DEVELOPING A TENSILE-SHEAR TESTING SETUP FOR ASPHALT LAYERS.

Prepared By

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THESIS

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CERTIFICATE OF RESEARCH

This is to certify that this thesis work has been done by our group of two members and neither this thesis nor any part of thereof has been submitted elsewhere for the award of any degree or diploma.

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Abstract

Interface bonding condition between asphalt courses plays a critical role in the pavement performance. One of the most common distresses is slippage failure, which usually occurs where heavy vehicles are often accelerating, decelerating, or turning. Other pavement problems that have been linked to poor bonding between pavement layers include premature fatigue, top down cracking, pothole, and surface layer delamination, which reduces the serviceability and performance of a pavement. There are many factors affecting the interface bonding condition, including 1) improperly cleaned interface; 2) cold temperature during placement; 3) insufficient curing, and 4) improper selection and application rate of material.

Since an asphalt pavement has multi-layered structure system, the interfaces between layers are essential to the pavement performance. An interface between a surface course and an intermediate course is more emphasized since critical temperature and stress conditions for asphalt top-down cracking, rutting, and shearing are present near the pavement surface.

Many test methods have been developed to evaluate the interface condition in the lab and the field.There is, however, no standard test method for the evaluation. In addition, available test methods has limitation including:

1) indirect measurement, 2) limited application to the field, 3) limited measurement range, 4) acquisition of undisturbed-interface sample from coring process, and 5) lack of practicality for QC/QA.

Correlation of the interface bonding to pavement performances is essential in a performance based specification for a tack coat practice. A tack coat is inexpensive, but it's influence on pavement performance is significant.

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Chapter 1

Introduction

1.1What is pavement striping

Moisture damage in asphalt pavement has been documented for long time. Stripping is considered as the moisture sensitivity for hot mixed asphalt pavement, which is major cause of deterioration in asphalt pavement. Stripping could be demonstrated by several other kind of distresses such as fatigue cracking, premature rutting, and raveling. Stripping is a substantial distress in asphalt pavement which is basically separation or loss of bond between asphalt binder and aggregate due the effect of moisture or moisture vapor. High moisture content in the asphalt pavement is major a cause of stripping distress

Figure: Effect of stripping distress on HMA pavement layer.

1.2 Objective of our work

Knowing the tensile and shear strength, we can

-Estimate stripping potential of asphalt layers

-Fracture and deformation properties of asphalt layers

-Provide constitutive information for modelling

Chapter 2

Analysis Of Shear-Stress in Asphalt Pavement

2.1 Measurement Of Tire-Pavement Contact Pressure:

In order to measure the tire-pavement contact pressure distribution under realistic condition, a static laboratory test device was developed .In this device, a series of instrumented pins are embedded in the asphalt concrete specimen to measure the stress induced by the tire. The tire load is applied using servo-hydraulic actuators. All measurements are automatically recorded using a data logger. Though this method may seem simple and may result in slight inaccuracy as compared with an actual pavement, the results are undoubtedly much more reliable than when uniform contact pressure is assumed.

The tire used for testing was new longitudinally pattern truck tire. In the subsequent analysis, the tire loading area had to be simplified to build a more efficient three-dimensional finite element model.

2.2 Effect Of Horizontal stress

In this section, vertical load is only considered. The maximum shear stress occurs directly under the tire edge irrespective of loading conditions. Figure 4 shows that, in all cases, shear stress under the tire edge increases initially with depth, reaching the maximum value at a depth approximately 60 mm after which it decreases from the peak value. It seems that loading conditions have little effect on the location of the shear stress maximum. However, both tire load and tire pressure make a significant contributions to the magnitude of shear stress. Relatively, overloading is more dangerous than overpressure

2.3 Effect of Asphalt Mixture Layer Thickness

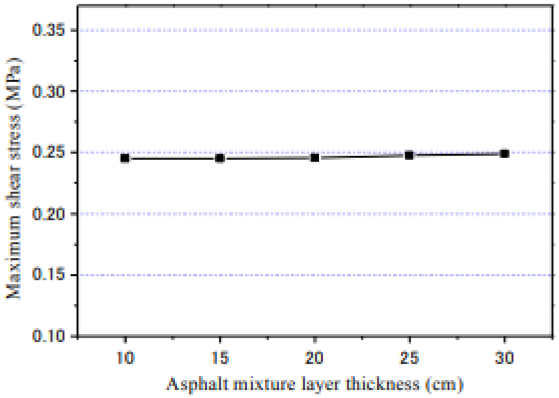


Figure : Shear stress at different asphalt mixture layer thickness

For asphalt mixture layers of 100 mm to 300 mm in thickness, the maximum shear stress remains almost constant. This is illustrated in Figure, which shows that a thinner asphalt 16 mixture layer does not lead to significantly greater shear stress than a thicker one. In other words, for a particular asphalt mixture, a thinner layer leads to barely greater risk of rutting and TDC compared with a thicker one.

2.4 Effect of Interface Condition

In a multi-layered pavement system, the condition of the interfaces between layers makes an important contribution to pavement performance. Here, the effect of interface condition on shear stress is evaluated, focusing on the cases of no bonding and full bonding between the asphalt mixture layer and the base course.

Chapter 3

Review Of Existing Literature:

Leutner Shear Test applies a vertical shear load to a double layered specimen with a strain controlled mode at a constant rate of 2.0 in/min at 21.1 °C until failure. The maximum shear load and corresponding displacement are measured to evaluate the bonding property of interface (Mohammad, et al., 2012).

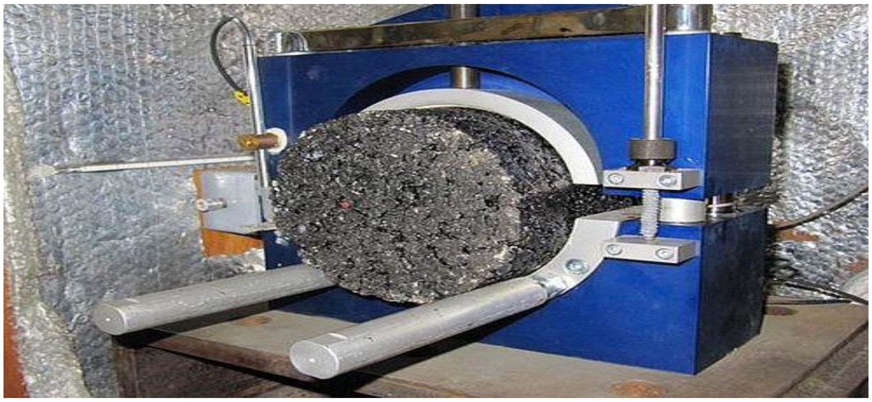


Figure: Leutner Shear Test (Mohammad, et al., 2012)

Louisiana Transportation Research Center (LTRC) Direct Shear Test applies a horizontal shear load to a dual layered specimen of asphalt concrete with a stress control mode at a constant rate of 50 lb/min at a given temperature until failure (i.e., separation). The testing temperature can be selected ranging from -20 to 80 °C using a climate chamber. The shear strength of the tack coat interlayer of specimen is measured to evaluate the bonding strength. The bonding strength is then used for determining the appropriateness of the material for the tact coat application (Mohammad, et al., 2012).

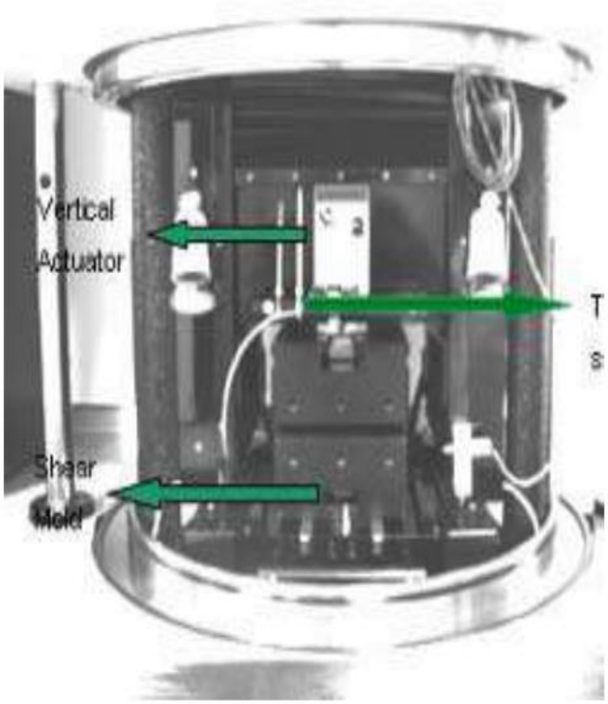


Figure : LTRC Direct Shear Test (Mohammad, et al., 2012)

Texas A&M Transportation Institute (TTI) Torsional Shear Test applies a twisting moment with constant rate of 2.9 E -04 radian/sec along with a normal load on the top of a double layered specimen until failure. The quality of tack coat in terms of the shear resistance of the tack coat interlayer is evaluated by measuring plastic shear strength in torsion (Mohammad, et al., 2012).

Florida Direct Shear Test, developed by Florida DOT, applies a vertical shear load to a dual layered specimen with strain control mode at a constant rate of 2.0 in./min at 25 °C until failure. Field cores can also be used for the testing. The performance of tack coat is evaluated by measuring the interlayer bonding strength (Mohammad, et al., 2012).

Figure : Florida Direct Shear Test (Mohammad, et al., 2012)

Ancona shear testing research and analysis (ASTRA) Shear Test applies a horizontal load along the interface of a dual layered sample at a constant rate until failure. A constant normal load is also applied on top of the sample during the testing. The maximum interface shear stress is measured (Mohammad, et al., 2012).

Layer-parallel direct shear (LPDS) applies a vertical load to a composite specimen with strain control mode. Both laboratory-fabricated and field core samples can be used for the testing. Nominal average shear stress and the maximum shear stiffness are measured(Mohammad, et al., 2012

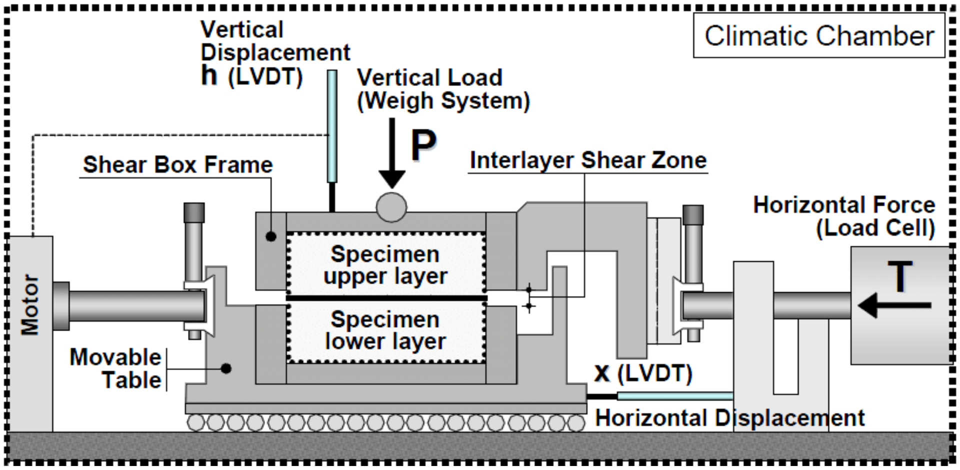


Figure: ASTRA test device (Canesrari, et al., 2005)

Switzerland pull-off test applies a tensile load to dual layered asphalt concrete specimen at a constant rate. It should be noted that the specimen is required to be glued together and the test should be conducted in accordance to German testing specification ZTV-SIB 90. The device measures tensile strength of interface (Raab & Partl, 2004).

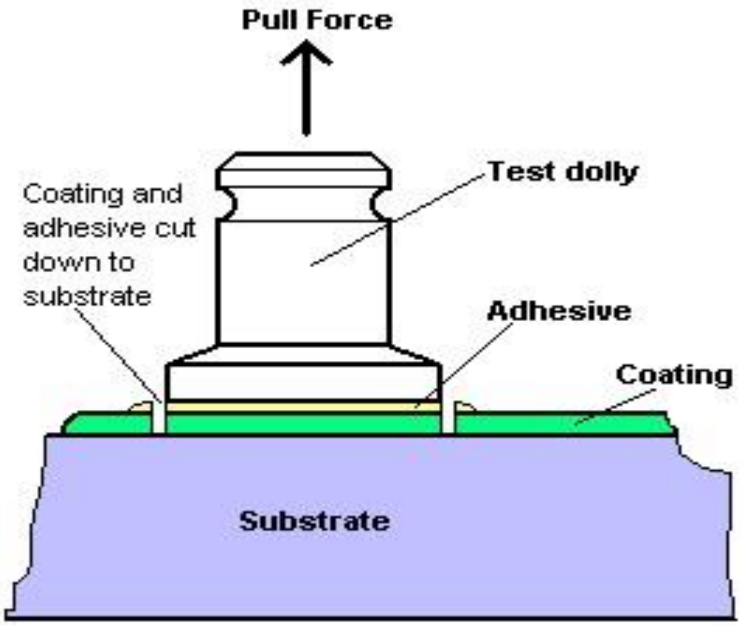


Figure: Pull-off test device (Raab & Partl, 2004)

The indirect tensile stress test has been widely used to determine the tensile strength and fatigue resistance of asphalt layers. (Dylan Berkley, Surface Tech, 2019)

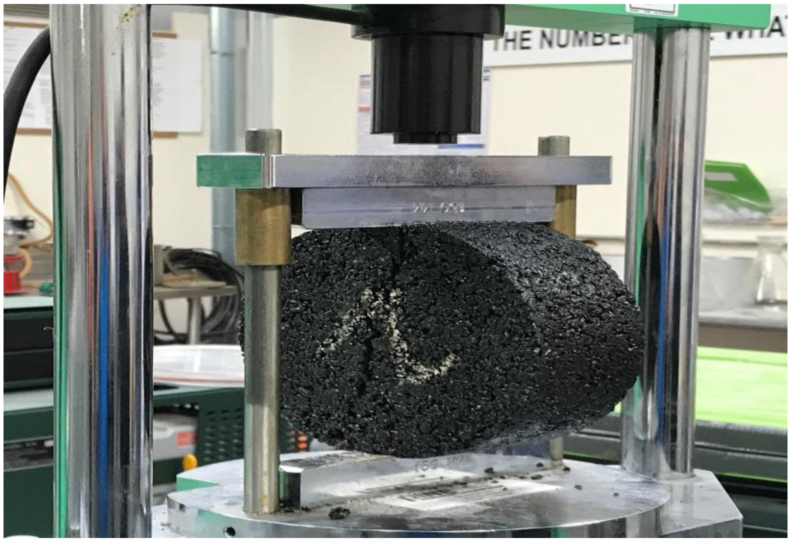


Figure: Indirect Tensile Stress test (Dylan Berkley, Surface Tech, 2019)

Chapter 4

Methodology

1. At first a device is made by which application of tensile force and shear force is possible can be done in bitumen samples.
2. This device is designed to be attached with the UTM machine.
3. A load cell is galvanized on top the grip bar of the device to measure the amount of load it can carry. The facility of UTM machine can’t be used in calculating the load because of the sensitive nature of sample.
4. Preparation of bitumen is done to get the bitumen sample in a size of 1 cubic inch.
5. The values of load and deformation are noted from the arduino and UTM machine respectively.
6. Process is repeated to obtain values of other samples. And the values are then averaged.
7. From the average value the final graph is drawn.

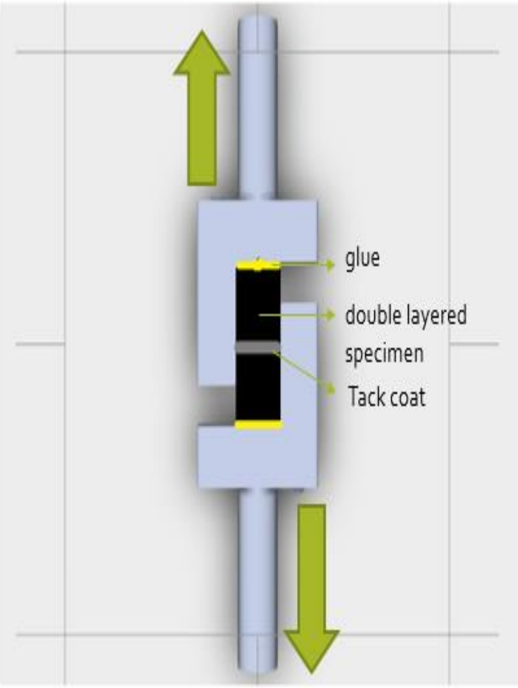


Figure: Setup for applying tensile stress.

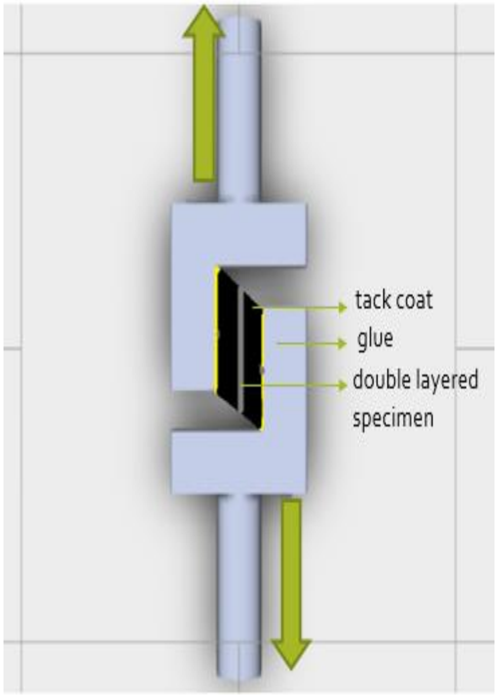
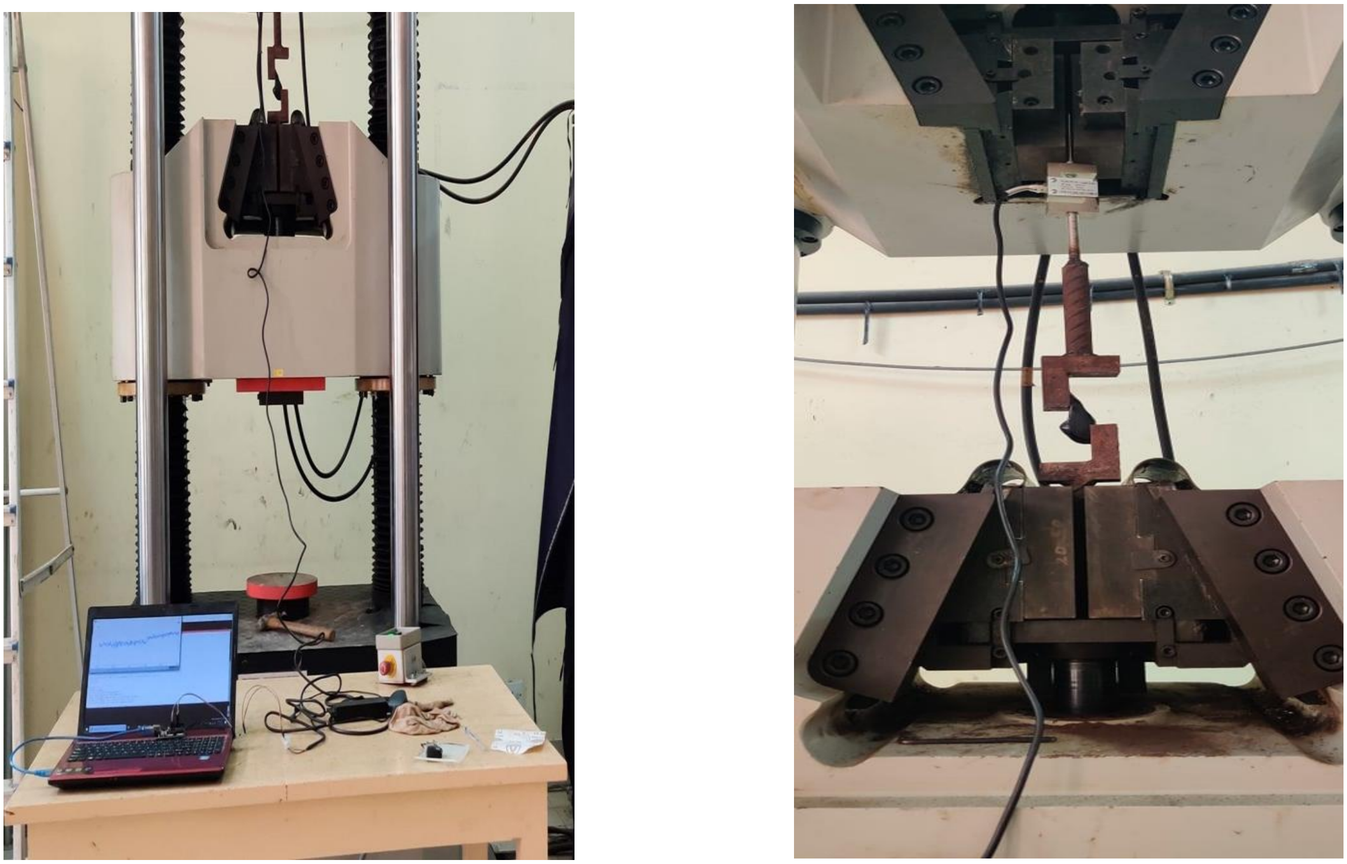


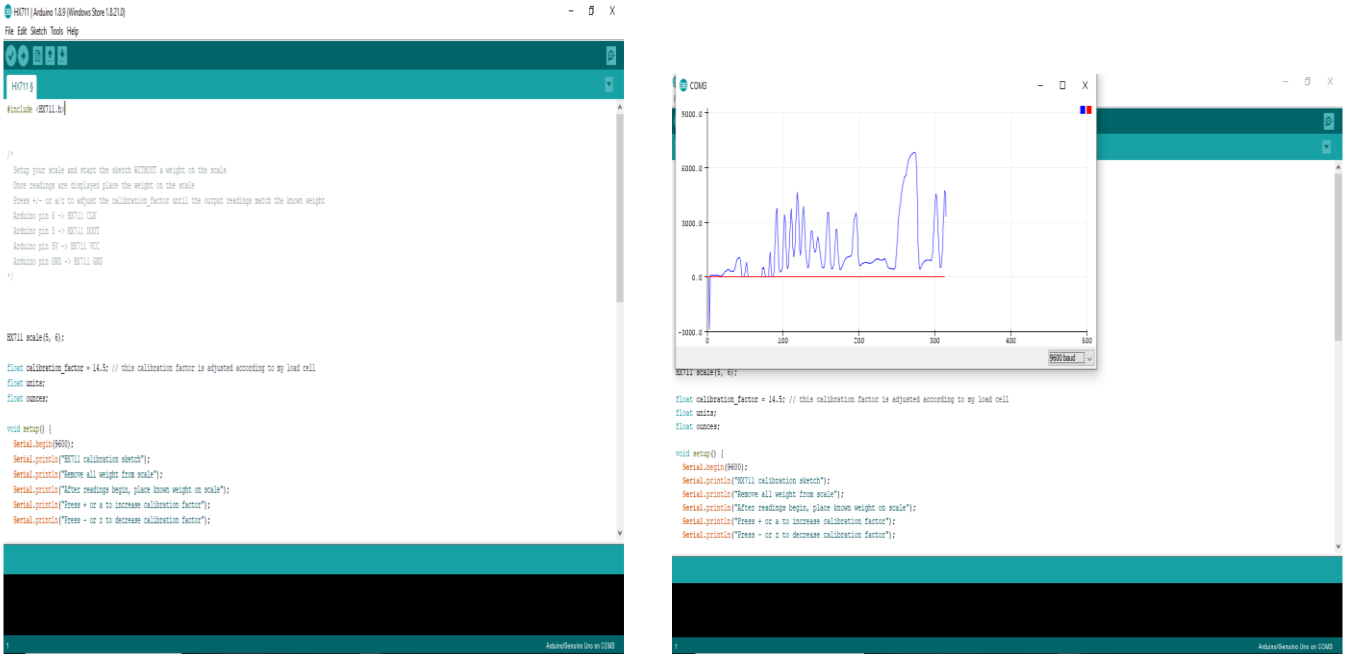
Figure: Setup for applying shear stress.

From first figure-we can see, a 1 inch*1 inch double layered specimen is kept in our hand-made device. Then we attach this device in UTM machine. Then tensile stress is applied in the sample through the machine. The applied load is very sensitive. That's why we have to use an external software named ARDUINO. This software help to get the sensitive load.

In second figure, Shear stress is applied in the sample through UTM machine. Then shear stress is applied in the sample through the machine. The applied load is very sensitive. That's why we have to use an external software named ARDUINO.



Figures: Tensile and Shear stress is applying in our sample through UTM.



```
#include <HX711.h>


/*
  Setup your scale and start the sketch WITHOUT a weight on the scale
  Once readings are displayed place the weight on the scale
  Press +/- or a/z to adjust the calibration_factor until the output readings match the known weight
  Arduino pin 6 -> HX711 CLK
  Arduino pin 5 -> HX711 DOUT
  Arduino pin 5V -> HX711 VCC
  Arduino pin GND -> HX711 GND
*/



HX711 scale(5, 6);

float calibration_factor = 14.5; // this calibration factor is adjusted according to my load cell
float units;
float ounces;

void setup() {
  Serial.begin(9600);
  Serial.println("HX711 calibration sketch");
  Serial.println("Remove all weight from scale");
  Serial.println("After readings begin, place known weight on scale");
  Serial.println("Press + or a to increase calibration factor");
  Serial.println("Press - or z to decrease calibration factor");
```

```
HX711 scale(5, 6);

float calibration_factor = 14.5; // this calibration factor is adjusted according to my load cell
float units;
float ounces;

void setup() {
  Serial.begin(9600);
  Serial.println("HX711 calibration sketch");
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  Serial.println("Press - or z to decrease calibration factor");
```

Figure: *Applied load is showing in ARDUINO software*

Chapter 5

Result and Discussion

1. The shear stress is obtained by the help of the load data shown by the arduino software.

2. And the deformation is found in the display of UTM machine by which the strain is obtained.

3. With the value of shear stress and strain a stress-strain curve is drawn.

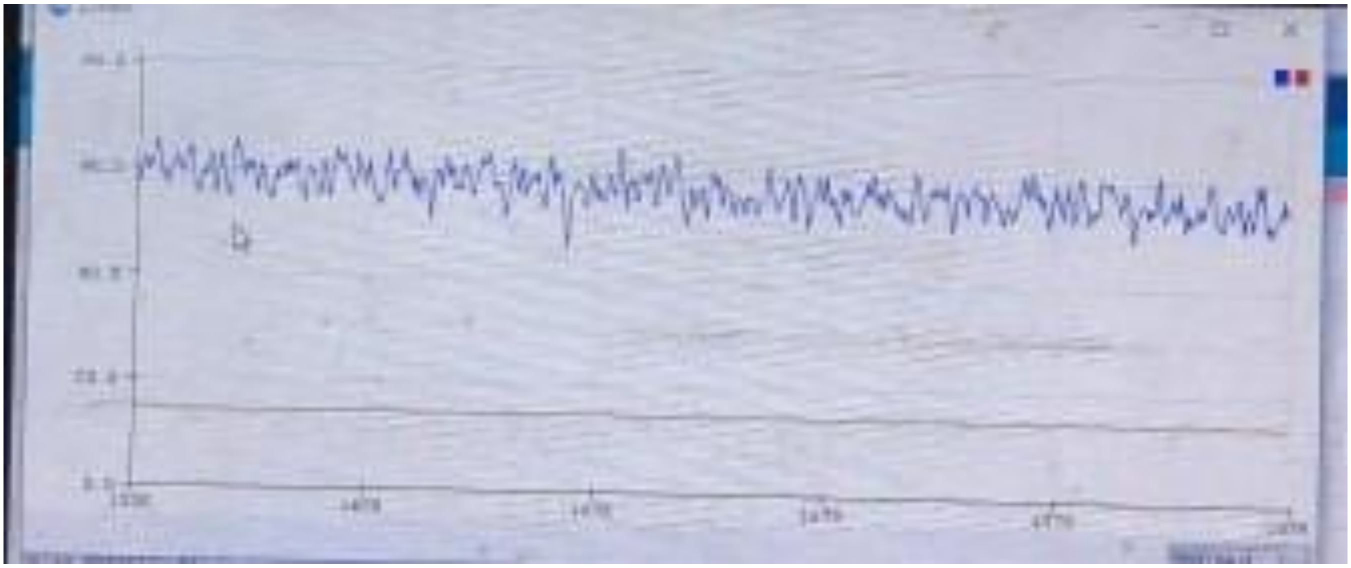
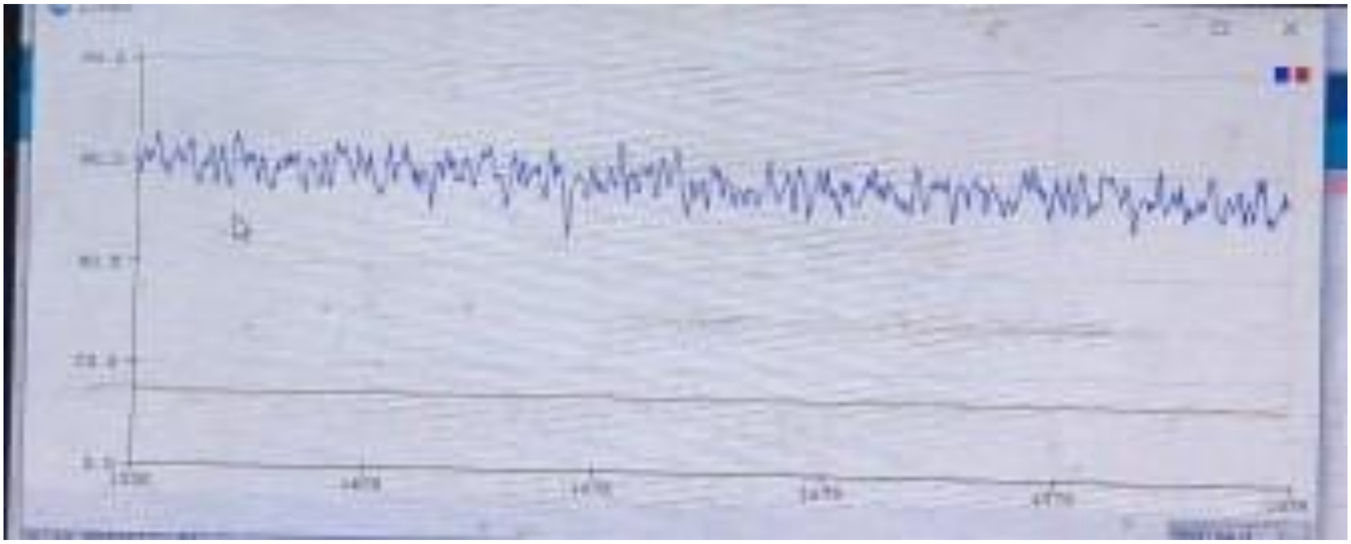


Figure : Load in different bitumen samples.



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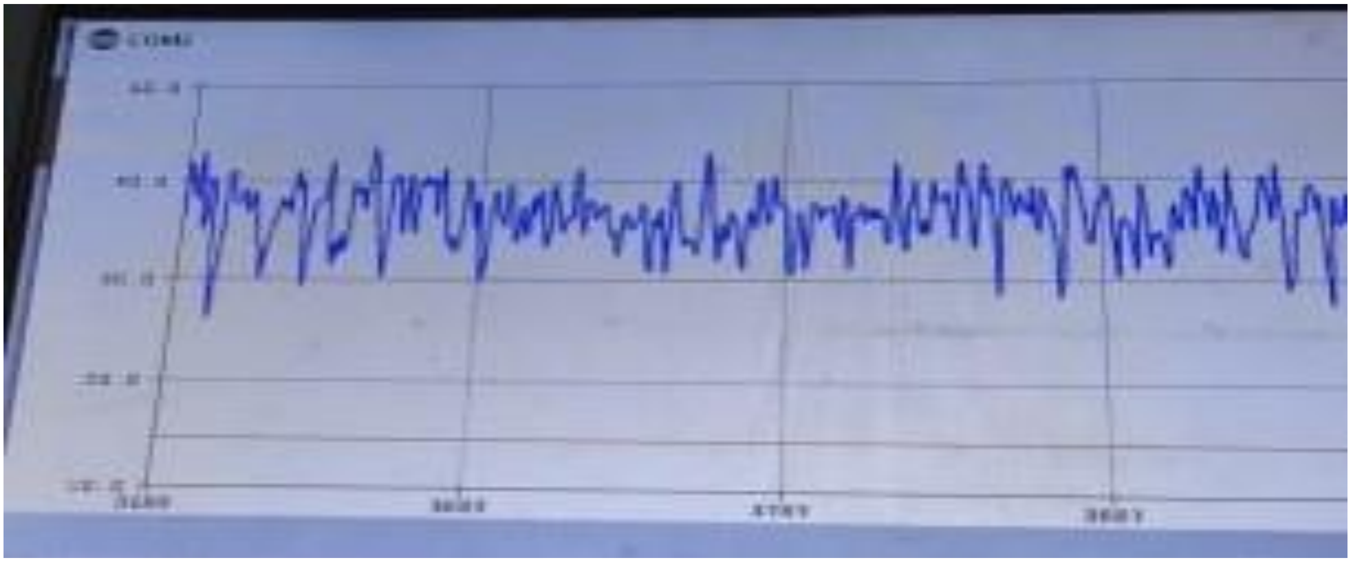

Figure: Load in different bitumen samples.

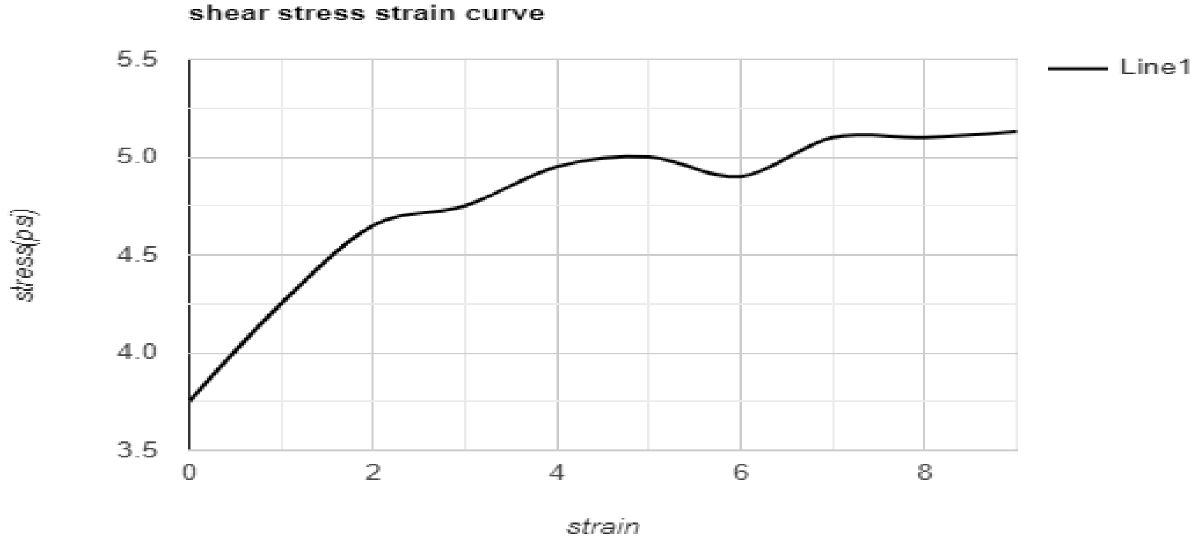

Figure: Strain versus Stress of load

4. The values of the graphs are taken as an average values given by different samples

5. In the graph we can see the elastic behaviour of the bitumen sample.

6. The loads are obtained in ounces which are then converted into stress

with a unit of Psi.

7. The results don’t show much fluctuation from the property of bitumen.

Chapter 6

Summary and Conclusion

Interface bonding condition between asphalt courses plays a critical role in the pavement performance. One of the most common distresses is slippage failure, which usually occurs where heavy vehicles are often accelerating, decelerating, or turning other pavement problems that have been linked to poor bonding between pavement layers include premature fatigue, top down cracking, pothole, and surface layer delamination, which reduces the serviceability and performance of a pavement. There are many factors affecting the interface bonding condition, including 1) improperly cleaned interface; 2)cold temperature; 3) insufficient curing, and 4) improper selection or/and application rate of material (i.e., tack coat).

Many test methods have been developed to evaluate the interface condition in the lab and the field. There is, however, no standard test method for the evaluation. In addition, available test methods has limitation including: 1) indirect measurement 2)limited application to the field 3) limited measurement range 4) acquisition of undisturbed-interface sample from coring process.

Different types of available test methods were explored for their ability to measure weak bonding condition, including nondestructive evaluation (NDE), and laboratory and in-situ measurements.

For in-situ tests, available test methods can be categorized by test modes, namely torque, shear, and tension. Limitations in application of each test methods for evaluation of interface bonding condition are illustrated in the following:

- Shear test (e.g., In-situ Shear Stiffness Test from Carleton University, Canada) measures the shear strength of asphalt pavement in the field; however, the shear force is not applied to the interface instead applied to the surface of pavements. Thus, the test results do not necessarily reflect the interface bonding condition of the pavements.

- Tension test (e.g., UTEP Simple Pull-off Test) determines bonding strength as a tensile force is directly applied to the surface of tack coated pavement or surface. For evaluation of in-situ pavement interface bonding condition, the tension test is not appropriate test methods due to its limited measurement capacity as it is designed to test tack coat material performance.

Besides, this device can be used to measure the tensile strength and shear strength of bitumen with the help of UTM machine available in IUT.

Modifying this device can give the opportunity to analyze bitumen with different specimen sizes.

This properties are measured for creating safer roads with higher tensile and shear resistance.

Future scope of our work

1. This device can be used to measure the tensile strength and shear strength of bitumen with the help of UTM machine available in IUT.

2. Modifying this device can give the opportunity to analyze bitumen with different specimen sizes.

3. This properties are measured for creating safer roads with higher tensile and shear resistance.

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LIST OF REFERENCES

References

Al-Qadi, I. L., Carpenter, S. H., Leng, Z. & Ozer, H., 2008. Tack Coat Optimization for HMA Overlays: Laboratory Testing, Springfield: Illinois Center for Trasnportation.

Canesrari, F., Ferrotti, G., Partl, M. N. & Santagata, E., 2005. Advanced Testing and Characterization of Interlayer Shear Resistance. Transporation Research Record, Volume 1929, pp. 69-78

Chang, G., Xu, Q., Horan, B. & Michael, L., 2010. Accelerated Implementation Of Intelligent Compaction Technology for Embankment Subgrade Soils, Aggregate Base, And Asphalt Pavement Materials, Washington DC: Federal Highway Administration.

Donovan, E. P., Al-Qadi, I. L. & Loulizi, A., 2000. Optimization of Tack Coat Application Rate for Geocomposite Membrane on Bridge Deck. Trasporation Reserach Record, Volume 1740, pp. 143-150.

Guide For The Evaluation of Shotcrete (ACI 506.4R), 1994. Farmington Hills, MI: American Concrete Institute.

International Concrete Repair Institute, 2004. Guideline for the Evaluation of Unbonded

Post-Tensioned Concrete Structures, s.l.: s.n.

Kulkarni, M. B., 2004. Effect of Tack and Prime Coats, and Baghouse Fines on Composite Asphalt Pavements. Raleigh, NC: Thesis at North Carolina State University.

Manuel Celaya, S. N. C. R. H. V. Q., 2011. Delamination Detection of Asphalt Pavements with Nondestructive Testing Devices. Washington, DC: Transportation Research Board of The National Academies.

Mehta, Y. A., June 2007. Evaluation of Interlayer Bonding In HMA Pavements, Madison, WI: Wiscosin Department of Transportation.

Mohammad, L., Button, J. & Scherocman, J. A., 2012. Optimization of Tack Coat for HMA Placement, Washington, D. C.: Transportation Research Board.

Munoz, D. M., 2009. Finite Element Modeling of Nondestructive Test Methods Used For Detection of Delamination in Hot Mixed Asphalt Pavements. El Paso, TX: Thesis at the University of Texas at El Paso.

NCHRP, n.d. Mechanistic-Empirical Pavement Design Guide. [Online]
Available at: http://onlinepubs.trb.org/onlinepubs/archive/mepdg/home.htm
[Accessed 15 June 2014].

Orosz, K. & Taljsten, B., 2009. Development of a new test method for mineral based composites. Concrete repair. rehabilitation and retrofitting.

Standard Method of Test for Prediction of Asphalt-Bound Pavement Layer Temperatures (AASHTO T 317), 2004. Washington, DC: American Association of State Highway and Transportation Officials.

Standard Method of Test for Quantitative Extraction and Recovery of Asphalt Binder from Asphalt Mixtures (AASHTO T 319), 2008. Washington, DC: American Association of State and Highway Transportation Officials.