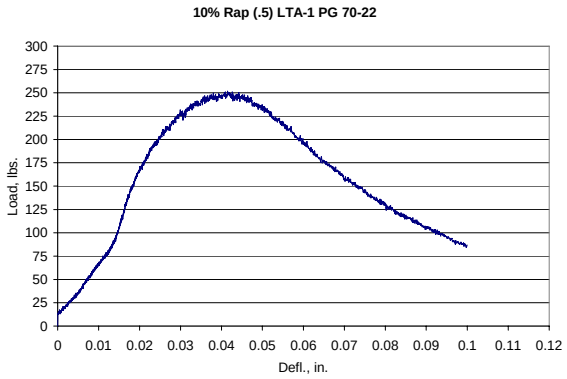
Short term age

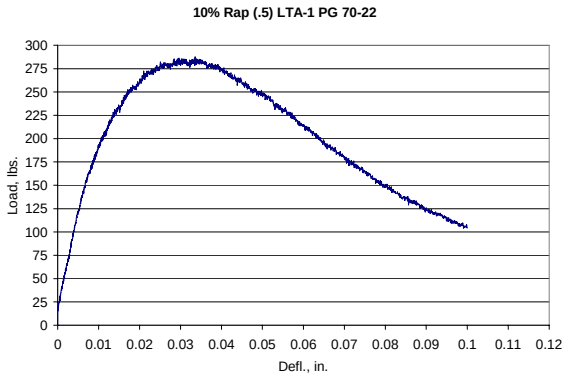


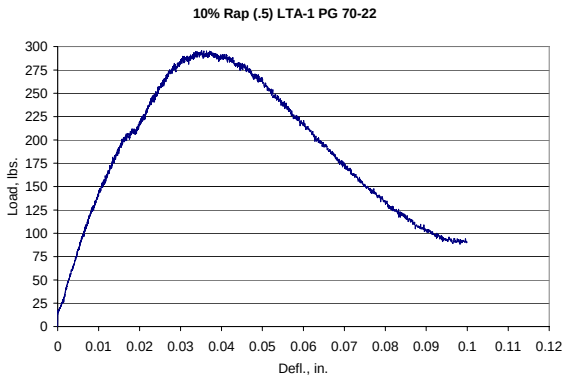




Long term age

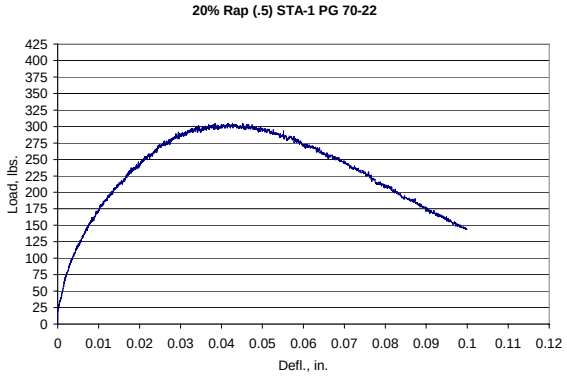


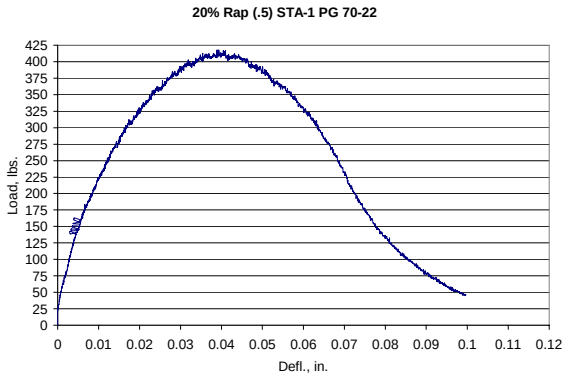


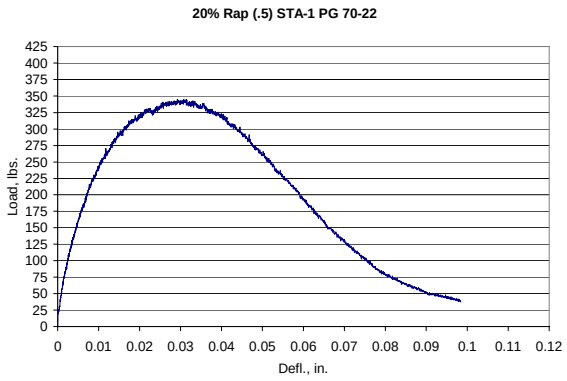


Gravel 70-22 0.5” 20%

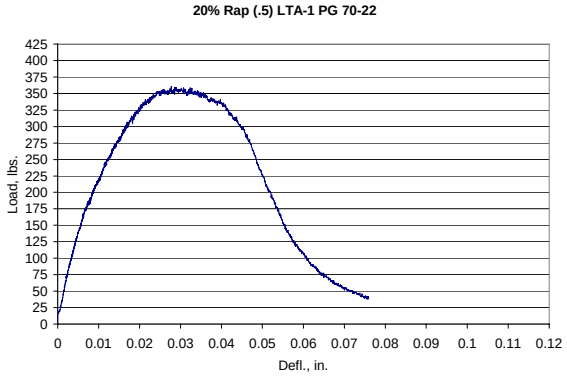
Short term age

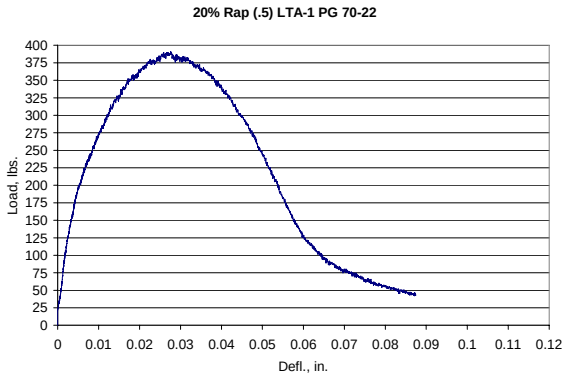


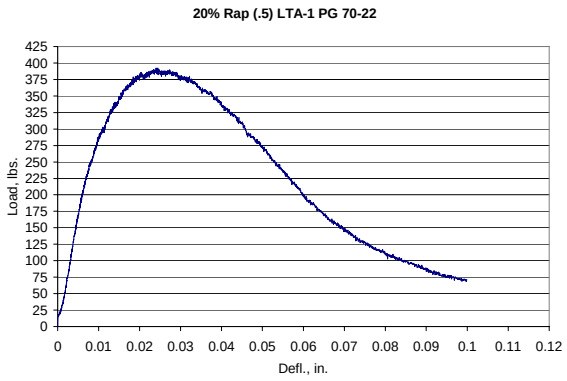




Long term age

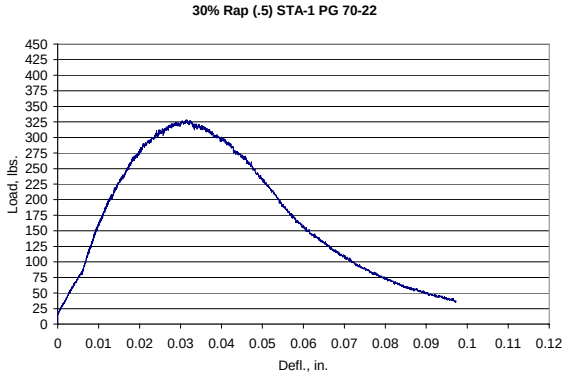


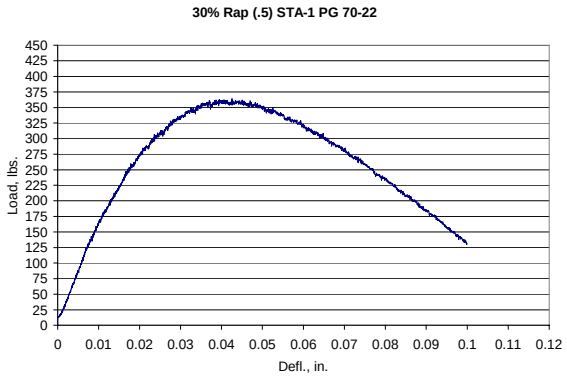


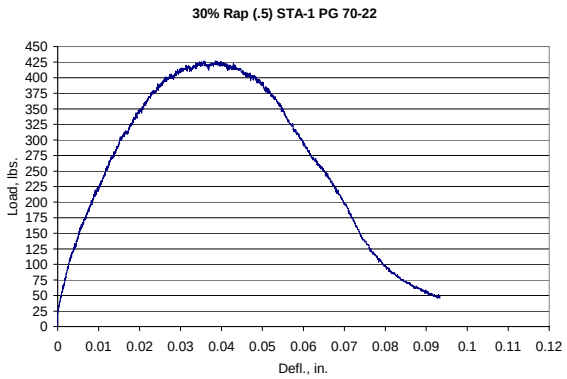


Gravel 70-22 0.5” 30%

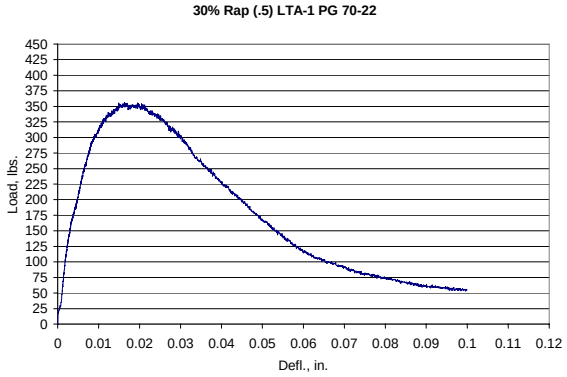
Short term age

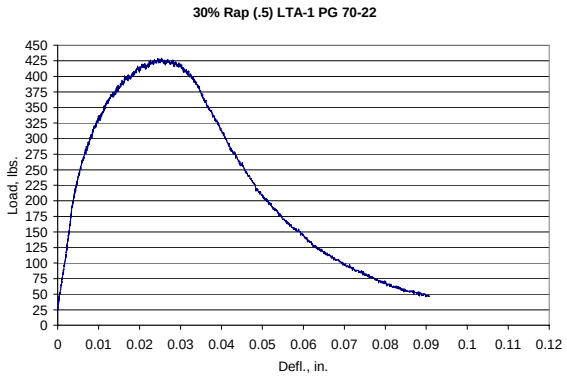


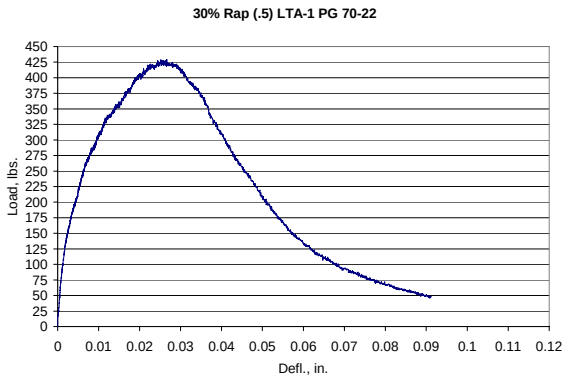




Long term



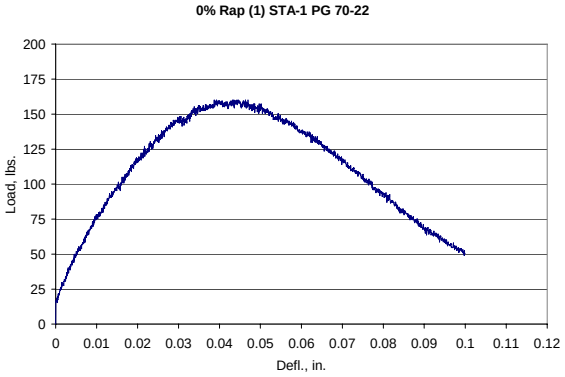


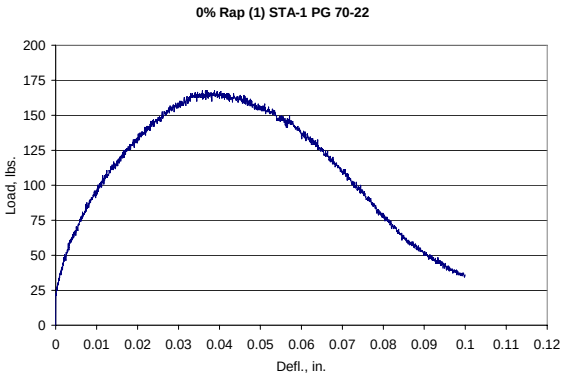


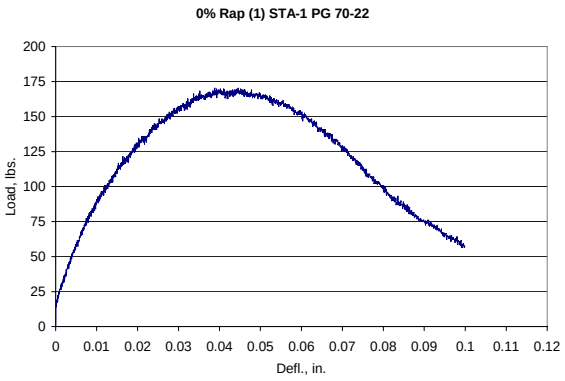
	1" Notched Samples									Peak Load			
										Origin	Origin	Origin	Origin
	ID	Notch		Width		Peak		Defl.		Area	Area	Strain Energy	Strain Energy
		in.	mm	in.	m	lbs.	newtons	in.	mm	lb-in.	N-m	lbs/in.^2	J/m
0%		1	25.4	1.020	0.026	171.10	761.09	0.044	1.123	4.9639	0.560845189	4.867	21.648
		1	25.4	1.020	0.026	183.50	816.25	0.037	0.930	4.35073	0.491566307	4.265	18.974
		1	25.4	1.020	0.026	193.15	859.17	0.039	0.986	4.5306	0.511888881	4.442	19.758
	Average	**1**	**25.4**	**1.02**	**0.025908**	**182.58333**	**812.170835**	**0.0398667**	**1.0126133**	**4.615076667**	**0.521433459**	**4.524584967**	**20.12634934**
	STD Dev.	**0.00**	**0.00**	**0.00**	**0.00**	**11.05**	**49.17**	**0.00**	**0.10**	**0.32**	**0.04**	**0.31**	**1.37**
	COV	**0.0**	**0.0**	**0.0**	**0.0**	**6.1**	**6.1**	**9.8**	**9.8**	**6.8**	**6.8**	**6.8**	**6.8**
		1	25.4	1.030	0.026	160.07	712.03	0.029	0.726	3.6278	0.409886214	3.522	15.667
		1	25.4	1.010	0.026	167.66	745.79	0.044	1.125	5.9093	0.667661008	5.851	26.026
		1	25.4	1.020	0.026	170.41	758.02	0.024	0.602	3.2108	0.362771557	3.148	14.002
	Average	**1**	**25.4**	**1.02**	**0.025908**	**166.04667**	**738.6121036**	**0.0322**	**0.81788**	**4.2493**	**0.48010626**	**4.17359038**	**18.5650482**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**5.36**	**23.82**	**0.01**	**0.27**	**1.45**	**0.16**	**1.46**	**6.51**
	COV	**0.0**	**0.0**	**1.0**	**1.0**	**3.2**	**3.2**	**33.4**	**33.4**	**34.2**	**34.2**	**35.1**	**35.1**
10%		1	25.4	1.020	0.026	165.59	736.58	0.033	0.831	3.8153	0.431070862	3.740	16.639
		1	25.4	1.020	0.026	180.75	804.02	0.036	0.902	4.5853	0.518069148	4.495	19.996
		1	25.4	1.020	0.026	165.59	736.58	0.037	0.935	4.3059	0.486501199	4.221	18.778
	Average	**1**	**25.4**	**1.02**	**0.025908**	**170.64333**	**759.0590882**	**0.035**	**0.889**	**4.2355**	**0.47854707**	**4.15245098**	**18.4710155**
	STD Dev.	**0.00**	**0.00**	**0.00**	**0.00**	**8.75**	**38.93**	**0.00**	**0.05**	**0.39**	**0.04**	**0.38**	**1.70**
	COV	**0.0**	**0.0**	**0.0**	**0.0**	**5.1**	**5.1**	**6.0**	**6.0**	**9.2**	**9.2**	**9.2**	**9.2**
		1	25.4	1.020	0.026	138.02	613.94	0.050	1.257	5.0582	0.571499655	4.959	22.059
		1	25.4	1.020	0.026	171.09	761.05	0.052	1.318	6.0198	0.680145827	5.902	26.252
		1	25.4	1.010	0.026	186.26	828.53	0.056	1.420	7.2625	0.820552023	7.191	31.985
	Average	**1**	**25.4**	**1.0166667**	**0.0258233**	**165.12333**	**734.5049138**	**0.0524333**	**1.3318067**	**6.1135**	**0.690732501**	**6.017126124**	**26.76550077**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**24.67**	**109.73**	**0.00**	**0.08**	**1.11**	**0.12**	**1.12**	**4.98**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**14.9**	**14.9**	**6.2**	**6.2**	**18.1**	**18.1**	**18.6**	**18.6**
20%		1	25.4	1.020	0.026	197.29	877.59	0.028	0.721	4.2073	0.475360899	4.125	18.348
		1	25.4	1.010	0.026	200.04	889.82	0.019	0.488	2.8427	0.321181857	2.815	12.520
		1	25.4	1.030	0.026	219.34	975.67	0.028	0.704	4.0551	0.458164614	3.937	17.513
	Average	**1**	**25.4**	**1.02**	**0.025908**	**205.55667**	**914.3612758**	**0.0251**	**0.63754**	**3.7017**	**0.41823579**	**3.625449556**	**16.12679722**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**12.02**	**53.45**	**0.01**	**0.13**	**0.75**	**0.08**	**0.71**	**3.15**
	COV	**0.0**	**0.0**	**1.0**	**1.0**	**5.8**	**5.8**	**20.4**	**20.4**	**20.2**	**20.2**	**19.5**	**19.5**
		1	25.4	1.010	0.026	168.34	748.81	0.046	1.166	5.4368	0.614275695	5.383	23.945
		1	25.4	1.020	0.026	160.07	712.03	0.026	0.663	3.0051	0.339530586	2.946	13.105
		1	25.4	1.030	0.026	187.64	834.66	0.045	1.148	5.9786	0.675490854	5.804	25.820
	Average	**1**	**25.4**	**1.02**	**0.025908**	**172.01667**	**765.167977**	**0.0390667**	**0.9922933**	**4.806833333**	**0.543099045**	**4.711204262**	**20.95647302**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**14.15**	**62.93**	**0.01**	**0.29**	**1.58**	**0.18**	**1.54**	**6.86**
	COV	**0.0**	**0.0**	**1.0**	**1.0**	**8.2**	**8.2**	**28.8**	**28.8**	**32.9**	**32.9**	**32.8**	**32.8**
30%		1	25.4	1.020	0.026	255.86	1138.12	0.016	0.404	3.1079	0.351145423	3.047	13.554
		1	25.4	1.030	0.026	273.09	1214.76	0.017	0.419	3.6362	0.410835286	3.530	15.704
		1	25.4	1.030	0.026	257.24	1144.26	0.026	0.671	3.9509	0.446391599	3.836	17.063
	Average	**1**	**25.4**	**1.0266667**	**0.0260773**	**262.06333**	**1165.715361**	**0.0196**	**0.49784**	**3.565**	**0.402790769**	**3.471025763**	**15.43988622**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**9.57**	**42.59**	**0.01**	**0.15**	**0.43**	**0.05**	**0.40**	**1.77**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**3.7**	**3.7**	**30.1**	**30.1**	**11.9**	**11.9**	**11.5**	**11.5**
		1	25.4	1.010	0.026	186.36	828.97	0.027	0.673	3.5393	0.39988706	3.504	15.588
		1	25.4	1.020	0.026	240.69	1070.64	0.028	0.716	4.7631	0.538157844	4.670	20.772
		1	25.4	1.020	0.026	232.43	1033.90	0.023	0.582	4.1349	0.4671808	4.054	18.032
	Average	**1**	**25.4**	**1.0166667**	**0.0258233**	**219.82667**	**977.8373752**	**0.0258667**	**0.6570133**	**4.145766667**	**0.468408568**	**4.075928946**	**18.13062866**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**29.28**	**130.23**	**0.00**	**0.07**	**0.61**	**0.07**	**0.58**	**2.59**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**13.3**	**13.3**	**10.5**	**10.5**	**14.8**	**14.8**	**14.3**	**14.3**

Gravel 70-22 1” 0%

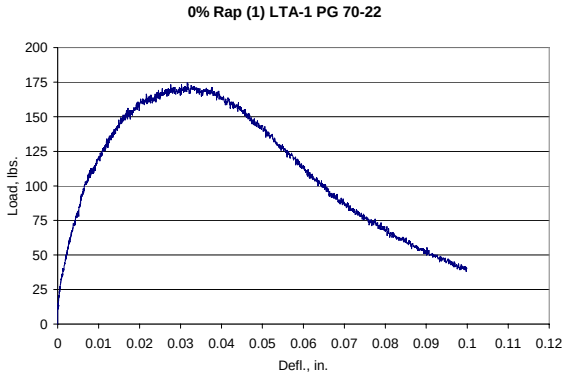
Short term age

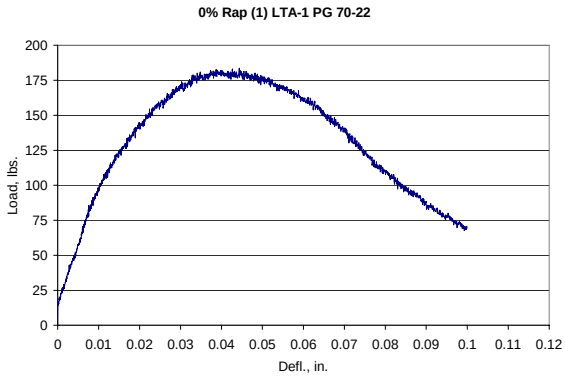


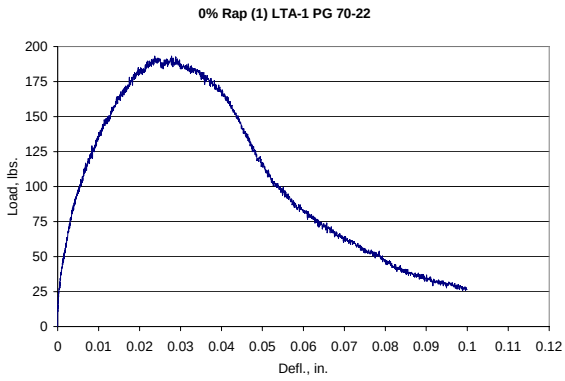




Long term age

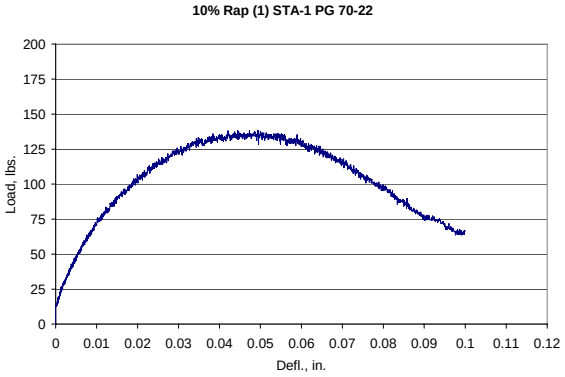


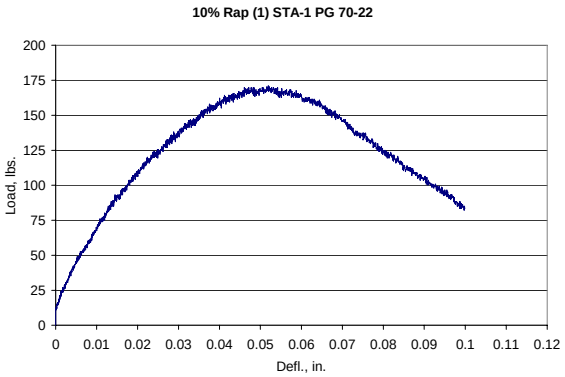


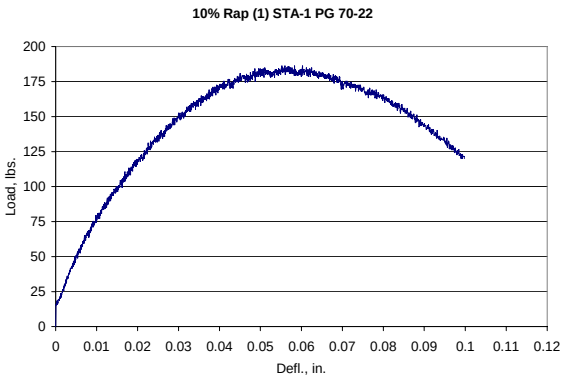


Gravel 70-22 1” 10%

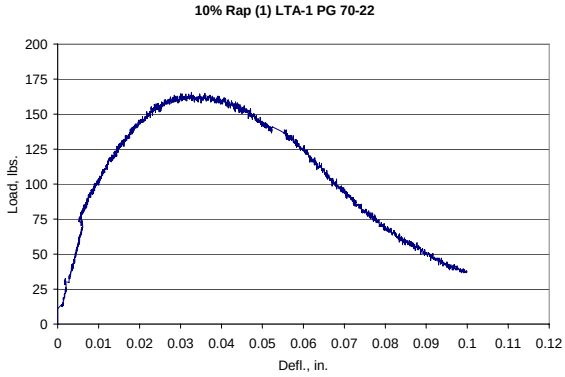
Short term age

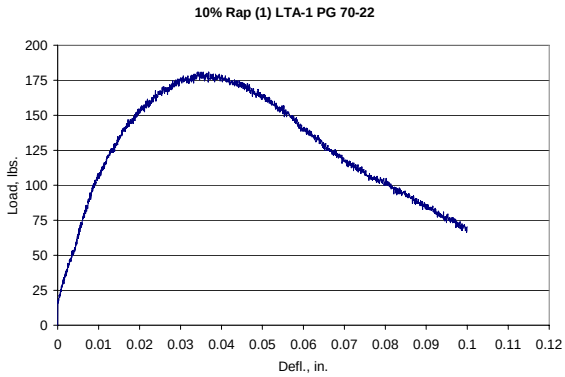


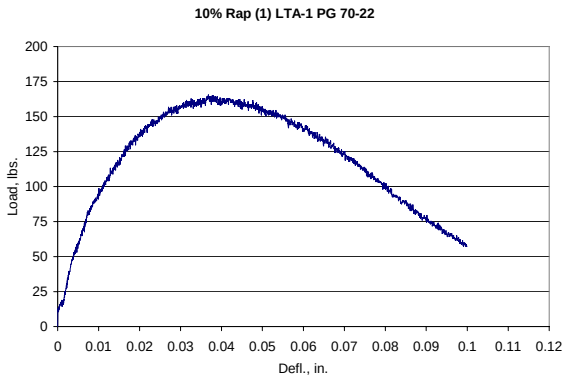




Long term age

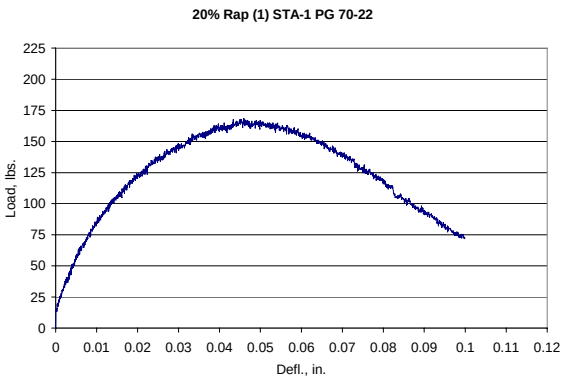


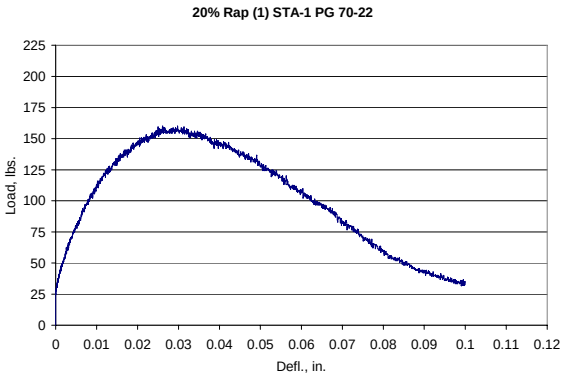


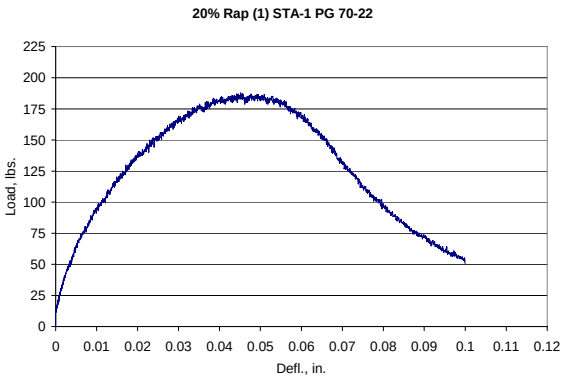


Gravel 70-22 1” 20%

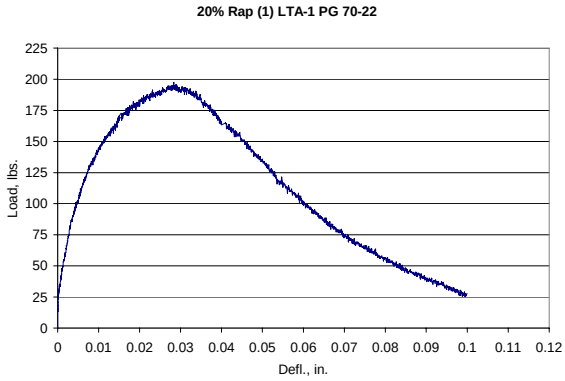
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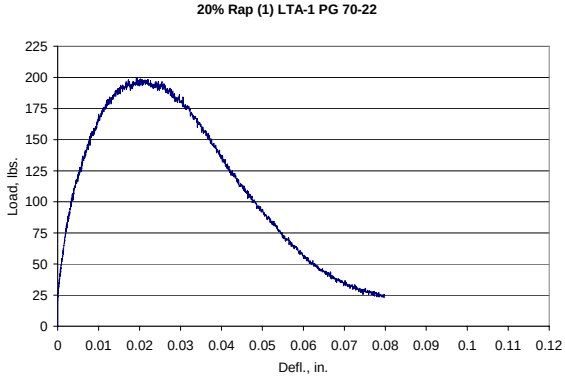


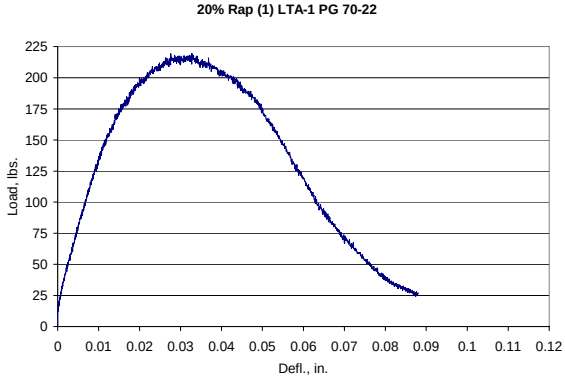




Long term age

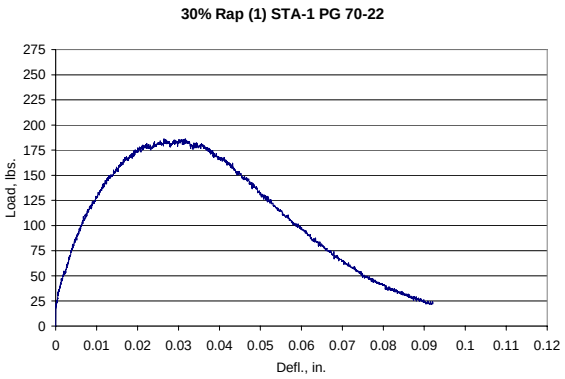


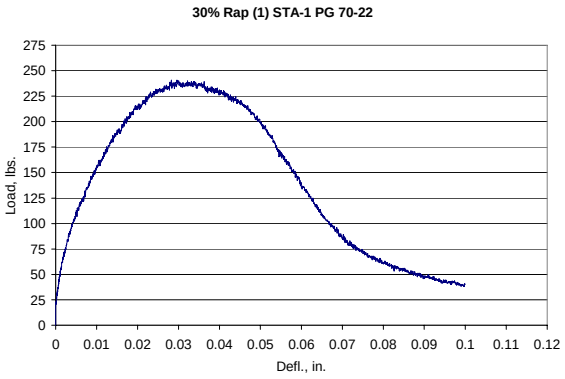


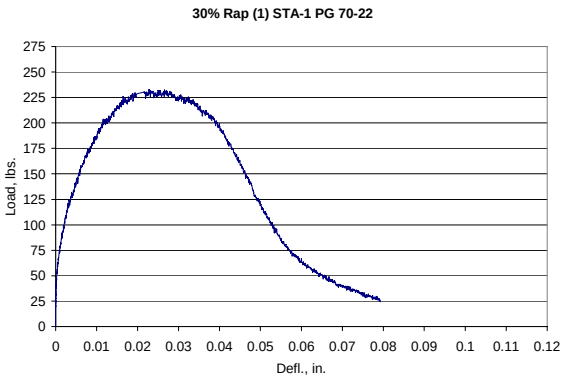


Gravel 70-22 1” 30%

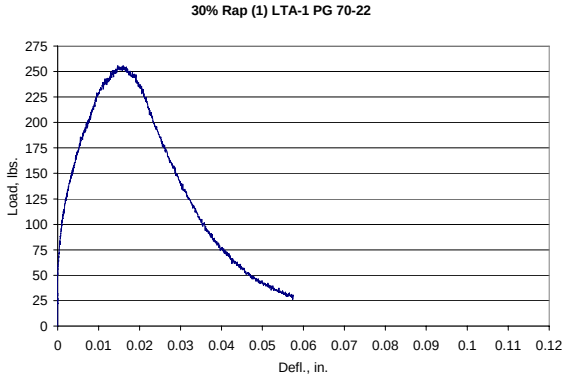
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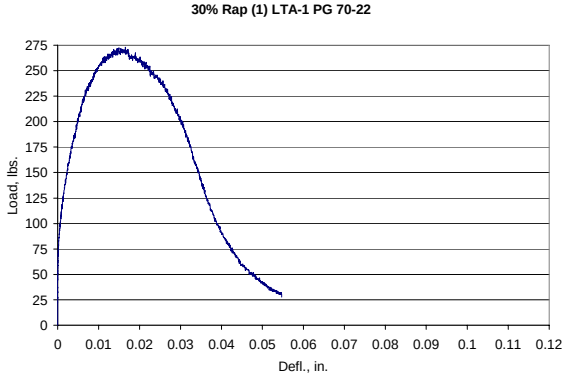


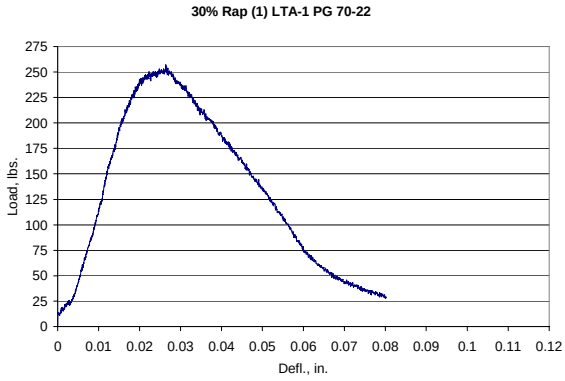




Long term age





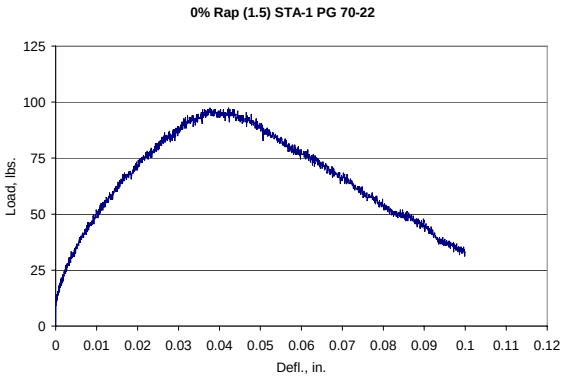


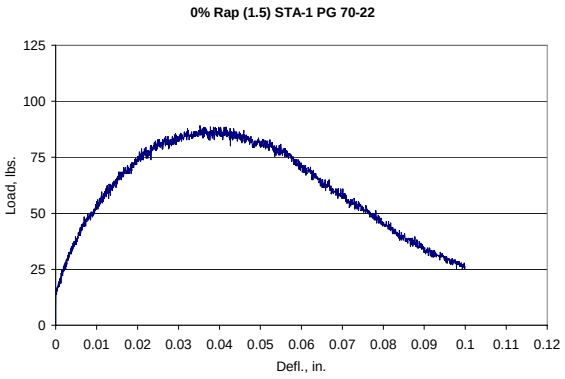
	1.5" Notched Samples								Peak Load			
									Origin	Origin	Origin	Origin
	ID	Notch		Width		Peak		Defl.		Area	Strain Energy	Strain Energy
		in.	mm	in.	m	lbs.	newtons	in.	mm	lb-in.	N-m	lbs/in.^2	J/m
0%		1.5	38.1	1.010	0.026	119.42	531.21	0.028	0.706	2.3338	0.263683898	2.311	10.278
		1.5	38.1	1.030	0.026	111.15	494.42	0.033	0.848	2.7317	0.308640545	2.652	11.797
		1.5	38.1	1.020	0.026	108.39	482.14	0.021	0.536	1.6598	0.187532151	1.627	7.238
	Average	**1.5**	**38.1**	**1.02**	**0.025908**	**112.98667**	**502.5895504**	**0.0274333**	**0.6968067**	**2.241766667**	**0.253285532**	**2.196694631**	**9.771380992**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**5.74**	**25.53**	**0.01**	**0.16**	**0.54**	**0.06**	**0.52**	**2.32**
	COV	**0.0**	**0.0**	**1.0**	**1.0**	**5.1**	**5.1**	**22.4**	**22.4**	**24.2**	**24.2**	**23.8**	**23.8**
		1.5	38.1	1.030	0.026	97.36	433.08	0.042	1.072	2.8919	0.326740708	2.808	12.489
		1.5	38.1	1.010	0.026	89.09	396.29	0.035	0.894	2.2507	0.254294862	2.228	9.912
		1.5	38.1	1.020	0.026	102.19	454.56	0.043	1.085	3.2213	0.363957898	3.158	14.048
	Average	**1.5**	**38.1**	**1.02**	**0.025908**	**96.213333**	**427.9780736**	**0.0400333**	**1.0168467**	**2.787966667**	**0.314997823**	**2.731407666**	**12.14990221**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**6.62**	**29.47**	**0.00**	**0.11**	**0.49**	**0.06**	**0.47**	**2.09**
	COV	**0.0**	**0.0**	**1.0**	**1.0**	**6.9**	**6.9**	**10.5**	**10.5**	**17.7**	**17.7**	**17.2**	**17.2**
10%		1.5	38.1	1.030	0.026	52.57	233.86	0.022	0.556	0.8179	0.092410258	0.794	3.532
		1.5	38.1	1.030	0.026	132.50	589.39	0.033	0.833	3.2822	0.370838671	3.187	14.175
		1.5	38.1	1.030	0.026	122.86	546.51	0.030	0.772	2.8049	0.316911032	2.723	12.113
	Average	**1.5**	**38.1**	**1.03**	**0.026162**	**127.68**	**567.9487296**	**0.0316**	**0.80264**	**3.04355**	**0.343874852**	**2.954902913**	**13.14405823**
	STD Dev.	**0.00**	**0.00**	**0.00**	**0.00**	**6.82**	**30.32**	**0.00**	**0.04**	**0.34**	**0.04**	**0.33**	**1.46**
	COV	**0.0**	**0.0**	**0.0**	**0.0**	**5.3**	**5.3**	**5.4**	**5.4**	**11.1**	**11.1**	**11.1**	**11.1**
		1.5	38.1	1.030	0.026	92.54	411.64	0.031	0.792	2.0448	0.231031295	1.985	8.831
		1.5	38.1	1.020	0.026	93.92	417.77	0.046	1.158	3.1442	0.35524677	3.083	13.712
		1.5	38.1	1.030	0.026	103.57	460.70	0.033	0.846	2.523	0.28506062	2.450	10.896
	Average	**1.5**	**38.1**	**1.0266667**	**0.0260773**	**96.676733**	**430.0393787**	**0.0367**	**0.93218**	**2.570666667**	**0.290446228**	**2.505768767**	**11.14621074**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**6.01**	**26.73**	**0.01**	**0.20**	**0.55**	**0.06**	**0.55**	**2.45**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**6.2**	**6.2**	**21.2**	**21.2**	**21.4**	**21.4**	**22.0**	**22.0**
20%		1.5	38.1	1.020	0.026	140.09	623.15	0.014	0.351	1.4484	0.163647167	1.420	6.316
		1.5	38.1	1.030	0.026	147.67	656.87	0.018	0.457	1.8484	0.208841082	1.795	7.983
		1.5	38.1	1.020	0.026	147.67	656.87	0.017	0.422	1.8861	0.213100609	1.849	8.225
	Average	**1.5**	**38.1**	**1.0233333**	**0.0259927**	**145.14333**	**645.6294782**	**0.0161333**	**0.4097867**	**1.727633333**	**0.195196286**	**1.687893585**	**7.508122001**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**4.38**	**19.47**	**0.00**	**0.05**	**0.24**	**0.03**	**0.23**	**1.04**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**3.0**	**3.0**	**13.3**	**13.3**	**14.0**	**14.0**	**13.8**	**13.8**
		1.5	38.1	1.020	0.026	107.01	476.00	0.026	0.653	2.0437	0.230907011	2.004	8.913
		1.5	38.1	1.030	0.026	111.84	497.49	0.040	1.021	2.9158	0.329441045	2.831	12.592
		1.5	38.1	1.020	0.026	120.79	537.30	0.031	0.775	2.7225	0.307601085	2.669	11.873
	Average	**1.5**	**38.1**	**1.0233333**	**0.0259927**	**113.21333**	**503.5978136**	**0.0321333**	**0.8161867**	**2.560666667**	**0.28931638**	**2.501206295**	**11.12591586**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**6.99**	**31.10**	**0.01**	**0.19**	**0.46**	**0.05**	**0.44**	**1.95**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**6.2**	**6.2**	**23.0**	**23.0**	**17.9**	**17.9**	**17.5**	**17.5**
30%		1.5	38.1	1.030	0.026	149.05	663.01	0.019	0.478	2.0559	0.232285426	1.996	8.879
		1.5	38.1	1.020	0.026	149.05	663.01	0.018	0.460	2.0771	0.234680703	2.036	9.058
		1.5	38.1	1.010	0.026	177.30	788.67	0.010	0.264	1.2009	0.135683432	1.189	5.289
	Average	**1.5**	**38.1**	**1.02**	**0.025908**	**158.46667**	**704.894596**	**0.0157667**	**0.4004733**	**1.777966667**	**0.200883187**	**1.740467289**	**7.741981405**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**16.31**	**72.55**	**0.00**	**0.12**	**0.50**	**0.06**	**0.48**	**2.13**
	COV	**0.0**	**0.0**	**1.0**	**1.0**	**10.3**	**10.3**	**29.6**	**29.6**	**28.1**	**28.1**	**27.5**	**27.5**
		1.5	38.1	1.030	0.026	107.01	476.00	0.027	0.696	2.0262	0.228929777	1.967	8.750
		1.5	38.1	1.020	0.026	123.55	549.58	0.020	0.503	1.6811	0.189938727	1.648	7.331
		1.5	38.1	1.030	0.026	133.19	592.46	0.019	0.493	1.8621	0.210388974	1.808	8.042
	Average	**1.5**	**38.1**	**1.0266667**	**0.0260773**	**121.25**	**539.346675**	**0.0222**	**0.56388**	**1.856466667**	**0.209752493**	**1.8077286**	**8.041174511**
	STD Dev.	**0.00**	**0.00**	**0.01**	**0.00**	**13.24**	**58.90**	**0.00**	**0.11**	**0.17**	**0.02**	**0.16**	**0.71**
	COV	**0.0**	**0.0**	**0.6**	**0.6**	**10.9**	**10.9**	**20.3**	**20.3**	**9.3**	**9.3**	**8.8**	**8.8**

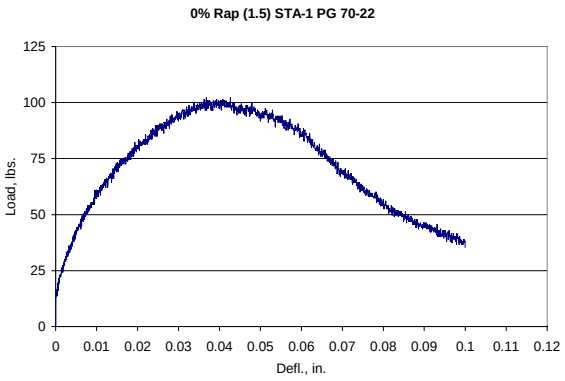
Specimend Bad

Gravel 70-22 1.5” 0%

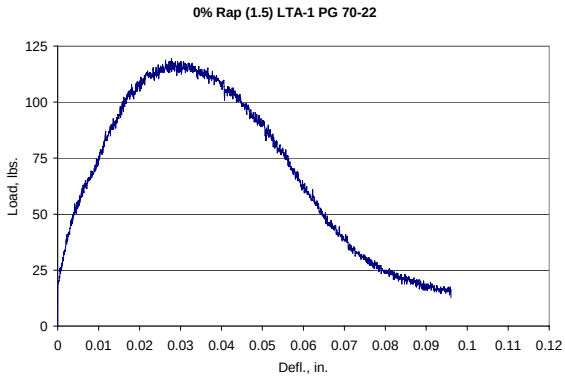
Short term age

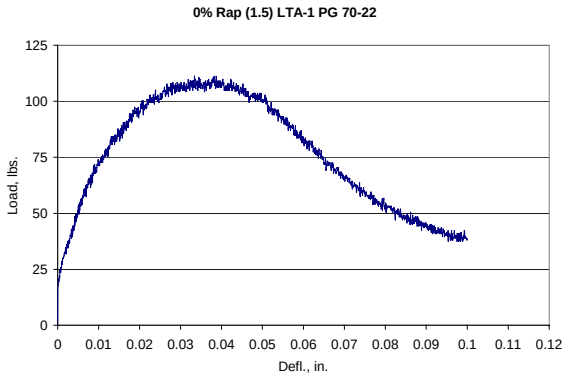


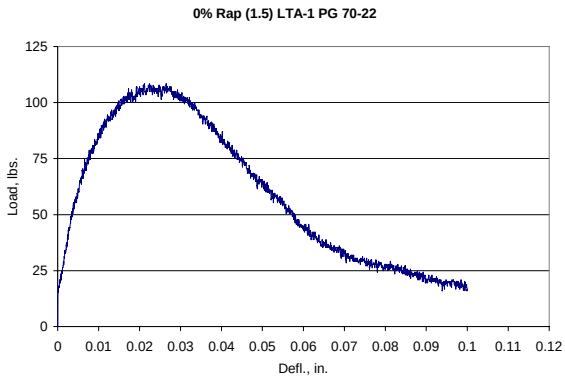




Long term age

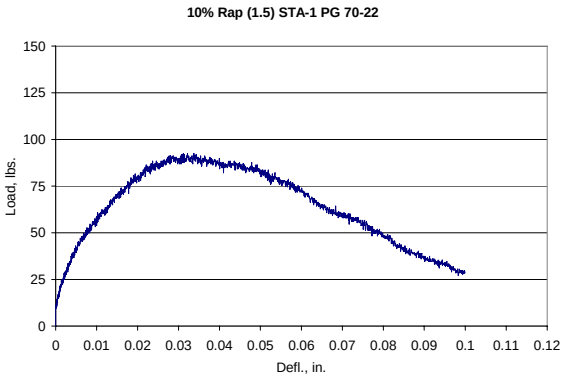


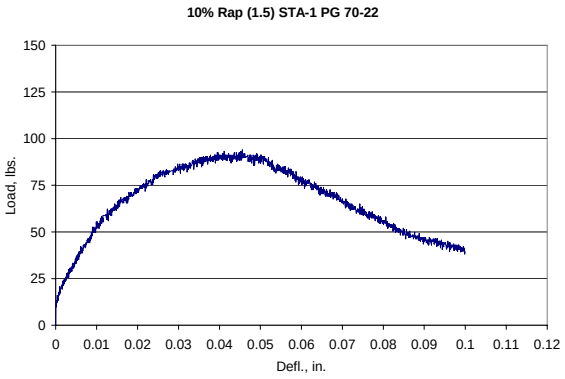


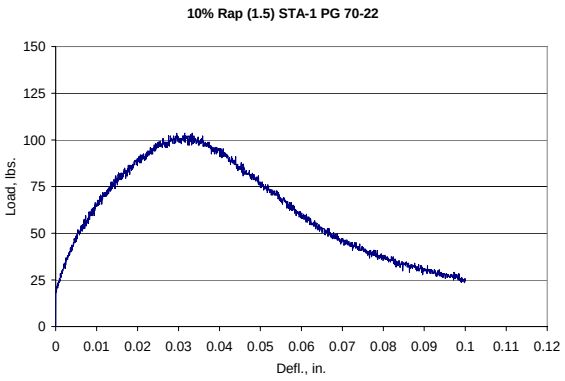


Gravel 70-22 1.5” 10%

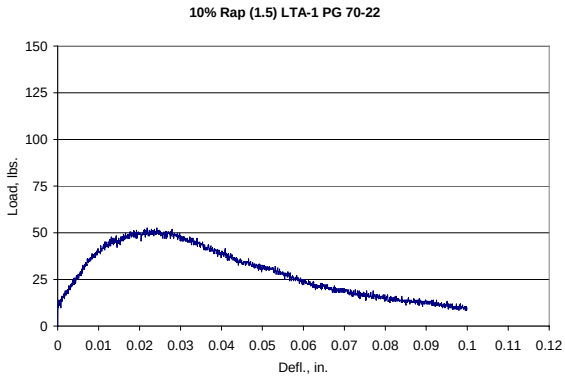
Short term age

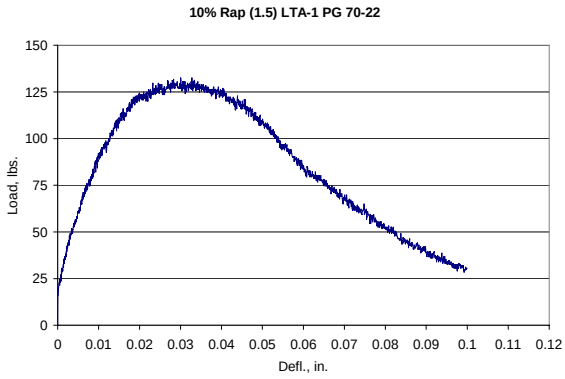


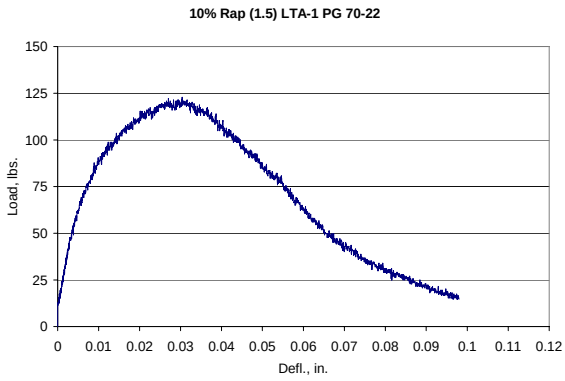




Long term age

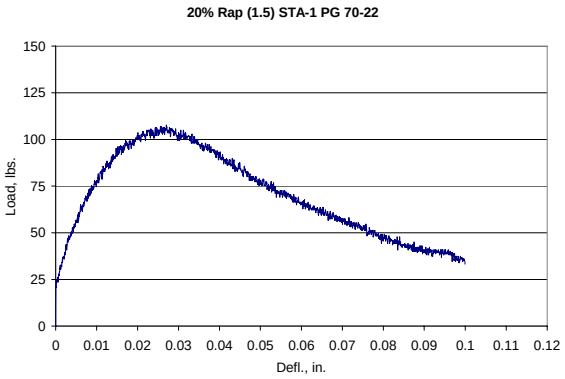


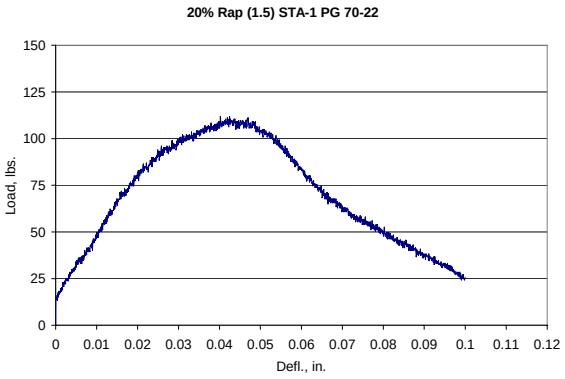


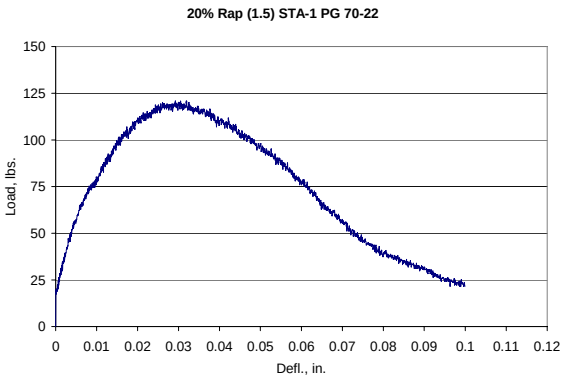


Gravel 70-22 1.5” 20%

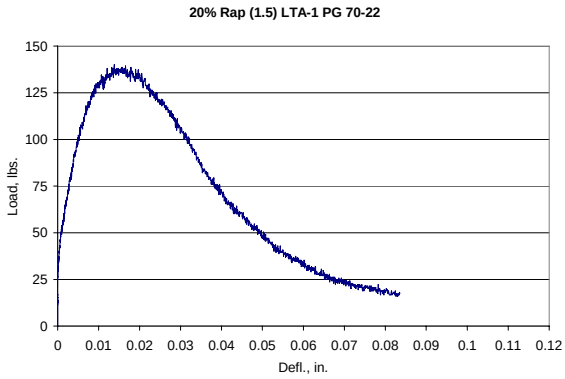
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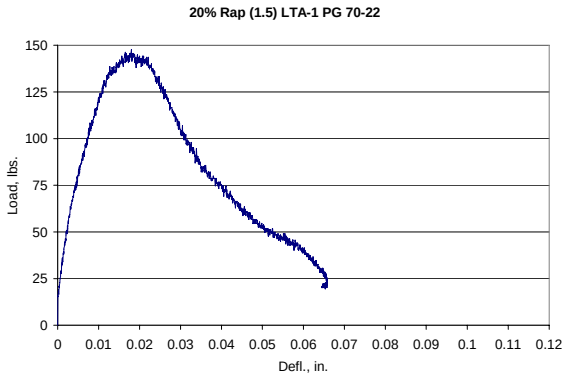


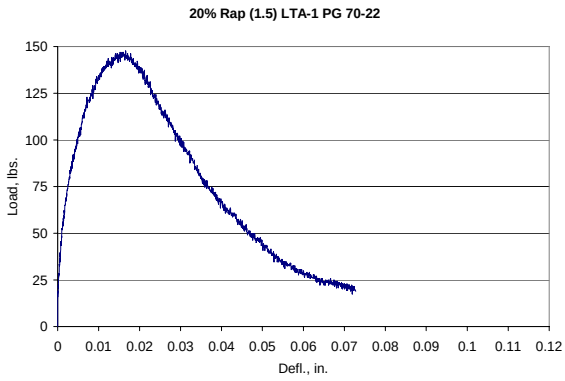




Long term age

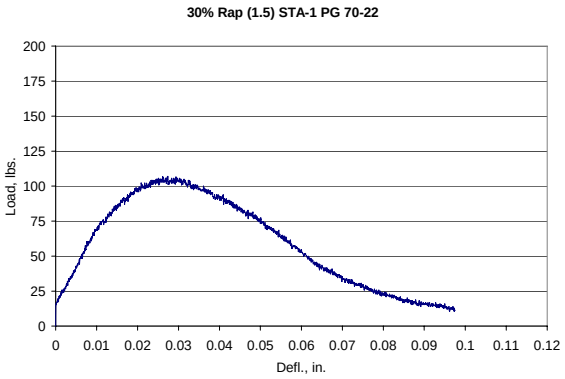


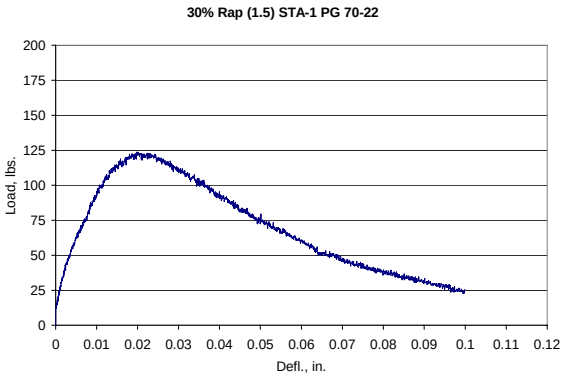


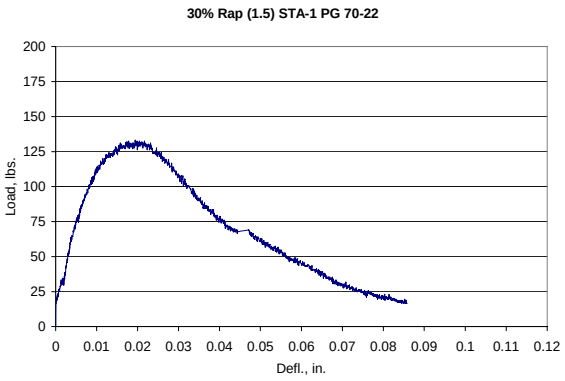


Gravel 70-22 1.5” 30%

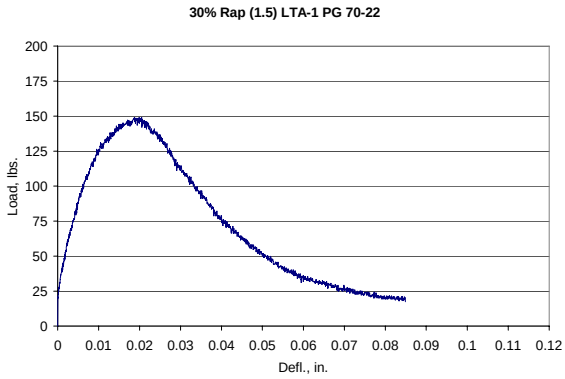
Short term age

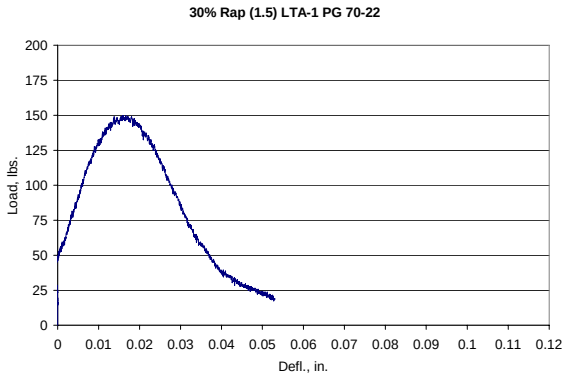


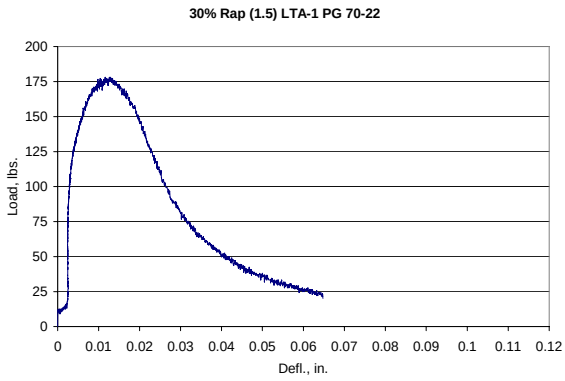




Long term age







APPENDIX F: FLEXULAR BEAM FATIGUE TEST DATA

Limestone Mixtures (Plateau Values)

PG 64-22 Beam Fatigue Plateau Value Test Summary						
% RAP	Short-term Aged			Long-term Aged		
	Sample	Dissipated Energy	Average	Sample	Dissipated Energy	Average
0	Left	1.79E-05		Left	2.16E-05	
	Middle	2.04E-05	1.969E-05	Middle	2.40E-05	2.241E-05
	Right	2.09E-05		Right	2.16E-05	
10	Left	2.08E-05		Left	2.38E-05	
	Middle	2.03E-05	2.055E-05	Middle	2.58E-05	2.329E-05
	Right			Right	2.02E-05	
20	Left	1.83E-05		Left	2.56E-05	
	Middle	2.56E-05	2.148E-05	Middle	4.52E-05	3.043E-05
	Right	2.06E-05		Right	2.05E-05	
30	Left	2.76E-05		Left	6.19E-05	
	Middle	2.23E-05	2.521E-05	Middle	2.62E-05	4.358E-05
	Right	2.57E-05		Right	4.26E-05	

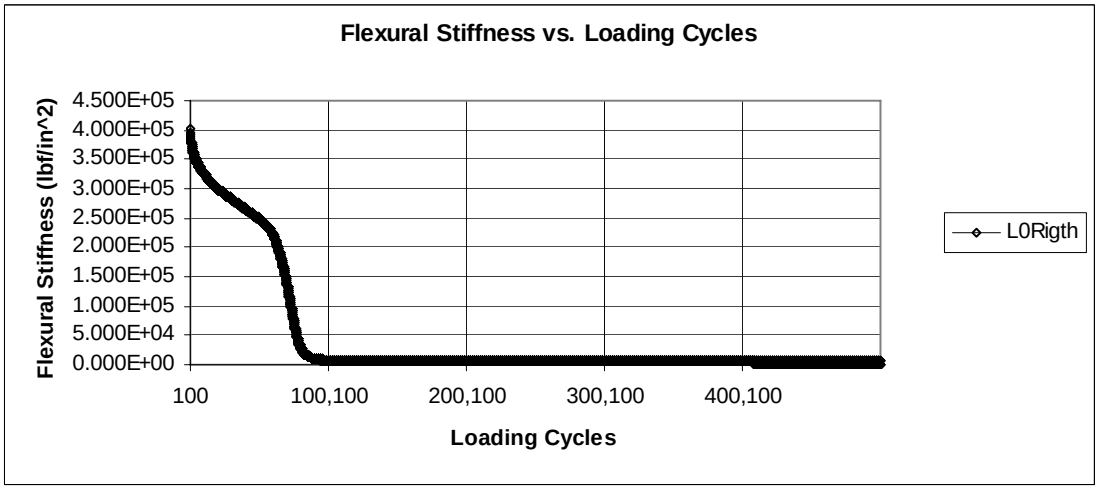
PG 76-22 Beam Fatigue Plateau Value						
% RAP	Short-term Aged			Long-term Aged		
	Sample	Dissipated Energy	Average	Sample	Dissipated Energy	Average
0	Left	1.78E-05		Left	2.01E-05	
	Middle	1.92E-05	1.857E-05	Middle	2.17E-05	2.013E-05
	Right	1.87E-05		Right	1.86E-05	
10	Left	1.90E-05		Left	1.92E-05	
	Middle	1.90E-05	1.913E-05	Middle	2.22E-05	2.110E-05
	Right	1.94E-05		Right	2.19E-05	
20	Left	2.07E-05		Left	2.31E-05	
	Middle	1.95E-05	1.967E-05	Middle	2.26E-05	2.203E-05
	Right	1.88E-05		Right	2.04E-05	
30	Left	2.26E-05		Left	2.33E-05	
	Middle	1.83E-05	2.010E-05	Middle	2.46E-05	2.377E-05
	Right	1.94E-05		Right	2.34E-05	

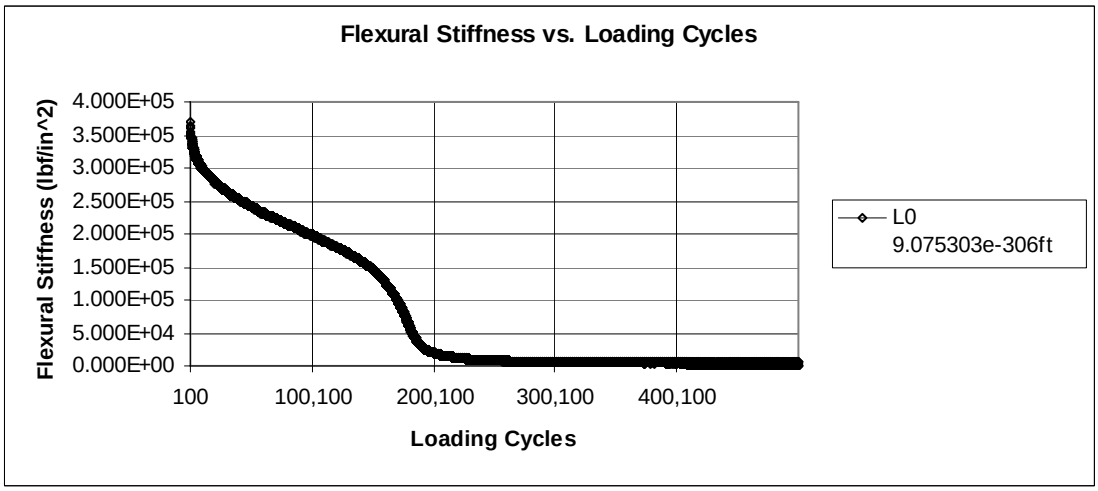
50% Initial Stiffness Failure

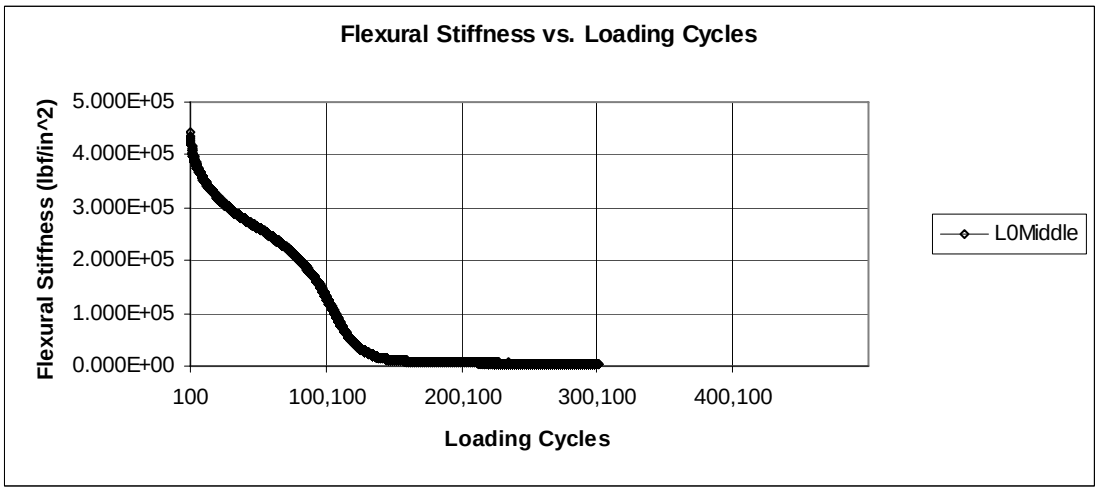
Limestone PG 64-22 Beam Fatigue Test Summary								
	Long-term Aged				Short-term Aged			
Percent Rap	Specimen	Cycles, N	Cummulative Dissipated Energy (in-lbf/in^3)	Stiffnes	Specimen	Cycles, N	Cummulative Dissipated Energy (in-lbf/in^3)	Stiffnes
0%	1	106,485	18,312	551,985	1	114,165	16,949	370,668
	2	100,034	17,704	595,904	2	71,712	11,544	444,250
	3	90,849	15,301	545,530	3	63,219	9,957	403,271
	Avg.	**99,123**	**17,106**	**564,473**	**Avg.**	**83,032**	**12,817**	**406,063**
	Std.	7,858	1,592	27,411	Std.	27,294	3,666	36,870
	COV	8	9	5	COV	33	29	9
10%	1	63,641	10,833	628,533	1	72,935	11,791	497,903
	2	168,304	28,925	582,351	2	124,380	21,059	490,820
	3	64,050	10,772	491,766	3	57,512	9,554	472,662
	Avg.	**98,665**	**16,843**	**567,550**	**Avg.**	**84,942**	**14,135**	**487,128**
	Std.	60,309	10,463	69,574	Std.	35,014	6,100	13,019
	COV	61	62	12	COV	41	43	3
20%	1	97,046	17,689	635,004	1	95,229	16,074	458,777
	2	158,389	27,717	589,084	2	96,049	16,817	535,437
	3	130,289	21,808	503,808	3	47,595	7,728	446,690
	Avg.	**128,575**	**22,405**	**575,965**	**Avg.**	**79,624**	**13,540**	**480,301**
	Std.	30,707	5,041	66,575	Std.	27,741	5,047	48,130
	COV	24	22	12	COV	35	37	10
30%	1	336,397	31,787	699,051	1	116,923	20,580	725,953
	2	106,274	17,080	620,083	2	120,771	19,720	548,714
	3	176,998	19,387	664,208	3	117,918	21,216	611,115
	Avg.	**206,556**	**22,751**	**661,114**	**Avg.**	**118,537**	**20,505**	**628,594**
	Std.	117,875	7,910	39,575	Std.	1,997	751	89,903
	COV	57	35	6	COV	2	4	14

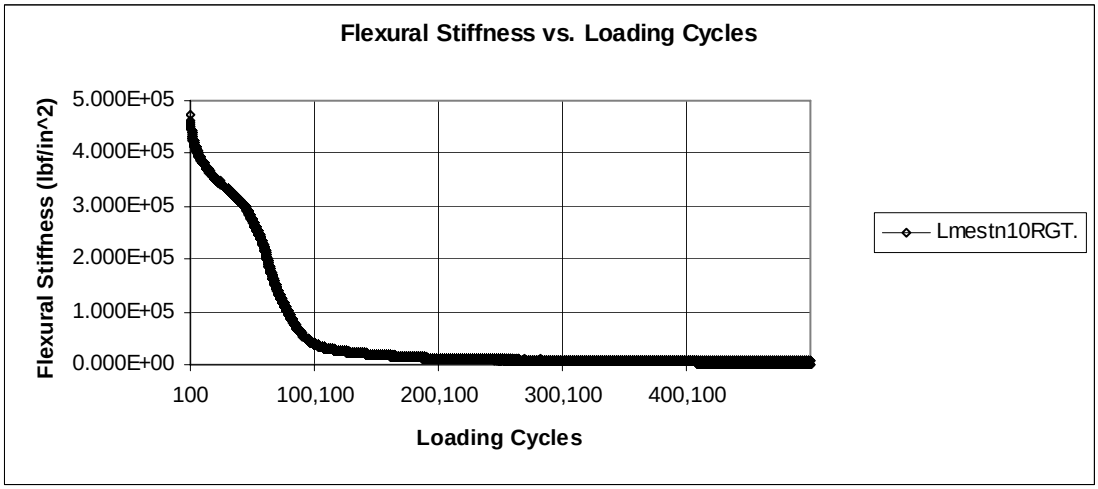
Limestone PG 76-22 Beam Fatigue Test Summary								
0	Long-term Aged				Unaged			
Percent Rap	Specimen	Cycles, N	Cummulative Dissipated Energy (in-lbf/in^3)	Stiffnes	Specimen	Cycles, N	Cummulative Dissipated Energy (in-lbf/in^3)	Stiffnes
0%	1	409,166	57,756	395,323	1	409,291	60,070	386,225
	2	409,194	56,933	427,843	2	409,216	67,182	438,887
	3	409,210	53,364	475,345	3	409,289	68,396	465,537
	Avg.	**409,190**	**56,018**	**432,837**	**Avg.**	**409,265**	**65,216**	**430,216**
	Std.	22	2,335	40,244	Std.	43	4,498	40,361
	COV	0	4	9	COV	0	7	9
10%	1	409,217	57,019	423,723	1	409,220	66,748	479,054
	2	409,146	69,795	483,940	2	409,276	70,068	496,633
	3	409,190	65,829	450,608	3	409,223	71,590	542,570
	Avg.	**409,184**	**64,214**	**452,757**	**Avg.**	**409,240**	**69,469**	**506,086**
	Std.	36	6,539	30,166	Std.	32	2,476	32,796
	COV	0	10	7	COV	0	4	6
20%	1	408,989	66,804	521,059	1	409,260	71,573	599,148
	2	409,504	68,971	537,696	2	409,246	67,545	529,596
	3	408,931	59,587	536,561	3	409,247	63,019	481,542
	Avg.	**409,141**	**65,121**	**531,772**	**Avg.**	**409,251**	**67,379**	**536,762**
	Std.	315	4,913	9,295	Std.	8	4,279	59,130
	COV	0	8	2	COV	0	6	11
30%	1	409,109	64,629	524,248	1	409,212	70,213	557,734
	2	409,189	66,996	564,048	2	409,685	63,668	441,483
	3	409,675	66,412	591,803	3	409,200	66,479	502,932
	Avg.	**409,324**	**66,012**	**560,033**	**Avg.**	**409,366**	**66,787**	**500,716**
	Std.	306	1,233	33,956	Std.	277	3,283	58,157
	COV	0	2	6	COV	0	5	12

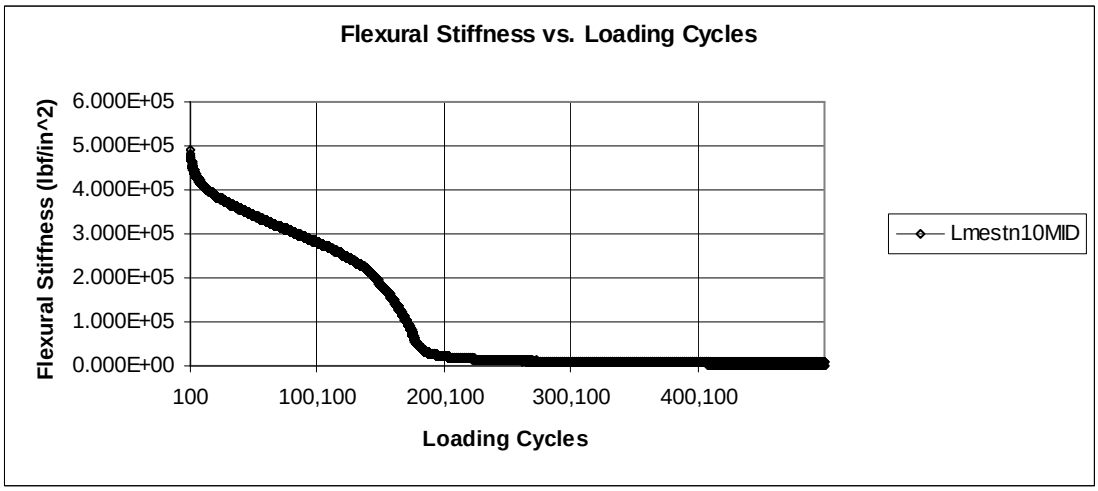
Limestone 64-22 STA 0%

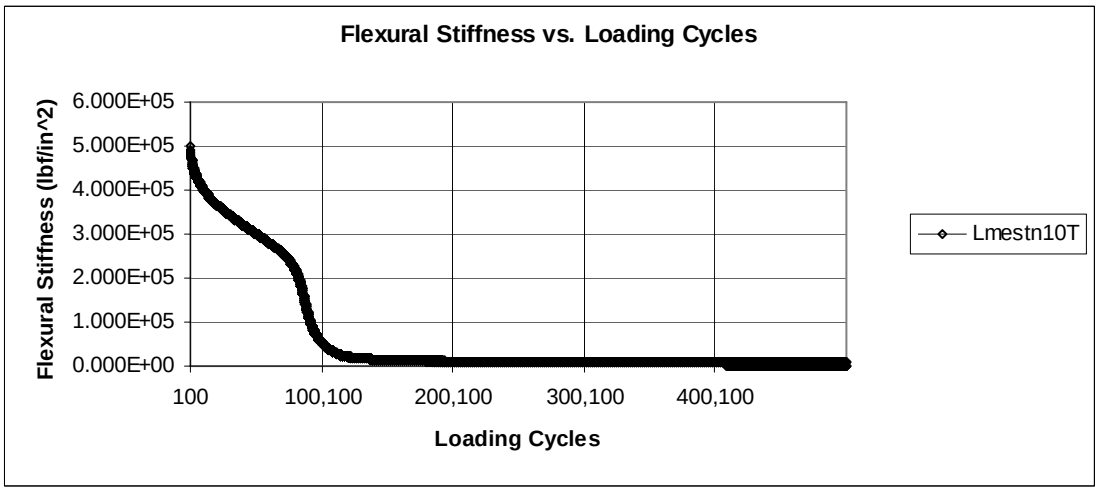




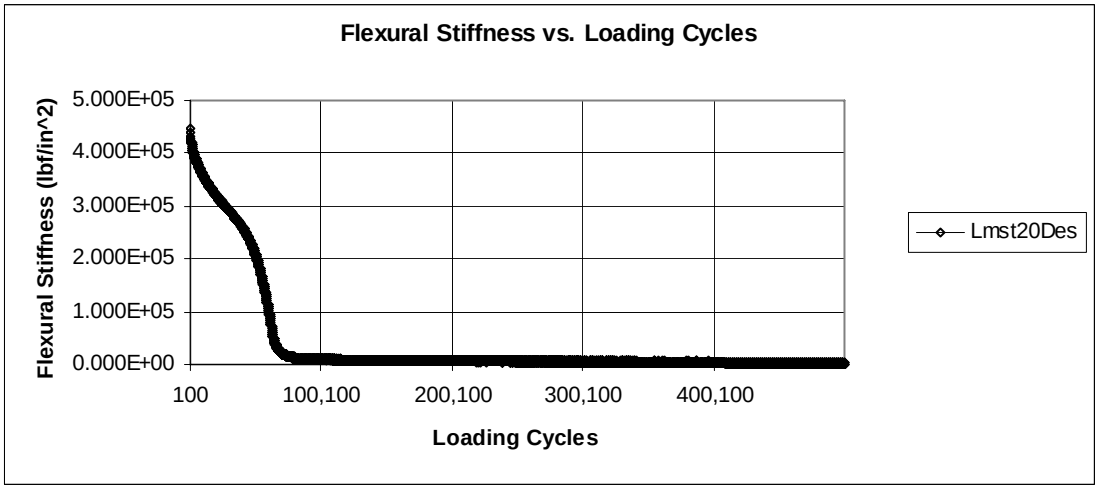


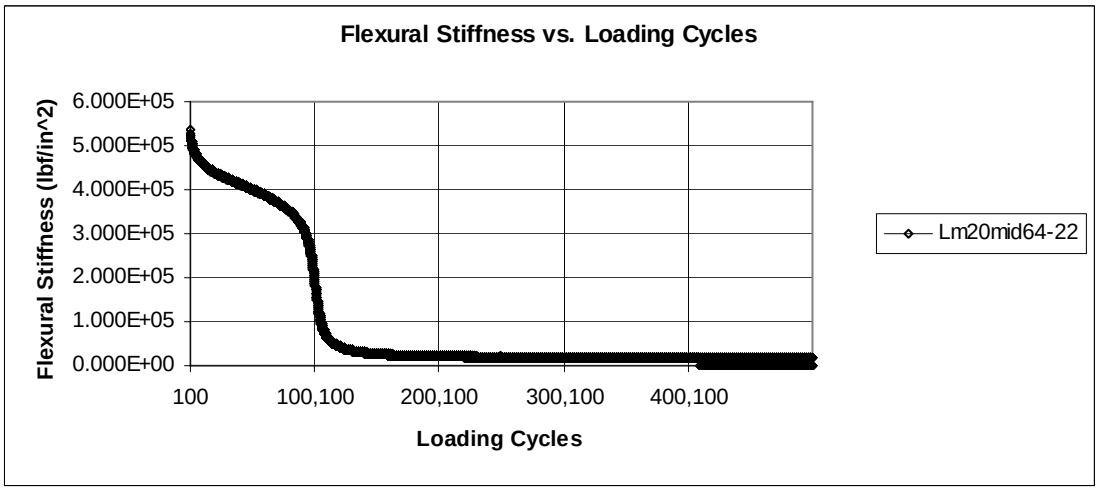

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
Lmestn10RGT.

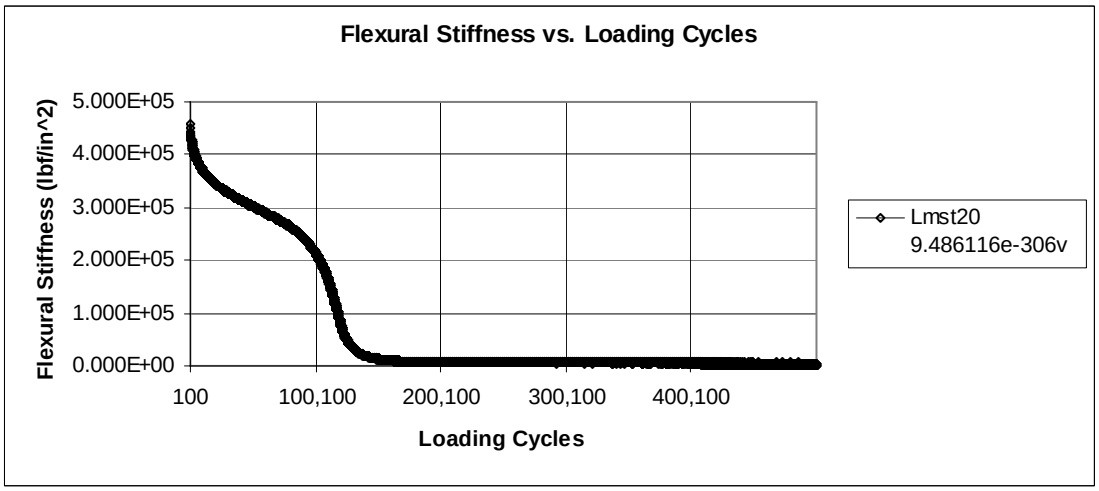

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
Lmestn10MID

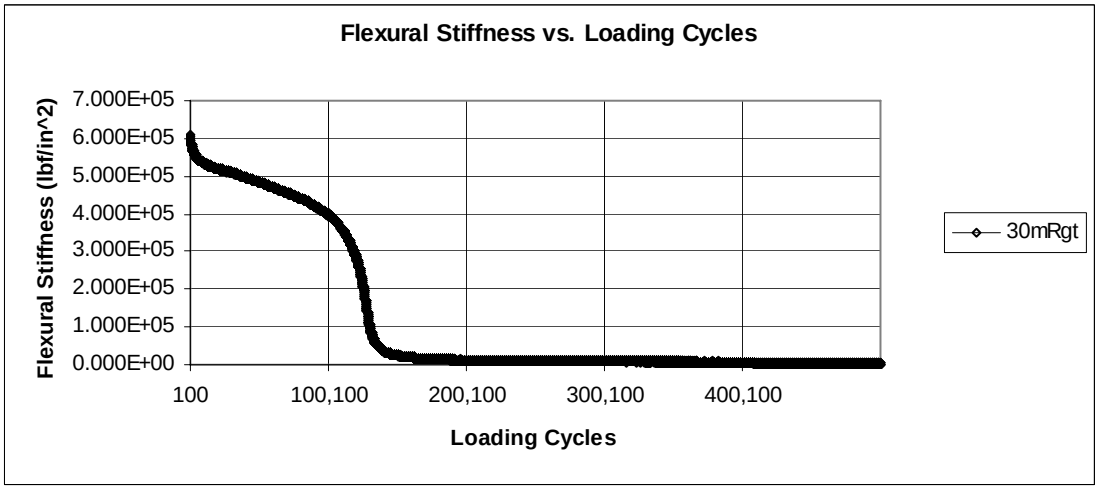

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
Lmestn10T

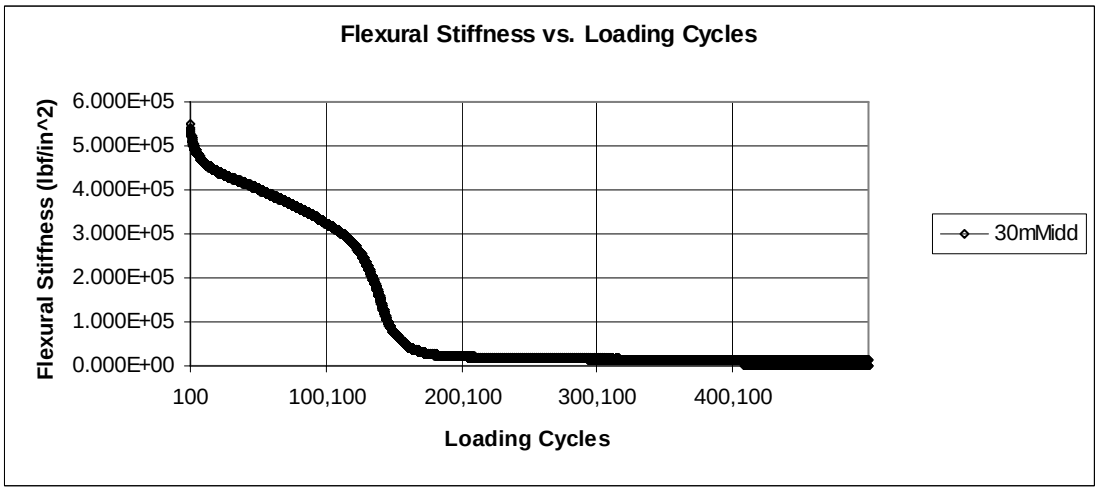
Limestone 64-22 STA 20%

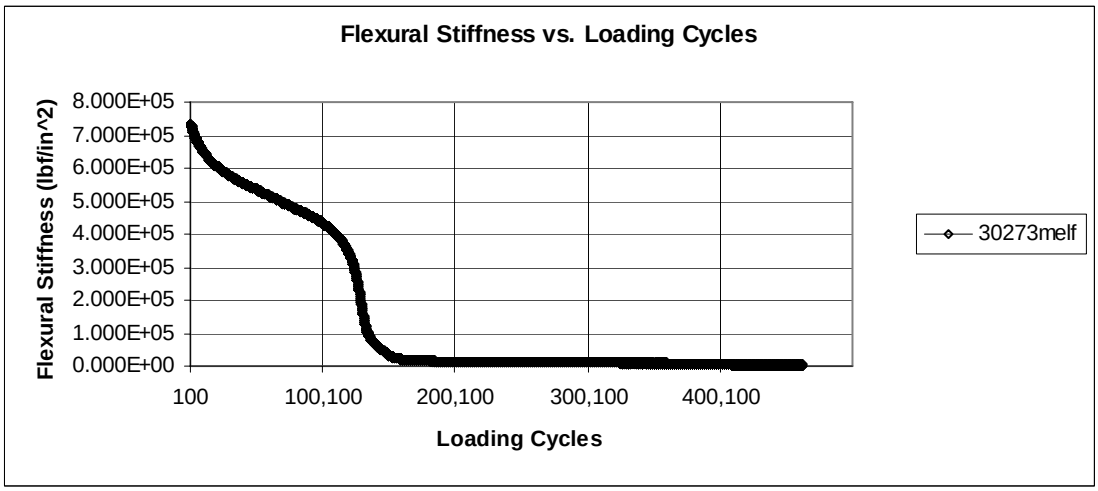




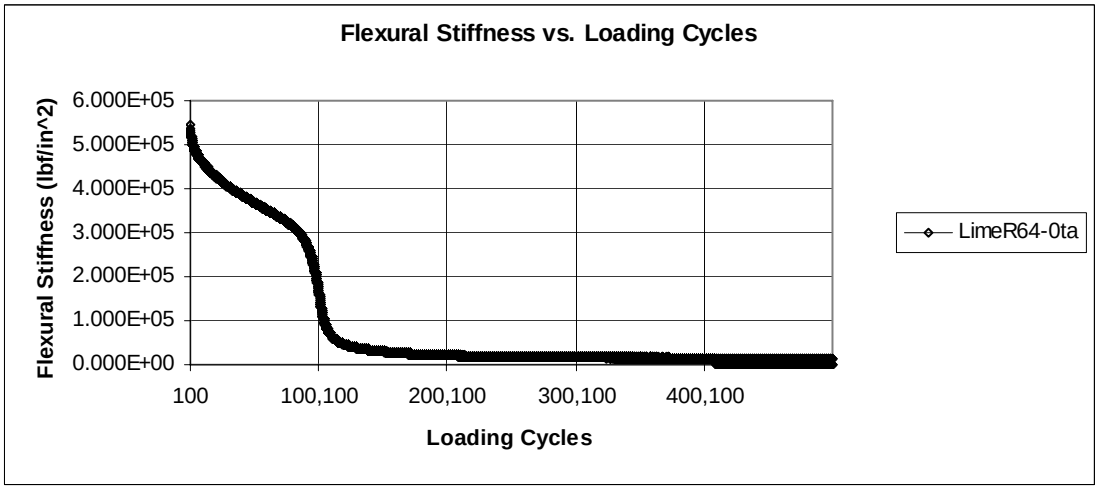


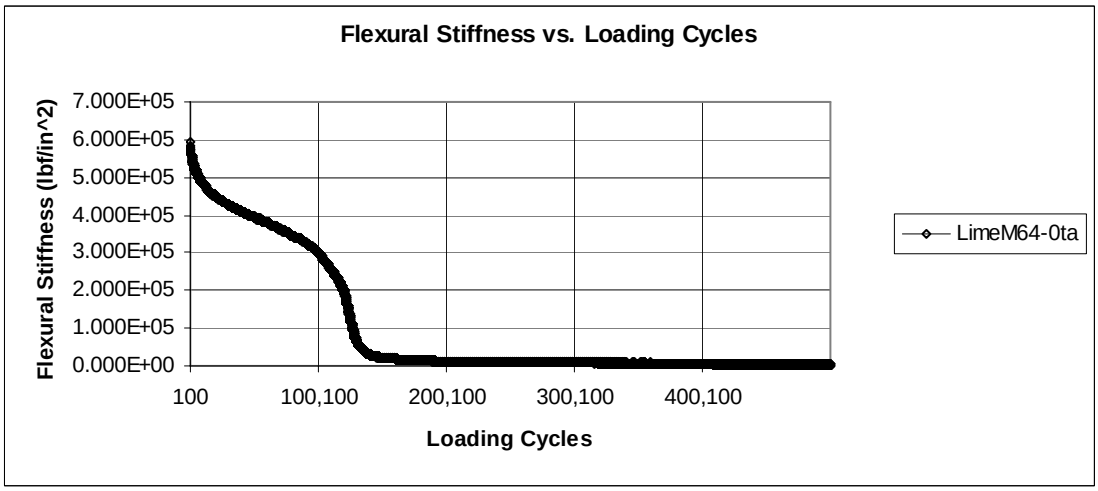

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
7.000E+05
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
30mRgt

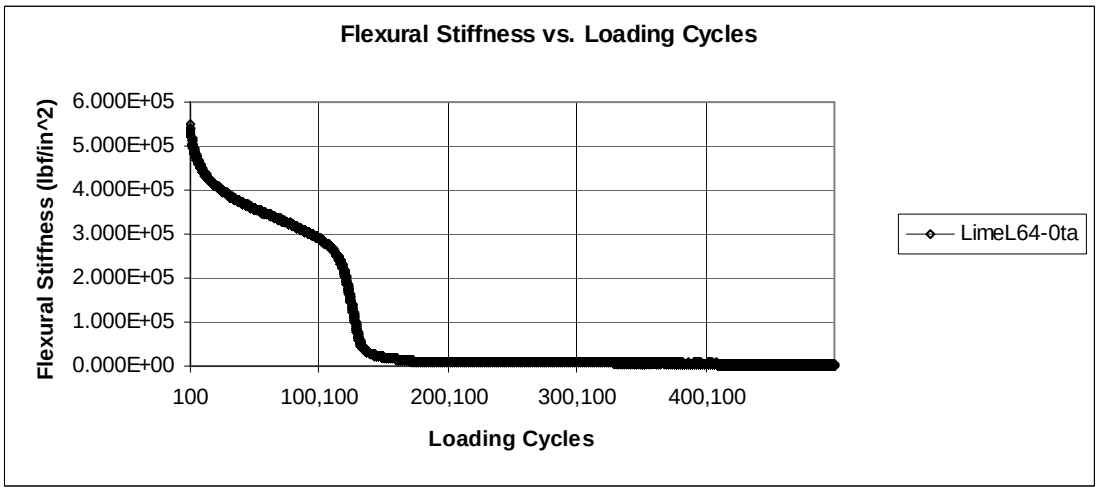

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
30mMidd


Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
8.000E+05
7.000E+05
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
30273melf

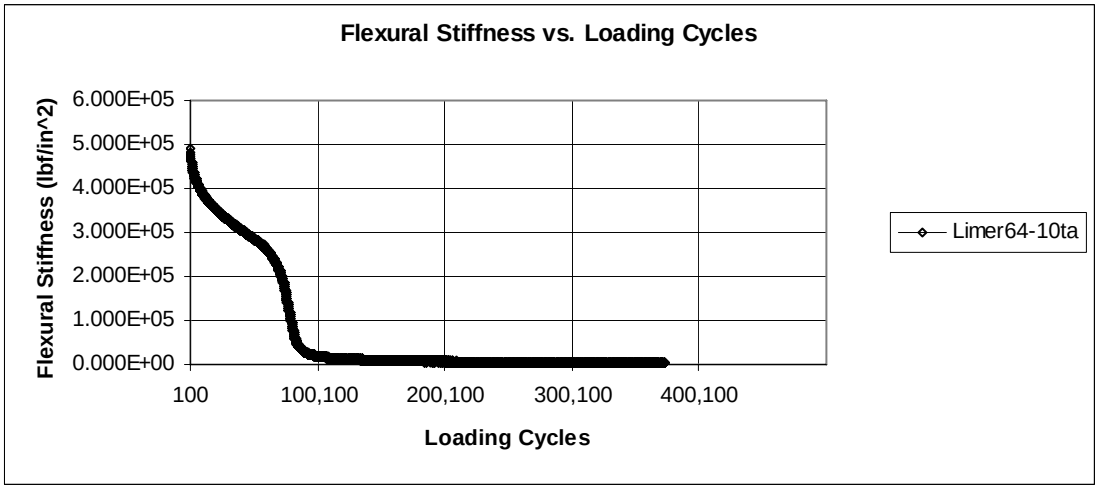
Limestone 64-22 LTA 0%

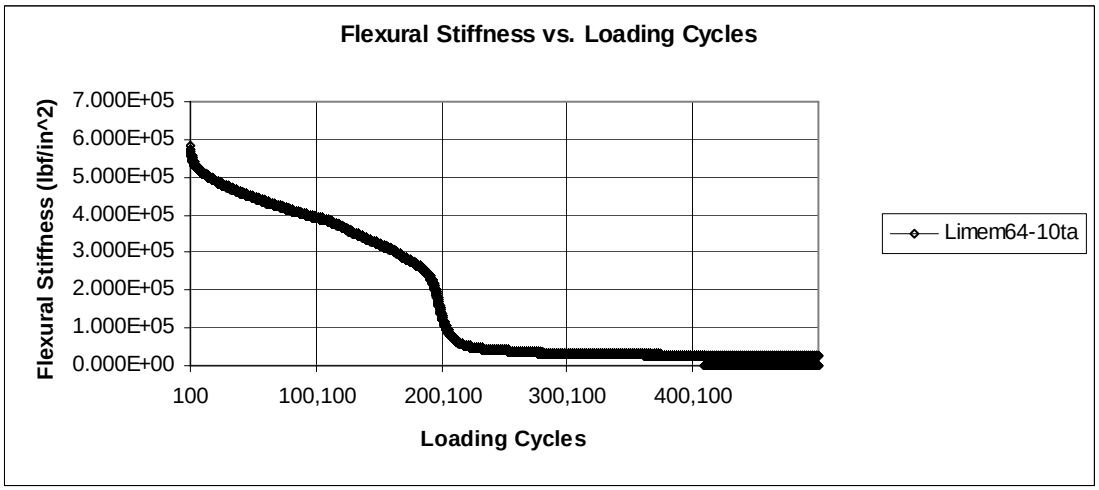


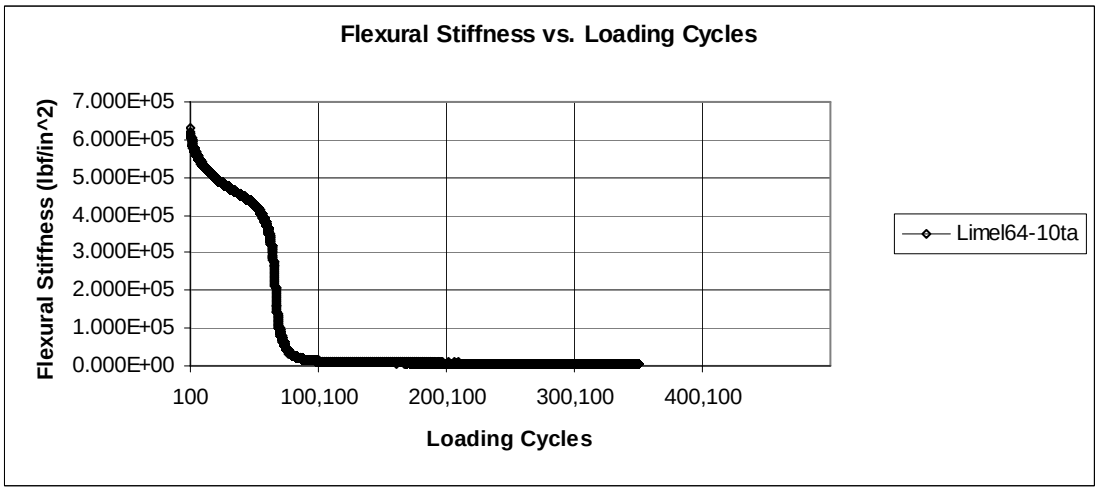


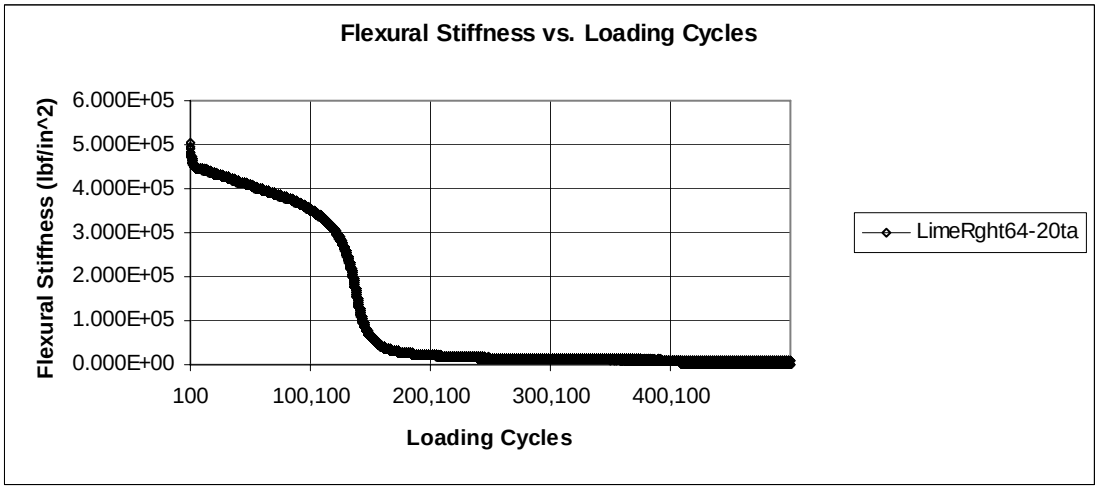


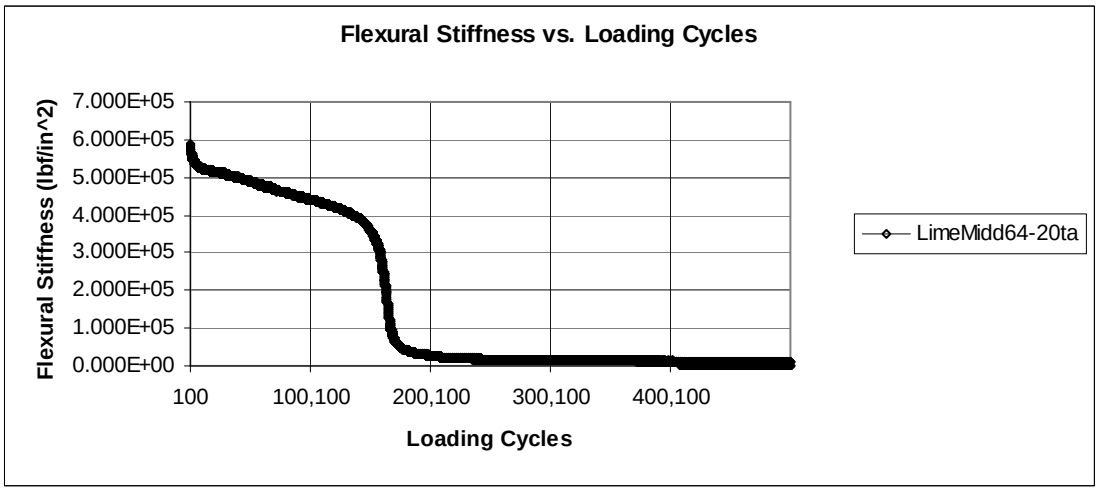
Limestone 64-22 LTA 10%

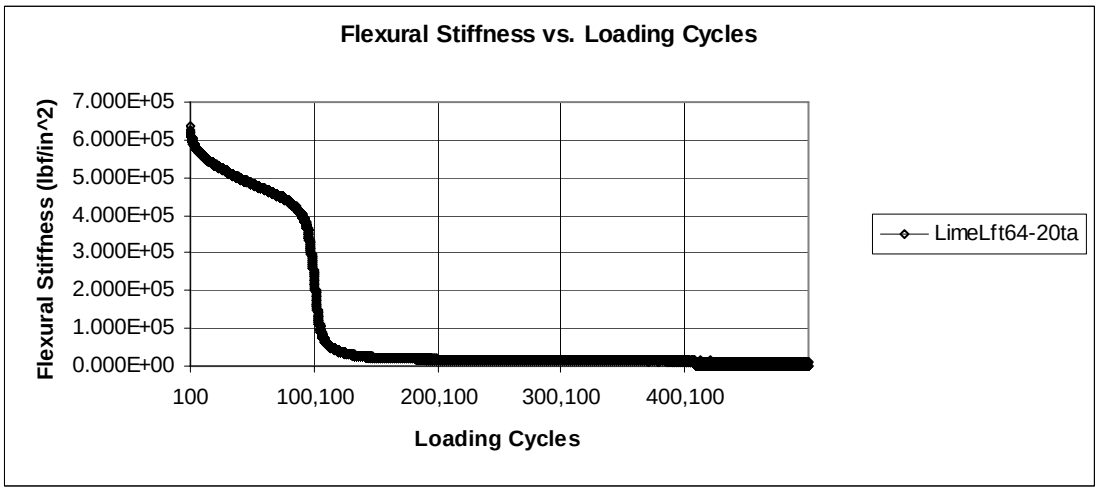




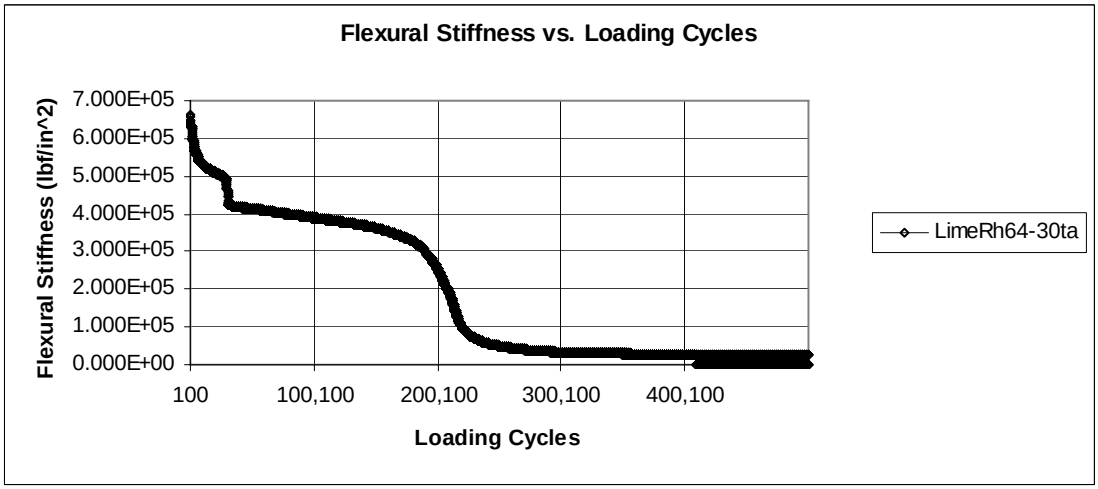


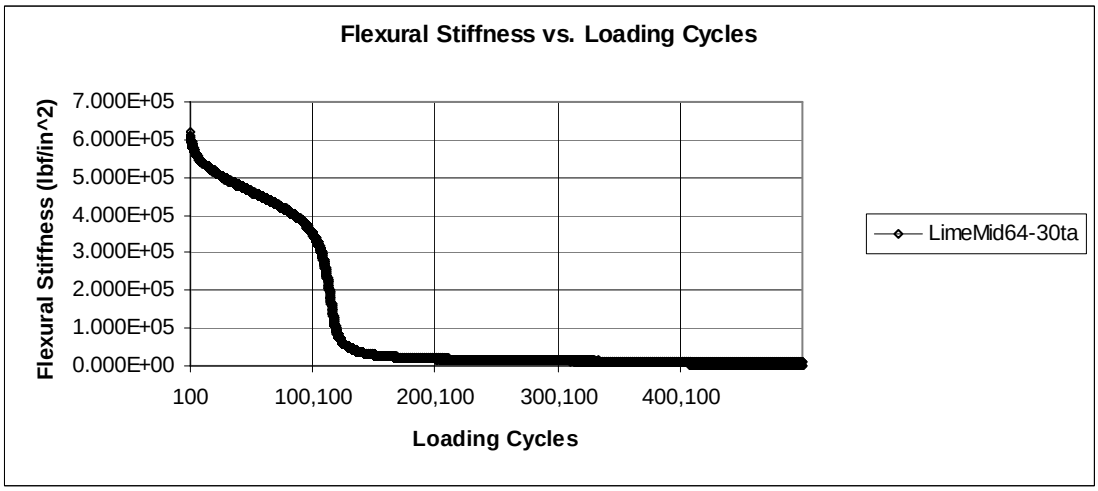

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
LimeRght64-20ta

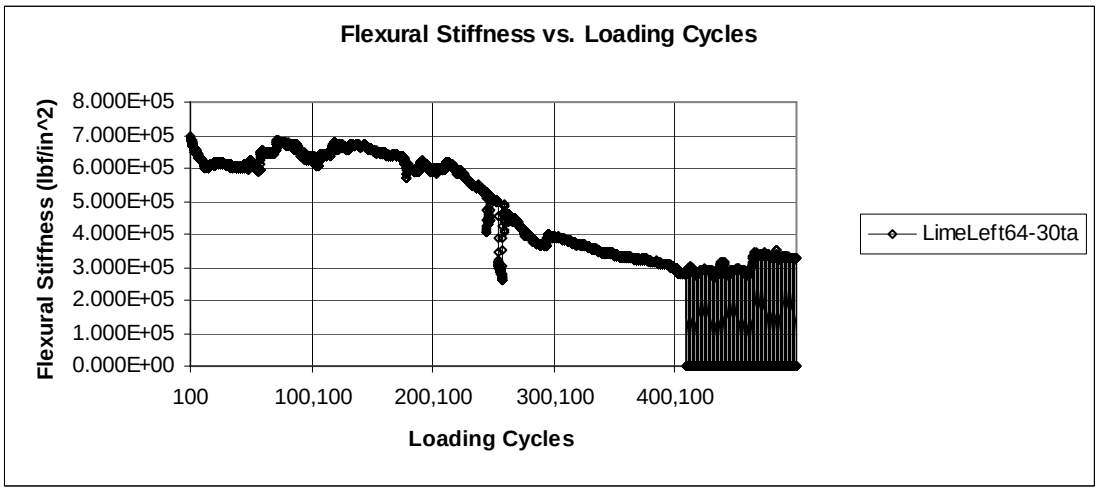

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
7.000E+05
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
LimeMidd64-20ta


Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
7.000E+05
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
LimeLft64-20ta

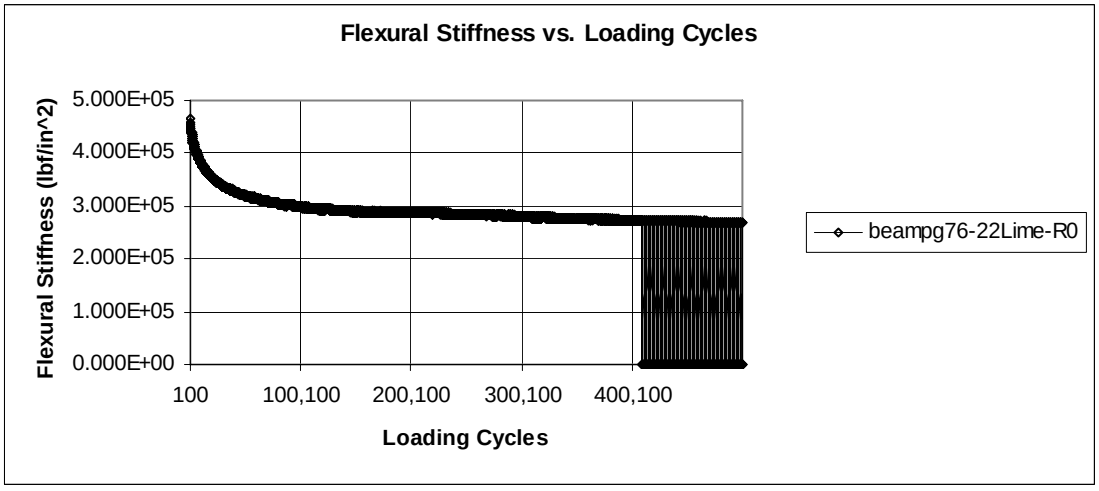
Limestone 64-22 LTA 30%

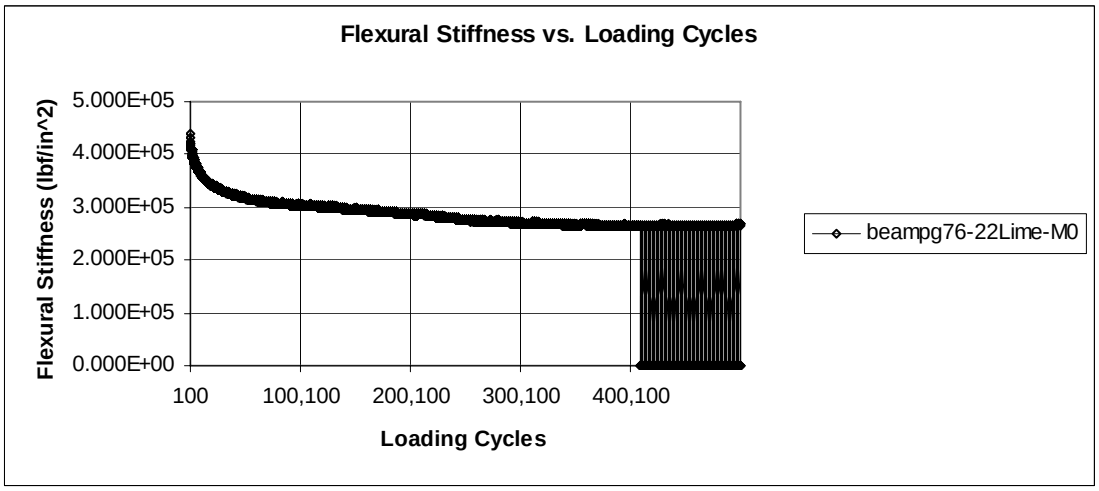


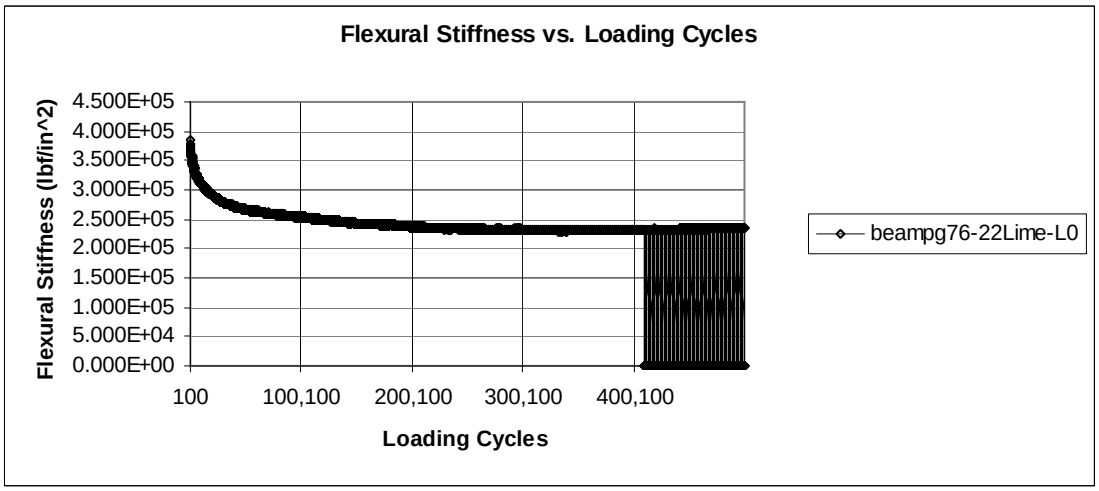




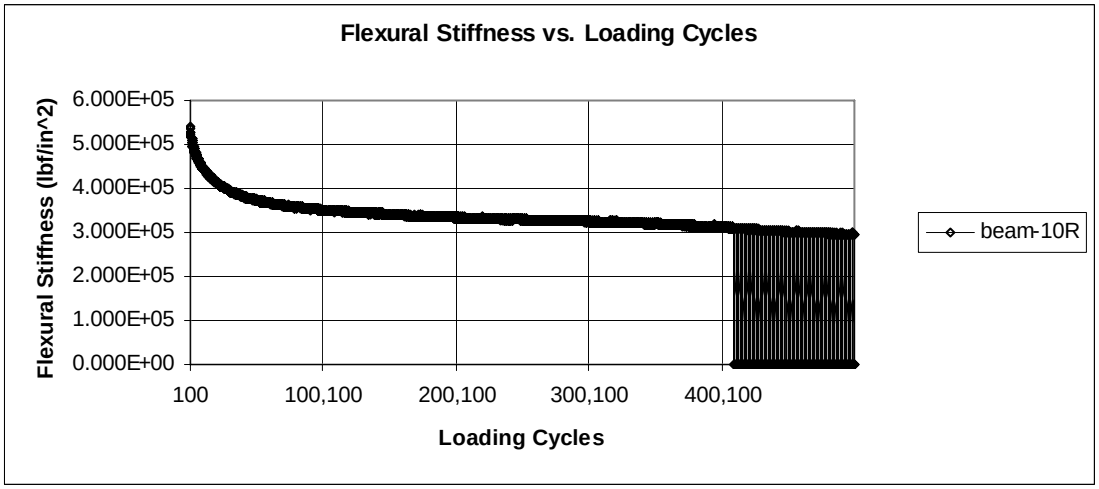
Limestone 76-22 STA 0%

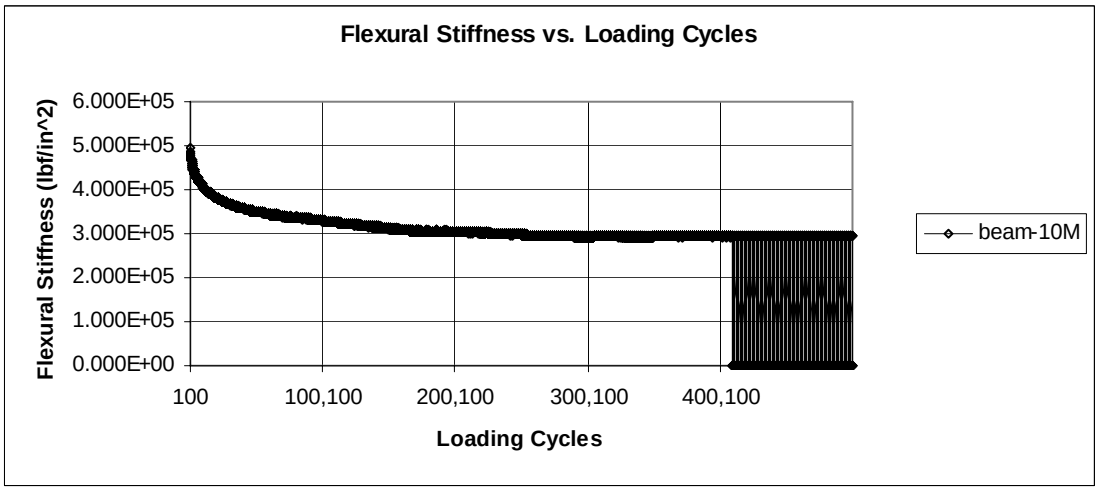


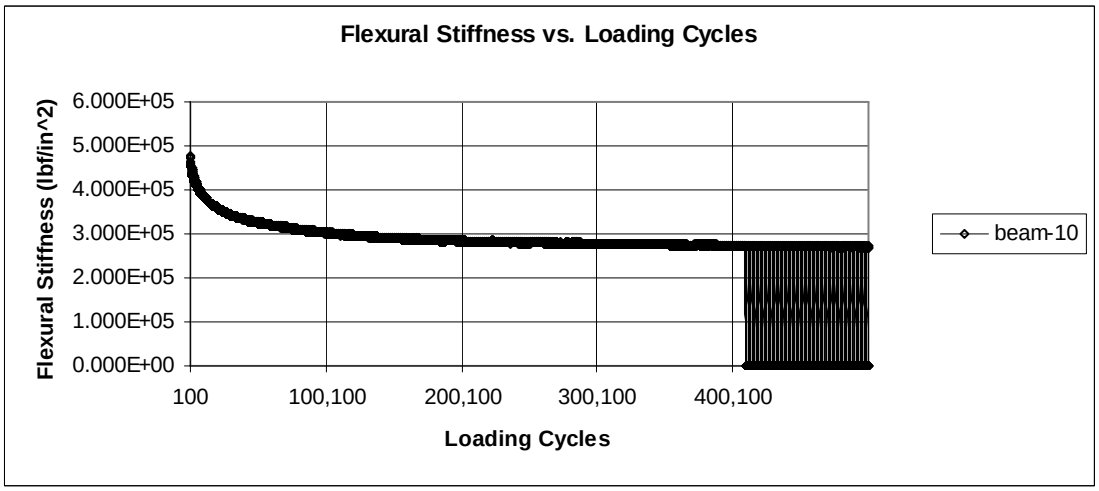


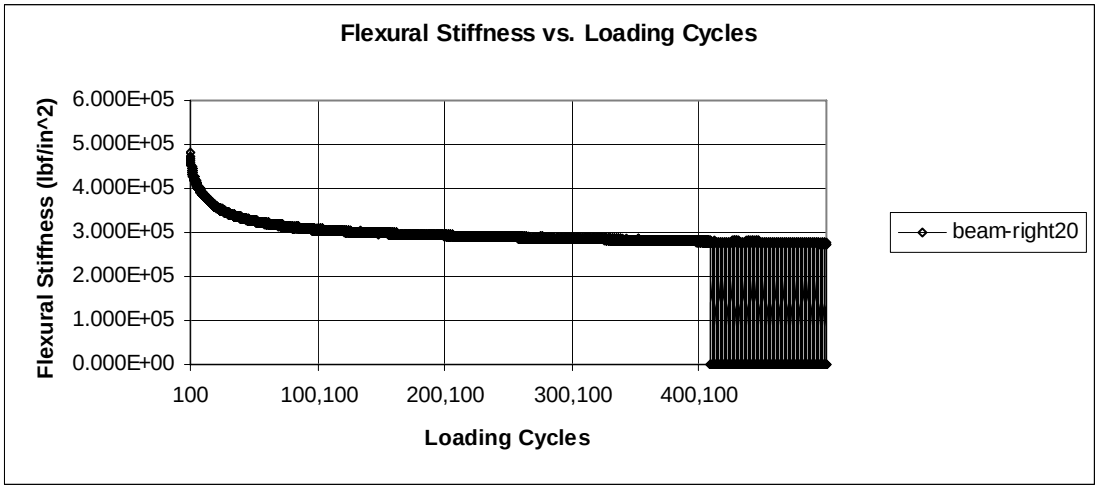


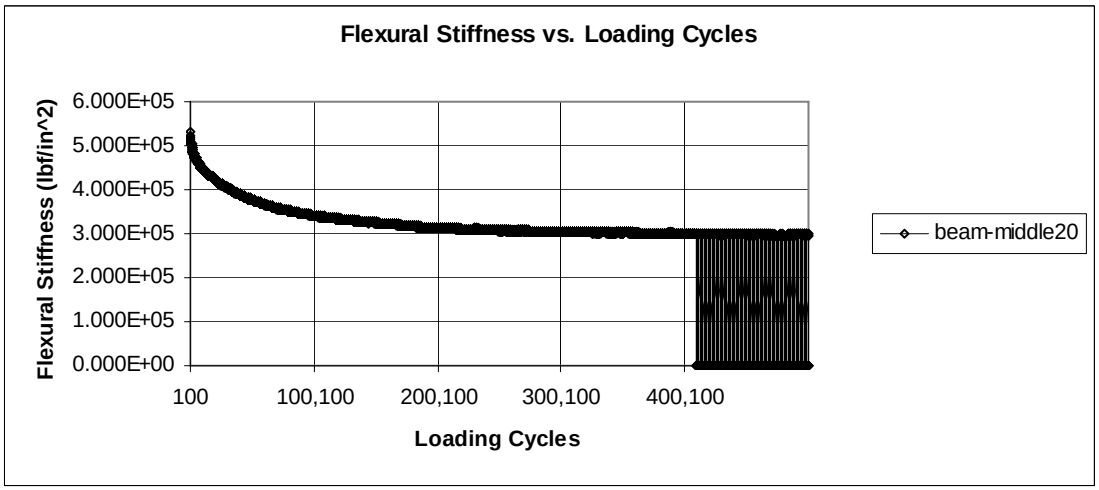
Limestone 76-22 STA 10%

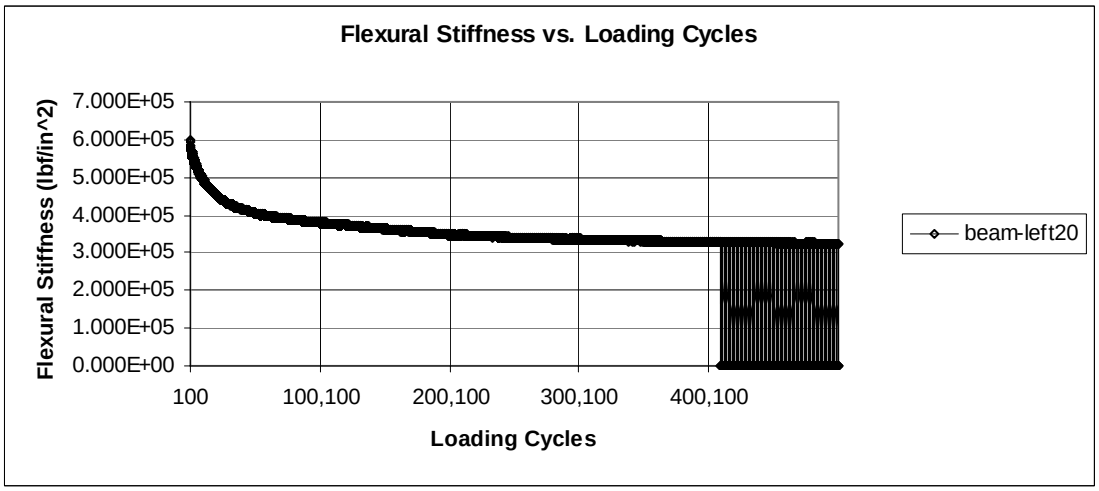




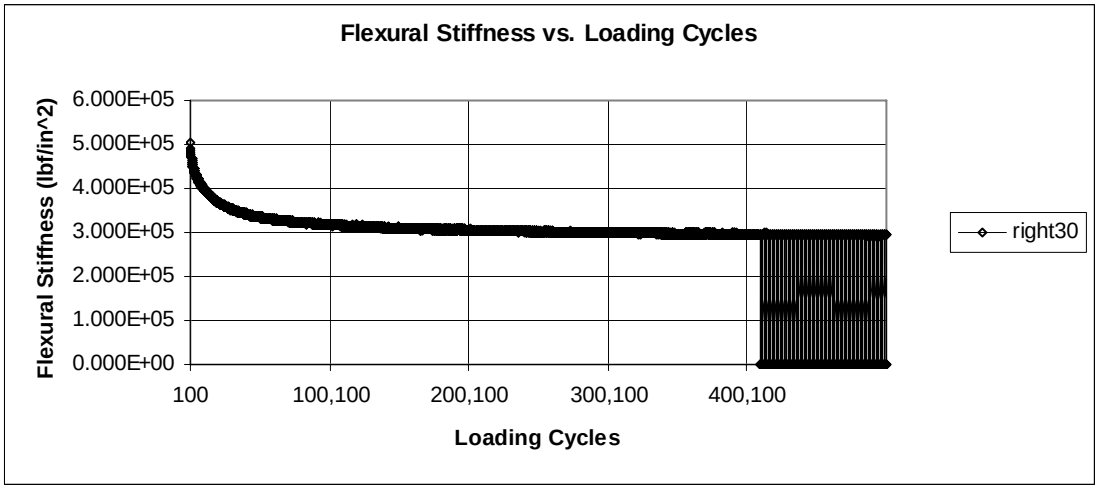


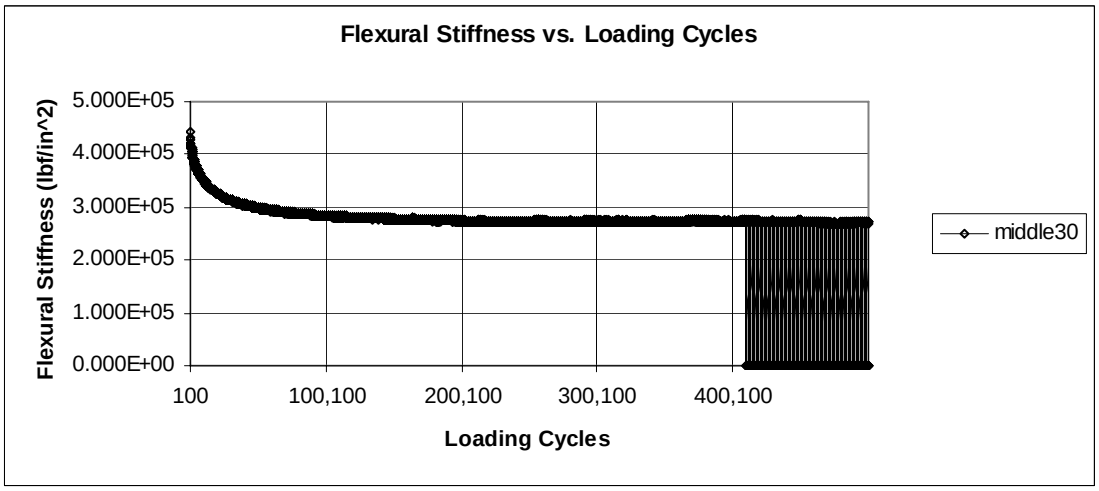

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
beam-right20

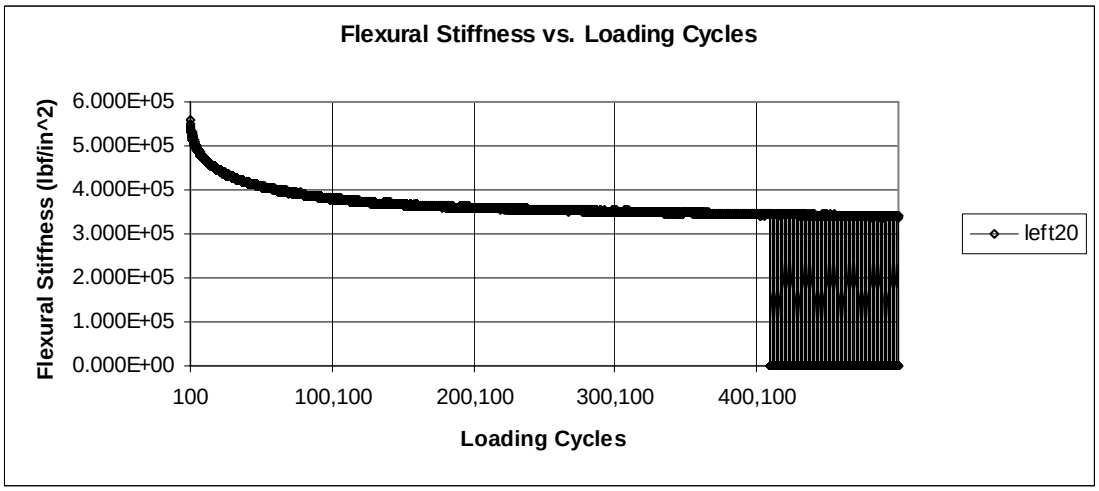

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
beam-middle20


Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
7.000E+05
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
beam-left20

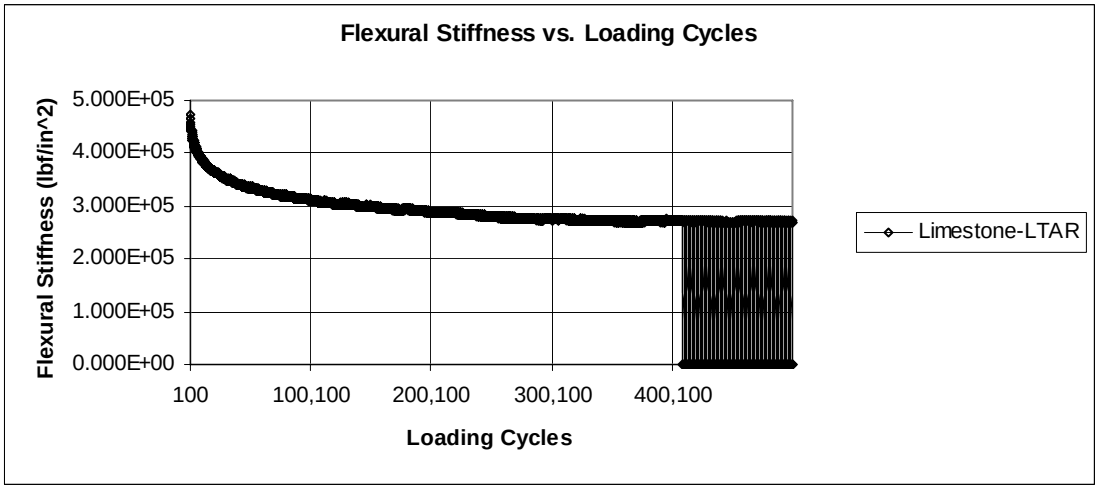
Limestone 76-22 STA 30%

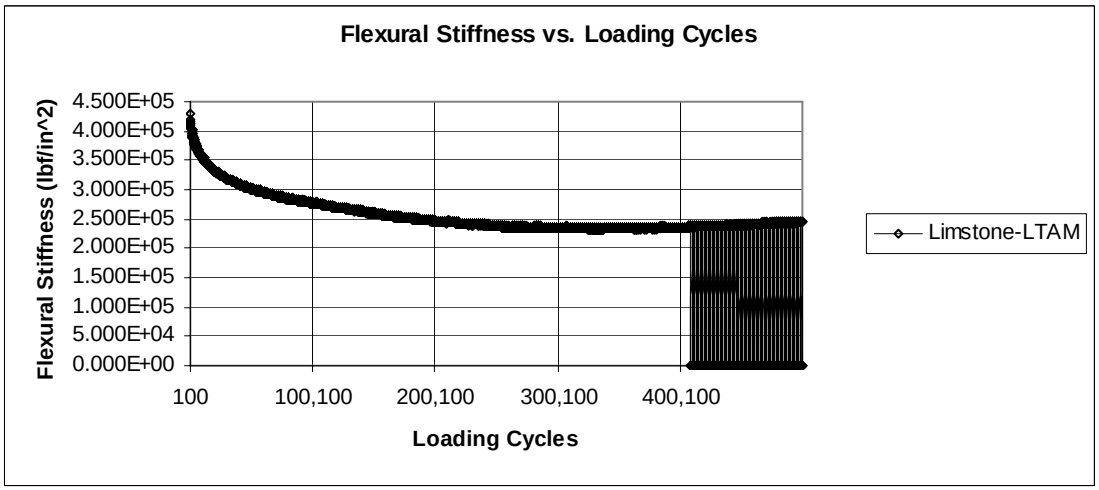


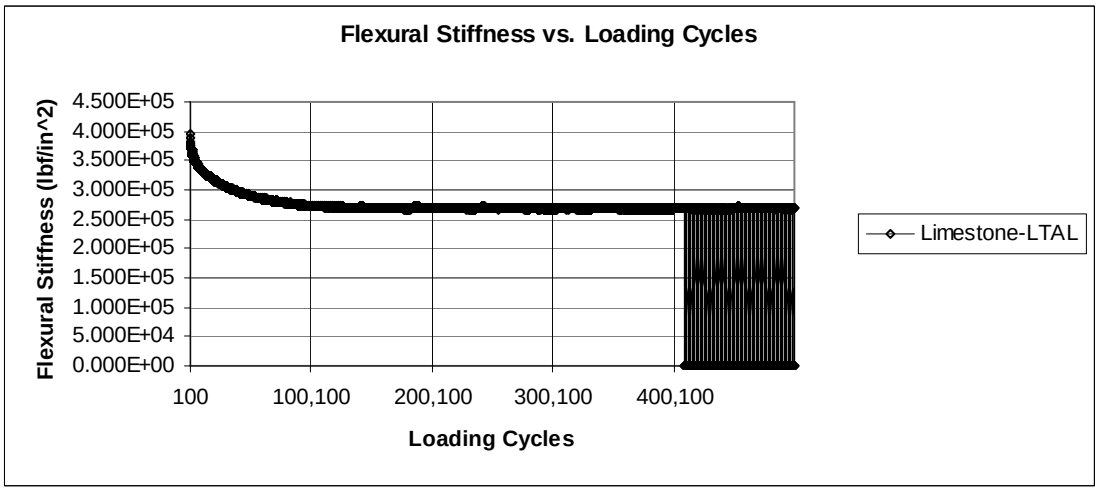




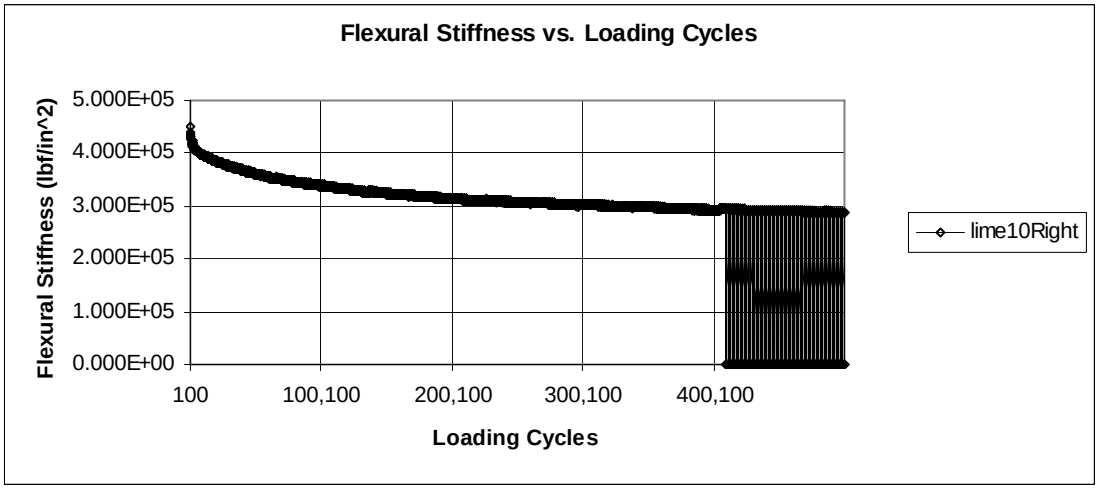
Limestone 76-22 LTA 0%

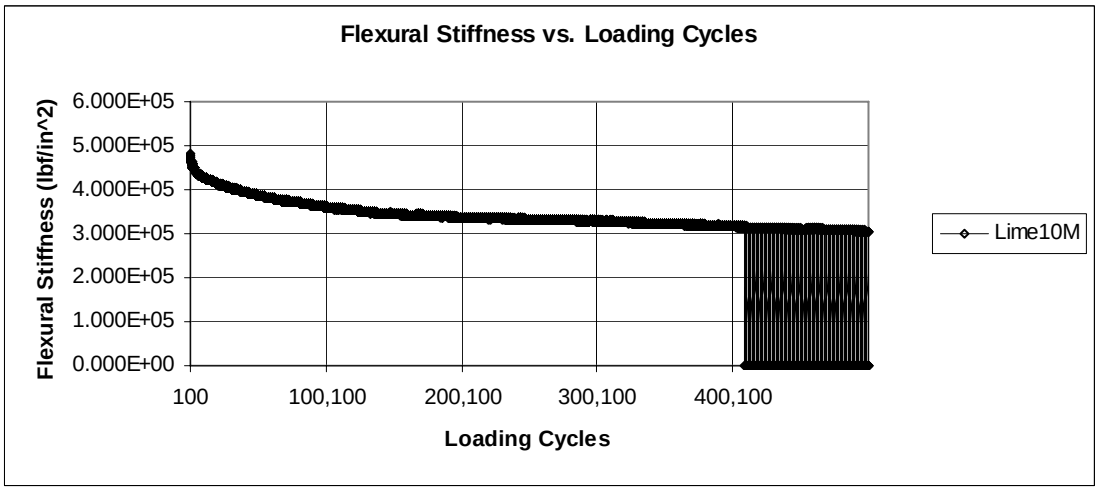


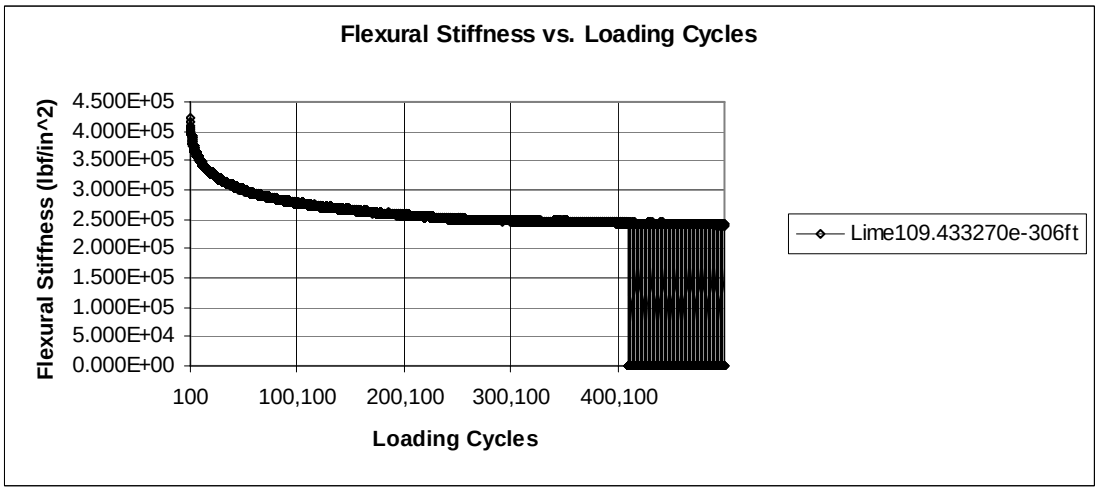




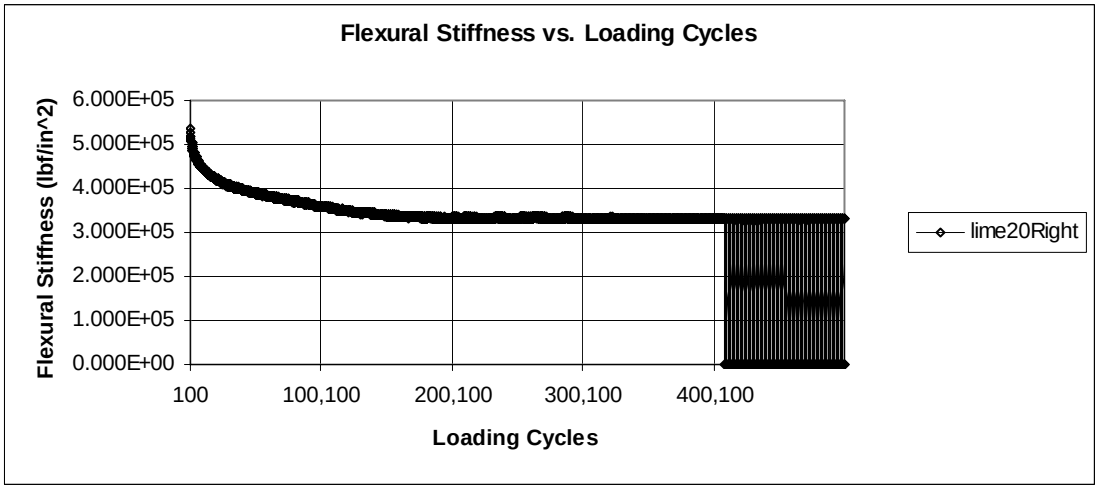
Limestone 76-22 LTA 10%

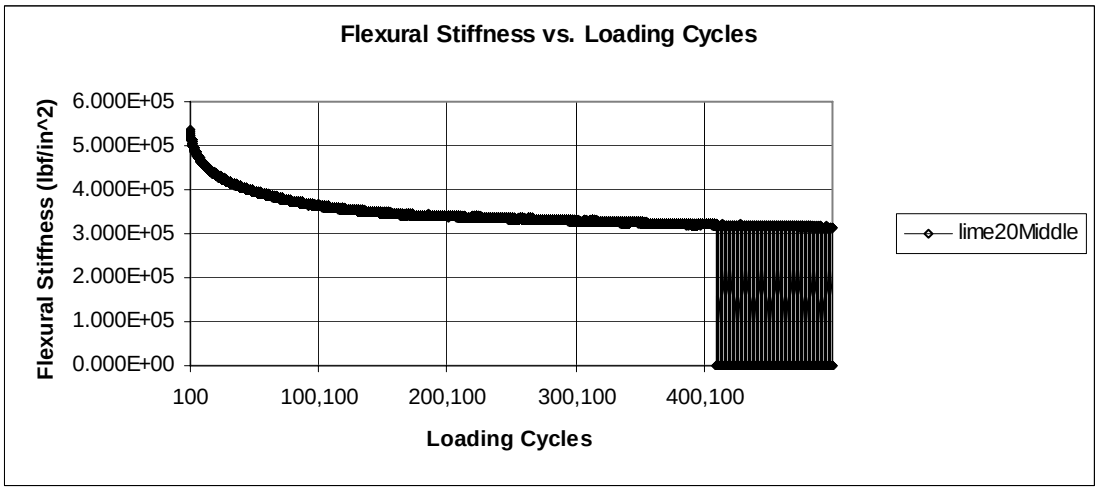


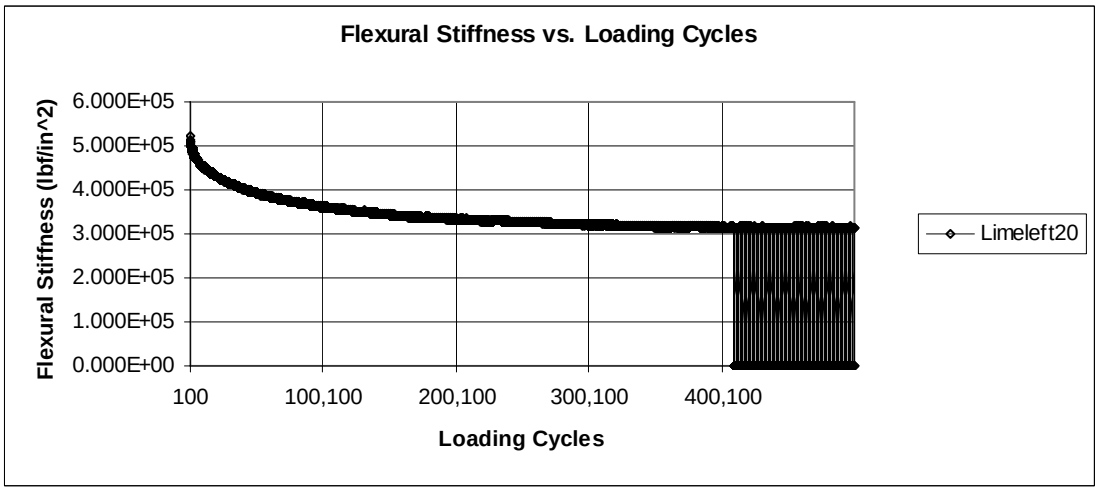




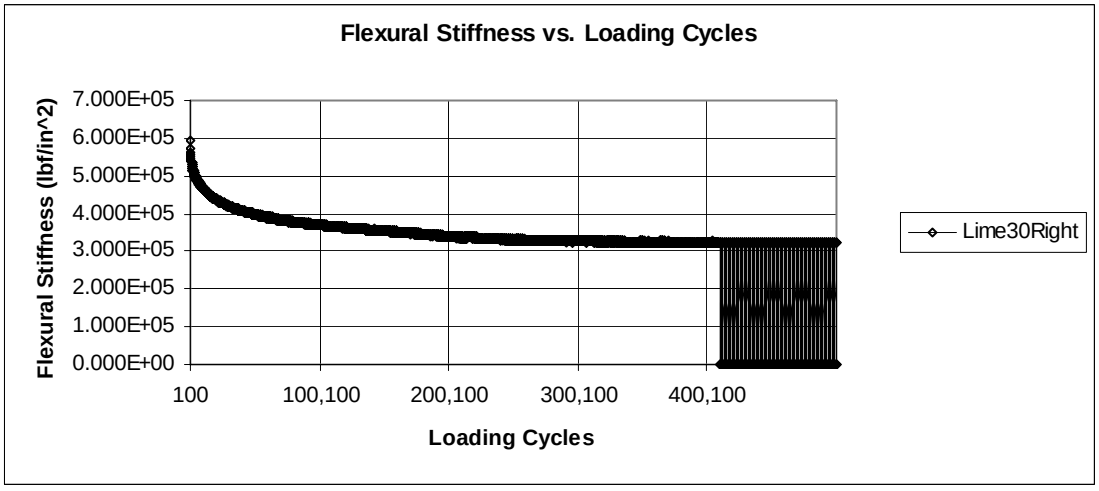
Limestone 76-22 LTA 20%

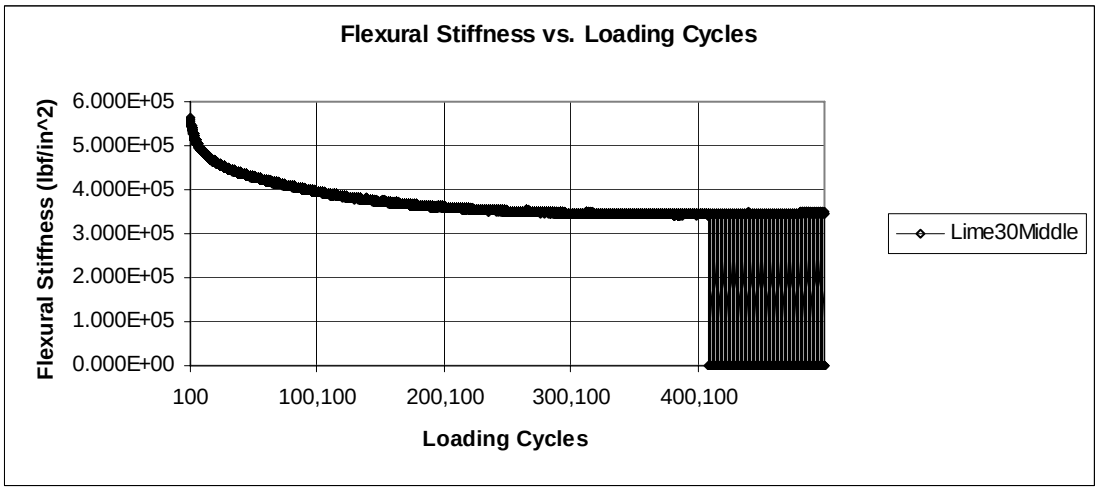


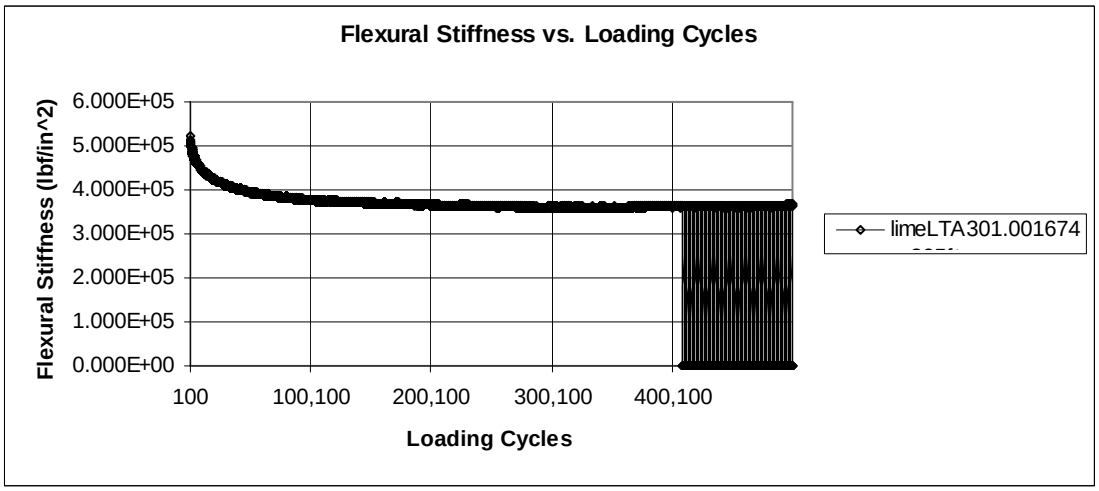




Limestone 76-22 LTA 30%







Gravel Mixtures (Plateau Values)

PG 64-22 Beam Fatigue Plateau Value Test Summary						
% RAP	Short-term Aged			Long-term Aged		
	Sample	Dissipated Energy	Average	Sample	Dissipated Energy	Average
0	Left	1.99E-05		Left	2.32E-05	
	Middle		2.054E-05	Middle	2.50E-05	2.410E-05
	Right	2.11E-05		Right		
10	Left	2.08E-05		Left	2.46E-05	
	Middle	2.38E-05	2.238E-05	Middle	2.68E-05	2.570E-05
	Right	2.25E-05		Right		
20	Left	2.36E-05		Left		
	Middle	2.41E-05	2.318E-05	Middle	2.64E-05	2.621E-05
	Right	2.18E-05		Right	2.60E-05	
30	Left	2.51E-05		Left	3.04E-05	
	Middle	2.40E-05	2.459E-05	Middle	3.78E-05	3.500E-05
	Right			Right	3.68E-05	

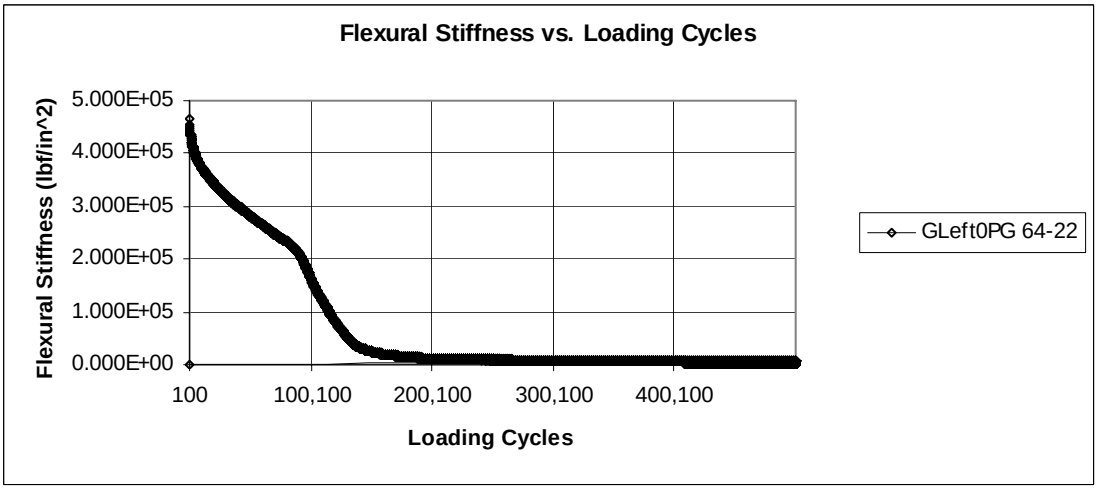
PG70-22 Beam Fatigue Plateau Value Test Summary						
% RAP	Short -term Aged			Long-term Aged		
	Sample	Dissipated Energy	Average	Sample	Dissipated Energy	Average
0	Left	2.04E-05		Left	1.98E-05	
	Middle	1.97E-05	2.037E-05	Middle	2.19E-05	2.051E-05
	Right	2.10E-05		Right	1.99E-05	
10	Left	1.85E-05		Left	2.04E-05	
	Middle	2.30E-05	2.090E-05	Middle	2.01E-05	2.009E-05
	Right	2.12E-05		Right	1.98E-05	
20	Left	2.81E-06		Left		
	Middle	2.18E-05	1.233E-05	Middle	2.04E-05	2.176E-05
	Right			Right	2.32E-05	
30	Left	2.28E-05		Left	2.44E-05	
	Middle	2.68E-05	2.388E-05	Middle		4.050E-05
	Right	2.21E-05		Right	5.66E-05	

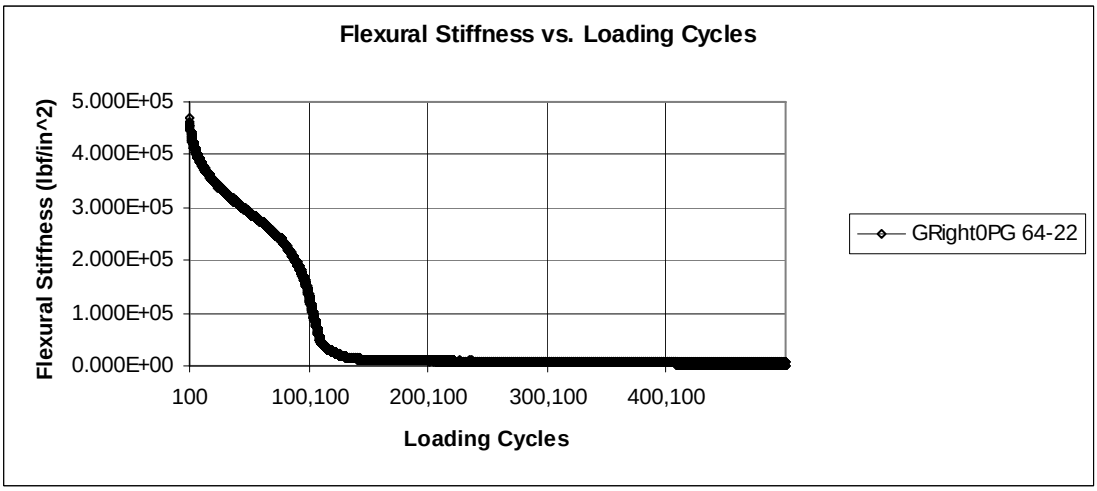
50% Initial Stiffness Failure

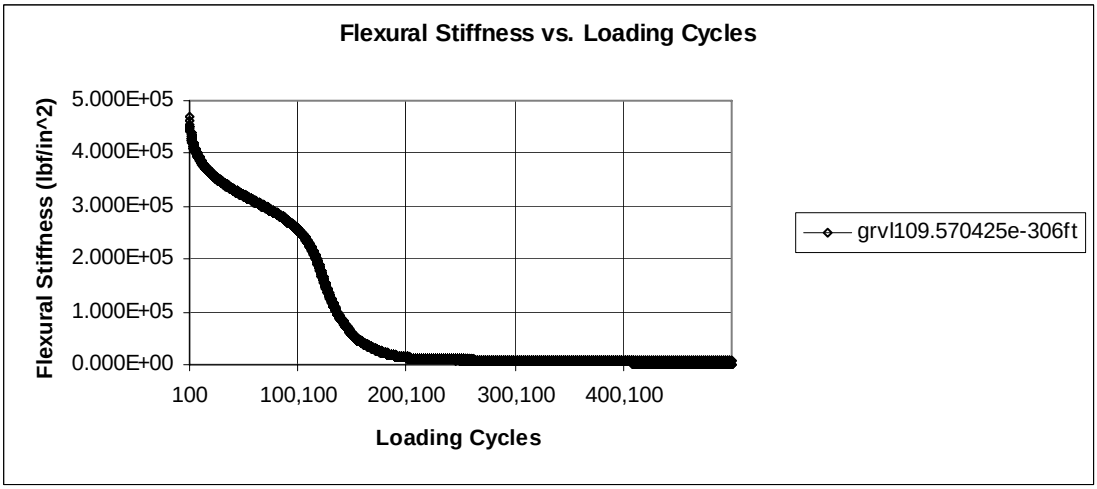
Gravel PG 64-22 Beam Fatigue Test Summary								
	Long-term Aged				Unaged			
Percent Rap	Specimen	Cycles, N	Cummulative Dissipated Energy (in-lbf/in^3)	Stiffnes	Specimen	Cycles, N	Cummulative Dissipated Energy (in-lbf/in^3)	Stiffnes
0%	1	35,110	5,719	456,717	1	80,400	11,044	465,330
	2	20,174	3,248	489,202	2			
	3	52,299	8,082	482,791	3	78,471	12,626	470,797
	Avg.	**35,861**	**5,683**	**476,237**	**Avg.**	**79,436**	**11,835**	**468,064**
	Std.	16,076	2,417	17,206	Std.	1,364	1,119	3,866
	COV	45	43	4	COV	2	9	1
10%	1	134,098	19,233	601,456	1	108,504	15,564	467,900
	2	86,383	12,766	495,134	2	61,184	8,752	459,595
	3	15,267	2,159	497,824	3	116,285	16,988	492,271
	Avg.	**78,583**	**11,386**	**531,471**	**Avg.**	**95,324**	**13,768**	**473,255**
	Std.	59,798	8,620	60,623	Std.	29,821	4,402	16,984
	COV	76	76	11	COV	31	32	4
20%	1	113,992	16,808	583,219	1	52,609	7,993	531,042
	2	121,832	17,501	541,675	2	33,571	5,118	486,289
	3	88,169	13,141	590,654	3	60,050	8,676	477,098
	Avg.	**107,998**	**15,817**	**571,849**	**Avg.**	**48,743**	**7,262**	**498,143**
	Std.	17,614	2,343	26,395	Std.	13,656	1,888	28,860
	COV	16	15	5	COV	28	26	6
30%	1	58,987	8,565	607,524	1			
	2	76,162	10,911	742,427	2	84,805	13,097	551,608
	3	63,321	8,442	641,435	3	118,639	17,805	518,457
	Avg.	**66,157**	**9,306**	**663,795**	**Avg.**	**101,722**	**15,451**	**535,033**
	Std.	8,932	1,391	70,176	Std.	23,924	3,329	23,441
	COV	14	15	11	COV	24	22	4

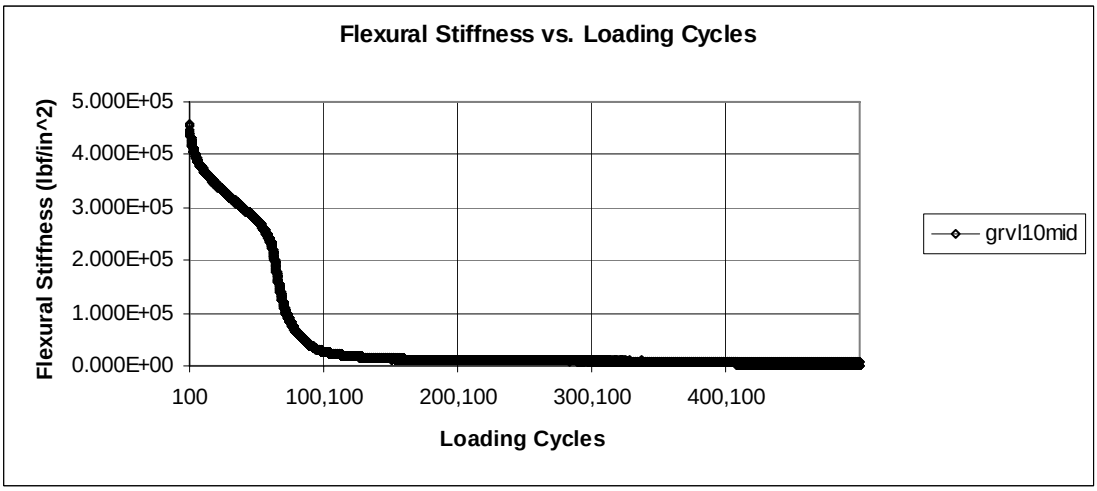
Gravel PG 70-22 Beam Fatigue Test Summary								
	Long-term Aged				Unaged			
Percent Rap	Specimen	Cycles, N	Cummulative Dissipated Energy (in-lbf/in^3)	Stiffnes	Specimen	Cycles, N	Cummulative Dissipated Energy (in-lbf/in^3)	Stiffnes
0%	1	195,122	26,846	436,385	1	324,043	50,647	411,718
	2	269,866	44,450	463,120	2	138,176	22,199	549,025
	3	299,168	48,292	496,782	3	239,417	36,780	486,238
	Avg.	**254,719**	**39,863**	**465,429**	**Avg.**	**233,879**	**36,542**	**482,327**
	Std.	53,651	11,435	30,265	Std.	93,057	14,225	68,737
	COV	21	29	7	COV	40	39	14
10%	1	205,341	32,514	507,479	1	315,819	51,917	468,183
	2	333,546	53,301	486,142	2	409,195	67,472	432,183
	3	409,653	66,378	483,268	3	173,123	26,859	479,340
	Avg.	**316,180**	**50,731**	**492,296**	**Avg.**	**299,379**	**48,749**	**459,902**
	Std.	103,257	17,078	13,227	Std.	118,892	20,491	24,645
	COV	33	34	3	COV	40	42	5
20%	1				1			
	2	175,795	26,563	604,555	2	409,793	61,698	437,303
	3	206,604	34,957	616,244	3	134,734	21,218	536,835
	Avg.	**127,466**	**20,507**	**406,933**	**Avg.**	**181,509**	**27,639**	**324,713**
	Std.	21,785	5,935	8,265	Std.	194,496	28,624	70,380
	COV	17	29	2	COV	107	104	22
30%	1	317,302	48,525	649,320	1	290,492	46,279	644,090
	2	55,815	8,052	640,959	2	70,283	9,773	514,631
	3	409,660	48,880	767,347	3	203,832	31,935	578,158
	Avg.	**260,926**	**35,152**	**685,875**	**Avg.**	**188,202**	**29,329**	**578,960**
	Std.	183,536	23,470	70,680	Std.	110,933	18,392	64,733
	COV	70	67	10	COV	59	63	11

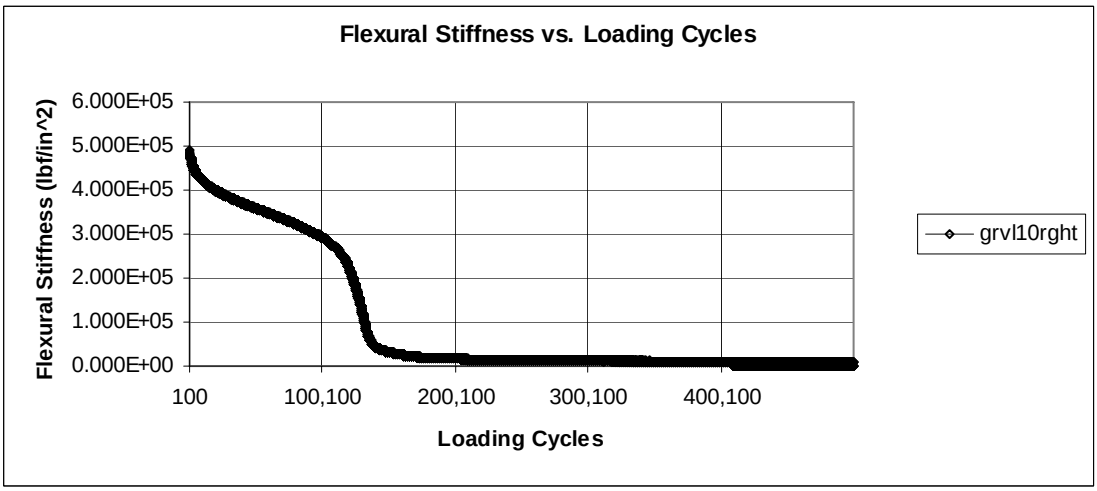
Gravel 64-22 STA 0%

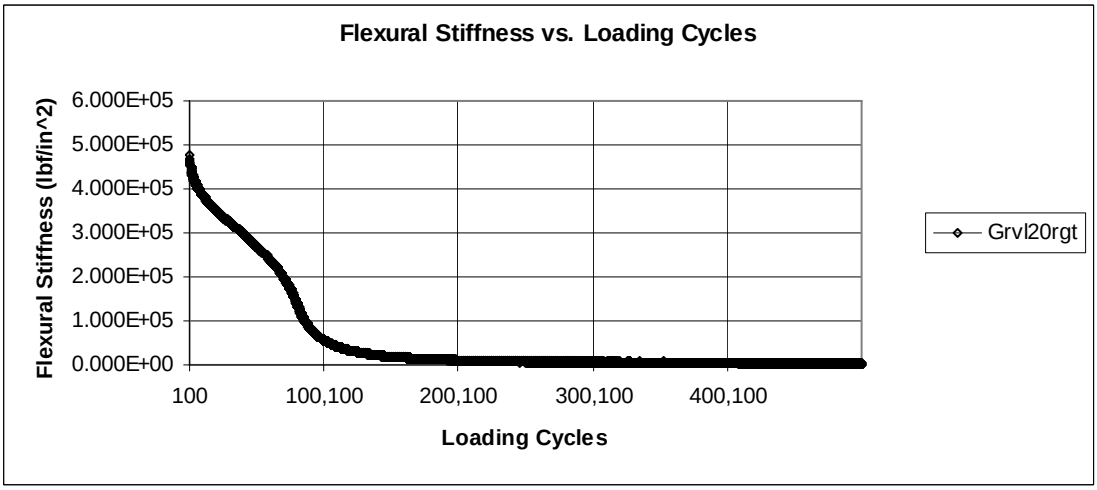


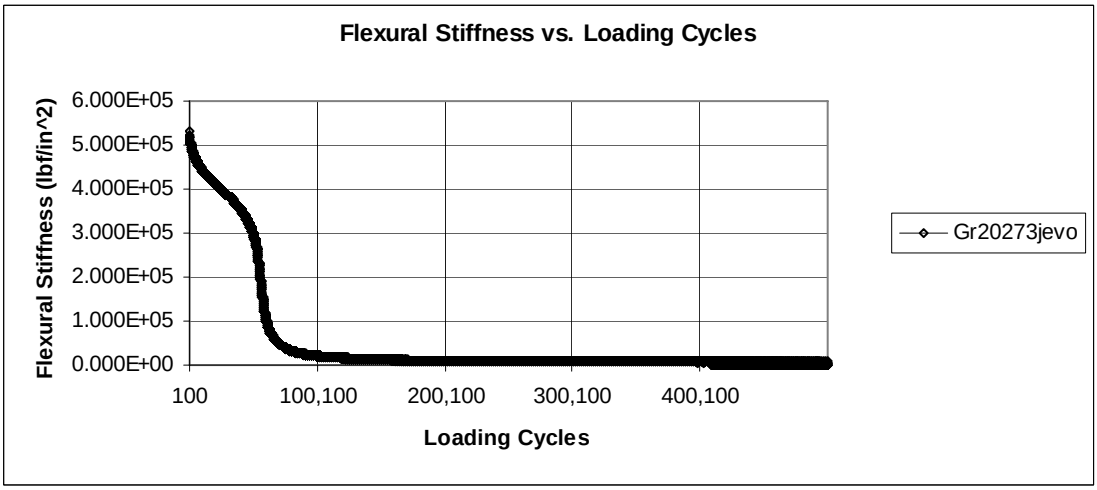


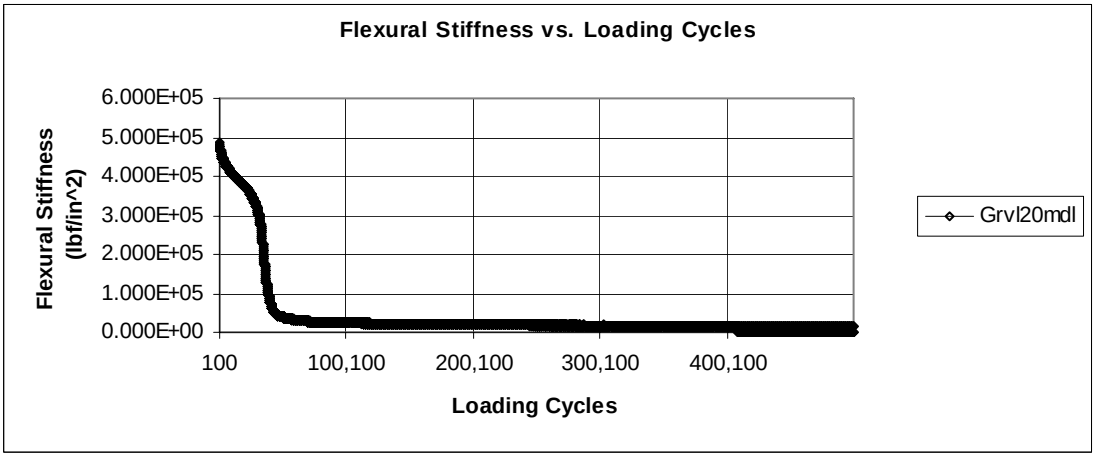

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
grvl109.570425e-306ft


Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
grvl10mid

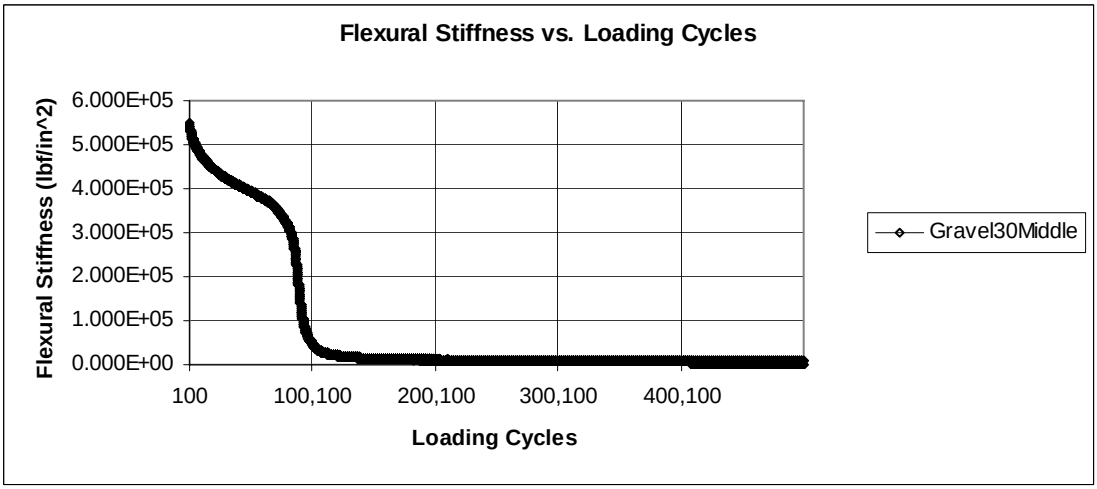

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
grvl10rght

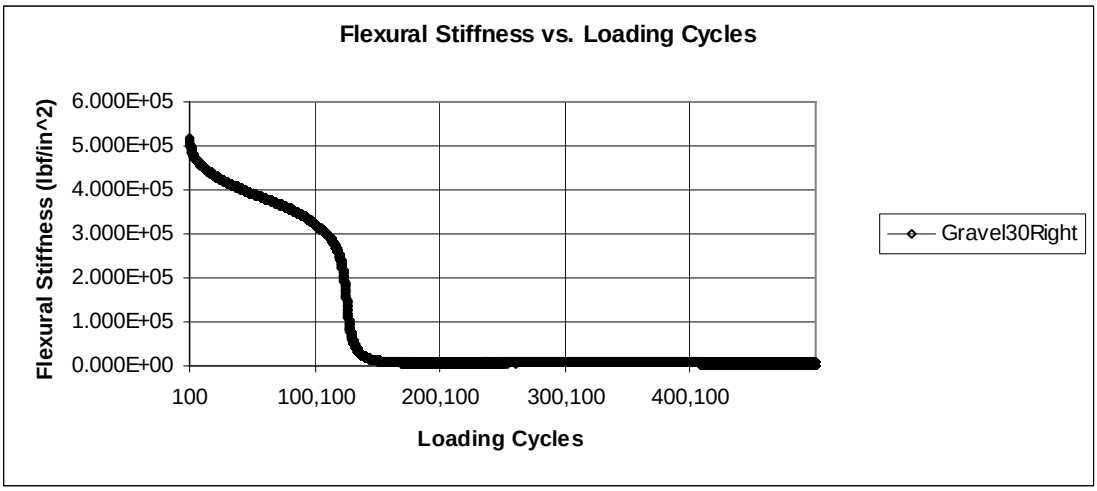

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
Grvl20rgt

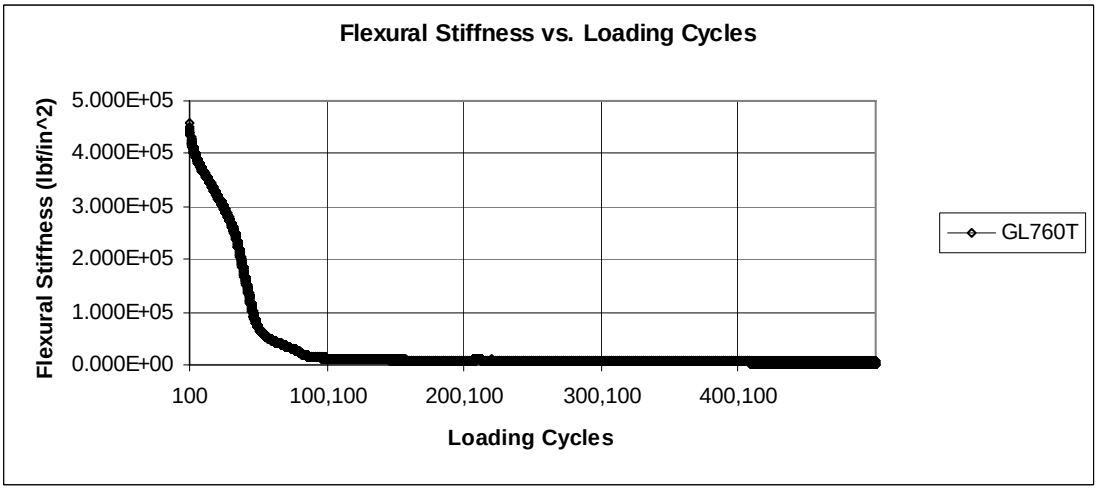

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
Gr20273jevo

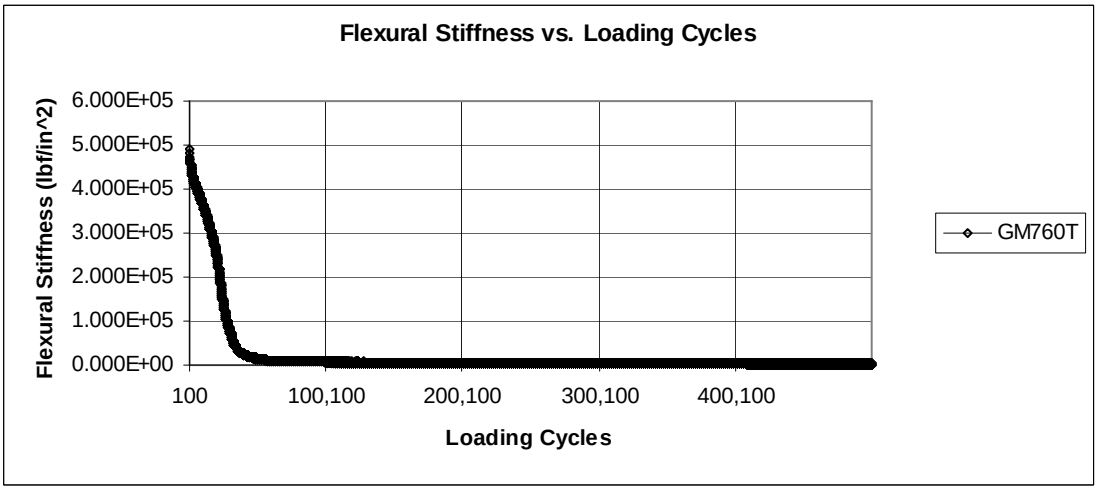

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
Grvl20mdl

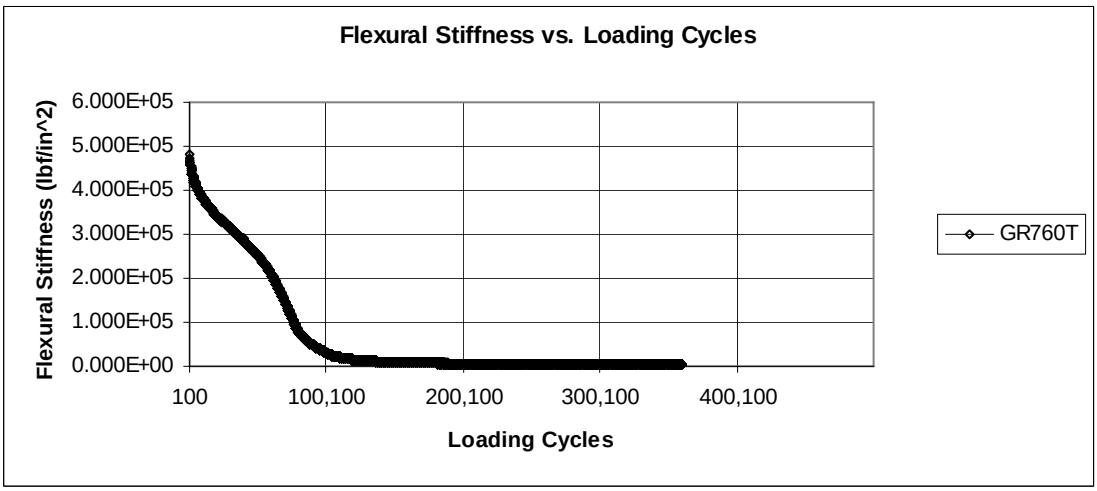
Gravel 64-22 STA 30%

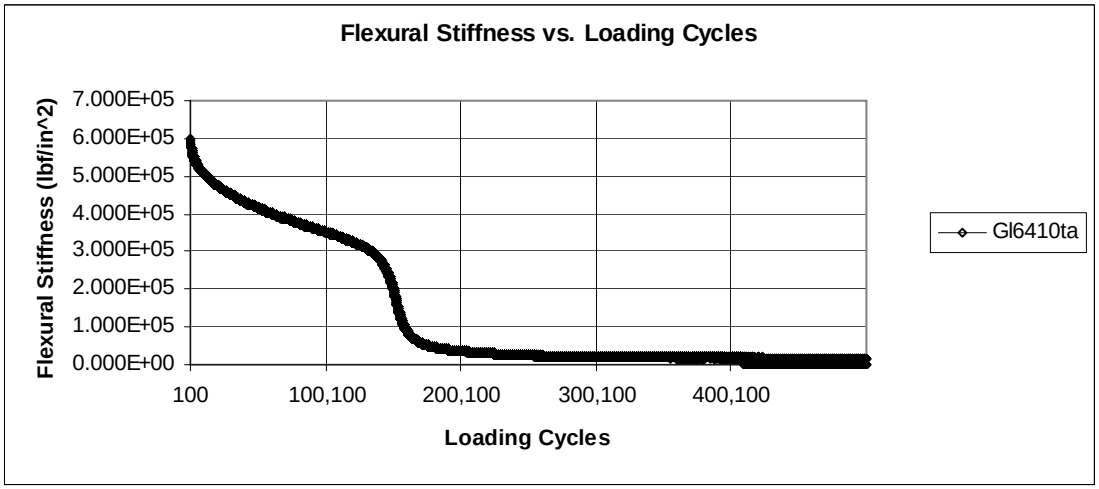


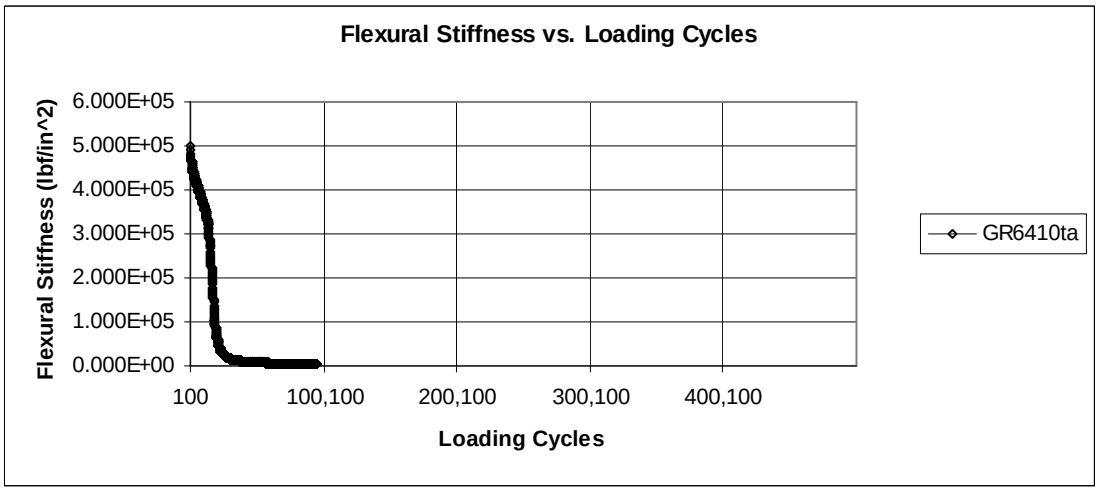


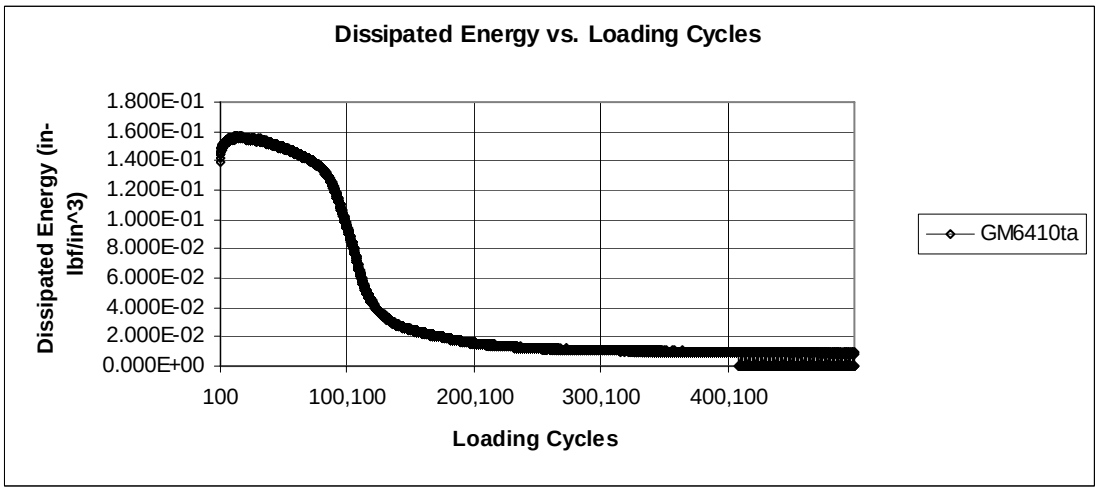

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
GL760T


Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
GM760T

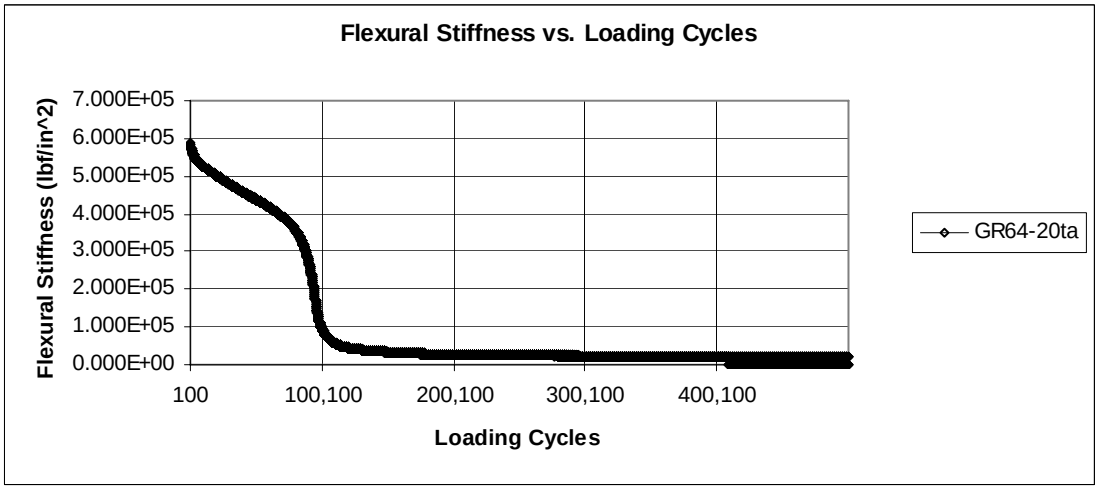

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
GR760T

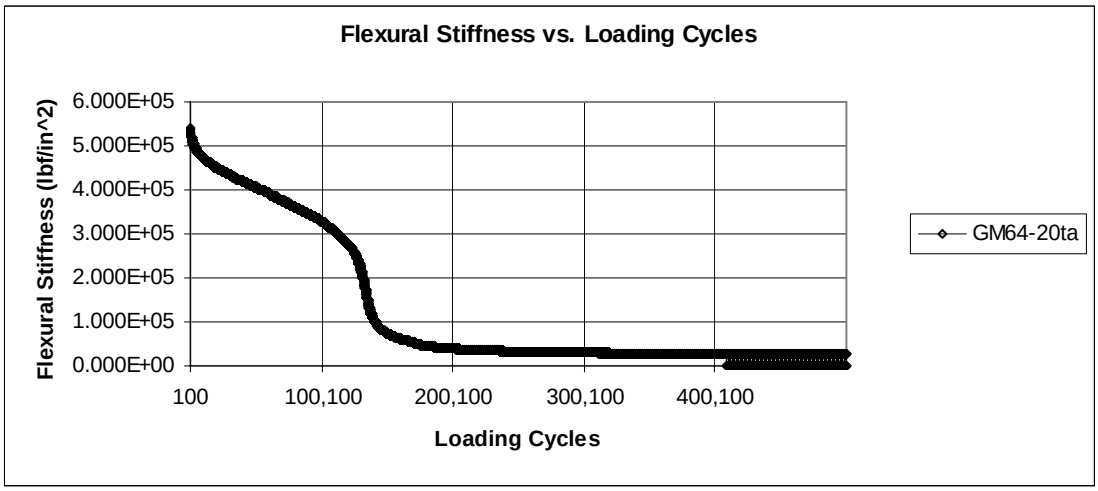

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
7.000E+05
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
Gl6410ta

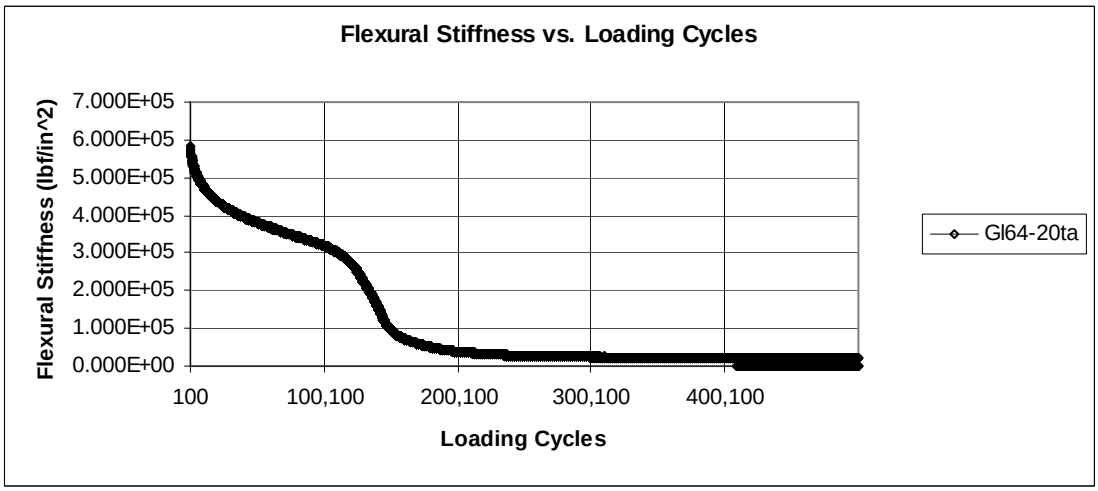

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
GR6410ta


Dissipated Energy vs. Loading Cycles
Dissipated Energy (in-lbf/in^3)
1.800E-01
1.600E-01
1.400E-01
1.200E-01
1.000E-01
8.000E-02
6.000E-02
4.000E-02
2.000E-02
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
GM6410ta

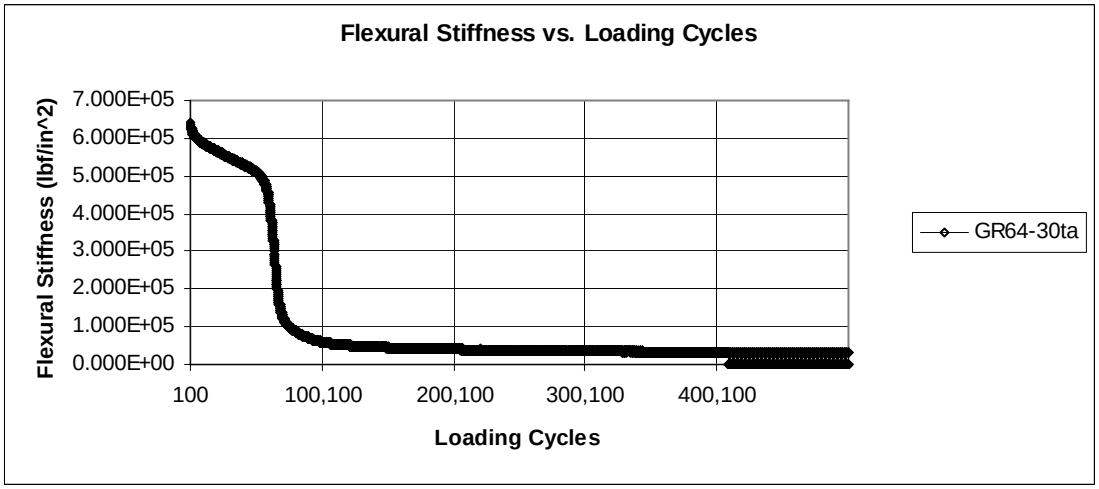
Gravel 64-22 LTA 20%

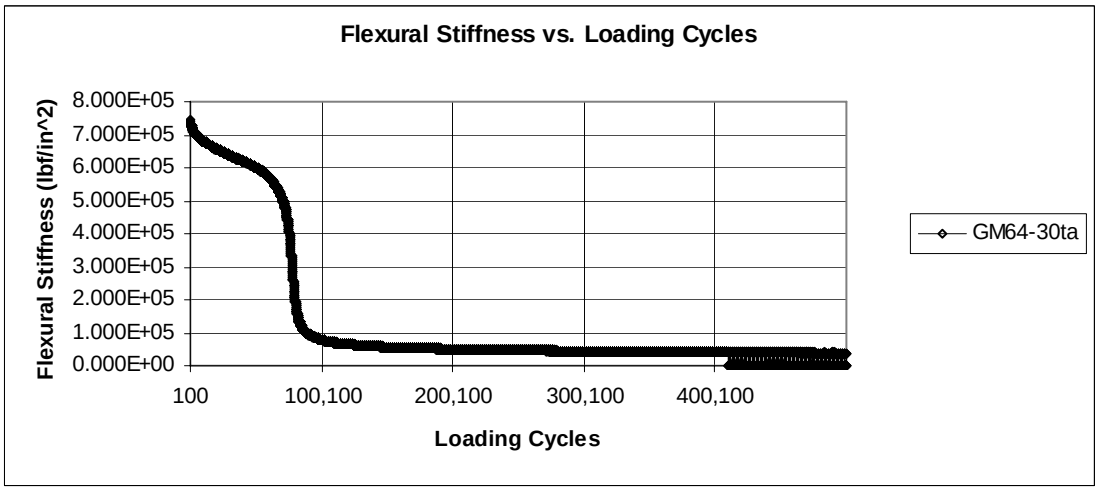


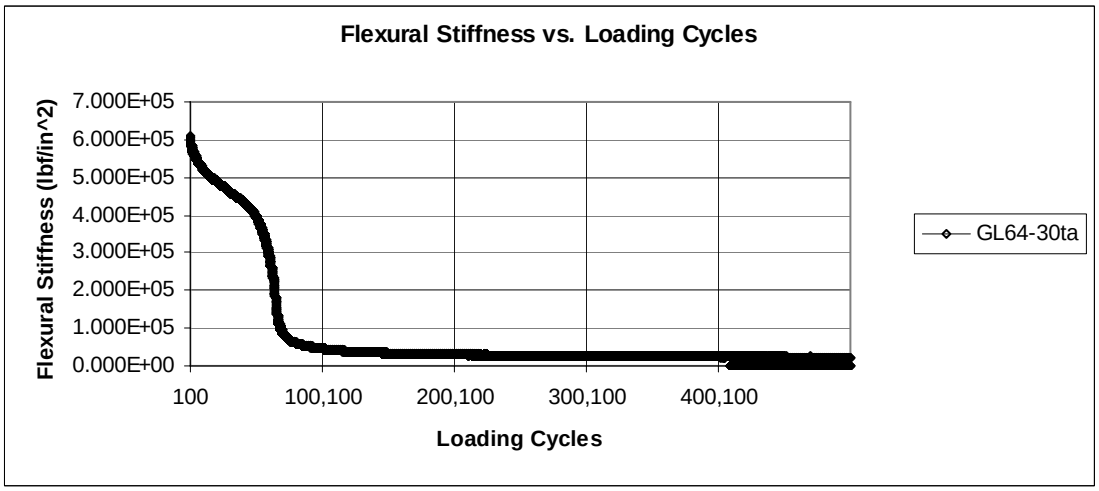




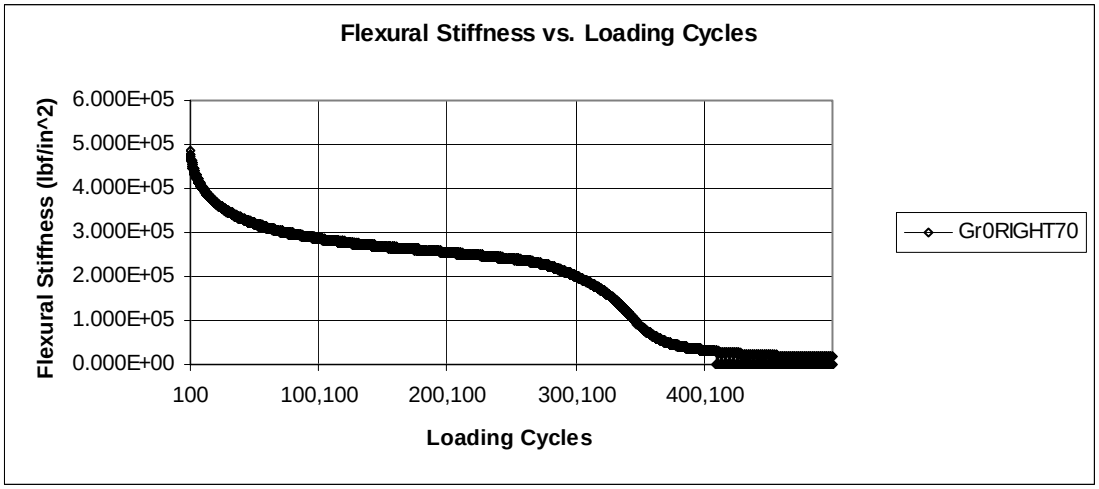
Gravel 64-22 LTA 30%

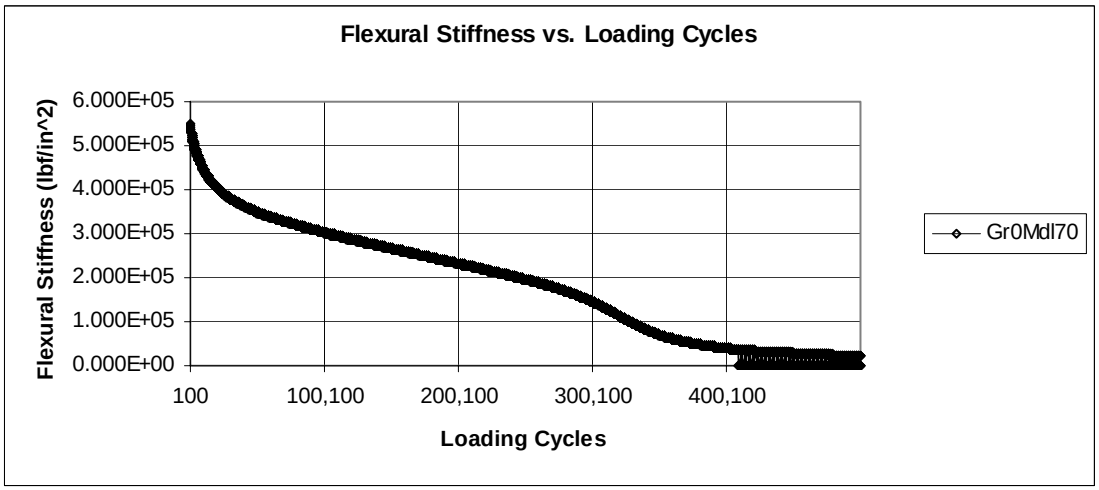


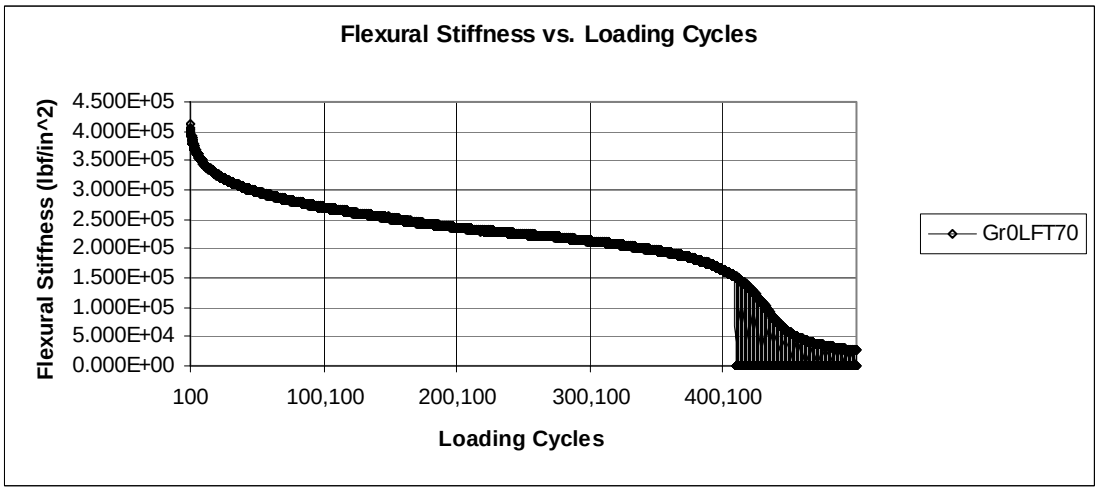


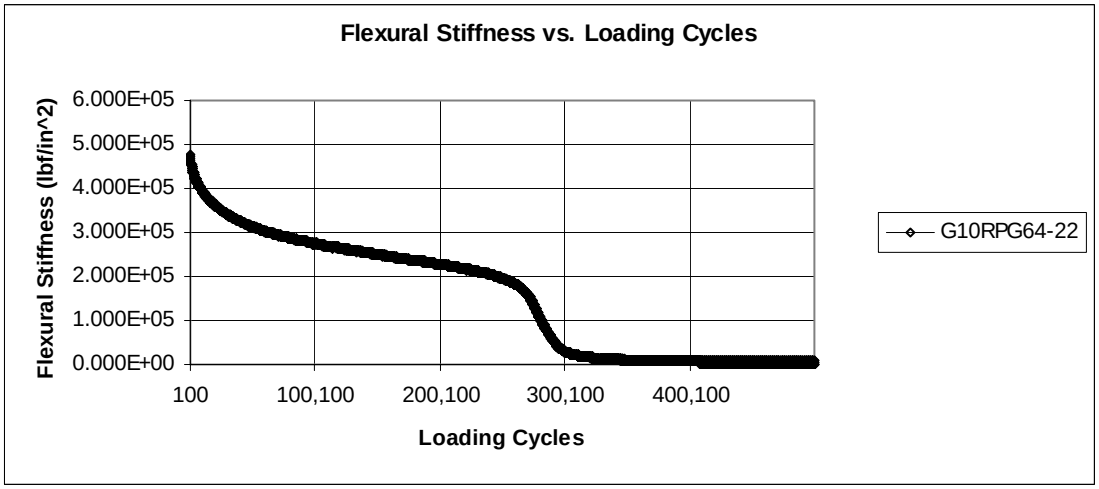


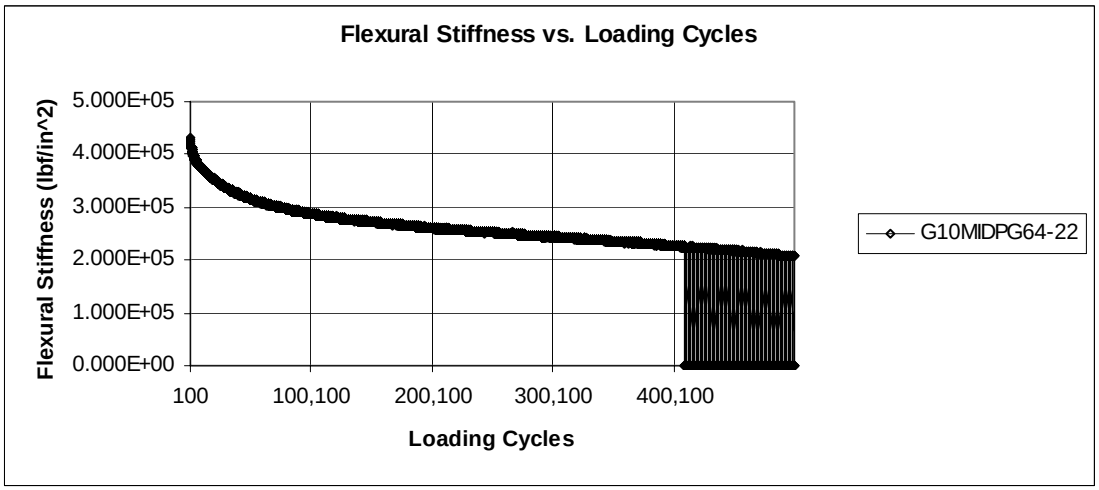
Gravel 70-22 STA 0%

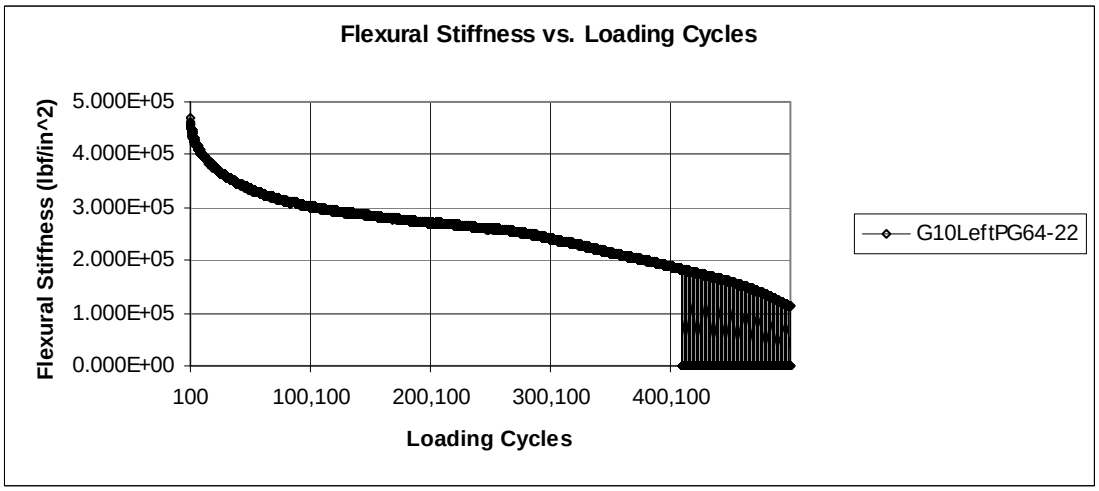




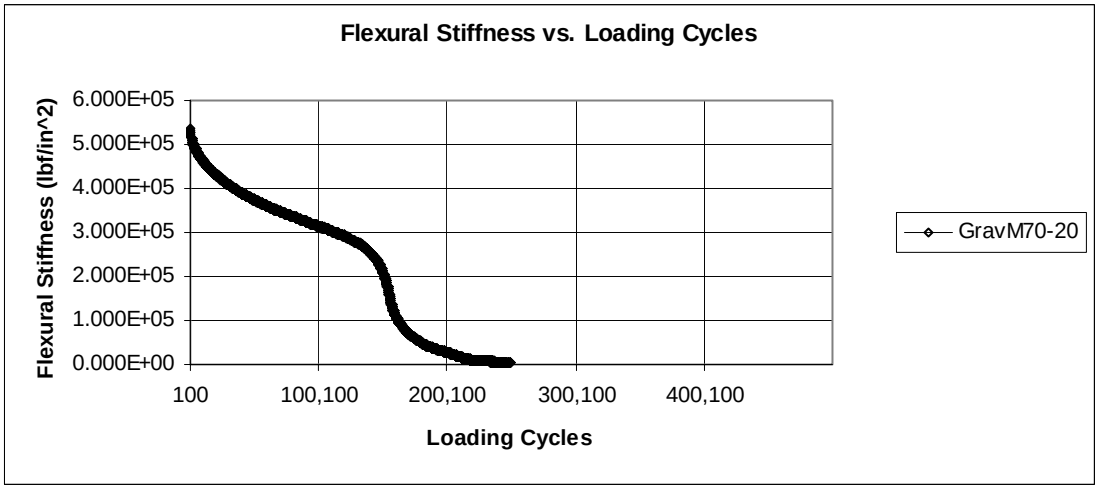


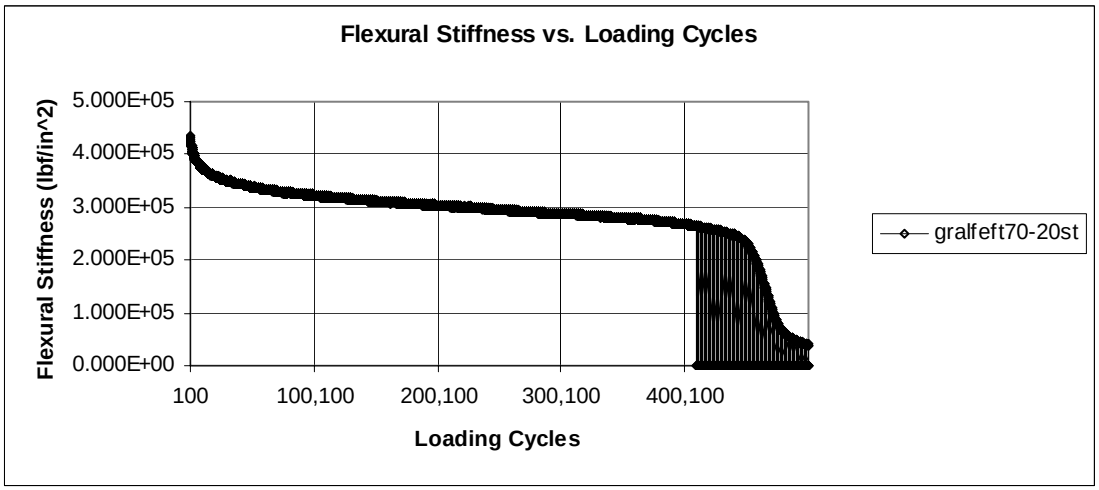

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
G10RPG64-22


Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
G10MIDPG64-22

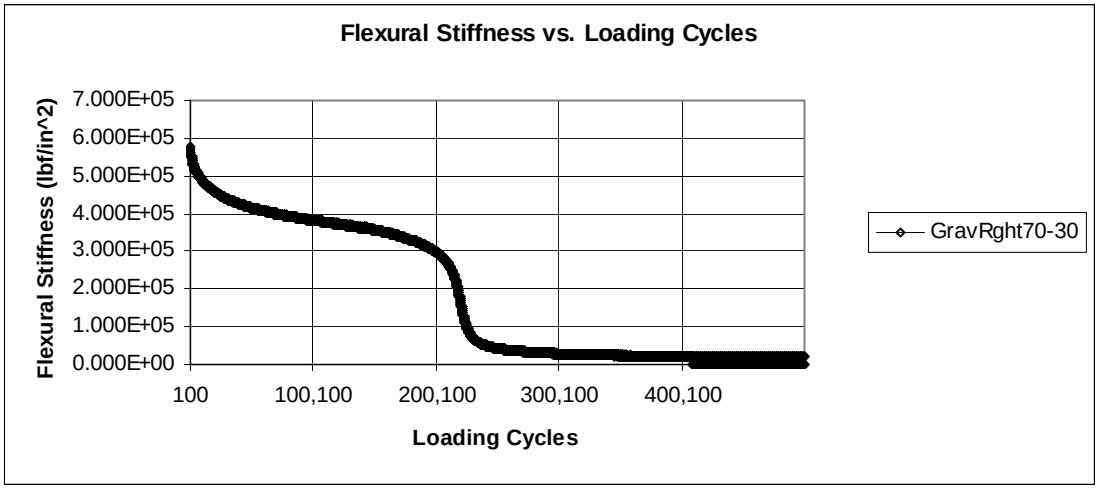

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
G10LeftPG64-22

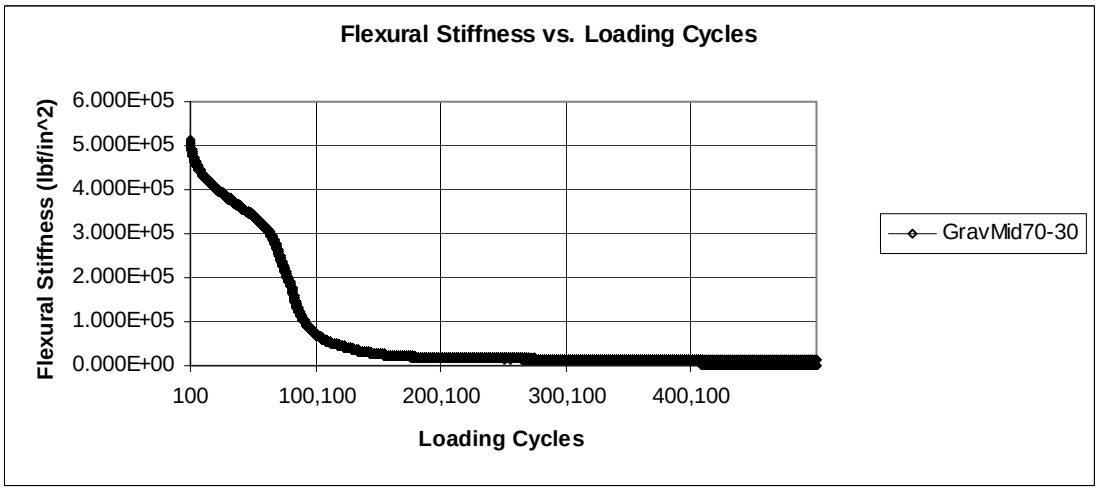
Gravel 70-22 STA 20%

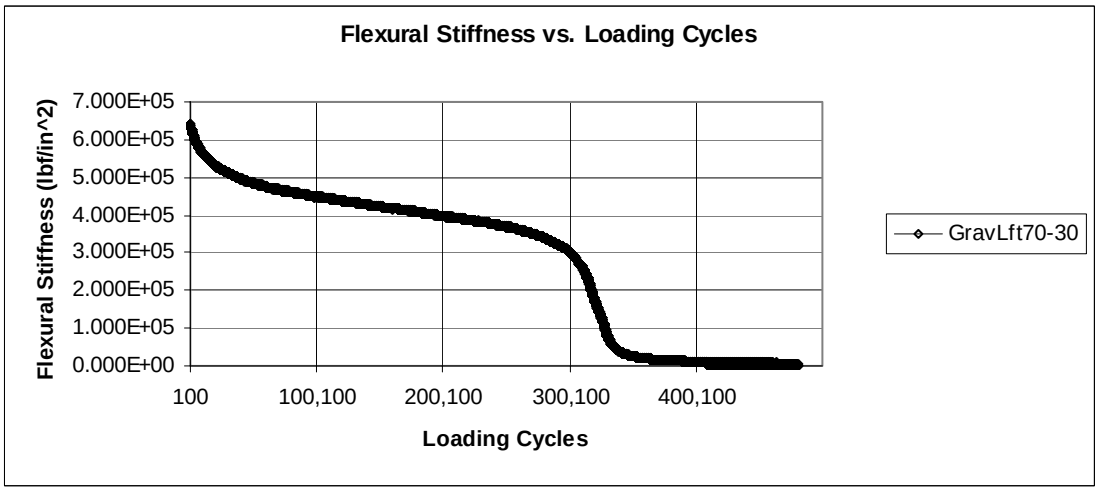


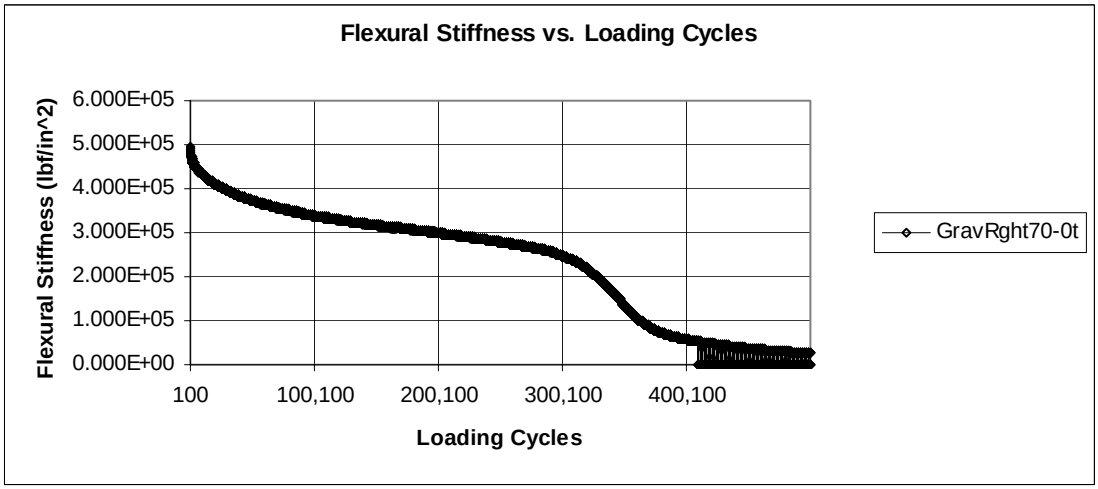


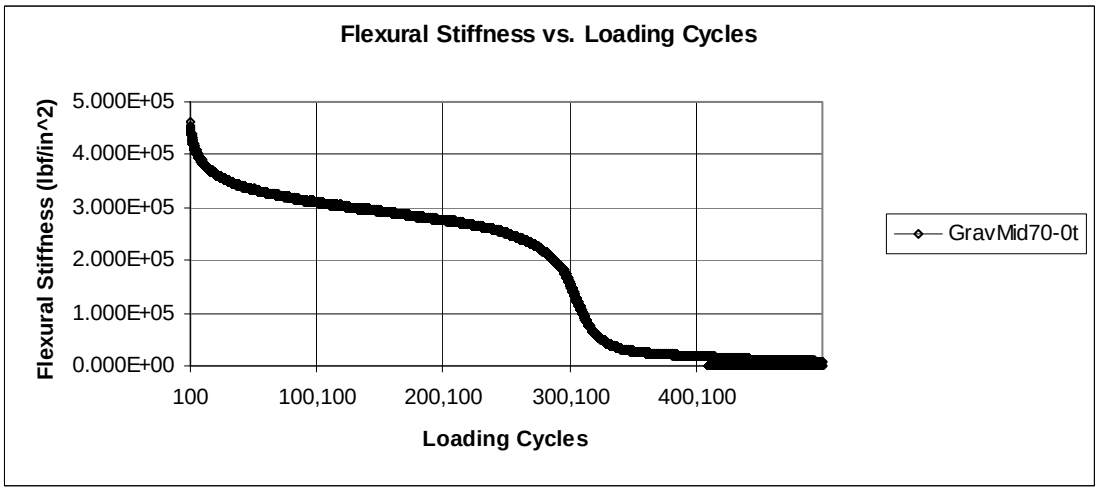
Gravel 70-22 STA 30%

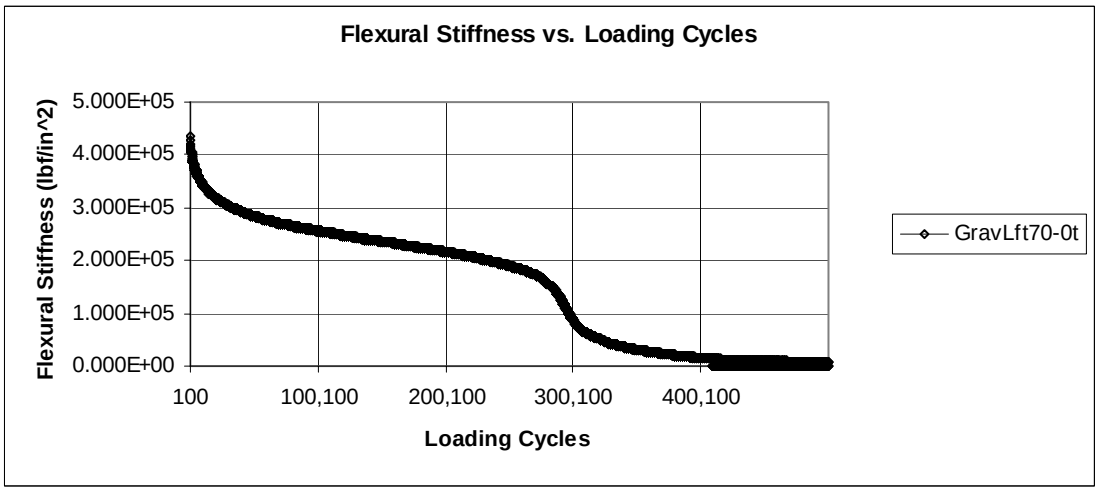


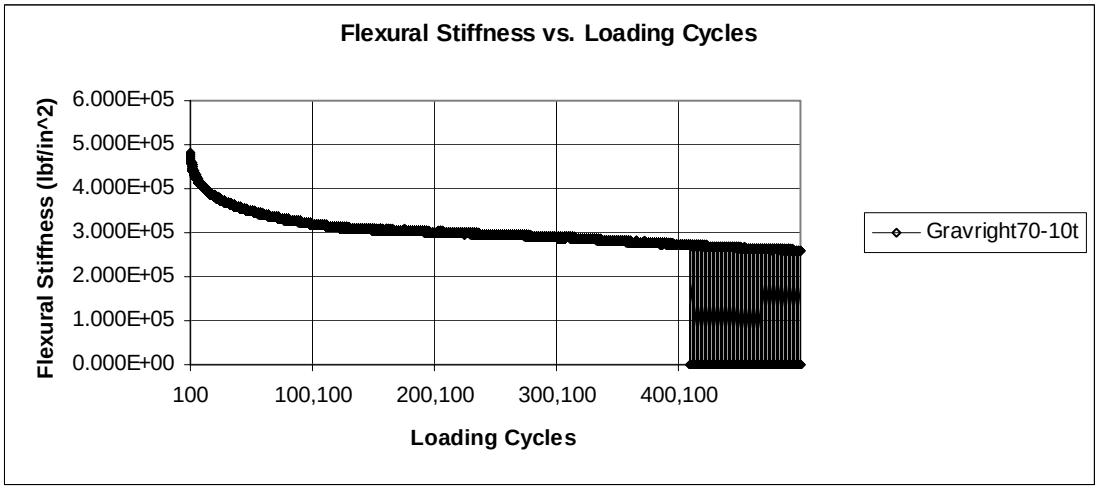


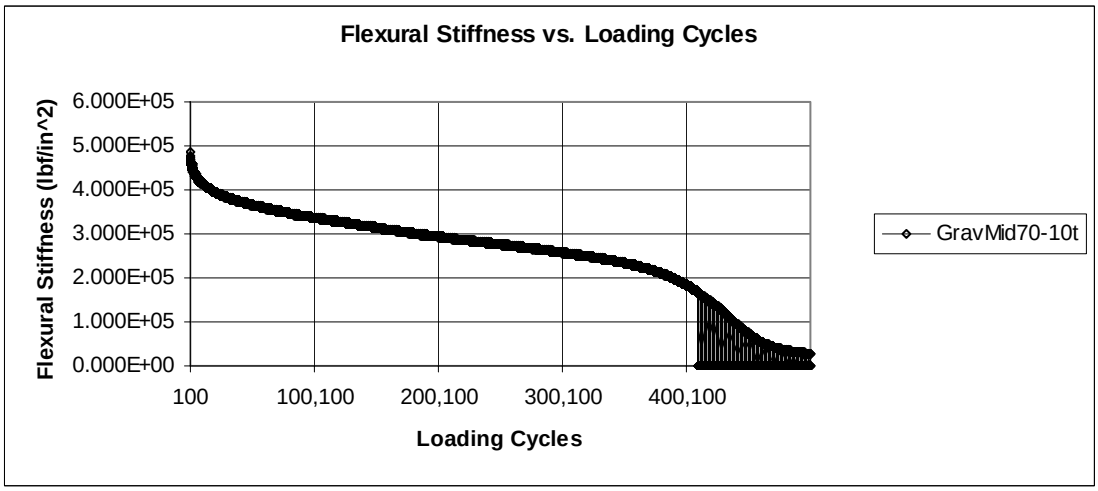


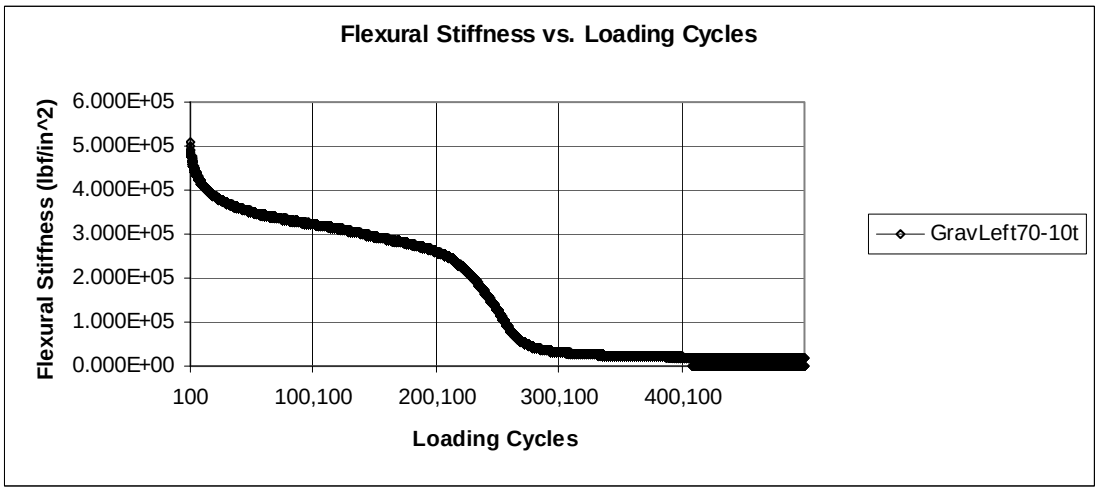

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
GravRght70-0t

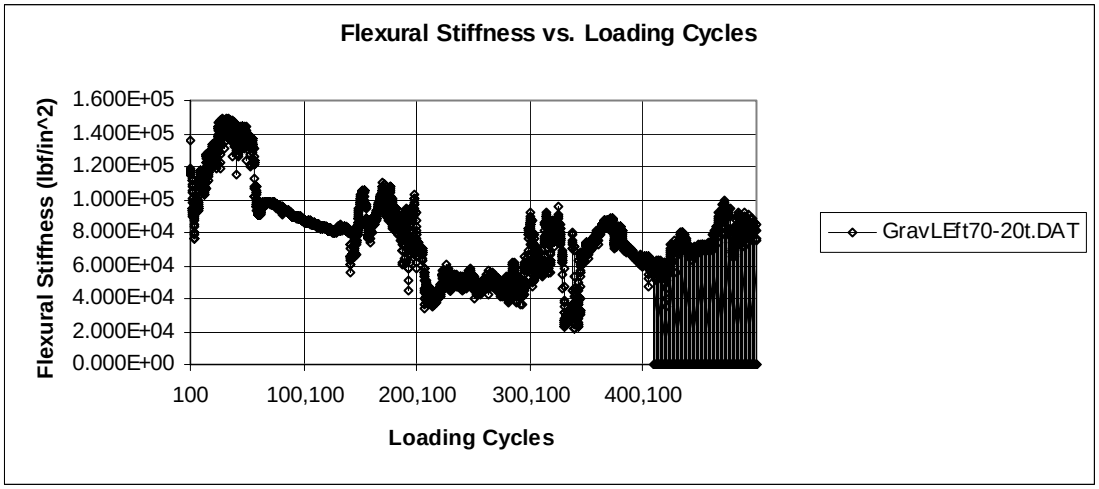

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
GravMid70-0t

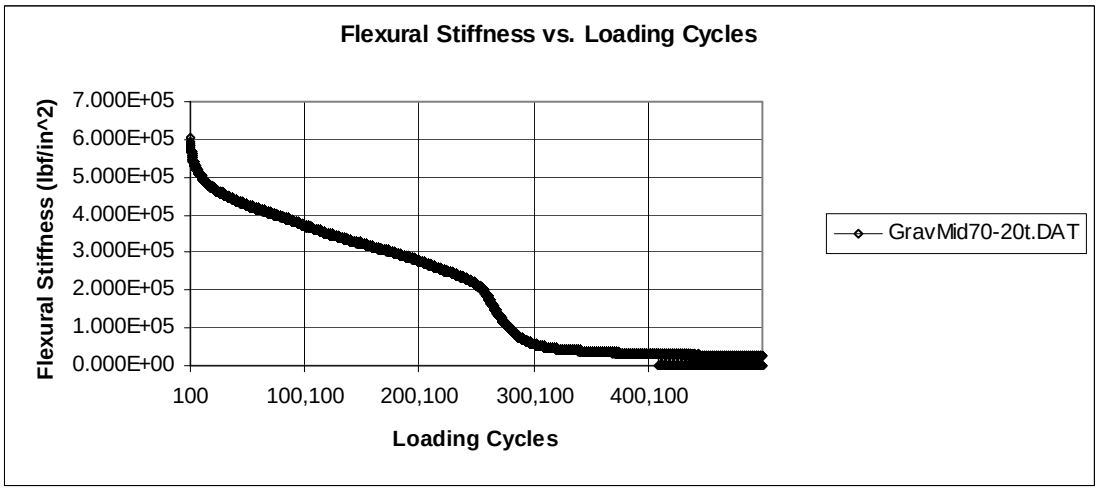

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
GravLft70-0t

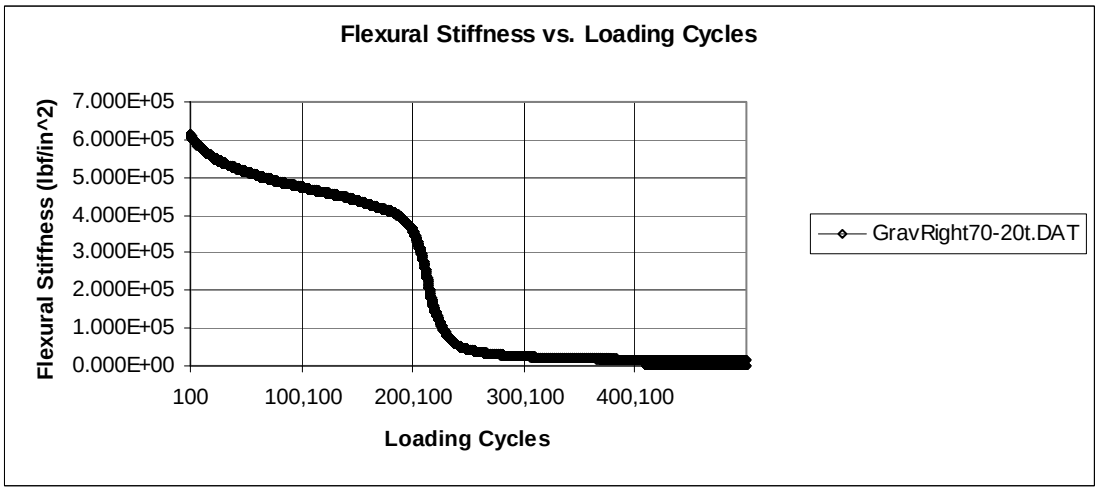

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
Gravright70-10t

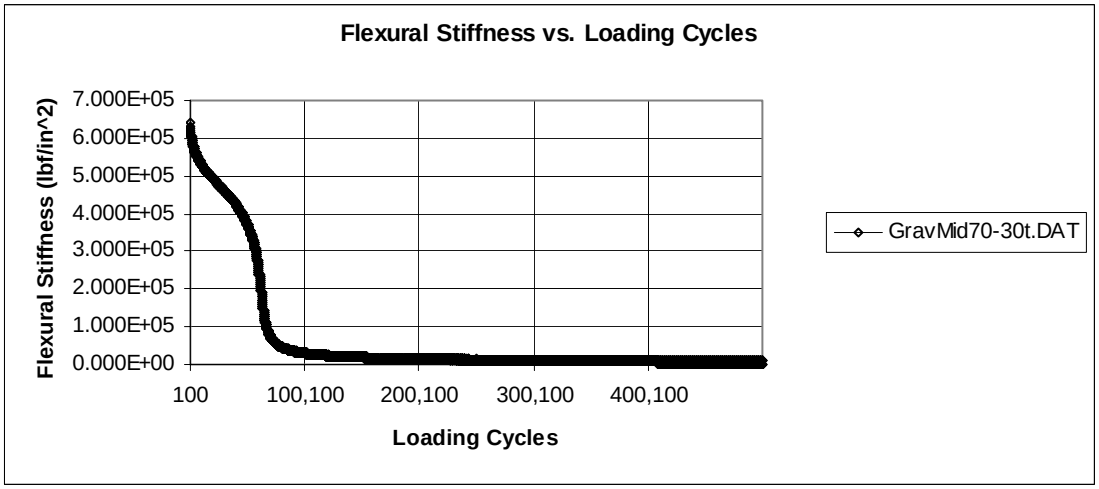

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
GravMid70-10t

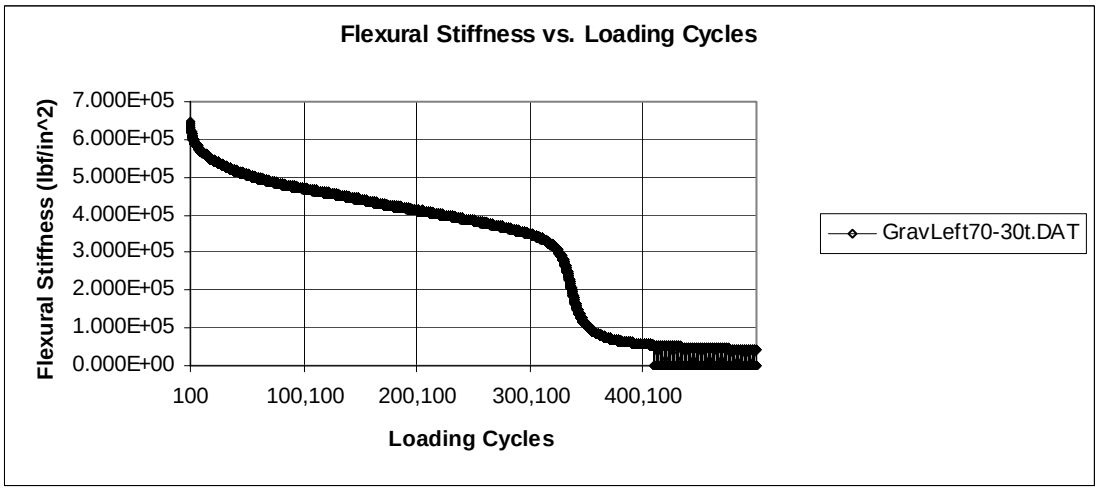

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
GravLeft70-10t

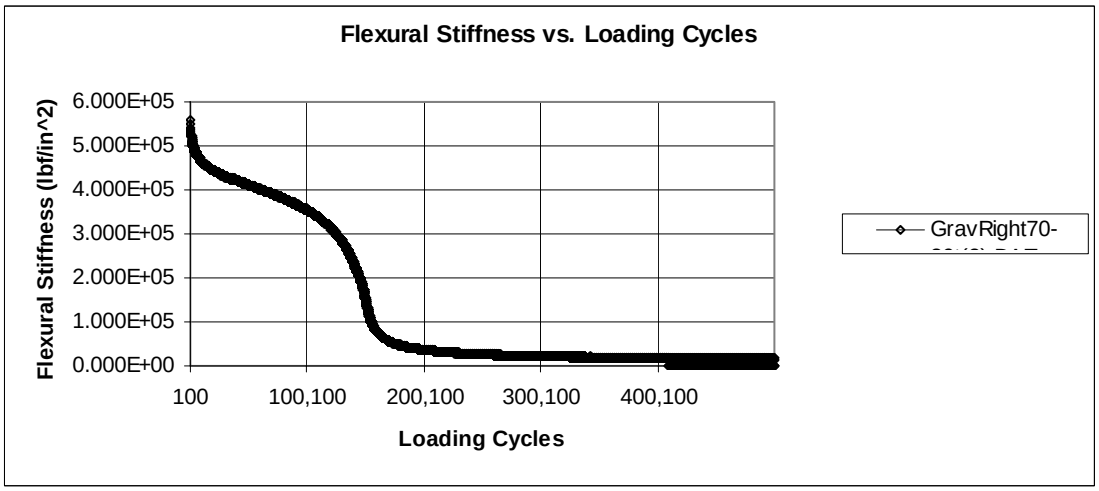

Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
1.600E+05
1.400E+05
1.200E+05
1.000E+05
8.000E+04
6.000E+04
4.000E+04
2.000E+04
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
GravLEft70-20t.DAT


Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
7.000E+05
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
GravMid70-20t.DAT


Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
7.000E+05
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
GravRight70-20t.DAT


Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
7.000E+05
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
GravMid70-30t.DAT


Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
7.000E+05
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
GravLeft70-30t.DAT


Flexural Stiffness vs. Loading Cycles
Flexural Stiffness (lbf/in^2)
6.000E+05
5.000E+05
4.000E+05
3.000E+05
2.000E+05
1.000E+05
0.000E+00
100
100,100
200,100
300,100
400,100
Loading Cycles
GravRight70-

APPENDIX G: MIXTURE AGGREGATE PROPERTIES DATA

Limestone Mixtures PG 64-22 (Aggregate Properties)

0%	**Truck 1**										
	Gradation	100	95.5	85.3	58.9	39.8	28.1	19.3	11.1	4.5	1.3
		100	94.2	84.2	57.4	38.5	26.6	17.7	9.7	3.3	1.1
		100	96.8	86.4	60.4	41.1	29.6	20.9	12.5	5.7	1.5
	Average	**100.0**	**95.5**	**85.3**	**58.9**	**39.8**	**28.1**	**19.3**	**11.1**	**4.5**	**1.3**
	Truck 2										
	Gradation	100	95.6	88.1	65.7	46.4	34.1	24.7	12.8	5.4	3.4
		100	94.3	87	64.2	45.1	32.6	23.1	11.4	4.2	3.2
		100	96.9	89.2	67.2	47.7	35.6	26.3	14.2	6.6	3.6
	Average	**100.0**	**95.6**	**88.1**	**65.7**	**46.4**	**34.1**	**24.7**	**12.8**	**5.4**	**3.4**
	Truck 3										
	Gradation	100	96	88.3	67	50.4	37	26.7	13.5	5.3	3.2
		100	94.7	87.2	65.5	49.1	35.5	25.1	12.1	4.1	3
		100	97.3	89.4	68.5	51.7	38.5	28.3	14.9	6.5	3.4
	Average	**100.0**	**96.0**	**88.3**	**67.0**	**50.4**	**37.0**	**26.7**	**13.5**	**5.3**	**3.2**
	AVERAGE OF 3	***100.0***	***95.7***	***87.2***	***63.9***	***45.5***	***33.1***	***23.6***	***12.5***	***5.1***	***2.6***
10%	**Truck 1**										
	Gradation	100	95.3	86	63.8	45.9	33.6	24.2	12.4	4.9	2.7
		100	94	84.9	62.3	44.6	32.1	22.6	11	3.7	2.5
		100	96.6	87.1	65.3	47.2	35.1	25.8	13.8	6.1	2.9
	Average	**100.0**	**95.3**	**86.0**	**63.8**	**45.9**	**33.6**	**24.2**	**12.4**	**4.9**	**2.7**
	Truck 2										
	Gradation	100	95.9	88.5	66	47.4	34.4	24.5	12.2	4.6	2.5
		100	94.6	87.4	64.5	46.1	32.9	22.9	10.8	3.4	2.3
		100	97.2	89.6	67.5	48.7	35.9	26.1	13.6	5.8	2.7
	Average	**100.0**	**95.9**	**88.5**	**66.0**	**47.4**	**34.4**	**24.5**	**12.2**	**4.6**	**2.5**
	Truck 3										
	Gradation	100	95.8	86.4	64.5	46.1	33.5	24	12	4.5	2.5
		100	94.5	85.3	63	44.8	32	22.4	10.6	3.3	2.3
		100	97.1	87.5	66	47.4	35	25.6	13.4	5.7	2.7
	Average	**100.0**	**95.8**	**86.4**	**64.5**	**46.1**	**33.5**	**24.0**	**12.0**	**4.5**	**2.5**
	AVERAGE OF 3	***100.0***	***95.7***	***87.0***	***64.8***	***46.5***	***33.8***	***24.2***	***12.2***	***4.7***	***2.6***
20%	**Truck 1**										
	Gradation	100	95.8	87.2	64.3	46.9	34.3	24.7	12.4	4.7	2.6
			94.5	86.1	62.8	45.6	32.8	23.1	11	3.5	2.4
			97.1	88.3	65.8	48.2	35.8	26.3	13.8	5.9	2.8
	Average	**100.0**	**95.8**	**87.2**	**64.3**	**46.9**	**34.3**	**24.7**	**12.4**	**4.7**	**2.6**
	Truck 2										
	Gradation	100	96.5	87.9	65.1	47.7	34.7	24.9	12.3	4.7	2.5
			95.2	86.8	63.6	46.4	33.2	23.3	10.9	3.5	2.3
			97.8	89	66.6	49	36.2	26.5	13.7	5.9	2.7
	Average	**100.0**	**96.5**	**87.9**	**65.1**	**47.7**	**34.7**	**24.9**	**12.3**	**4.7**	**2.5**
	Truck 3										
	Gradation	100	95.7	85	61.1	44	32.4	23.3	11.6	4.4	2.5
			94.4	83.9	59.6	42.7	30.9	21.7	10.2	3.2	2.3
			97	86.1	62.6	45.3	33.9	24.9	13	5.6	2.7
	Average	**100.0**	**95.7**	**85.0**	**61.1**	**44.0**	**32.4**	**23.3**	**11.6**	**4.4**	**2.5**
	AVERAGE OF 3	***100.0***	***96.0***	***86.7***	***63.5***	***46.2***	***33.8***	***24.3***	***12.1***	***4.6***	***2.5***
30%	**Truck 1**										
	Gradation	100	97.9	91.5	69.7	49.4	35.3	25.2	12.7	5	2.8
			96.6	90.4	68.2	48.1	33.8	23.6	11.3	3.8	2.6
			99.2	92.6	71.2	50.7	36.8	26.8	14.1	6.2	3
	Average	**100.0**	**97.9**	**91.5**	**69.7**	**49.4**	**35.3**	**25.2**	**12.7**	**5.0**	**2.8**
	Truck 2										
	Gradation	100	97	90.8	68.6	48.5	34.7	24.7	12.6	5	2.8
			95.7	89.7	67.1	47.2	33.2	23.1	11.2	3.8	2.6
			98.3	91.9	70.1	49.8	36.2	26.3	14	6.2	3
	Average	**100.0**	**97.0**	**90.8**	**68.6**	**48.5**	**34.7**	**24.7**	**12.6**	**5.0**	**2.8**
	Truck 3										
	Gradation	100	97	88.6	64.1	44.8	32.1	23	11.2	4.3	2.3
			95.7	87.5	62.6	43.5	30.6	21.4	9.8	3.1	2.1
			98.3	89.7	65.6	46.1	33.6	24.6	12.6	5.5	2.5
	Average	**100.0**	**97.0**	**88.6**	**64.1**	**44.8**	**32.1**	**23.0**	**11.2**	**4.3**	**2.3**
	AVERAGE OF 3	***100.0***	***97.3***	***90.3***	***67.5***	***47.6***	***34.0***	***24.3***	***12.2***	***4.8***	***2.6***

0%	Truck 1			
		FAA Uncompacted Voids	Fine Aggregate Specific Gravity	Coarse Aggregate Specific Gravity
	1	40.953	2.507	2.561
	2	40.714	2.512	2.556
	3	40.953	2.501	2.565
	Average	**40.873**	**2.507**	**2.561**
	Truck 2			
		FAA Uncompacted Voids	Fine Aggregate Specific Gravity	Coarse Aggregate Specific Gravity
	1	39.677	2.481	2.578
	2	39.879	2.468	2.678
	3	40.082	2.446	2.479
	Average	**39.879**	**2.465**	**2.578**
	Truck 3			
		FAA Uncompacted Voids	Fine Aggregate Specific Gravity	Coarse Aggregate Specific Gravity
	1	42.150	2.549	2.571
	2	42.347	2.526	2.553
	3	42.426	2.542	2.589
	Average	**42.307**	**2.539**	**2.571**
	Average of 3	**41.020**	**2.504**	**2.570**

10%	Truck 1			
		FAA Uncompacted Voids	Fine Aggregate Specific Gravity	Coarse Aggregate Specific Gravity
	1	41.149	2.468	2.561
	2	41.189	2.486	2.528
	3	41.149	2.499	2.594
	Average	**41.162**	**2.484**	**2.561**
	Truck 2			
		FAA Uncompacted Voids	Fine Aggregate Specific Gravity	Coarse Aggregate Specific Gravity
	1	41.576	2.505	2.570
	2	41.456	2.498	2.559
	3	41.695	2.525	2.582
	Average	**41.576**	**2.509**	**2.570**
	Truck 3			
		FAA Uncompacted Voids	Fine Aggregate Specific Gravity	Coarse Aggregate Specific Gravity
	1	41.237	2.520	2.574
	2	41.355	2.532	2.582
	3	41.276	2.554	2.565
	Average	**41.289**	**2.535**	**2.574**
	Average of 3	**41.342**	**2.510**	**2.568**

20%	**Truck 1**			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate Specific Gravity**
	1	41.958	2.513	2.570
	2	42.236	2.520	2.584
	3	42.077	2.534	2.557
	Average	**42.091**	**2.522**	**2.570**
	Truck 2			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate Specific Gravity**
	1	41.235	2.494	2.573
	2	41.115	2.495	2.582
	3	41.356	4.495	2.565
	Average	**41.235**	**3.161**	**2.573**
	Truck 3			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate Specific Gravity**
	1	41.534	2.488	2.563
	2	41.494	2.506	2.572
	3	41.534	2.477	2.561
	Average	**41.521**	**2.490**	**2.565**
	Average of 3	**41.616**	**2.725**	**2.570**
30%	**Truck 1**			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate Specific Gravity**
	1	42.311	2.491	2.575
	2	42.390	2.521	2.586
	3	42.111	2.503	2.563
	Average	**42.271**	**2.505**	**2.575**
	Truck 2			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate Specific Gravity**
	1	40.201	2.483	2.574
	2	40.362	2.493	2.582
	3	40.081	2.494	2.565
	Average	**40.215**	**2.490**	**2.574**
	Truck 3			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate Specific Gravity**
	1	42.605	2.532	2.560
	2	42.803	2.527	2.568
	3	42.803	2.530	2.553
	Average	**42.737**	**2.530**	**2.560**
	Average of 3	**41.741**	**2.508**	**2.570**

APPENDIX H: RAP AGGREGATE PROPERTIES DATA

Recycled Asphalt Pavement (Aggregate Properties)

	Sample 1										
	Gradation	100	98.2	93.7	73.1	55.2	40.9	29.6	16.9	9	5.8
		100	98.3	89.6	62.9	43.4	30.2	21.6	12.7	7.2	4.8
		100	99.7	94.4	72.8	54	39.4	28.3	16.1	8.5	5.5
	Average	**100.0**	**98.7**	**92.6**	**69.6**	**50.9**	**36.8**	**26.5**	**15.2**	**8.2**	**5.4**
	Sample 2										
	Gradation	100	98.7	93.8	75.3	55.7	39.7	28.1	16	8.8	5.9
CNC		100	98	92.1	68.9	51.5	37.8	27.6	16.3	9.2	6.1
		100	98.6	91.9	67.7	48.4	35	25.4	14.9	8.4	5.5
294	Average	**100.0**	**98.4**	**92.6**	**70.6**	**51.9**	**37.5**	**27.0**	**15.7**	**8.8**	**5.8**
	Sample 3										
	Gradation	100	98.5	89.7	63.8	45.2	32.2	23.1	13.3	7.4	4.8
		100	98.3	91.8	70.4	51.1	37.1	26.9	15.9	9.1	5.8
		100	98.8	92.1	68.1	49.9	36.7	26.8	15.5	8.1	4.7
		100.0	**98.5**	**91.2**	**67.4**	**48.7**	**35.3**	**25.6**	**14.9**	**8.2**	**5.1**
	AVERAGE OF 3	***100.0***	***98.6***	***92.1***	***69.2***	***50.5***	***36.6***	***26.4***	***15.3***	***8.4***	***5.4***
	Sample 1										
	Gradation	100	99.1	96.1	79	59.9	45.1	32.6	16.1	9.7	6.9
		100	99.7	97	80.6	62	48	35.3	16.7	9.4	6.6
		100	99	94.5	79.4	61.2	47	33.6	14.8	7.5	4.8
	Average	**100.0**	**99.3**	**95.9**	**79.7**	**61.0**	**46.7**	**33.8**	**15.9**	**8.9**	**6.1**
	Sample 2										
	Gradation	100	98.8	95	78.4	60	46.1	33.7	14.8	7.4	4.7
CNC		100	99.2	96	77.7	58.2	44.1	32.1	14.7	8	5.5
		100	99.9	97.1	81.7	63.8	49.8	37	18.2	10.5	7.2
297	Average	**100.0**	**99.3**	**96.0**	**79.3**	**60.7**	**46.7**	**34.3**	**15.9**	**8.6**	**5.8**
	Sample 3										
	Gradation	100	99.2	96.4	83.9	67.5	53.7	39.8	18.7	10	6.2
		100	99.7	95.6	80.1	61.2	47.5	35.2	17.8	10.6	7.4
		100	99.5	96.9	83.3	65	50.7	37.4	18.2	10.4	6.8
	Average	**100.0**	**99.5**	**96.3**	**82.4**	**64.6**	**50.6**	**37.5**	**18.2**	**10.3**	**6.8**
	AVERAGE OF 3	***100.0***	***99.3***	***96.1***	***80.5***	***62.1***	***48.0***	***35.2***	***16.7***	***9.3***	***6.2***
	Sample 1										
	Gradation	100	99.7	98.5	78.8	57.4	43.9	32.2	13.1	5.8	3.3
		100	99.5	98.6	79	58.1	45.5	33.9	14.2	6.4	3.6
		100	98.7	97.8	78.6	59	46.6	35.1	15	7	4.1
	Average	**100.0**	**99.3**	**98.3**	**78.8**	**58.2**	**45.3**	**33.7**	**14.1**	**6.4**	**3.7**
	Sample 2										
	Gradation	100	99.8	99.4	81.7	63.2	50.9	38.1	15.7	7.1	4
CNC		100	99.8	97.5	82	63.9	52	39.4	16.7	7.5	4.2
		100	99.2	97.9	81	63.2	51.3	39.4	17.5	8.6	5.3
302	Average	**100.0**	**99.6**	**98.3**	**81.6**	**63.4**	**51.4**	**39.0**	**16.6**	**7.7**	**4.5**
	Sample 3										
	Gradation	100	99.8	99	79.8	60	47.2	34.9	14.2	6.8	4.2
		100	99.8	99.3	84.7	66.1	53.4	40.5	17.6	8.7	5.4
		100	99.9	99.3	81.1	61	48.5	36.5	15.6	7.2	4.1
	Average	**100.0**	**99.8**	**99.2**	**81.9**	**62.4**	**49.7**	**37.3**	**15.8**	**7.6**	**4.6**
	AVERAGE OF 3	***100.0***	***99.6***	***98.6***	***80.7***	***61.3***	***48.8***	***36.7***	***15.5***	***7.2***	***4.2***
	Sample 1										
	Gradation	100	99.8	99.7	86.8	58.8	40.5	28.1	17.9	10.6	5
		100	99.8	99.7	86.8	58.8	40.5	28.1	17.9	10.6	5
		100	99.8	99.7	86.8	58.8	40.5	28.1	17.9	10.6	5
	Average	**100.0**	**99.8**	**99.7**	**86.8**	**58.8**	**40.5**	**28.1**	**17.9**	**10.6**	**5.0**
	Sample 2										
	Gradation	100	100	100	89.7	64.4	44.5	30.2	19.4	12	6.9
CNC		100	100	100	89.7	64.4	44.5	30.2	19.4	12	6.9
		100	100	100	89.7	64.4	44.5	30.2	19.4	12	6.9
186	Average	**100.0**	**100.0**	**100.0**	**89.7**	**64.4**	**44.5**	**30.2**	**19.4**	**12.0**	**6.9**
	Sample 3										
	Gradation	100	100	100	90.4	66.1	46.3	31.6	20.2	12.3	7
		100	100	100	90.4	66.1	46.3	31.6	20.2	12.3	7
		100	100	100	90.4	66.1	46.3	31.6	20.2	12.3	7
	Average	**100.0**	**100.0**	**100.0**	**90.4**	**66.1**	**46.3**	**31.6**	**20.2**	**12.3**	**7.0**
	AVERAGE OF 3	***100.0***	***99.9***	***99.9***	***89.0***	***63.1***	***43.8***	***30.0***	***19.2***	***11.6***	***6.3***

CNC 294	**Sample 1**			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate**
	1	42.850	2.563	2.603
	2	42.845	2.568	2.610
	3	42.855	2.558	2.595
	Average	**42.850**	**2.563**	**2.603**
	Sample 2			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate**
	1	40.840	2.453	2.535
	2	40.827	2.450	2.539
	3	40.852	2.456	2.532
	Average	**40.840**	**2.453**	**2.535**
	Sample 3			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate**
	1	43.530	2.472	2.568
	2	43.549	2.479	2.575
	3	43.510	2.464	2.561
	Average	**43.530**	**2.472**	**2.568**
	Average of 3	**42.406**	**2.496**	**2.569**
CNC 297	**Sample1**			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate**
	1	36.440	2.412	2.661
	2	36.448	2.408	2.656
	3	36.432	2.415	2.665
	Average	**36.440**	**2.412**	**2.661**
	Sample2			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate**
	1	40.710	2.530	2.610
	2	40.720	2.537	2.615
	3	40.701	2.524	2.604
	Average	**40.710**	**2.530**	**2.610**
	Sample 3			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate**
	1	40.910	2.513	2.597
	2	40.902	2.516	2.602
	3	40.918	2.510	2.591
	Average	**40.910**	**2.513**	**2.597**
	Average of 3	**39.353**	**2.485**	**2.622**

CNC 302	**Sample 1**			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate**
	1	40.610	2.508	2.427
	2	40.700	2.515	2.434
	3	40.521	2.501	2.420
	Average	**40.610**	**2.508**	**2.427**
	Sample 2			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate**
	1	40.190	2.501	2.436
	2	40.325	2.512	2.439
	3	40.056	2.490	2.432
	Average	**40.190**	**2.501**	**2.436**
	Sample 3			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate**
	1	39.120	2.447	2.462
	2	39.141	2.442	2.458
	3	39.100	2.453	2.466
	Average	**39.120**	**2.447**	**2.462**
	Average of 3	**39.974**	**2.485**	**2.442**
CNC 186	**Sample 1**			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate**
	1	41.630	2.533	2.674
	2	41.744	2.524	2.669
	3	41.516	2.541	2.680
	Average	**41.630**	**2.533**	**2.674**
	Sample 2			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate**
	1	41.550	2.556	2.691
	2	41.489	2.545	2.671
	3	41.610	2.560	2.710
	Average	**41.550**	**2.554**	**2.691**
	Sample 3			
		FAA Uncompacted Voids	**Fine Aggregate Specific Gravity**	**Coarse Aggregate**
	1	42.240	2.578	2.686
	2	42.220	2.586	2.694
	3	42.260	2.569	2.677
	Average	**42.240**	**2.578**	**2.686**
	Average of 3	**41.807**	**2.555**	**2.684**

APPENDIX I: LIMESTONE PG 64-22 BINDER PROPERTIES DATA

0% PG 64-22

Truck	Temp [°C]	Strain [%]	Coef. Of Var. (%)	Complex Modulus [Pa]	Coef. Of Var. (%)	|G*|sin(delta)	Coef. Of Var. (%)	Phase Angle [°]	Coef. Of Var. (%)	G*/sin(delta [Pa]	Coef. Of Var. (%)
1	28	1.8947	4.51E+00	2.34E+06	4.78E+00	1.82E+06	4.68E+00	51.0	1.56E-01	3.02E+06	4.87E+00
	52	12.0873	9.80E-02	3.03E+04	3.06E+00	2.99E+04	3.04E+00	79.9	1.58E-01	3.08E+04	3.09E+00
	76	12.0467	1.49E-01	9.88E+02	2.75E+00	9.87E+02	2.74E+00	87.8	3.63E-01	9.88E+02	1.00E+00
2	28	1.8915	2.75E+00	2.34E+06	2.99E+00	1.81E+06	2.96E+00	50.4	3.86E-01	3.04E+06	3.04E+00
	52	12.0883	4.85E-02	3.08E+04	1.68E+00	3.03E+04	1.68E+00	79.7	2.11E-02	3.13E+04	1.67E+00
	76	12.0460	9.57E-02	9.98E+02	1.52E+00	9.97E+02	1.52E+00	87.9	8.36E-02	9.99E+02	1.53E+00
3	28	1.2369	1.29E+00	3.67E+06	1.33E+00	2.50E+06	7.84E-01	43.0	9.02E-01	5.38E+06	1.99E+00
	52	12.0953	7.68E-02	5.12E+04	1.19E+00	4.97E+04	1.18E+00	76.0	5.48E-02	5.27E+04	1.19E+00
	76	12.0310	1.51E-01	1.62E+03	1.28E+00	1.62E+03	1.27E+00	86.4	7.43E-02	1.63E+03	1.29E+00

Truck	Temp [°C]	Strain [%]	Coef. Of Var. (%)	Complex Modulus [Pa]	Coef. Of Var. (%)	|G*|sin(delta)	Coef. Of Var. (%)	Phase Angle [°]	Coef. Of Var. (%)	G*/sin(delta [Pa]	Coef. Of Var. (%)
1	0	0.0974	0.3602	1.18E+08	1.78E+00	4.79E+07	1.50E+00	23.9	3.16E-01	2.91E+08	2.06E+00
	-6	0.0996	0.1658	2.10E+08	5.12E+00	6.20E+07	2.68E+00	17.2	2.69E+00	7.13E+08	7.76E+00
	-12	0.1005	0.1741	2.96E+08	5.71E+00	6.69E+07	1.99E+00	13.1	4.18E+00	1.31E+09	9.95E+00
2	0	0.0974	0.4482	1.16E+08	7.04E+00	4.69E+07	6.06E+00	23.8	1.16E+00	2.89E+08	8.07E+00
	-6	0.0994	0.4067	2.13E+08	8.23E+00	6.10E+07	6.08E+00	16.7	2.22E+00	7.40E+08	1.04E+01
	-12	0.0998	0.5330	3.03E+08	1.00E+01	6.51E+07	5.59E+00	12.5	5.33E+00	1.41E+09	1.46E+01
3	0	0.0978	0.1620	1.27E+08	1.56E+00	4.81E+07	1.69E+00	22.2	1.80E-01	3.38E+08	1.43E+00
	-6	0.0993	0.0176	2.16E+08	2.11E+00	6.06E+07	1.98E+00	16.3	1.88E-01	7.73E+08	2.25E+00
	-12	0.1004	0.0600	3.00E+08	2.16E+00	6.49E+07	1.94E+00	12.5	2.66E-01	1.39E+09	2.39E+00

10% PG 64-22

Truck	Temp [°C]	Strain	Coef. Of Var. (%)	Complex Modulus [Pa]	Coef. Of Var. (%)	|G*|sin(delta)	Coef. Of Var. (%)	Phase Angle [°]	Coef. Of Var. (%)	G*/sin(delta [Pa]	Coef. Of Var. (%)
1	28	1.3865	0.6415	3.26E+06	6.86E-01	2.35E+06	6.18E-01	46.1	2.08E-01	4.52E+06	7.81E-01
	52	12.1430	0.1029	4.28E+04	6.46E-01	4.18E+04	6.39E-01	77.7	2.48E-02	4.38E+04	6.52E-01
	76	12.0413	0.0410	1.38E+03	2.26E-01	1.38E+03	2.25E-01	87.0	1.92E-02	1.38E+03	2.30E-01
2	28	1.5329	2.4377	2.93E+06	2.59E+00	2.16E+06	2.04E+00	47.6	7.30E-01	3.96E+06	3.15E+00
	52	12.1090	0.1811	3.92E+04	1.76E+00	3.83E+04	1.73E+00	78.1	1.13E-01	4.00E+04	1.79E+00
	76	12.0330	0.1461	1.28E+03	1.92E+00	1.28E+03	1.90E+00	86.7	3.40E-01	1.29E+03	1.94E+00
3	28	1.4381	9.9185	3.15E+06	9.95E+00	2.25E+06	8.55E+00	45.7	2.11E+00	4.41E+06	1.14E+01
	52	12.1493	0.3363	4.36E+04	4.71E+00	4.25E+04	4.82E+00	77.1	3.61E-01	4.48E+04	4.61E+00
	76	12.0423	0.0472	1.43E+03	6.61E-01	1.43E+03	6.60E-01	86.5	6.94E-01	1.44E+03	6.72E-01

Truck	Temp [°C]	Strain	Coef. Of Var. (%)	Complex Modulus [Pa]	Coef. Of Var. (%)	|G*|sin(delta)	Coef. Of Var. (%)	Phase Angle [°]	Coef. Of Var. (%)	G*/sin(delta [Pa]	Coef. Of Var. (%)
1	0	0.0982	0.0349	1.28E+08	1.48E+00	4.99E+07	1.79E+00	23.0	9.81E-01	3.26E+08	1.72E+00
	-6	0.1000	0.1474	2.10E+08	1.58E+00	6.23E+07	2.38E+00	17.2	2.04E+00	7.10E+08	2.73E+00
	-12	0.1005	0.0868	2.94E+08	1.64E+00	6.80E+07	2.91E+00	13.4	2.20E+00	1.27E+09	2.53E+00
2	0	0.0986	1.6467	1.28E+08	8.62E+00	4.92E+07	5.49E+00	22.7	3.92E+00	3.33E+08	1.22E+01
	-6	0.0994	0.2640	2.20E+08	6.65E+00	6.21E+07	4.10E+00	16.4	3.61E+00	7.82E+08	9.85E+00
	-12	0.1004	0.0811	3.07E+08	5.66E+00	6.63E+07	3.48E+00	12.5	3.71E+00	1.42E+09	8.90E+00
3	0	0.0977	0.5497	1.29E+08	2.03E+00	4.97E+07	1.50E+00	22.7	6.77E-01	3.34E+08	2.62E+00
	-6	0.1006	1.9560	2.24E+08	7.15E+00	6.20E+07	5.45E+00	16.1	1.83E+00	8.06E+08	8.84E+00
	-12	0.1007	0.7407	3.12E+08	9.27E+00	6.56E+07	5.31E+00	12.2	4.38E+00	1.49E+09	1.33E+01

20% PG 64-22

Truck	Temp [°C]	Strain [%]	Coef. Of Var. (%)	Complex Modulus [Pa]	Coef. Of Var. (%)	|G*|sin(delta)	Coef. Of Var. (%)	Phase Angle [°]	Coef. Of Var. (%)	G*/sin(delta [Pa]	Coef. Of Var. (%)
1	28	1.3624	7.98E-01	3.31E+06	9.07E-01	2.35E+06	1.50E+00	45.2	7.55E-01	4.67E+06	3.18E-01
	52	12.1240	2.86E-02	4.68E+04	7.03E-01	4.55E+04	6.87E-01	76.6	6.88E-02	4.81E+04	7.19E-01
	76	12.0443	9.97E-02	1.55E+03	1.08E+00	1.55E+03	1.08E+00	86.3	4.06E-02	1.56E+03	1.08E+00
2	28	1.3174	1.35E+00	3.43E+06	1.43E+00	2.41E+06	1.21E+00	44.5	3.19E-01	4.90E+06	1.66E+00
	52	12.1180	2.18E-02	4.86E+04	1.18E+00	4.72E+04	1.18E+00	76.3	2.75E-02	5.00E+04	1.19E+00
	76	12.0327	3.75E-02	1.61E+03	1.09E+00	1.60E+03	1.09E+00	86.2	1.52E-02	1.61E+03	1.09E+00
3	28	1.2553	1.09E+00	3.62E+06	1.21E+00	2.52E+06	1.49E+00	44.2	5.40E-01	5.18E+06	1.03E+00
	52	12.1257	6.67E-02	4.84E+04	5.42E-01	4.71E+04	5.47E-01	76.8	5.01E-02	4.97E+04	5.38E-01
	76	12.0387	1.50E-01	1.57E+03	3.58E-01	1.57E+03	3.56E-01	86.4	2.98E-02	1.58E+03	3.61E-01

Truck	Temp [°C]	Strain [%]	Coef. Of Var. (%)	Complex Modulus [Pa]	Coef. Of Var. (%)	|G*|sin(delta)	Coef. Of Var. (%)	Phase Angle [°]	Coef. Of Var. (%)	G*/sin(delta [Pa]	Coef. Of Var. (%)
1	0	9.76E-02	6.38E-01	1.29E+08	2.85E+00	4.99E+07	2.17E+00	22.8	7.23E-01	3.31E+08	3.54E+00
	-6	9.97E-02	8.25E-02	2.19E+08	2.75E+00	6.29E+07	1.99E+00	16.7	1.19E+00	7.65E+08	3.71E+00
	-12	1.01E-01	1.71E-01	3.07E+08	2.90E+00	6.79E+07	1.87E+00	12.8	1.18E+00	1.38E+09	4.00E+00
2	0	9.82E-02	1.74E-01	1.26E+08	5.42E+00	4.86E+07	5.15E+00	22.6	2.97E-01	3.29E+08	5.69E+00
	-6	9.95E-02	4.36E-01	2.26E+08	4.22E+00	6.22E+07	4.63E+00	16.0	4.27E-01	8.22E+08	3.81E+00
	-12	1.00E-01	2.49E-01	3.20E+08	2.96E+00	6.58E+07	4.89E+00	11.9	2.62E+00	1.56E+09	2.68E+00
3	0	9.81E-02	2.11E-01	1.38E+08	1.35E+00	5.20E+07	9.87E-01	22.2	3.85E-01	3.65E+08	1.71E+00
	-6	9.95E-02	1.60E-01	2.34E+08	1.17E+00	6.48E+07	8.02E-01	16.1	7.45E-01	8.43E+08	1.78E+00
	-12	1.00E-01	6.09E-02	3.24E+08	1.28E+00	6.89E+07	9.18E-01	12.3	9.38E-01	1.52E+09	2.05E+00

30% PG 64-22

Truck	Temp [°C]	Strain [%]	Coef. Of Var. (%)	Complex Modulus [Pa]	Coef. Of Var. (%)	|G*|sin(delta)	Coef. Of Var. (%)	Phase Angle [°]	Coef. Of Var. (%)	G*/sin(delta [Pa]	Coef. Of Var. (%)
1	28	1.35E+00	2.36E+00	3.36E+06	2.59E+00	2.38E+06	2.62E+00	45.1	1.39E-01	4.74E+06	2.55E+00
	52	1.21E+01	9.29E-02	4.79E+04	2.06E+00	4.65E+04	2.05E+00	76.4	4.46E-02	4.93E+04	2.06E+00
	76	1.20E+01	5.01E-02	1.62E+03	2.33E+00	1.62E+03	2.32E+00	86.0	3.51E-02	1.63E+03	2.33E+00
2	28	1.30E+00	2.06E+00	3.48E+06	2.22E+00	2.44E+06	1.99E+00	44.6	4.56E-01	4.96E+06	2.48E+00
	52	1.21E+01	5.77E-02	4.90E+04	1.71E+00	4.76E+04	1.71E+00	76.4	2.00E-03	5.04E+04	1.71E+00
	76	1.20E+01	5.01E-02	1.65E+03	2.04E+00	1.65E+03	2.04E+00	86.0	1.08E-02	1.66E+03	2.04E+00
3	28	1.31E+00	1.75E+00	3.45E+06	1.82E+00	2.45E+06	1.26E+00	45.3	9.31E-01	4.85E+06	2.47E+00
	52	1.21E+01	4.84E-02	4.70E+04	1.77E+00	4.57E+04	1.75E+00	76.9	9.21E-02	4.82E+04	1.80E+00
	76	1.20E+01	6.92E-02	1.56E+03	1.25E+00	1.56E+03	1.25E+00	86.3	2.40E-02	1.56E+03	1.26E+00

Truck	Temp [°C]	Strain [%]	Coef. Of Var. (%)	Complex Modulus [Pa]	Coef. Of Var. (%)	|G*|sin(delta)	Coef. Of Var. (%)	Phase Angle [°]	Coef. Of Var. (%)	G*/sin(delta [Pa]	Coef. Of Var. (%)
1	0	9.75E-02	5.34E-01	1.36E+08	5.61E-01	5.24E+07	5.99E-01	22.6	3.75E-01	3.55E+08	7.26E-01
	-6	9.99E-02	1.84E-01	2.46E+08	6.09E-01	6.66E+07	5.37E-01	15.7	4.30E-01	9.06E+08	8.99E-01
	-12	1.00E-01	2.18E-01	3.54E+08	3.30E+00	6.96E+07	3.65E-01	11.4	3.00E+00	1.80E+09	6.25E+00
2	0	9.72E-02	3.58E-01	1.33E+08	5.68E+00	5.09E+07	5.18E+00	22.6	5.65E-01	3.46E+08	6.19E+00
	-6	9.90E-02	3.46E-02	2.34E+08	5.56E+00	6.44E+07	4.77E+00	16.0	1.50E+00	8.47E+08	6.58E+00
	-12	1.00E-01	4.34E-02	3.25E+08	5.46E+00	6.82E+07	4.70E+00	12.1	2.09E+00	1.55E+09	6.81E+00
3	0	9.74E-02	6.00E-01	1.34E+08	2.44E+00	5.18E+07	1.96E+00	22.8	4.98E-01	3.45E+08	2.91E+00
	-6	9.93E-02	5.26E-01	2.42E+08	1.80E+00	6.61E+07	1.48E+00	15.9	3.29E-01	8.82E+08	2.12E+00
	-12	1.00E-01	9.98E-02	3.43E+08	1.79E+00	6.95E+07	1.48E+00	11.7	1.94E+00	1.69E+09	3.43E+00

APPENDIX J: RAP BINDER PROPERTIES DATA

CNC 294

Batch	Temp [°C]	Strain [%]	Coef. Of Var. (%)	Complex Modulus [Pa]	Coef. Of Var. (%)	|G*|sin(delta)	Coef. Of Var. (%)	Phase Angle [°]	Coef. Of Var. (%)	|G*|/sin(delta) [Pa]	Coef. Of Var. (%)
1	28	0.463	3.707	1.00E+07	3.974	4.46E+06	3.818	26.5	1.344	2.25E+07	4.466
	52	12.259	0.088	1.70E+05	1.308	1.56E+05	1.283	67.3	0.055	1.84E+05	1.332
	76	12.027	0.183	6.27E+03	0.400	6.17E+03	0.400	80.0	0.013	6.37E+03	0.399
2	28	0.476	5.032	9.73E+06	5.137	4.34E+06	4.336	26.5	1.502	2.18E+07	6.141
	52	12.247	0.029	1.67E+05	2.817	1.54E+05	2.765	67.3	0.106	1.81E+05	2.867
	76	12.035	0.099	6.11E+03	2.939	6.01E+03	2.942	79.9	0.052	6.20E+03	2.936
3	28	0.427	8.904	1.09E+07	9.369	4.70E+06	6.244	25.6	3.272	2.53E+07	12.543
	52	12.278	0.148	1.74E+05	6.966	1.61E+05	6.763	67.9	0.475	1.87E+05	7.172
	76	12.039	0.066	6.00E+03	6.945	5.92E+03	6.894	81.0	0.323	6.07E+03	6.996

CNC 297

Batch	Temp [°C]	Strain [%]	Coef. Of Var. (%)	Complex Modulus [Pa]	Coef. Of Var. (%)	|G*|sin(delta)	Coef. Of Var. (%)	Phase Angle [°]	Coef. Of Var. (%)	|G*|/sin(delta) [Pa]	Coef. Of Var. (%)
1	28	0.737	1.705	6.20E+06	1.911	3.24E+06	2.295	31.5	0.428	1.19E+07	1.532
	52	12.246	0.135	1.21E+05	0.350	1.12E+05	0.327	68.2	0.145	1.30E+05	0.381
	76	12.033	0.029	4.35E+03	0.768	4.31E+03	0.736	82.1	0.158	4.39E+03	0.799
2	28	0.706	3.316	6.51E+06	3.532	3.44E+06	2.691	31.9	0.950	1.23E+07	4.386
	52	12.235	0.097	1.23E+05	3.005	1.14E+05	2.914	68.0	0.189	1.33E+05	3.098
	76	12.029	0.053	4.45E+03	3.291	4.41E+03	3.255	82.0	0.176	4.50E+03	3.327
3	28	0.735	10.706	6.29E+06	11.373	3.33E+06	9.619	32.0	1.957	1.19E+07	13.137
	52	12.255	0.699	1.24E+05	4.015	1.15E+05	3.989	68.1	0.173	1.33E+05	4.042
	76	12.038	0.063	4.63E+03	2.735	4.58E+03	2.715	81.9	0.126	4.67E+03	2.756

Greene

Batch	Temp [°C]	Strain [%]	Coef. Of Var. (%)	Complex Modulus [Pa]	Coef. Of Var. (%)	|G*|sin(delta)	Coef. Of Var. (%)	Phase Angle [°]	Coef. Of Var. (%)	|G*|/sin(delta) [Pa]	Coef. Of Var. (%)
1	28	0.287	10.168	1.64E+07	11.410	6.19E+06	11.413	22.1	2.123	4.37E+07	11.696
	52	12.325	0.148	2.14E+05	2.243	1.96E+05	2.271	66.2	0.076	2.34E+05	2.215
	76	12.032	0.021	7.29E+03	1.582	7.17E+03	1.577	79.9	0.018	7.40E+03	1.586
2	28	0.279	13.129	1.69E+07	14.226	6.12E+06	13.431	21.3	0.840	4.66E+07	15.022
	52	12.258	0.729	2.37E+05	2.505	2.15E+05	2.480	65.4	0.069	2.60E+05	2.528
	76	12.035	0.129	8.31E+03	1.903	8.16E+03	1.898	79.4	0.054	8.45E+03	1.908
3	28	0.340	18.895	1.40E+07	17.636	5.47E+06	13.539	23.1	4.944	3.58E+07	21.619
	52	12.247	0.773	2.02E+05	10.079	1.85E+05	10.056	65.9	0.069	2.22E+05	10.101
	76	12.026	0.108	7.34E+03	5.741	7.22E+03	5.748	79.5	0.036	7.47E+03	5.734

CNC 302

Batch	Temp [°C]	Strain [%]	Coef. Of Var. (%)	Complex Modulus [Pa]	Coef. Of Var. (%)	|G*|sin(delta)	Coef. Of Var. (%)	Phase Angle [°]	Coef. Of Var. (%)	|G*|/sin(delta) [Pa]	Coef. Of Var. (%)
1	28	0.127	6.380	3.63E+07	6.550	8.80E+06	6.739	14.0	1.027	1.50E+08	6.522
	52	8.166	1.048	5.10E+05	1.068	4.39E+05	0.916	59.2	0.313	5.94E+05	1.230
	76	12.052	0.055	1.82E+04	0.634	1.77E+04	0.624	75.8	0.053	1.88E+04	0.644
2	28	0.108	2.327	4.19E+07	2.580	8.86E+06	5.062	12.2	3.451	1.98E+08	3.409
	52	6.626	5.005	6.33E+05	5.232	5.33E+05	4.577	57.3	1.021	7.53E+05	5.888
	76	12.073	0.107	2.23E+04	4.643	2.15E+04	4.528	74.9	0.322	2.31E+04	4.756
3	28	0.102	26.009	4.62E+07	23.364	9.51E+06	21.743	11.9	3.357	2.24E+08	25.358
	52	6.233	4.811	6.74E+05	5.069	5.66E+05	4.976	57.0	0.141	8.04E+05	5.162
	76	12.075	0.129	2.35E+04	3.746	2.27E+04	3.723	74.7	0.137	2.44E+04	3.770

APPENDIX K: COST ANALYSIS

Fiscal Year 2004

0% RAP Mixture				10% RAP Mixture			
Material	Price ($/ton)	Used (%)	Cost ($/ton)	Material	Price ($/ton)	Used (%)	Cost ($/ton)
D-Rock	8.45	50	4.23	D-Rock	8.45	50	4.23
#10 Screenings	8.45	15	1.27	#10 Screenings	8.45	10	0.85
Natural Sand	6.00	25	1.50	Natural Sand	6.00	20	1.20
Manufactured Sand	9.95	10	1.00	Manufactured Sand	9.95	10	1.00
*RAP	5.00			*RAP	5.00	10	0.50
PG 64-22	170.00	5.7	9.69	PG 64-22	170.00	5.1	8.67
Cost			**17.68**	Cost			**16.44**
20% RAP Mixture				**30% RAP Mixture**			
Material	Price ($/ton)	Used (%)	Cost ($/ton)	Material	Price ($/ton)	Used (%)	Cost ($/ton)
D-Rock	8.45	50	4.23	D-Rock	8.45	50	4.23
#10 Screenings	8.45	0	0.00	#10 Screenings	8.45	0	0.00
Natural Sand	6.00	20	1.20	Natural Sand	6.00	10	0.60
Manufactured Sand	9.95	10	1.00	Manufactured Sand	9.95	10	1.00
*RAP	5.00	20	1.00	*RAP	5.00	30	1.50
PG 64-22	170.00	4.5	7.65	PG 64-22	170.00	4.0	6.80
Cost			**15.07**	Cost			**14.12**

***Average Cost for Processing of RAP**

Percent RAP	Cost ($/ton)	Savings ($/ton)	Savings (%)
0%	17.68		0
10%	16.44	1.24	7
20%	15.07	2.61	15
30%	14.12	3.56	20

Fiscal Year 2006

0% RAP Mixture				10% RAP Mixture			
Material	Price ($/ton)	Used (%)	Cost ($/ton)	Material	Price ($/ton)	Used (%)	Cost ($/ton)
D-Rock	9.50	50	4.75	D-Rock	9.50	50	4.75
#10 Screenings	9.50	15	1.43	#10 Screenings	9.50	10	0.95
Natural Sand	9.00	25	2.25	Natural Sand	9.00	20	1.80
Manufactured Sand	11.95	10	1.20	Manufactured Sand	11.95	10	1.20
*RAP	7.00			*RAP	7.00	10	0.70
PG 64-22	325.00	5.7	18.53	PG 64-22	325.00	5.1	16.58
Cost			**28.15**	Cost			**25.97**
20% RAP Mixture				**30% RAP Mixture**			
Material	Price ($/ton)	Used (%)	Cost ($/ton)	Material	Price ($/ton)	Used (%)	Cost ($/ton)
D-Rock	9.50	50	4.75	D-Rock	9.50	50	4.75
#10 Screenings	9.50	0	0.00	#10 Screenings	9.50	0	0.00
Natural Sand	9.00	20	1.80	Natural Sand	9.00	10	0.90
Manufactured Sand	11.95	10	1.20	Manufactured Sand	11.95	10	1.20
*RAP	7.00	20	1.40	*RAP	7.00	30	2.10
PG 64-22	325.00	4.5	14.63	PG 64-22	325.00	4.0	13.00
Cost			**23.77**	Cost			**21.95**

***Average Cost for Processing of RAP**

Percent RAP	Cost ($/ton)	Savings ($/ton)	Savings (%)
D-Mix	28.15		0
10%	25.97	2.18	8
20%	23.77	4.38	16
30%	21.95	6.20	22

APPENDIX L: MTS TEST TEMPLATES

Indirect Tensile Strength Test Template (IDT)

TestWare-SX

Procedure Name = IDT Default Procedure
File Specification = C:\WINNT\Profiles\All Users\Start Menu\Programs\MTS Pavement Testing\4 in. IDT.000

IDT : Step
Step Done Trigger 1 = Retract
Step Done Trigger 2 = Stop

Pre-load : Monotonic Command
Start Trigger = Step Start
End Trigger = <none>
Segment Shape = Ramp
Rate = 5 (lbf/Sec)
Control Channel 1
Control Mode = Force sg
End level = -10 (lbf)

Hold : Hold Command
Start Trigger = Pre-load
End Trigger = <none>
Hold Time = 1 (Sec)
Control Channel 1
Control Mode = Force sg

Dectect : Operator Event
Start Trigger = Hold
End Trigger = <none>
Button ID = Button 2
Single Shot = Yes
Button Label = Start
Description = Begin IDT
Grab Focus = Yes

IDT Test : Monotonic Command
Start Trigger = Dectect
End Trigger = Fail
Segment Shape = Ramp
Rate = 2 in/Min
Control Channel 1
Control Mode = Disp sg
End level = -1.0 (in)

Data : Data Acquisition
Start Trigger = Hold
End Trigger = <none>
Mode = Timed
Buffer Type = Single
Master Channel = Force
Slave Channel 1 = Time
Slave Channel 2 = Displacement
Data Header = IDT
Time Increment = 0.1 (Sec)
Buffer Size = 1024

Peak : Data Acquisition
Start Trigger = Hold
End Trigger = <none>
Mode = Valley / Peak
Buffer Type = Single
Master Channel = Force
Data Header = Ultimate Force
Sensitivity = 100 (lbf)
Buffer Size = 1024

Fail : Failure Detector
Start Trigger = Hold
End Trigger = <none>
Input Signal = Force
Record Data = 0
Data Header =
Event Type = Minimum
Noise Bandwidth = 100 (lbf)
Event Trigger = 10 %

Retract : Monotonic Command
Start Trigger = IDT Test
End Trigger = <none>
Segment Shape = Ramp
Rate = 2 in/Min
Control Channel 1
Control Mode = Disp sg
End level = 0.1 (in)

Stop : Operator Event
Start Trigger = Step Start
End Trigger = <none>
Button ID = Button 1

Single Shot = Yes
Button Label = Stop
Description =
Grab Focus = Yes

Recovery : Step
Step Done Trigger 1 = Recover

Recover : Monotonic Command
Start Trigger = Step Start
End Trigger = <none>
Segment Shape = Ramp
Rate = 1.0 (in/Sec)
Control Channel 1
Control Mode = Disp sg
End level = 0.1 (in)

Resilient Modulus Test Template (Mr)

TestWare-SX

Procedure Name = Asphalt Resilient Modulus Test Default Procedure
File Specification = C:\TS2\twsx\HMA testing templates\Asphalt Resilient Modulus Test.000
Software Version = 4.0C
Printout Date = 5/2/06 1:39:29 AM

Data File Options
File Format = Excel Text File
Log Events = Yes
Include Procedure Description = No

Recovery Options
Autosave disabled.

Pre-test Information : Step
Step Done Trigger 1 = Operator Initiate Test

Record Test Type : Program Control
Start Trigger = Step Start
End Trigger = <none>
Action = Message Only
Message = KEY_TEST_TYPE ASPHALT_MR

This is a keyword phrase that gets written to the data file only. Do not change it.
Send To:
Screen = No
LUC Display = No
Data File = Yes

Pre-test Information : Operator Information
Start Trigger = Step Start
End Trigger = <none>
Form fields
Label = ~~~Pre-test Specimen Characteristics~~~
Default Entry =
Type = String
Attribute = Non-Editable

Label = Identifier

Default Entry =
Type = String
Attribute = Non-Blank

Label = Age
Default Entry =
Type = String
Attribute = None

Label = Diameter
Default Entry = 3.937008 (in)
Minimum = 0 (in)
Type = Real
Attribute = Non-Blank

Label = Thickness
Default Entry = 2.362205 (in)
Minimum = 0 (in)
Type = Real
Attribute = Non-Blank

Label = ~~~Additional Pre-test Information~~~
Default Entry =
Type = String
Attribute = Non-Editable

Label = Test Date
Default Entry =
Type = String
Attribute = Non-Blank

Label = Test Temperature
Default Entry = 67.99995 (deg_F)
Type = Real
Attribute = Non-Blank

Operator Initiate Test : Operator Event
Start Trigger = Pre-test Information
End Trigger = <none>
Button ID = Button 1
Single Shot = Yes
Button Label = Start
Description = Press to start the test.
Grab Focus = Yes

Test Execution : Step
Step Done Trigger 1 = Pulse Command
Step Done Trigger 2 = Data Acquisition [User Triggered]
Step Done Trigger 3 = Detect Maximum Displacement

Ramp to Level Reference : Run-time Rate Control
Start Trigger = Step Start
End Trigger = <none>
Segment Shape = Ramp
Visible at Run Time = 1
Record Data = 0
Axial
Control Mode = Force sg
Rate Type = 2.000000 lbf/Sec
Minimum Rate = 1.000000 lbf/Sec
Maximum Rate = 5.000000 lbf/Sec
Endlevel = -20 (lbf)

Record Segment Offset : Data Acquisition
Start Trigger = Ramp to Level Reference
End Trigger = <none>
Mode = Timed
Buffer Type = Single
Master Channel = Force
Slave Channel 1 = Time
Slave Channel 2 = Displacement
Slave Channel 3 =
Slave Channel 4 =
Slave Channel 5 =
Slave Channel 6 =
Slave Channel 7 = Axial Segments
Data Header = Segment Offset
Time Increment = 0.001 (Sec)
Buffer Size = 16000

Pulse Command : File Playback Command
Start Trigger = Ramp to Level Reference
End Trigger = <none>
File Name... = C:\TS2\MTS Pavement Testing\Resilient Modulus.sfp
Passes = 100
Time Multiplier = 100 (%)
Compensation = None
Axial
Control Mode = Force sg
Level Reference = -10 (lbf)

Level Multiplier = -600 lbf

Auto Trigger Data Acquisition : Data Limit Detector
Start Trigger = Ramp to Level Reference
End Trigger = <none>
Data Channel = Displacement
Limit Value = 0 (in)
Limit Value is = Absolute
Detector Options = Greater than Limit Value
Trigger Option = Trigger Once

Data Acquisition [Auto Triggered] : Data Acquisition
Start Trigger = Auto Trigger Data Acquisition
End Trigger = <none>
Mode = Timed
Buffer Type = Continuous
Master Channel = Force
Slave Channel 1 = Time
Slave Channel 2 = Displacement
Slave Channel 3 =
Slave Channel 4 =
Slave Channel 5 =
Slave Channel 6 =
Slave Channel 7 = Axial Segments
Data Header = Test Data
Time Increment = 0.005 Sec
Buffer Size = 16000

User Trigger Data Acquisition : Operator Event
Start Trigger = Ramp to Level Reference
End Trigger = <none>
Button ID = Button 1
Single Shot = Yes
Button Label = Data
Description = Press to start data acquisition.
Grab Focus = Yes

Data Acquisition [User Triggered] : Data Acquisition
Start Trigger = User Trigger Data Acquisition
End Trigger = <none>
Mode = Timed
Buffer Type = Single
Master Channel = Force
Slave Channel 1 = Time
Slave Channel 2 = Displacement

Slave Channel 3 =
Slave Channel 4 =
Slave Channel 5 =
Slave Channel 6 =
Slave Channel 7 = Axial Segments
Data Header = Test Data
Time Increment = 0.005 Sec
Buffer Size = 1200

Detect Maximum Displacement : Data Limit Detector
Start Trigger = Step Start
End Trigger = <none>
Data Channel =
Limit Value = -2.54 ((none))
Limit Value is = Relative
Detector Options = Less than Limit Value
Trigger Option = Trigger Once

Retract Actuator : Step
Step Done Trigger 1 = Retract Actuator

Detect Minimal Load : Data Limit Detector
Start Trigger = Step Start
End Trigger = <none>
Data Channel = Force
Limit Value = -10 (lbf)
Limit Value is = Absolute
Detector Options = Greater than Limit Value
Trigger Option = Trigger Once

Retract Actuator : Run-time Rate Control
Start Trigger = Step Start
End Trigger = Detect Minimal Load
Segment Shape = Ramp
Visible at Run Time = 1
Record Data = 0
Axial
Control Mode = Disp sg
Rate Type = 2.000000 in/Sec
Minimum Rate = 1.000000 in/Sec
Maximum Rate = 3.000000 in/Sec
Endlevel = 0.1 (in)

Post-test Information : Step
Step Done Trigger 1 = Post-test Information

Post-test Information : Operator Information
Start Trigger = Step Start
End Trigger = <none>
Form fields
Label = ~~~Post-test Observations~~~
Default Entry =
Type = String
Attribute = Non-Editable

Label = Specimen Appearance
Default Entry =
Type = String
Attribute = None

Label = Test Completion Status
Default Entry = Normal
Type = String
Attribute = None

Label = Additional Comments
Default Entry =
Type = String
Attribute = None

Semi-Circular Bending Strength Test Template (SCB IDT)

TestWare-SX

Procedure Name = Idt_Semi Default Procedure
File Specification = C:\WINNT\Profiles\All Users\Start Menu\Programs\MTS Pavement Testing\SCB IDT.000

SCB IDT : Step
Step Done Trigger 1 = Retract
Step Done Trigger 2 = Stop

Plot : Run-time Plotting
Start Trigger = Step Start
End Trigger = <none>
Title = Plot Title
X Axis = X
Channel = Time
Scaling = Linear
Minimum = 0.000000 Sec
Maximum = 1.000000 Sec
Y Axis = Y
Channel 1 = Force
Color = Red
Style = Solid
Channel 2 = <none>
Color = Blue
Style = Solid
Channel 3 = <none>
Color = Black
Style = Solid
Scaling = Linear
Minimum = 0.000000 lbf
Maximum = 224.808945 lbf
X Axis Level Cross = Not Enabled
Y Axis Level Cross = Not Enabled
Reduce Rate on Decimation = Not Enabled

Pre-load : Monotonic Command
Start Trigger = Step Start
End Trigger = <none>
Segment Shape = Ramp
Rate = 5 (lbf/Sec)
Control Channel 1
Control Mode = Force sg

End level = -10 (lbf)

Dectect : Operator Event
Start Trigger = Pre-load
End Trigger = <none>
Button ID = Button 2
Single Shot = Yes
Button Label = Start
Description = Begin IDT
Grab Focus = Yes

IDT Test : Monotonic Command
Start Trigger = Dectect
End Trigger = Fail
Segment Shape = Ramp
Rate = 2 in/Min
Control Channel 1
Control Mode = Disp sg
End level = -0.5 (in)

Data : Data Acquisition
Start Trigger = Dectect
End Trigger = <none>
Mode = Timed
Buffer Type = Single
Master Channel = Force
Slave Channel 1 = Time
Slave Channel 2 = Displacement
Data Header = IDT
Time Increment = 0.2 (Sec)
Buffer Size = 16000

Peak : Data Acquisition
Start Trigger = Pre-load
End Trigger = <none>
Mode = Valley / Peak
Buffer Type = Single
Master Channel = Force
Data Header = Ultimate Force
Sensitivity = 100 (lbf)
Buffer Size = 1024

Fail : Failure Detector
Start Trigger = Pre-load
End Trigger = <none>

Input Signal = Force
Record Data = 0
Data Header =
Event Type = Minimum
Noise Bandwidth = 100 (lbf)
Event Trigger = 10 %

Retract : Monotonic Command
Start Trigger = IDT Test
End Trigger = <none>
Segment Shape = Ramp
Rate = 2 in/Min
Control Channel 1
Control Mode = Disp sg
End level = 0.1 (in)

Stop : Operator Event
Start Trigger = Step Start
End Trigger = <none>
Button ID = Button 1
Single Shot = Yes
Button Label = Stop
Description =
Grab Focus = Yes

Recovery : Step
Step Done Trigger 1 = Recover

Recover : Monotonic Command
Start Trigger = Step Start
End Trigger = <none>
Segment Shape = Ramp
Rate = 1.0 (in/Sec)
Control Channel 1
Control Mode = Disp sg
End level = 0.1 (in)

Semi-Circular Bending Notched IDT Test Template (SCB Notched IDT)

TestWare-SX

Procedure Name = Notched IDT Default Procedure (modified)
File Specification = C:\WINNT\Profiles\All Users\Start Menu\Programs\MTS Pavement Testing\Notched IDT.000

SCB Notched IDT : Step
Step Done Trigger 1 = Retract
Step Done Trigger 2 = Stop

Plot : Run-time Plotting
Start Trigger = Step Start
End Trigger = <none>
Title = Plot Title
X Axis = X
Channel = Time
Scaling = Linear
Minimum = 0.000000 Sec
Maximum = 1.000000 Sec
Y Axis = Y
Channel 1 = Force
Color = Red
Style = Solid
Channel 2 = <none>
Color = Blue
Style = Solid
Channel 3 = <none>
Color = Black
Style = Solid
Scaling = Linear
Minimum = 0.000000 lbf
Maximum = 224.808945 lbf
X Axis Level Cross = Not Enabled
Y Axis Level Cross = Not Enabled
Reduce Rate on Decimation= Not Enabled

Pre-load : Monotonic Command
Start Trigger = Step Start
End Trigger = <none>
Segment Shape = Ramp
Rate = 5 (lbf/Sec)
Control Channel 1

Control Mode = Force sg
End level = -10 (lbf)

Dectect : Operator Event
Start Trigger = Pre-load
End Trigger = <none>
Button ID = Button 2
Single Shot = Yes
Button Label = Start
Description = Begin IDT
Grab Focus = Yes

IDT Test : Monotonic Command
Start Trigger = Dectect
End Trigger = Fail
Segment Shape = Ramp
Rate = 0.02 in/Min
Control Channel 1
Control Mode = Disp sg
End level = -0.5 (in)

Data : Data Acquisition
Start Trigger = Dectect
End Trigger = <none>
Mode = Timed
Buffer Type = Single
Master Channel = Force
Slave Channel 1 = Time
Slave Channel 2 = Displacement
Data Header = IDT
Time Increment = 0.2 (Sec)
Buffer Size = 16000

Peak : Data Acquisition
Start Trigger = Pre-load
End Trigger = <none>
Mode = Valley / Peak
Buffer Type = Single
Master Channel = Force
Data Header = Ultimate Force
Sensitivity = 100 (lbf)
Buffer Size = 1024

Fail : Failure Detector
Start Trigger = Pre-load

End Trigger = <none>
Input Signal = Force
Record Data = 0
Data Header =
Event Type = Minimum
Noise Bandwidth = 100 (lbf)
Event Trigger = 10 %

Retract : Monotonic Command
Start Trigger = IDT Test
End Trigger = <none>
Segment Shape = Ramp
Rate = 2 in/Min
Control Channel 1
Control Mode = Disp sg
End level = 0.1 (in)

Stop : Operator Event
Start Trigger = Step Start
End Trigger = <none>
Button ID = Button 1
Single Shot = Yes
Button Label = Stop
Description =
Grab Focus = Yes

Recovery : Step
Step Done Trigger 1 = Recover

Recover : Monotonic Command
Start Trigger = Step Start
End Trigger = <none>
Segment Shape = Ramp
Rate = 0.9999999 (in/Sec)
Control Channel 1
Control Mode = Disp sg
End level = 0.1 (in)

Flexural Beam Fatigue Test

TestWare-SX

Procedure Name = Asphalt Flexural Fatigue Test Default Procedure
File Specification = C:\TS2\MTS Pavement Testing\Asphalt Flexural Fatigue Test.000
Software Version = 4.0C

Pre-test Information : Step
Step Done Trigger 1 = Operator Initiate Test

Record Test Type : Program Control
Start Trigger = Step Start
End Trigger = <none>
Action = Message Only
Message = KEY_TEST_TYPE ASPHALT_FLEX_FATIGUE

This is a keyword phrase that gets written to the data file only. Do not change it.
Send To:
Screen = No
LUC Display = No
Data File = Yes

Pre-test Information : Operator Information
Start Trigger = Step Start
End Trigger = <none>
Form fields
Label = ~~~Pre-test Specimen Characteristics~~~
Default Entry =
Type = String
Attribute = Non-Editable

Label = Identifier
Default Entry =
Type = String
Attribute = Non-Blank

Label = Age
Default Entry =
Type = String
Attribute = None

Label = Width

Default Entry = 2.5 (in)
Minimum = 0 (in)
Type = Real
Attribute = Non-Blank

Label = Height
Default Entry = 1.968504 (in)
Minimum = 0 (in)
Type = Real
Attribute = Non-Blank

Label = Distance Between Outside Clamps [L]
Default Entry = 14.05512 (in)
Minimum = 0 (in)
Type = Real
Attribute = Non-Blank

Label = Distance Between Inside Clamps [a]
Default Entry = 4.68504 (in)
Minimum = 0 (in)
Type = Real
Attribute = Non-Blank

Label = ~~~Additional Pre-test Information~~~
Default Entry =
Type = String
Attribute = Non-Editable

Label = Test Date
Default Entry =
Type = String
Attribute = Non-Blank

Label = Test Temperature
Default Entry = 67.99995 (deg_F)
Type = Real
Attribute = Non-Blank

Operator Initiate Test : Operator Event
Start Trigger = Pre-test Information
End Trigger = <none>
Button ID = Button 1
Single Shot = Yes
Button Label = Start

Description = Press to start the test.
Grab Focus = Yes

Test Execution : Step
Step Done Trigger 1 = Cyclic Command
Step Done Trigger 2 = Operator Terminate Test

Cyclic Command : Cyclic Command
Start Trigger = Step Start
End Trigger = Dynamic Properties Monitor
Segment Shape = Haversine
Frequency = 5 -10 (Hz)
Repeats = 1000000 cycles
Compensation = Phase/Amplitude (PAC)
Control Channel 1
Control Mode = Disp sg
End level 1 = -Enter Desired Strain Level (in)
End level 2 = Enter Desired Strain Level (in)

Trigger Dynamic Properties Monitor : Data Limit Detector
Start Trigger = Step Start
End Trigger = <none>
Data Channel = Control Channel 1 Segments
Limit Value = 50 cycles
Limit Value is = Relative
Detector Options = Greater than Limit Value
Trigger Option = Trigger Once

Dynamic Properties Monitor : Dynamic Property Monitor
Start Trigger = Trigger Dynamic Properties Monitor
End Trigger = <none>
Control Channel = Control Channel 1
Force Sensor = Force
Length Sensor = Displacement
Plot Update Rate = 20 cycles
Reduce Plot Rate When Decimation Occurs = Yes
Save Data = Yes
X Axis Scaling = Logarithmic
K*
Axis Scaling
Minimum = 0 (lbf/in)
Maximum = 5.710147 (lbf/in)
Limit Detector = Relative
Minimum = 50 %

Maximum = Off
Auto Scaling = Yes
Phase
Axis Scaling
Minimum = -1 (deg)
Maximum = 1 (deg)
Limit Detector = Absolute
Minimum = Off
Maximum = Off
Auto Scaling = Yes
Displacement
Axis Scaling
Minimum = 0 (in)
Maximum = 0.0003937008 (in)
Limit Detector = Absolute
Minimum = Off
Maximum = Off
Auto Scaling = Yes
Load
Axis Scaling
Minimum = 0 (lbf)
Maximum = 2.248089 (lbf)
Limit Detector = Absolute
Minimum = Off
Maximum = Off
Auto Scaling = Yes
Total Energy
Axis Scaling
Minimum = 0 (in-lbf)
Maximum = 0.0008850746 (in-lbf)
Limit Detector = Absolute
Minimum = Off
Maximum = Off
Auto Scaling = Yes

Operator Terminate Test : Operator Event
Start Trigger = Step Start
End Trigger = <none>
Button ID = Button 1
Single Shot = Yes
Button Label = Terminate
Description = Press to terminate the test.
Grab Focus = Yes

Go To Zero Load : Step
Step Done Trigger 1 = Go To Zero Load

Go To Zero Load : Monotonic Command
Start Trigger = Step Start
End Trigger = <none>
Segment Shape = Ramp
Time = 2 (Sec)
Control Channel 1
Control Mode = Disp sg
End level = 0 (in)

Post-test Information : Step
Step Done Trigger 1 = Post-test Information

Post-test Information : Operator Information
Start Trigger = Step Start
End Trigger = <none>
Form fields
Label = ~~~Post-test Observations~~~
Default Entry =
Type = String
Attribute = Non-Editable

Label = Specimen Appearance
Default Entry =
Type = String
Attribute = None

Label = Test Completion Status
Default Entry = Normal
Type = String
Attribute = None

Label = Additional Comments
Default Entry =
Type = String
Attribute = None

Vita

Dragon Vukosavljevic was born in Sarajevo, Yugoslavia, on August 12, 1979. He moved to United States in 1995 where he attended Science Hill High School in Johnson City, TN. where he graduated in 1998. Upon completion of high school he attended East Tennessee State University for two years. In the fall of 2000 he enrolled at the University of Tennessee, Knoxville (UTK) to pursue a degree in Civil Engineering. In December of 2003 he received a Bachelor of Science degree in Civil Engineering from UTK. After graduation he enrolled in graduate school at UTK to pursue a Masters Degree in Geotechnical and Materials Engineering. He received his Master's of Science in Civil Engineering from UTK in August 2006.