THE USE OF MARINE SAND IN BITUMINOUS MIXER

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The Use of Marine Sand in Bituminous Mixer

by

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
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BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

Approved by,

(Assoc. Prof. Dr Madzlan Napiah)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2008

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

HASMI SAIFUDDIN BIN SEBI @ HASBI

ABSTRACT

Over the past decade, dramatic increasing in truck traffic, heavier axle loads, various environmental impacts and higher tire pressure had contributed to severe pavement distortions. In Malaysia, permanent deformation (creep deformation) is a continuously pavement distortion problems which caused by effect of temperature, successive stresses, excessive high bitumen content from improper mix design and insufficient compaction during roadway construction. In bituminous mix, fine aggregate's recent trend is using mining sand. Comparison in term of performance towards creep deformation between marine sand and mining sand as fine aggregate are key purpose for the study. For experiments, aggregate gradation are done for coarse aggregate; granite, fine aggregate; marine sand and mining sand as well as filler; ordinary Portland cement. It is to determine the percentages of material used for making Marshall Mix sample. After conducting Marshall Mix design, stability tests is conducted upon each of sample to determine the optimum bitumen content by plotting graph of stability, density and void in mineral aggregate versus binder content. Dynamic creep test is performed to compare the performance of both samples. The result revealed that marine sand reaching stages of failures is twice as much compared with mining sand. It proves that usage of marine sand in bituminous mix increased its resistance towards permanent deformation (creep deformation).

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Contents

List of Tables

List of Figures

List of Appendices

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND STUDY

The best way to build a durable and long lasting structure such as a road pavement is to have a solid wearing course at road surfacing. The designing of a road with a strong wearing course can provide the load bearing capacity needed to handle heavy axle loads. Strong wearing course also provides the load spreading ability to relieve stresses and strains from heavy axle loads.

With an increasing demand in highway's construction, scientist and engineers are constantly trying to improve the performance of bitumen pavement. In recent years, with increases in cars and trucks, various environmental effects, the road services have been exposed to the high traffic that causing constant and excessive stresses on roadway pavement which leads to permanent deformation (creep deformation).

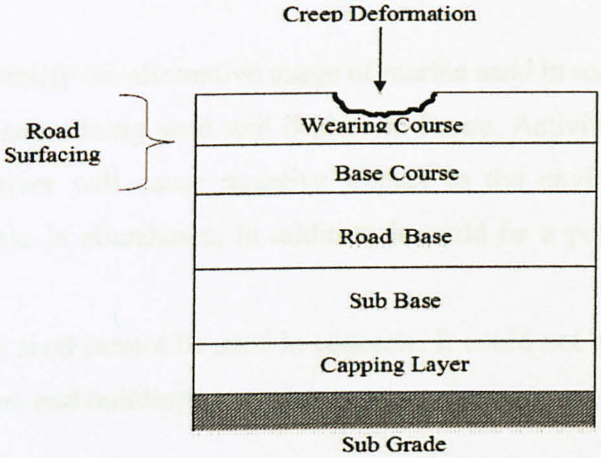


Figure 1.1 Sketch of Creep Deformation on Wearing Course

Creep deformation define as the tendency of a bitumen pavement at the wearing course of road surfacing to slowly move or deform permanently under the influence of stresses. It occurs as a result of long term exposure to levels of stress that are below the yield strength or ultimate strength of the material. Creep is more severe in materials that are subjected to heat for long periods, and near the melting point. Creep is a monotonically increasing function of temperature. Several searches have been carried out on modifying and replacing the fine aggregates to increase it's resistance towards permanent deformation. Nowadays bituminous mixer recent trend for fine aggregate are using mining sand and river sand. So with the new development in highway engineering's technology, marine sand could be the potential alternative for fine aggregate in bituminous mix. For this paper, the marine sand existed at Telok Batek, Perak Darul Ridzuan would be used as the raw material in bituminous mixer.

1.2 PROBLEM STATEMENT

Nowadays, highway engineering requires continuous development of new technologies in order to explore the potential use of marine sand in bituminous mixer. So this study diversifies the source of material for mining and river sand. Marine sand is used as alternative for stated sand. The problem statement includes:

a) To diversify the alternative usage of marine sand in road construction materials.
b) River and mining sand will deplete in future. Activities such as mining the sand from river will cause negative impact to the environment. Marine sands are available in abundance. In addition it could be a potential replacement of river sand.
c) Marine sand cannot be used in concrete. It could not be applied in construction of structure and building.

1.3 RESEARCH OBJECTIVE

The main objectives of this research are as follows:

a) To determine the suitability of using marine sand in road construction material.
b) To assess the performance of bituminous mix in term of resistance to permanent deformation (creep deformation) by using marine sand.

1.4 SCOPE OF RESEARCH

The study will provide a detail description on the characteristic, the requirement and laboratory experiments regarding marine sand. These processes would be done through literature review on journal papers, reference books, browsing through the websites and so on. Besides that, the characteristics of marine sand could be studied through conducting specific laboratory experiments.

The study would focus on the factors such to determine the suitability of using marine sand in road construction material. This would be done through various experiments that have been chosen which suite the purpose of the study. The research includes assessing the performance of bituminous mix in term of resistance to permanent deformation (creep deformation) by using marine sand simply by conducting stages of experiments.

CHAPTER 2

LITERATURE REVIEW

2.1 BITUMINIOUS MIXER

Bitumen pavement is becoming the most popular type of pavement used in highway construction. It is envisaged that the use of bitumen pavement in highway construction will continue to increase, particularly with the additional knowledge that will be obtained from research conducted over the next few years. The engineering properties of different bituminous mix materials is therefore of significant importance in highway engineering.

This chapter would present information on the different types of bituminous mix materials, their physical characteristics, and some of the tests usually conducted on these materials when used in the maintenance and construction of highway pavements. The mix design methods for bitumen pavement (Marshall Method) have also been provided so that it could enhance the understanding of the principles involved in determining the optimum binder content for bitumen pavement's sample. The chapter contains the sufficient material on the subject to have more understanding with the fundamental engineering properties and characteristics of those bituminous mix materials used in pavements engineering.

Bituminous mixture refers to any of a variety of different types of mixtures in which bituminous material is blended together with aggregates. Bituminous mix design is a delicate balancing act among the proportions of various aggregate sizes and bitumen content. For a given aggregate gradation, the optimum bitumen content is estimated by satisfying a number of mix design parameters (Animesh Das, 2005).

2.2 SELECTION OF MIX CONSTITUENTS/ RAW MATERIALS

Binder and aggregates are the two main constituents of bituminous mix. Selection of suitable bituminous mix material to be used as the foundation for the highway pavement surface is the primary importance in the design and construction for any highways. Use of unsuitable material will often result in premature failure of the pavement surface and reduction of the ability of the pavement to carry the design traffic load

2.2.1 Bitumen 80 Penetration

Generally binders are selected based on some simple tests and other site-specific requirements. These tests could be different depending of the type of binder viz. penetration grade, cutback, emulsion, modified binder etc. For most of these tests, the test conditions are pre-fixed in the specifications. Temperature is an important parameter which affects the modulus as well as the aging of binder (Nicholas J. Garber, Lester A. Hoel, 2002) (Animesh Das, 2005). For this study, bitumen 80p is used as the binder. In Malaysia, bitumen 80/100 is the most widely used based on the specifications set by JKR.

The penetration refers to the hardness of the bitumen at 25°C and is described in bitumen 80 PEN. The higher the prefix numbers the softer the bitumen. This is due to the visco-elastic rheology property of bitumen.

Bitumen 80 penetration is a visco-elastic material and may exhibit either elastic or viscous behavior, or a combination of both, depending on the temperature and time over which the bitumen is observed. Bitumen will show liquid-like viscous behavior on a long time scale or at higher temperatures, but solid-like elastic behavior at short times/low temperatures (Nicholas J. Garber, Lester A. Hoel, 2002).

2.2.2 Aggregate

Aggregate is a collective term for the mineral materials such as granite, marine sand, and mining sand that are used with a binding medium (bitumen, Portland cement) to form compound materials (such as bituminous mixer). By volume, aggregate generally accounts for 92 to 96 percent of bituminous mixer (HAPI Asphalt Pavement Guide)(Herda Yati Bt Karman, 2005).

Numbers of tests are recommended in the specifications to judge the properties of the aggregates, e.g. strength, hardness, toughness, durability, angularity, shape factors, clay content, adhesion to binder etc. Angularity ensures adequate shear strength due to aggregate interlocking, and limiting flakiness ensures that aggregates will not break during compaction and handling (Animesh Das, 2005).

Aggregate physical properties are the most readily apparent aggregate properties and they also have the most direct effect on how an aggregate performs as either a wearing pavement material constituent. Commonly measured physical aggregate properties are (Roberts et al., 1996):

- Gradation and size.
- Toughness and abrasion resistance.
- Durability and soundness.
- Particle shape and surface texture.
- Specific gravity.
- Cleanliness and deleterious materials.

The physical attributes of aggregate includes size, shape of particle, the surface texture of particle, and the density (Roberts et al., 1996). The successful qualification of aggregate geometric irregularities is essential for understanding their effects on pavement performance and for selecting aggregates to produce pavements with adequate quality. Thus the quantification of the angularity, shape, and surface texture is important as high quality pavements are needed to meet increases traffic volume and load. Angular particles, a property found in most crushed stone, provide a better interlocking property than rounded particles (Washington State Department of Transportation, no date). This provides better performance and less rutting under repetitive traffic loads. However, this property makes the workability more difficult during the compaction stage of construction. A rough surface provides a greater bonding strength with binder and frictional resistance between particles, thus maintaining the mixtures with higher creep resistance.

The key characteristics of aggregate used in bituminous construction include:

- Gradation: The distribution of the different size particles of the aggregate (% by weight).
- Sand equivalent: The proportion of sand to finer-like particles.
- Fractured faces: The angularity of the coarse particles (un-worn fractured surfaces versus smooth or rounded surfaces).
- Flakiness: Particle shape in terms of flatness.
- Percent carbonates: Percent by weight of calcium-based aggregate.
- Uncompacted voids: Measure of the voids occurring in a loose sample of fine aggregate.
- Flat and elongated particles: Comparison of least to the greatest dimension.
- Porosity: Provide the void towards the interlocking between aggregate

2.2.2.1 Coarse Aggregate; Granite

The coarse aggregates use in designing the Marshall Mix design is inert material that does not react with cement. For the purpose of the study, granites been chosen to be the coarse aggregates. One of major requirements for coarse aggregates used in bituminous mix is the gradation of the material. The material is well graded, with the maximum size specified. Material retained in a NO. 4 sieve is considered coarse aggregate. Coarse aggregate must be clean (Nicholas J. Garber, Lester A. Hoel, 2002).

Granite is nearly always massive (lacking internal structures), hard and tough, and therefore it has gained widespread use as a construction stone. The average density of granite is 2.75 g/cm^3. The function of coarse aggregate in the mix is to provide stability in the pavement due to interlocking behavior between the coarse particles (Wikipedia, 2007d). The shapes and surface textures of the aggregates both contribute to the stability of the mix. A good quality aggregate is an aggregate which is hard and round in shape with overall angular surface texture.

According to Section 900 (Flexible Surfacing) of the PLUS Specification; Coarse aggregates must be hard, unweathered, durable, clean, crushed rock, angular in shape and free from dust. When tested in accordance with BS 812, it should have the following properties:

Aggregate Crushing Value	-	Not more than 25
Flakiness Index	-	Not more than 30
Water Absorption	-	Not more than 2%
Polished Stone Value	-	Not less than 49

Rock Type	Hardness, Toughness	Resistance to Stripping	Surface Texture	Crushed Shape
Granite	Fair	Fair	Fair	Fair

Table 2.1 Desirable Properties of Rocks for Bituminous Mixer
(From Cordon, 1979 as referenced in Roberts et al., 1996)

2.2.2.2 Fine Aggregates; Marine Sand, Mining Sand

Sand is mainly used as the fine aggregate in bituminous mix. Specifications for this material usually include grading requirements and cleanliness (Nicholas J. Garber, Lester A. Hoel, 2002). As for cleanliness the presence of large amount of organic materials in the fine aggregates may reduce the hardening properties of the cement (Washington State Department of Transportation).

Fine aggregates enhance the stability of the mix with its interlocking characteristics and in the same time fill up the voids left out by the composition of the coarse aggregates. Fine aggregates shall have a good gradation from sieve size of 5mm to 75μm.

Surface textures of fine aggregates are also an important criterion in determining the stability of the mix. It is shown that the stability of mix increases with the increase of the roughness of the fine aggregates. Particles with the bigger size within the fine particles, which have the sieve size of 5mm to 1.18mm, play an important role in providing a rough surface on the pavement where its function is to give a frictional surface for the pavement.

Fine materials from sieve sizes of 600μm to 75μm are also important in a mix to increase the surface area of the aggregates. This will enable the mix to absorb a high content of bitumen and directly enhancing the binding force of the mix. Thus, it can be concluded that the gradation of fine materials is very important and a balance mixture of coarse aggregates and fine aggregates is needed in order to provide required frictional effects and optimum binder content (John R. Anderson, no date).

Mining sand consist of ion oxides that make the sand look brownish in color. The sand resulting from channel, stream, alluvial and fresh water deposit. It is poorly sorted which consist of wide range of sizes from big to small. Mining have more angular in shape that comes not in uniform shape (Pamela J. W. Gore, 2004).

With new development of technologies in highway engineering, marine sand could be used as the alternative for fine aggregate. Marine sand's chemical composition consists of silica SiO_2, quartz, corals, shells which contain high calcium carbonate, living organism and sodium chloride. For physical attributes, the marine sand have more rounded in shape. The marine sand have less porosity compared with mining sand which give the ideology that marine sand is much better to cover the voids possibility in bituminous mix. Marine sand is cheaper than mining sand.

2.2.2.3 Filler; Ordinary Portland Cement

Filler in the mix will act as the final void filler left by the aggregates, namely the coarse and fine aggregates. The most suitable materials that can be used as filler is Portland cement which at least 75% of it shall pass 75 micron test sieve. One of the criteria that will affect the suitability of a filler to be used is its fineness.

2.3 MARSHALL MIX DESIGN

The design of a bituminous mix involves the aggregate type, aggregate grading, bitumen grade and the determination of a bitumen content, which will optimize the engineering properties to the desired behavior in service. The basic concept of the Marshall mix design method were originally developed by Bruce Marshall of the Mississippi highway department around 1939 and then refined by the us army. Currently the Marshall method is used in some capacity by about 38 states. The Marshall method seeks to select the bituminous mix content at a desired density that satisfies minimum stabilities and range of flow values (White, 1985 cited by Washington State Department of Transportation, no date).

The Marshall Stability and flow test provides the performance prediction measure for the Marshall Mix design method (Tom V. Mathew, K V Krishna Rao, 2007). The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8mm/minute. Load is applied to the specimen till failure, and the maximum load is designated as stability. During the loading, an attached dial gauge measures the specimen's plastic flow (deformation) due to the loading. The flow value is recorded in 0.25 mm (0.01 inch) increment at the same time when the maximum load is recorded.

Generally, the Marshall Mix design method consists of five basic steps:

1. Aggregate selection.
2. Bitumen selection.
3. Sample preparation (including compaction).
4. Stability determination using the Marshall Stability and Flow test.
5. Optimum bitumen content selection.

Basic Marshall Mix design specifications from the Asphalt Institute are shown in the table below.

Mix Criteria	Light Traffic (< 10^4 ESALs)		Medium Traffic (10^4 - 10^6 ESALs)		Heavy Traffic (> 10^6 ESALs)	
	Min.	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
Compaction (Number of Blows on Each End of the Sample)	35		50		75	
Stability	500 lbs.		750 lbs.		1500 lbs.	
Flow (in Units of 0.01 Inches)	8	20	8	18	8	16
Percent Air Voids	3	5	3	5	3	5

Table 2.2 Basic Marshall Mix Design Specifications

2.4 CREEP DEFORMATION

Creep deformation define as the tendency of a bitumen pavement at the wearing course of road surfacing to slowly move or deform permanently under the influence of stresses. It occurs as a result of long term exposure to levels of stress that are below the yield strength or ultimate strength of the material (Wikipedia, 2007a). Creep is more severe in materials that are subjected to heat for long periods, and near the melting point. Creep is a monotonically increasing function of temperature.

To determine the permanent deformation resistance of a bituminous mix, the low stiffness response of the material must be analyzed, for example the response at high temperatures or long loading time. When the stiffness of bitumen is< 5x10^6 Pa, mix behavior is much complex than it is in the elastic zone. Under these conditions, the stiffness of the mix not only depends on that of the bitumen and the volume of aggregate and bitumen, but also on a variety of other factors. These include the aggregate grading, its shape, texture and degree of interlock, and the method and the degree of compaction (David Whiteoak, 1990).

CHAPTER 3

METHODOLOGY

3.1 RESEARCH METHODOLOGY

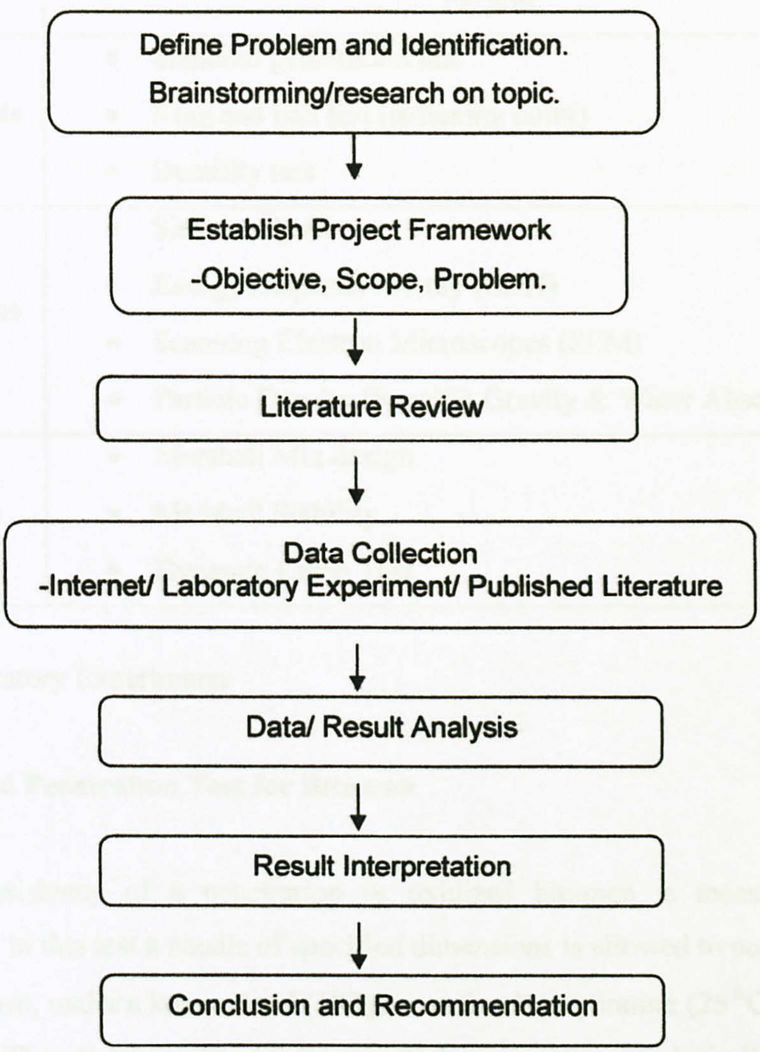


Figure 3.1 Flow Chart of Research Methodology

3.2 LABORATORY EXPERIMENTS

A summary of some of the current procedures and techniques used for testing and identification is presented in this part. The techniques presented are those currently used in highway pavement design. This chapter described the procedures used to develop sample for bituminous mix. There are 3 main experiments that needed to be conducted.

Tests	Purpose
Bitumen 80 Tests	• Standard penetration test • Ring and ball test (softening point) • Ductility test
Aggregates Tests	• Sieve analysis • Energy Dispersive X-ray (EDX) • Scanning Electron Microscopes (SEM) • Particle Density (Specific Gravity & Water Absorption)
Mixture Tests	• Marshall Mix design • Marshall Stability • Dynamic Creep Test

Table 3.1 Laboratory Experiments

3.2.1 Standard Penetration Test for Bitumen

The consistency of a penetration or oxidized bitumen is measured by the penetration test. In this test a needle of specified dimensions is allowed to penetrate into a sample of bitumen, under a known load (100g), at a fixed temperature (25 ^{0}C), for known time (5 secs). The distance the needle penetrates, in units of decimilimitre, dmm (0.1mm), is termed the penetration. Therefore the greater the penetration of the needle the softer the bitumen. Penetrations less than 2 and greater than 500 cannot be determined with accuracy and even within this range the specified procedure has to be followed closely to obtain reliable results. This test is the basis upon which penetration grade bitumen are classified into standards penetration ranges (British Standard Institution, 1983a).

It is essential that the test methods are followed precisely, as even the slight variation can cause large differences in results. The most common errors are; poor sampling and sample preparation; badly maintained apparatus and needles; and incorrect temperature and timing. Temperature control is critical, control to $\pm 0.1\,^0$C s essential. Needles must be checked regularly for straightness, correct profile and cleanliness. Automatic timing devices are needed for accuracy but these must be checked regularly.

3.2.2 Ring and Ball Test (Softening Point)

The consistency of a penetration or oxidized bitumen can also be measured by determining its softening point. In this test a steel ball (3.5g) is placed on a sample of bitumen contained in a brass ring; this is suspended in a water or glycerol bath. Water is used for bitumen with a softening point of 80 ^{0}C or below, and glycerol is used for softening points greater than 80 ^{0}C. the bath temperature is raised at 5 ^{0}C per minute, the bitumen soften and eventually deforms slowly with the ball through the ring. At the moment the bitumen and steel ball touch a base plate 25mm below the ring, the temperature of the water is recorded. The test is performed in duplicate and the mean of the two measured temperatures is reported, to the nearest 0.2 ^{0}C for penetration grade bitumen and 0.5 ^{0}C for oxidized bitumen. If the difference between the two results exceeds 1.0 ^{0}C the test must be repeated. The reported temperature is designated the softening point of the bitumen, and represents and equi-viscous temperature. In the ASTM version of the softening point test the bath is nit strirred, whereas in the Bs and IP versions the water or glycerol is stirred; consequently the softening points determined by using these two methods differ. The ASTM results are generally 1.5 ^{0} C higher than for the BS or IP method (British Standard Institution, 1983b).

As with the penetration test, the procedure for carrying out the softening point test must be followed precisely to obtain accurate results. Sample preparation, rate of heating and accuracy of temperature measurement are critical. Automatic softening point machines are available which ensure close temperature control and which automatically record the result at the end of the test.

3.2.3 Ductility Test

The cohesive strength of penetration grade bitumen is characterized by low temperature ductility. In this test three dumb-bells of bitumen are immersed in water bath with a standard test temperature of 25 ^{0} C and stretched at a constant speed of 50mm per minute until fracture occurs. The distance the specimen is stretched before failure is reported as the ductility. Other temperatures can be used depending on the penetration of bitumen (ASTM D113-07).

3.2.4 Sieve Analysis

A study of the effect of sieve loading, particle size and duration of sieving on tests results showed a close correlation between the percentages retained by the sieves used for fine aggregate and sieve loading. This loading effect was found to be determined by the proportion of near mesh particles present and their shape. The study indicated that these inaccuracies were more effectively remedied by reducing the sample size than by sieving for a longer period of time. Recommendations were given to the 'maximum permissible amount of sand that should be retained' on each sieve size in order to avoid overloading. These provided the basis of our specification for 'minimum masses to be retained' on each sieve (British Standard Institution, 1985b).

The particle size distribution of an aggregate is determined by shaking the sample in a prescribed manner through an opposite succession on test sieves. The coarser sieves (5 mm aperture and above) are in perforated-plate for greater accuracy and the finer sieves are in woven-wire. Sieves normally used for road making aggregates are specified in BS410 and are as follows:

(i) Perforated-plate sieves (all sizes in mm):
75.0, 63.0, 50.0, 37.5, 28.0, 20.0, 14.0, 10.0, 6.30, & 5.00

(ii) Wire cloath (in mm):
3.35, 2.36, 1.70, 1.18

(iii) Wire cloath (in μm):
850, 600, 425, 300, 212, 150 & 75 (sometimes 63)

Results are normally reported as the cumulative percentage by mass passing each appropriate test sieve and are, for many purposes, plotted on appropriate graph paper as a cumulative grading curve. For single-sized aggregates, however, it is more usual to report the percentage retained between successive sieves. Overloading of sieves during test can lead to serious errors and care should be taken to keep within the appropriate specified maximum sample masses to be retained on each sieve at the end of the sieving. A specimen chart for recording sieve analysis results is included in BS812: Part 103: 1985.

Figure 3.2 Sieve Analysis

3.2.5 Energy Dispersive X-ray (EDX)

Energy dispersive X-ray spectroscopy (EDS or EDX) is an analytical technique used for the elemental analysis or chemical characterization of a sample. As a type of spectroscopy, it relies on the investigation of a sample through interactions between electromagnetic radiation and matter, analyzing x-rays emitted by the matter in response to being hit with the electromagnetic radiation. Its characterization capabilities are due in large part to the fundamental principle that each element has a unique atomic structure allowing x-rays that are characteristic of an element's atomic structure to be identified uniquely from each other.

To stimulate the emission of characteristic x-rays from a specimen, a high energy beam of charged particles such as electrons or protons, or a beam of x-rays, is focused into the sample being studied. At rest, an atom within the sample contains ground state (or unexcited) electrons in discrete energy levels or electron shells bound to the nucleus. The incident beam may excite an electron in an inner shell, ejecting it from the shell while creating an electron hole where the electron was. An electron from an outer, higher-energy shell then fills the hole, and the difference in energy between the higher-energy shell and the lower energy shell is released in the form of an x-ray. The x-ray released by the electron is then detected and analyzed by the energy dispersive spectrometer. These x-rays are characteristic of the difference in energy between the two shells, and of the atomic structure of the element form which they were emitted (Wikipedia, 2007b).

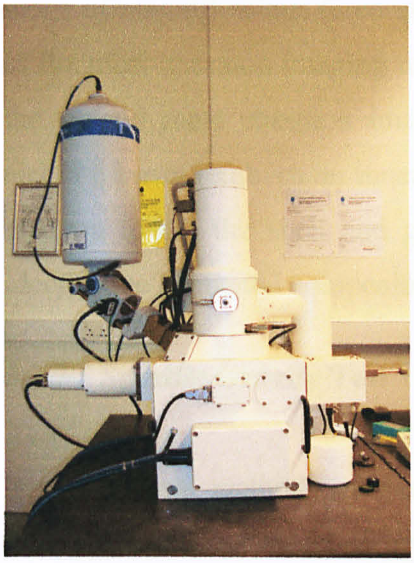


Figure 3.3 Energy Dispersive X-ray (EDX)

3.2.6 Scanning Electron Microscopes (SEM)

Scanning electron microscopes are equipped with a cathode and magnetic lenses to create and focus a beam of electrons, and since the 1960s they have been equipped with elemental analysis capabilities. A detector is used to convert X-ray energy into voltage signals; this information is sent to a pulse processor, which measures the signals and passes them onto an analyzer for data display and analysis. This method is appropriate to collect data on physical attributes to each raw material.

The scanning electron microscope (SEM) is a type of electron microscope that images the sample surface by scanning it with a high-energy beam of electrons in a raster scan pattern. The electrons interact with the atoms that make up the sample producing signals that contain information about the sample's surface topography, composition and other properties such as electrical conductivity.

Due to the way these images are created, SEM micrographs have a very large depth of focus yielding a characteristic three-dimensional appearance useful for understanding the surface structure of a sample. This great depth of field and the wide range of magnifications (commonly from about 25 times to 250,000 times) are available in the most common imaging mode for specimens in the SEM. Characteristic x-rays are the second most common imaging mode for an SEM. X-rays are emitted when the electron beam removes an inner shell electron from the sample, causing a higher energy electron to fill the shell and give off energy. These characteristic x-rays are used to identify the elemental composition of the sample (Wikipedia, 2007c).

3.2.7 Specific Gravity Test

Several methods of measuring the specific gravity of aggregates are specified which make use of measurements of the mass of the sample in air and in water. Either a wire basket, a gas jar or a pynometer is employed to contain the sample, the choice being governed by the grading of the sample concerned.

For this purpose, Ultrapycnometer 1000 Version 2.2 is used. It features improvements in design that allow the volume of small amounts of sample to be accurately detected and measured with enhanced reliability to within a fraction of a microliter. High-compression, minimum-volume seals around the pressure transducer minimize helium storage and leakage. However, particle size is limited by the dimensions of the specimen container of the particular pycnometer being used.

3.2.8 Marshall Method Procedure

Test specimen of 4 inches diameter and 2½ in height are used in this method. They are prepared by a specified procedure of heating, mixing, and compacting the mixture of asphalt and aggregates, which is then subjected to a stability-flow test and a density-voids analysis. The density is defined as the maximum load resistance *N* in pounds that the specimen, in units of 0.01 in. during the stability test, as the load is increased from zero to the maximum.

Test specimens for the Marshall method are prepared for a range of asphalt contents within the prescribed limits. The asphalt content is measured by 0.5% increments fro the minimum of 4.5% up to 7%, ensuring at least 3 are below the optimum and 3 are above the optimum so that the curve obtained from the result will indicate a well-defined optimum. For the study, mixtures of 4.5%, 5%, 5.5%, 6%, 6.5% and 7% are prepared. At least 3 specimens are provided for each asphalt content to facilitate the provision of adequate data. For the experiments of 6 different asphalt contents, therefore, a total minimum number of 18 specimens required. Total of the specimen would be 36 consist of Marshall Mix design using marine sand and mining sand. The amount of aggregates required for each specimen is about 1.2kg. A quantity of the aggregates having the designed gradation is dried at temperature between 105'C and 110'C until a constant weight is obtained.

The specimens containing the appropriate amounts of aggregates and asphalt are then prepared by thoroughly mixing and compacting each mixture. The compactive effort used is 75 blows of the hammer falling distance of 18 in. after the application of one face, the sample mold is reversed and the same numbers of blows is applied to the other face of the sample. The specimen is then cooled and tested for stability and flow after determining its bulk density. The bulk density of the sample is determined usually by weighing the sample in air and in water.

Figure 3.4 Marshall Hammer

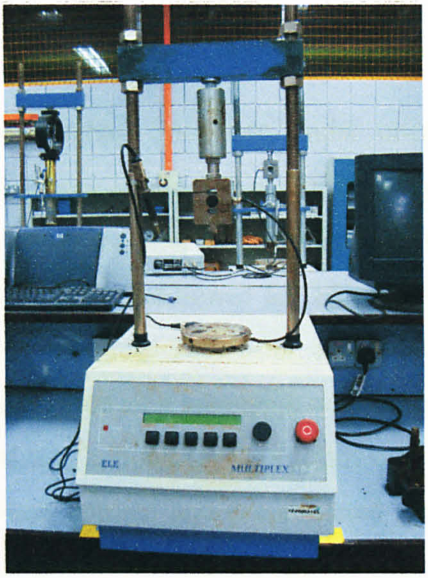


Figure 3.5 Marshall Stability Test

3.2.9 Stability Test

In conducting the stability test, the specimen is immersed in a bath of water at a temperature of 60^{0}C for a period of 30 to 40 minutes. It is then placed in the Marshall Stability testing machine, and loaded at a constant rate of deformation of 2 in. (5mm) per minute until failure occurs. The total load N in pounds that causes failure of the specimen at 60^{0}C is noted as the Marshall Stability value of the specimen. The total amount of deformation in units of 0.01 in. that occurs up to the point the load starts decreasing is recorded as the flow value. The total time between removing the specimen from the bath and completion of the test should not exceed 30 seconds.

3.2.10 Dynamic Creep Test

Dynamic creep test was conducted on Marshall Specimen under unconfined condition according to British Standards. The test was conducted at 40 ^{0}C temperature and specimens were conditioned in an environmental chamber for 2 hours prior to their testing. During testing also, the specimen was initially conditioned for 10 minutes with 100 kPa static load to compensate for any sample variation. Thereafter, it was subjected to repeat axial loading. The loading parameters consisted of a haversine wave shape with 100kPa peak stress and 1 Hz frequency. The load was applied for 0.1s followed by a rest period of 0.9s. Maximum of 1800 load cycles were applied and accumulated strain and creep modulus were evaluated.

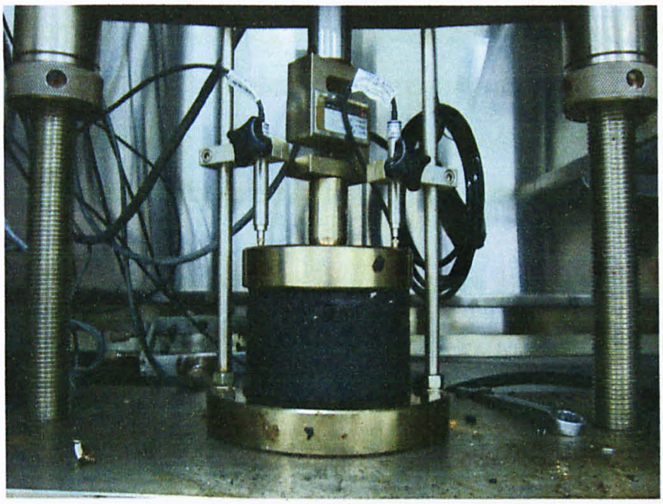


Figure 3.6 Dynamic Creep Test

3.3 HAZARDS ASSESMENTS

3.3.1 Noise Hazards

A noise hazard is an unwanted sound that may damage a person's hearing. As a guide, if it is necessary to raise your voice to have a conversation with someone face-to-face, there is a noise problem in the workplace. Excessive noises are generated within the laboratory by machinery and tools. They include Marshall Compactor and sieve analysis machine.

Repeated exposure to excessive noise levels results in noise-induced hearing loss. The hair cells of the cochlea that generate nerve impulses will be damaged or destroyed when their supporting structures are overworked. Only a few hair cells may be lost at a time, but with repeated exposure over days, months and years, the cumulative effect can be substantial. This type of hearing loss is permanent, when the microscopic structures are damaged; there is no way to repair them to restore reasonable hearing.

The best way to prevent noise hazards is by wearing noise protection or ringing ears. It prevents the amount of noise from workplace coming straight to the ear. Below are among the type of ear protection;

- Pre-formed or molded ear plugs.
- Self-forming ear plugs
- Sealed earmuffs that can be adjusted to create a seal around each ear.

3.3.2 Temperatures Extreme

Temperatures extreme became an issue. In the lab the heat resulting from the oven and mixing machine.

The precautions that could be taken in the lab include wearing heat resistance hand glove. It is to prevent the amount of heat that could possibly be access by direct to the skin. The heat hazards also cause the surrounding in the lab to be hot. Working in heat can be unpleasant, can lead to illness and under extreme circumstances can be fatal.

Effects of heat

The body's natural cooling system does not cope with heat - and heat illness can occur - if:

- The circulation is overloaded by too much heat and physical workload
- Too little sweat is produced e.g. if the person is dehydrated
- Sweat cannot evaporate freely from the skin (e.g. high humidity, excessive clothing or low air movement).

Early symptoms of heat illness are feeling sick, weak, clumsy and/or dizzy. Cramps can also be caused by heat. People with these symptoms who keep on working may collapse (heat exhaustion). In extreme cases, this may even be fatal (heat stroke).

Preventing heat illness

- Generate air movement using electric fans.
- Remove heated air or steam from hot processes using local exhaust ventilation.
- Install evaporative coolers to reduce air temperature and generate air movement..
- Locate hot processes away from people. Hot processes may also be enclosed, or the control.

3.3.3 Dust Hazards

Dust can be formed from a wide range of sources such as construction work or machinery. In my lab the dust coming from the material used and the machinery itself.

Your body protects you against some dust. Not all the dust that you breathe in gets into your lungs. The larger particles are filtered out in your nose and the tubes leading to your lungs. These particles are coughed up, spat out or swallowed.

Only the finest dust particles reach your lungs. Usually these dusts are too fine for you to see them. These fine dust particles, which can enter deep into the lungs, are called 'respirable dust'.

Much of the dust that does get into your lungs is cleared out by the lungs own defense system. Macrophages (Large immune system cells that kill foreign invaders) in the lungs virtually 'swallow' some dust particles and are then carried out of the lungs. Proteins in the lungs can also 'neutralize' some dust particles. But your body cannot protect you against all dust particles.

Control measures

1. *Safe machinery and equipment*: Dusty work processes should be isolated if possible. An exhaust ventilation system is often needed to suck dust away. Vacuum tools or negative pressure portable tools are often useful. Ordinary household vacuum cleaners don't effectively trap respirable dust particles. You need a vacuum with a HEPA (high efficiency particulate air) filter. Where there is an explosion hazard you need an explosion proof vacuum cleaner.

2. *Safe procedures*: Standardized working procedures are needed in areas where dust can be a problem. Information and training is important. Warning signs may be needed. Good housekeeping procedures (e.g. vacuuming or wet sweeping dusty work areas) are needed.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 RESULT AND ANALYSIS OF TESTS RESULTS

4.1.1 Bitumen 80p

The bitumen used in the present study was bitumen 80 penetration which was characterized for various physical properties. The test result are obtained are shown in table 4.1. The values obtained are compared with specified values as per BS 3690: Part 1 specifications for penetration grade bitumen. Results indicate that bitumen used was indeed 80 penetration grades. This bitumen was used for preparation of bituminous mixer.

Property	Results	Specified Limits as per BIS: 73, 1992
Penetration at 25 ^{o} C/100gm /5 sec, dmm	85	80-90
Softening point, ^{o} C	51.7	40-55
Ductility, cm	+75	>75

Table 4.1 Bitumen 80 Penetration Properties

4.1.2 Raw Material; Physical Attributes

Granite; coarse aggregate

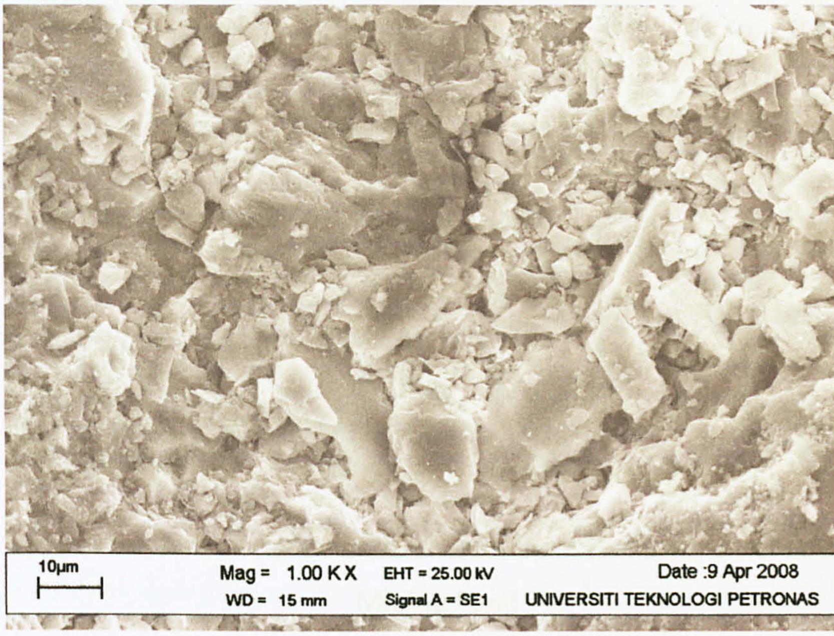
Mining sand; fine aggregate

Mining sand; fine aggregate

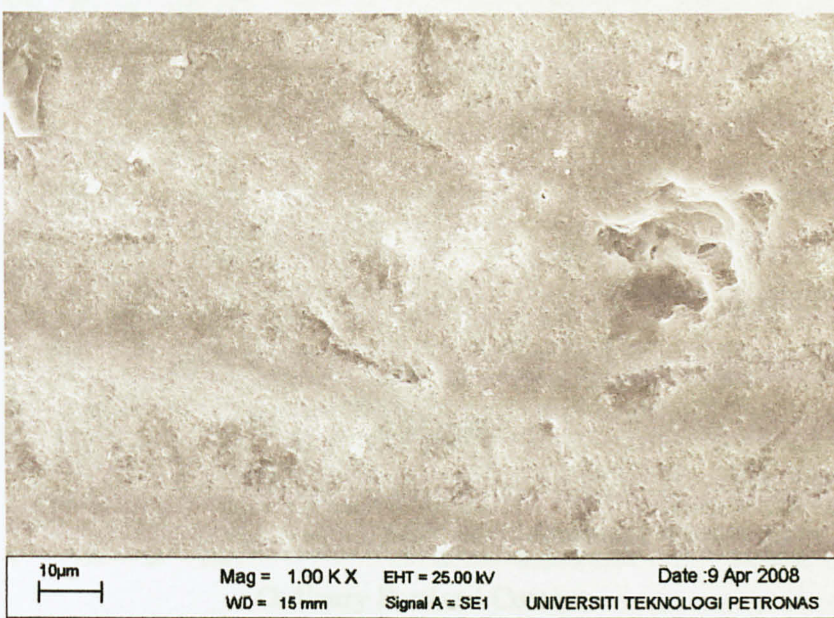
Ordinary Portland cement; filler

Figure 4.1 Physical Attributes of Raw Material for Bituminous Mixer

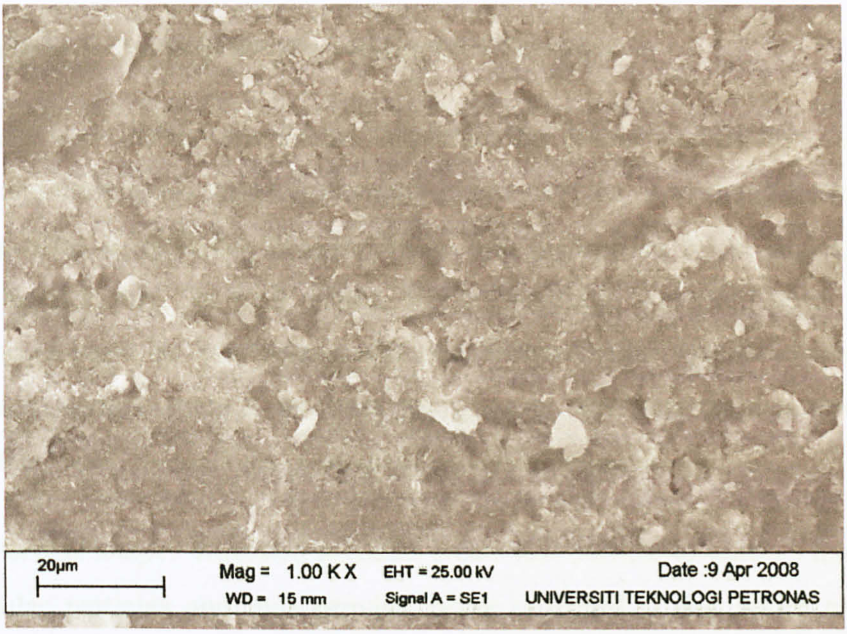
4.1.3 Surface Textures for Bituminous Mix Materials



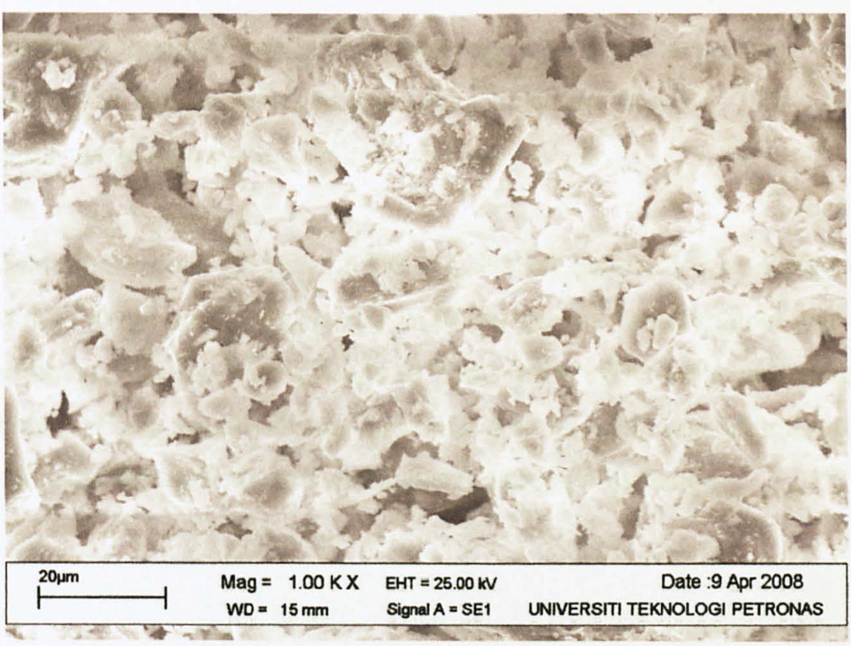
Granite



Marine sand



Mining Sand



Ordinary Portland Cement

Figure 4.2 Surface Textures of Raw Material

4.1.4 Analysis on Particle Shapes and Surface Textures

Particle shape and surface texture are important for proper compaction, deformation resistance, and bituminous mixer workability. However, the ideal shape for marine sand and mining sand is different because those fine aggregates serve slightly different properties in each mix. In both mixes, since aggregates are relied upon to provide stiffness and strength by interlocking with one another, cubic angular-shaped particles with a rough surface texture are best for granite. Relevant particle shape/texture characteristics based on result for physical attributes of materials are:

- *Particle shape*. Rounded particles create less particle-to-particle interlock than angular particles and thus provide better workability and easier compaction. Marine sand had rounded shape n more uniform compared with mining sand.

- *Flat or elongated particles*. These particles tend to impede compaction or break during compaction and thus, may decrease strength. This could be seen towards coarse aggregate, granite and mining sand.

- *Smooth-surfaced particles*. These particles have a lower surface-to-volume ratio than rough-surfaced particles and thus may be easier to coat with binder. In bituminous mix, the binder tends to bond more effectively with rough-surfaced particles. Thus, rough-surface particles are desirable for bituminous mixer to enhance the strength towards resistance to creep deformation.

4.1.5 Aggregate Gradation

B.S Sieve	Coarse Aggregate	Marine Sand	Filler	Gradation Limit (calculated)	JKR Standards Specifications
				% Passing by weight	
28.0 mm	100	100	100	100	100
20.0 mm	88.375	100	100	93.03	76-100
14.0 mm	75.4	100	100	85.24	64-89
10.0 mm	44.28	100	100	66.57	56-81
5.0 mm	17.99	98.6	100	50.32	46-71
3.35 mm	0.44	96.9	100	39.21	32-58
1.18 mm	0.32	90.4	100	36.93	20-42
425 μm	0.05	55.1	100	24.76	12-28
150 μm	0	2.8	100	6.95	6-16
75 μm	0	1.6	80	5.34	4-8

Table 4.2 Aggregate Gradation for Marine Sand

B.S Sieve	Coarse Aggregate	Mining Sand	Filler	Gradation Limit (calculated)	JKR Standards Specifications
				% Passing by weight	
28.0 mm	100	100	100	100	100
20.0 mm	88.375	100	100	93.61	76-100
14.0 mm	75.4	100	100	86.47	64-89
10.0 mm	44.28	100	100	69.35	56-81
5.0 mm	17.99	94.2	100	52.57	46-71
3.35 mm	0.44	88.9	100	40.80	32-58
1.18 mm	0.32	74.13	100	34.83	20-42
425 μm	0.05	32.13	100	17.88	12-28
150 μm	0	3.87	100	6.55	6-16
75 μm	0	2.73	80	5.09	4-8

Table 4.3 Aggregate Gradation for Mining Sand

4.1.6 Percentage/ Weight for Material Used in Bituminous Mixer

Type of Mix	Granite – Coarse Aggregates		Sands – Fine Aggregates		Ordinary Portland Cement - Filler	
	%	grams	%	grams	%	grams
Bituminous Mix with Marine Sand	60	720	34	408	6	72
Bituminous Mix with Mining Sand	55	660	40	480	5	60

Table 4.4 Percentage/Weight for Material Used in Bituminous Mixer

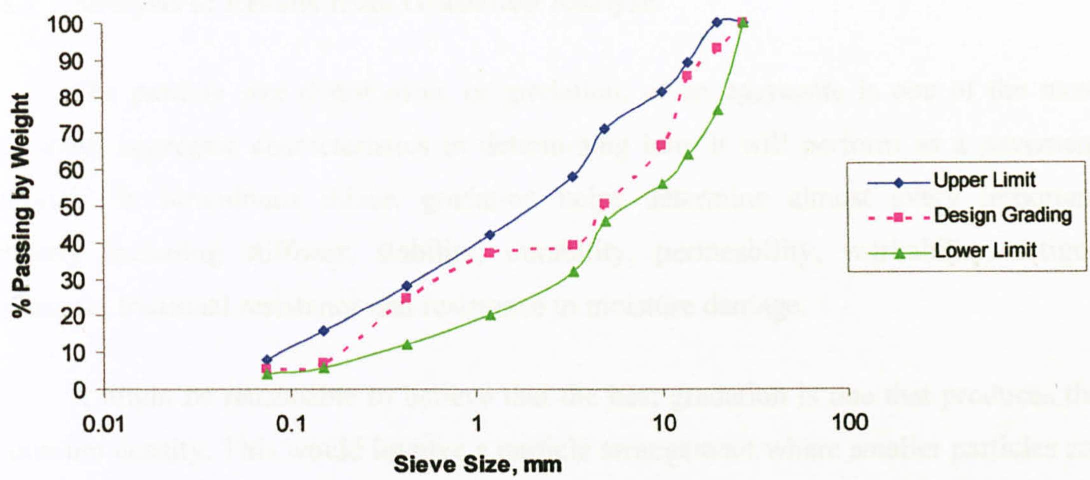


Figure 4.3 Adopted Gradation and Specification Limits for Marine Sand Mixtures

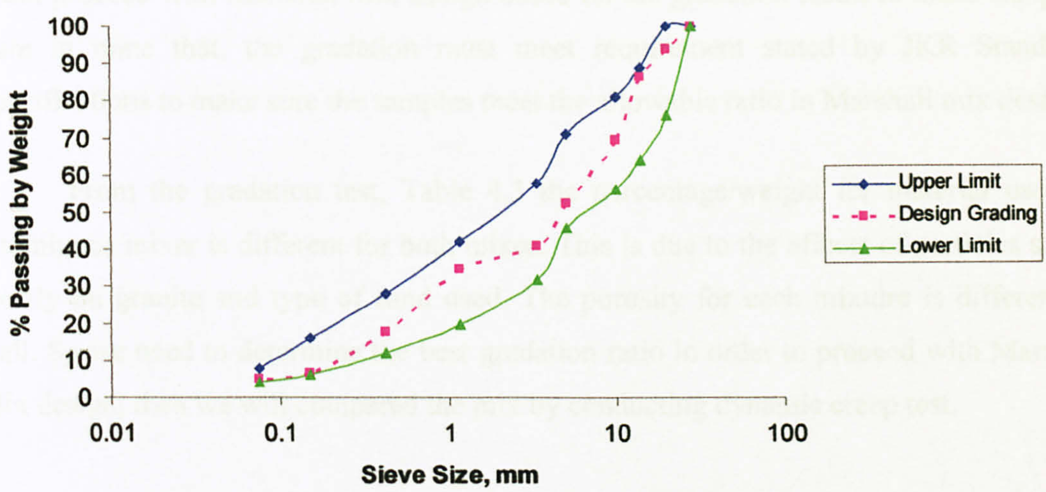


Figure 4.4 Adopted Gradation and Specification Limits for Mining Sand Mixtures

4.1.7 Analysis of Results from Gradation Analysis

The particle size distribution, or gradation, of an aggregate is one of the most influential aggregate characteristics in determining how it will perform as a pavement material. In bituminous mixer, gradation helps determine almost every important property including stiffness, stability, durability, permeability, workability, fatigue resistance, frictional resistance and resistance to moisture damage.

It might be reasonable to believe that the best gradation is one that produces the maximum density. This would involve a particle arrangement where smaller particles are packed between the larger particles, which reduce the void space between particles. This creates more particle-to-particle contact, which in bituminous mixer would increase stability and reduce percentage of porosity in mixture.

From table of percentage/weight for material used in bituminous mixer, then we could proceed with Marshall Mix design based on the gradation result to make samples. Bare in mine that, the gradation must meet requirement stated by JKR Standards Specifications to make sure the samples meet the allowable ratio in Marshall mix design.

From the gradation test, Table 4.3 the percentage/weight for material used in bituminous mixer is different for both mixes. This is due to the effects of particles shape mostly on granite and type of sand used. The porosity for each mixture is different as well. So we need to determine the best gradation ratio in order to proceed with Marshall Mix design, then we will compared the mix by conducting dynamic creep test.

4.1.8 Specific Gravity Test

Bituminous mix materials	Specific gravity
Granites – coarse aggregate	2.67
Marine sand – fine aggregate	2.82
Mining sand – fine aggregate	2.74
Ordinary Portland cement – filler	3.35
Bitumen 80	1.02

Table 4.5 Specific Gravity for Raw Material

Specific gravity defines as the ratio of the mass of a unit volume of a material at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature, 23° C (73.4° F). A typical aggregate particle consists of some amount of solid material along with a certain amount of air voids. These air voids within the aggregate particle (Figure 4.1) can become filled with binder. It takes a finite amount of time for binder to penetrate these pores.

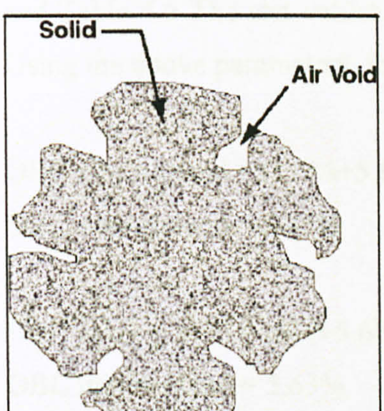


Figure 4.5 Air Voids in Aggregate Particle

By comparison marine sand has higher value for specific gravity compared with mining sand. It has less air void than mining sand which could provide better coating by bitumen 80p.

4.1.9 Marshall Mix Design

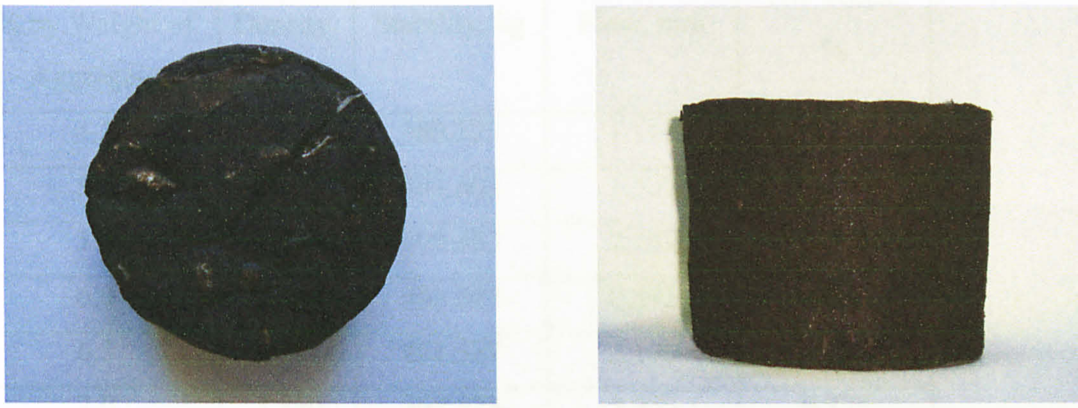


Figure 4.6 Marshall Mix Samples for Bituminous Mix with Marine Sand

4.1.10 Determination of Optimum Bitumen Content with Bitumen 80p

Marshall Method of the mix design as per ASTM D1559 was used for determination of optimum bitumen content. To determine the optimum bitumen content (OBC), Marshall samples were casts at varying percentage of 80p binder. Volumetric and mechanical parameters obtained from mixtures such as bulk density, Marshall stability, flow, and other volumetric properties were then obtained which are given in Table 4.5 and Table 4.6 The test values obtained are plotted graphically and shown in Figure 4.3. Using the above parameters, the optimum bitumen content for both mixes are;

OBC marine sand = (5.3%+5.65%+5.45%)/3

OBC marine sand = 5.46%

OBC mining sand = (6%+5.65%+5.25%)/3

OBC mining sand = 5.63%

The % optimum binder content will be used for evaluating the effects different in dynamic creep test.

Binder Content, % by Weight of Aggregate	Bulk Density, gm/cc	Stability, kg	Flow, mm	Air Voids, %
4.5	2.375	380.123	1.113	12.620
5.0	2.390	491.603	1.557	11.313
5.5	2.386	500.483	2.267	5.729
6.0	2.377	489.587	2.893	10.271
6.5	2.371	421.587	2.120	9.732
7.0	2.350	368.323	3.223	9.777

Table 4.6 Volumetric and Mechanical Parameters Obtained for Bituminous with Marine Sand

Binder Content, % by Weight of Aggregate	Bulk Density, gm/cc	Stability, kg	Flow, mm	Air Voids, %
4.5	2.283	788.277	2.257	15.629
5.0	2.299	877.910	2.637	13.938
5.5	2.314	920.317	3.577	12.617
6.0	2319	923.040	4.607	11.718
6.5	2.317	921.010	5.927	11.054
7.0	2.303	634.840	7.413	10.838

Table 4.7 Volumetric and Mechanical Parameters Obtained for Bituminous with Mining Sand

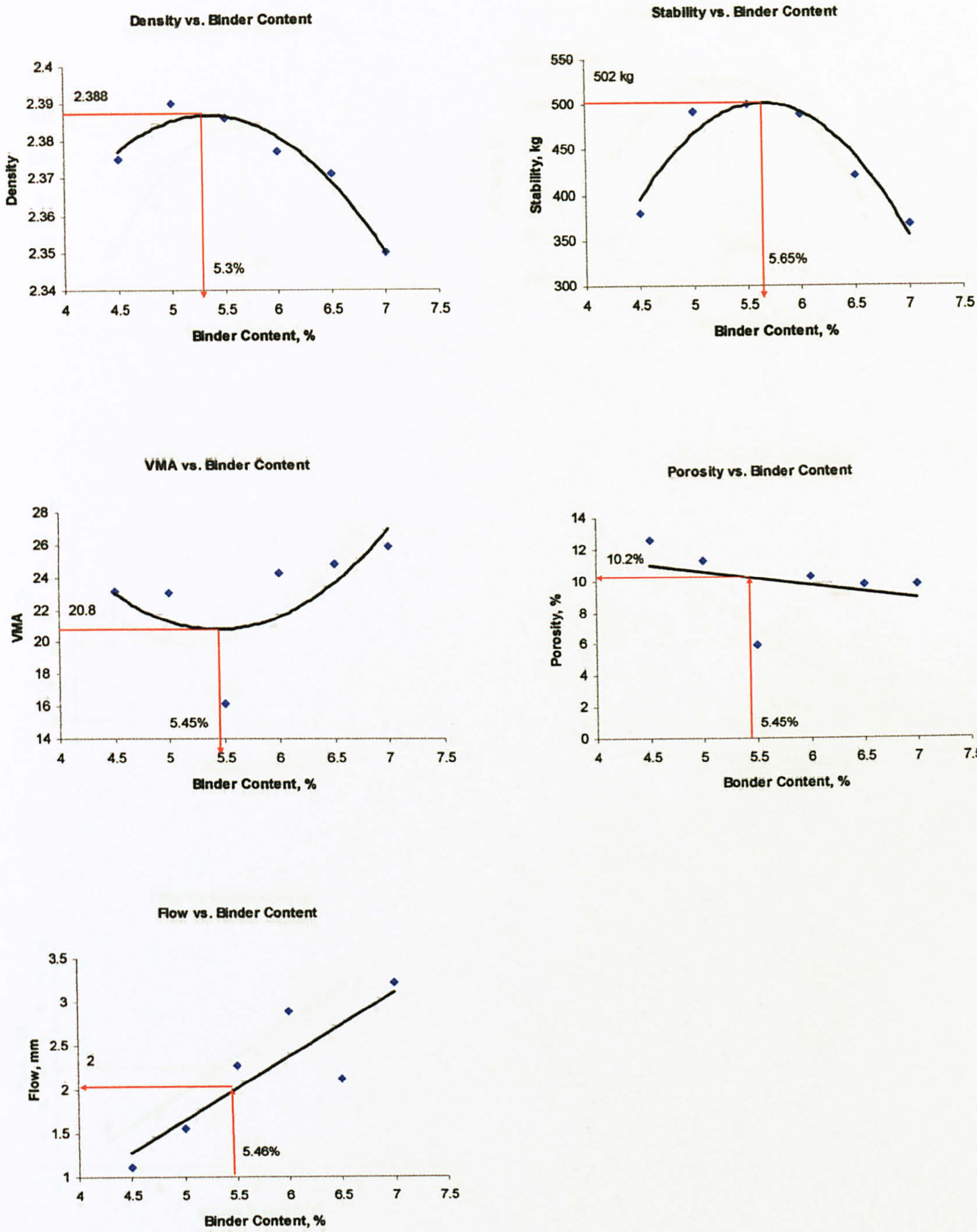


Figure 4.7 Marshall Parameters Obtained for Bituminous Mix with Marine Sand

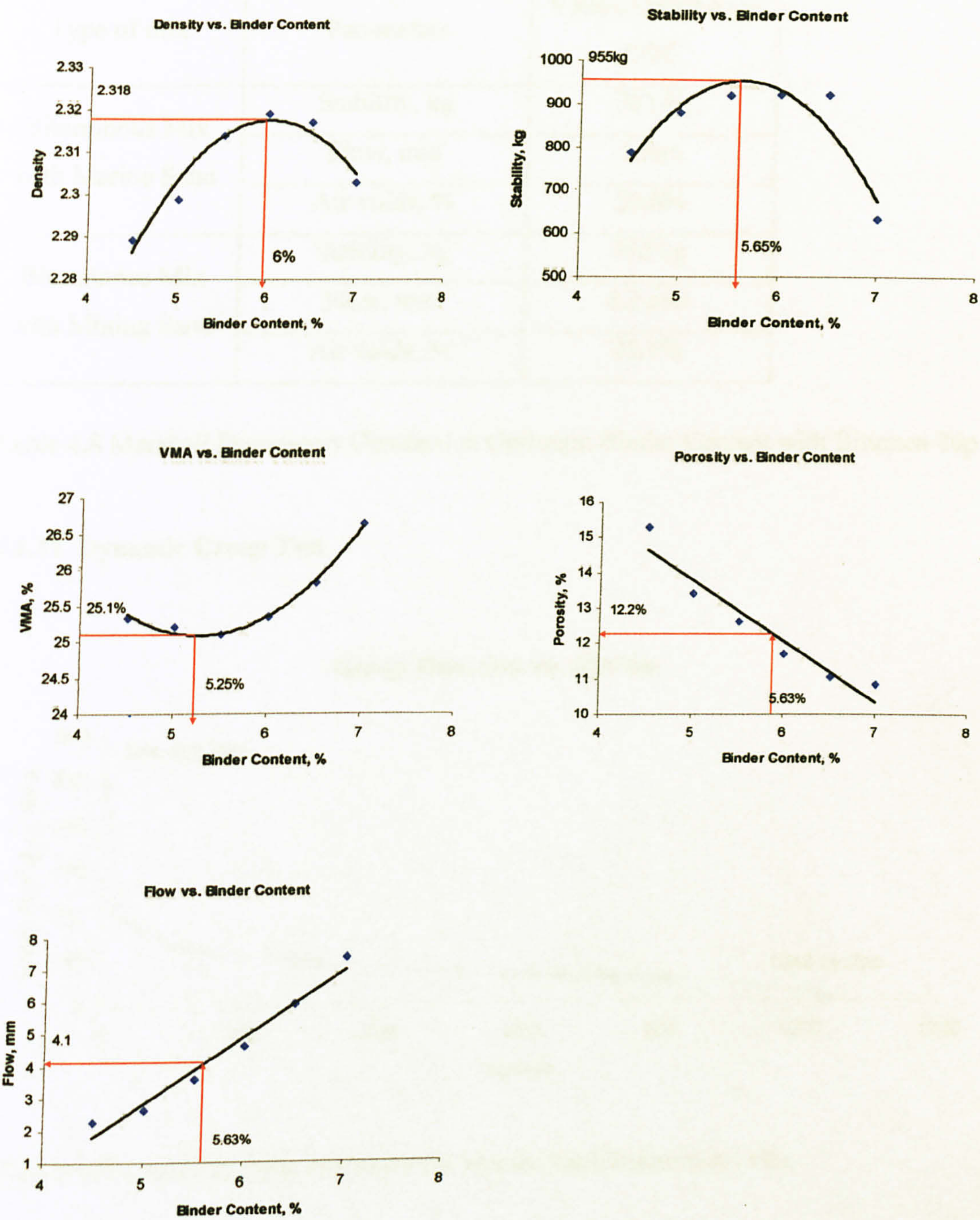


Figure 4.8 Marshall Parameters Obtained for Bituminous Mix with Mining Sand

Type of mix	Parameters	Values Obtained at OBC
Bituminous Mix with Marine Sand	Stability, kg	502 kg
	Flow, mm	2 mm
	Air voids, %	20.8%
Bituminous Mix with Mining Sand	Stability, kg	955 kg
	Flow, mm	4.2 mm
	Air voids, %	25.1%

Table 4.8 Marshall Parameters Obtained at Optimum Binder Content with Bitumen 80p

4.1.11 Dynamic Creep Test

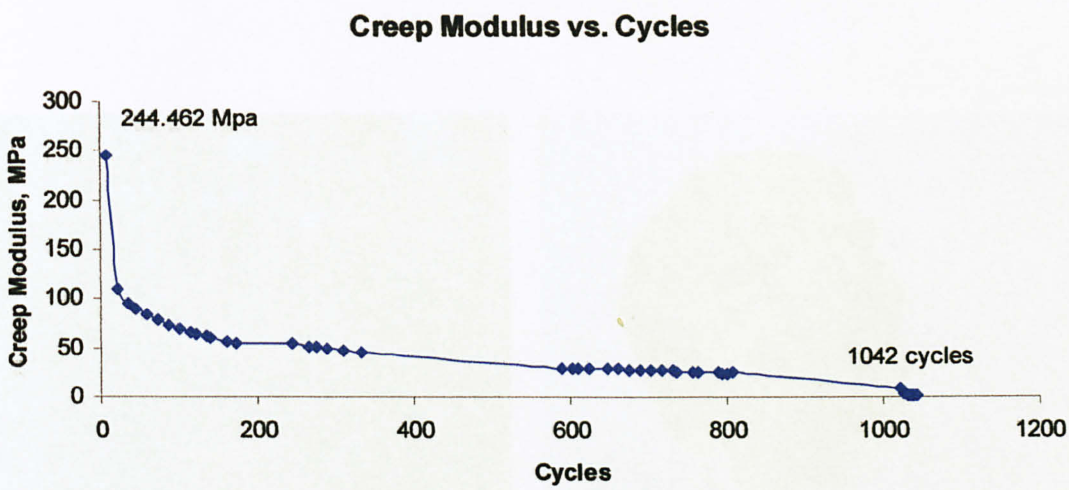


Figure 4.9 Creep Modulus vs Cycles for Marine Sand Bituminous Mix

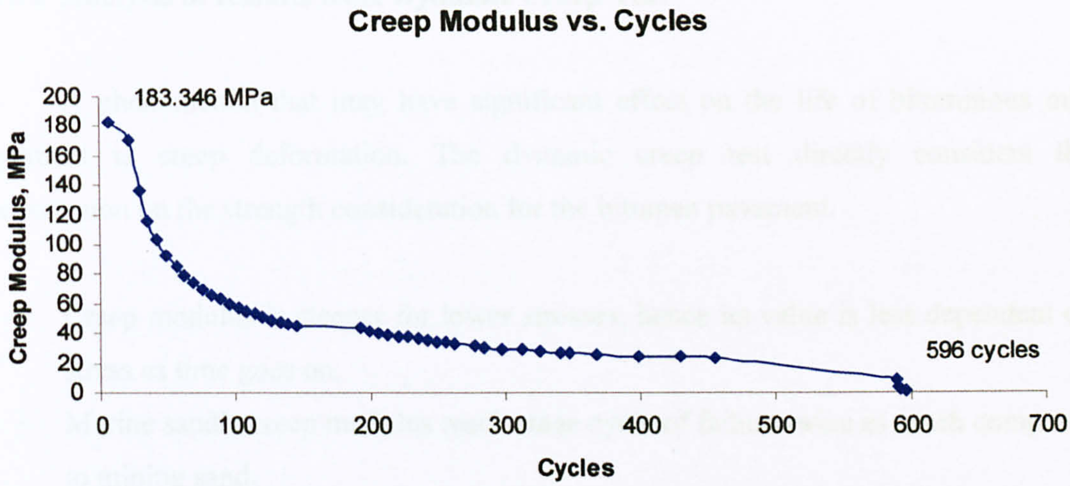


Figure 4.10 Creep Modulus vs Cycles for Mining Sand Bituminous Mix

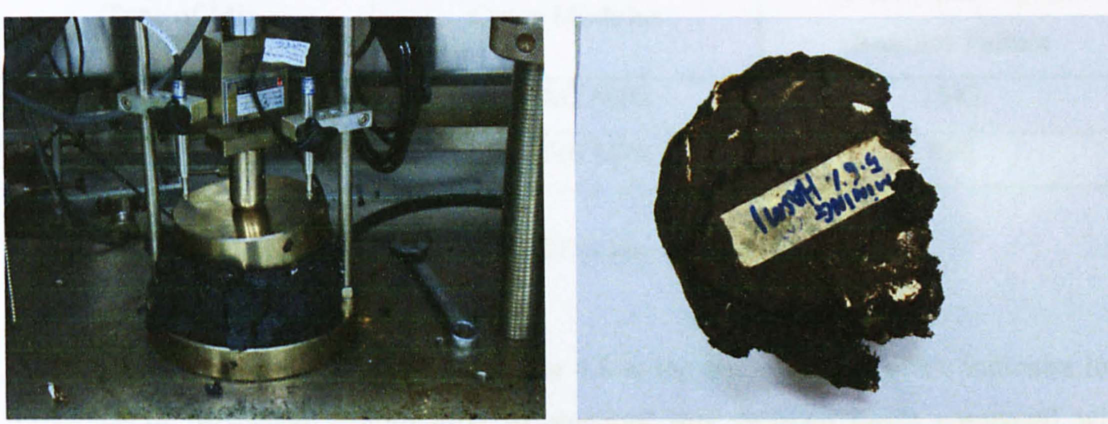


Figure 4.11 Sample of Dynamic Creep Test

4.1.12 Analysis of Results from Dynamic Creep Test

A phenomenon that may have significant effect on the life of bituminous mix pavement is creep deformation. The dynamic creep test directly considers the phenomenon on the strength consideration for the bitumen pavement.

- Creep modulus is steeper for lower stresses; hence its value is less dependent on stress as time goes on.
- Marine sand's creep modulus reach stage cycle of failure twice as much compared to mining sand.

The value accumulated cycles and creep modulus of both the bituminous mixer at end of 1800 cycles, with standard mix and marine sand mix are shown in table below;

Type of Mix	Creep Modulus	Accumulated Cycles Reaches Failure
Mix of Marine Sand	244.462 MPa	1042
Mix of Mining Sand	183.346 MPa	596

Table 4.9 Creep Modulus and Accumulated Cycles for Both Mixes

Lower accumulated cycles for Table 4.8 at the end of 1800 cycles, indicates low resistance to permanent deformation of standard mix (mining sand) compared with modified mix (marine sand). Marine sand's creep modulus reach stage cycle of failure twice as much compared to mining sand As regards creep modulus, bituminous mixer with marine sand showed value higher than conventional bituminous mix indicating high resistance to creep deformation.

4.2 ADVANTAGES USAGE OF MARINE SAND IN BITUMINOUS MIXER

- Sands can either be natural or manufactured. Mining sand generally extracted from larger rock formations through an open excavation (quarry). Extracted mining sand is typically reduced to usable sizes by mechanical crushing. Mining sand is produced in a quarry or mine whose basic function is to convert in situ rock into sand. The mining sand then needed to be washed as well to meet the cleanliness standard. So to produce mining sand requires a lot of energy, cost, and manpower compared with marine sand.
- Marine sand is available in abundance.
- Most economic alternatives to naturally-occurring road making materials.
- Less usage compared with mining sand to reach the satisfied aggregate gradation. More economic in terms of quantity.
- Easy access to resource compared with mining sand and river sand.
- Reaching stages of failures twice as much compared with mining sand. (Proven in creep analysis).

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 CONCLUSION

The laboratory results obtained under this study demonstrate that there is a significant improvement in the properties of bituminous mixer with marine sand such as porosity as indicated by void in mineral aggregates and retained stability, Marshall stability, resistance of bituminous mixer with marine sand to permanent deformation as indicated by dynamic creep test. The laboratory result also indicates that the use of marine sand in bituminous mixer has shown improvement in the volumetric, mechanical and performance related properties of the binder course.

The use of marine sand in bituminous mix could enhance mixtures resistance to permanent deformation, and it will provide the pavement with good performance when there is heavy traffic. The replacement by marine sand can bring real benefits to highway performance in term of better and long lasting road, and saving in total road costing.

5.2 RECOMMENDATION

This project should continually offer for next couple of years ahead. The research should be done much detail in order to have the precise value. Should this obtain, the usage of marine sand in bituminous mixer could be commercialized since its transportation and production cost is much lesser than mining sand.

The fine aggregate to marine sand in as evaluated in the laboratory under this study for use as replacement to fine aggregates in application to wearing course is indeed a potential material which does improve the properties of the bituminous mix. The usage of marine sand in bituminous mix will however, need to be applied in full scale use in the country. In addition the economics of the product in comparison to other modifiers will need to be established before it can find large scale applications.

The research should be done much detail in order to have the precise value. They include conducting rutting, fatigue cracking and wheel tracking as well as static creep test. Should this obtain, the usage of marine sand in bituminous mixer could be commercialized since its transportation and production cost is much lesser than mining sand.

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APPENDIX A

Sieve Analysis for Marine Sand

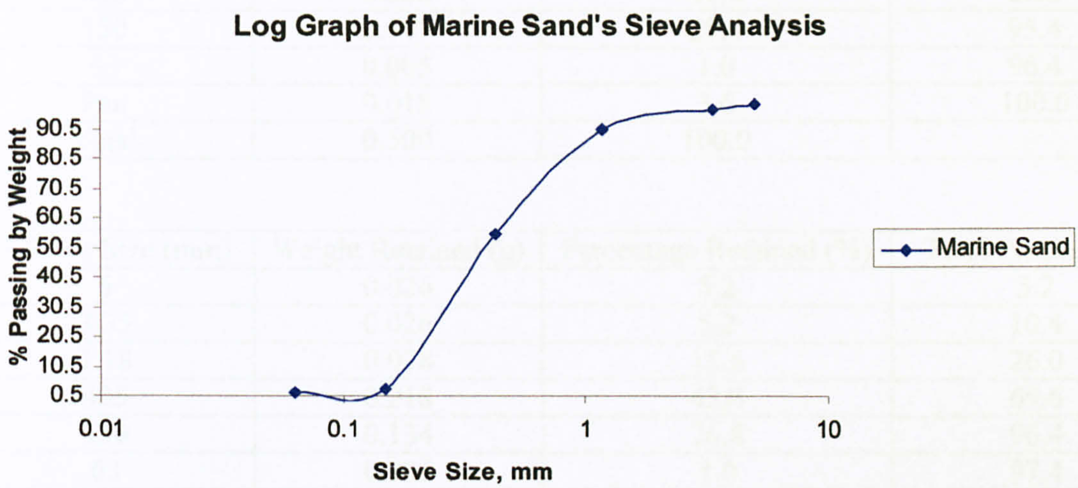
Test Method: BS812: Part 1985
Dry mass before sieving = 500g

BS Sieve Size (mm)	Weight Retained (g)	Percentage Retained (%)	Total Passing (%)
5	0.002	0.4	0.4
3.35	0.001	0.2	0.6
1.18	0.002	0.4	1.0
425	0.149	29.8	30.8
150	0.332	66.4	97.2
63	0.010	2.0	99.2
Pan	0.004	0.8	100.0
Total	0.500	100.0	

BS Sieve Size (mm)	Weight Retained (g)	Percentage Retained (%)	Total Passing (%)
5	0.019	3.8	3.8
3.35	0.023	4.6	8.4
1.18	0.073	14.6	23.0
425	0.229	45.8	68.8
150	0.137	27.4	96.2
63	0.004	0.8	97.0
Pan	0.015	3.0	*100.0*
Total	0.500	100.0	

BS Sieve Size (mm)	Weight Retained (g)	Percentage Retained (%)	Total Passing (%)
5	0.000	0.0	0.0
3.35	0.002	0.4	0.4
1.18	0.022	4.4	4.8
425	0.152	30.4	35.2
150	0.315	63	98.2
63	0.004	0.8	99.0
Pan	0.005	1.0	100.0
Total	0.500	100.0	

BS Sieve Size (mm)	Average Total Passing (%)
5	98.6
3.35	96.9
1.18	90.4
425	55.1
150	2.8
63	1.6



APPENDIX B

Sieve Analysis for Mining Sand

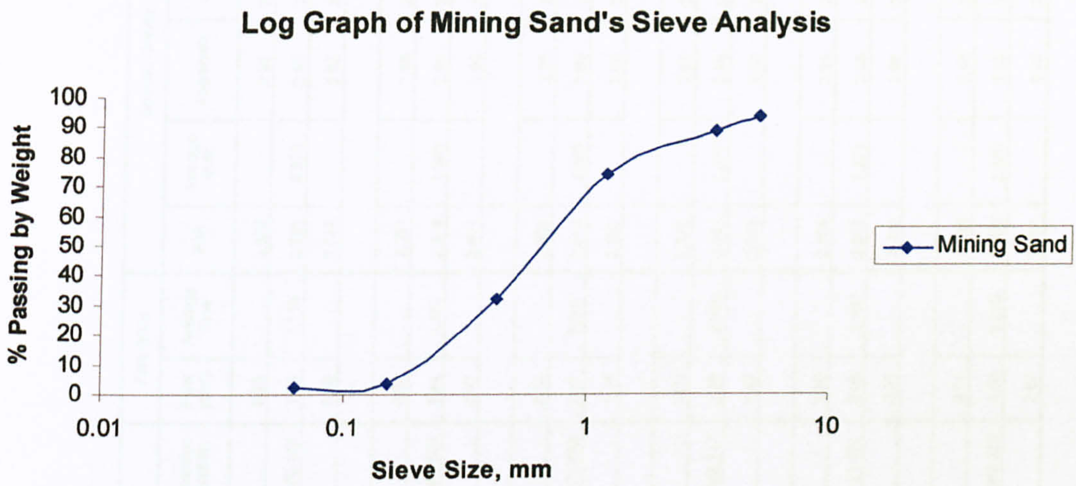
Test Method: BS812: Part 1985
Dry mass before sieving = 500g

BS Sieve Size (mm)	Weight Retained (g)	Percentage Retained (%)	Total Passing (%)
5	0.033	6.6	6.6
3.35	0.026	5.2	11.8
1.18	0.071	14.2	26.0
425	0.200	40.0	66.0
150	0.147	29.4	95.4
63	0.005	1.0	96.4
Pan	0.018	3.6	100.0
Total	0.500	100.0	

BS Sieve Size (mm)	Weight Retained (g)	Percentage Retained (%)	Total Passing (%)
5	0.026	5.2	5.2
3.35	0.026	5.2	10.4
1.18	0.078	15.6	26.0
425	0.218	43.6	69.6
150	0.134	26.8	96.4
63	0.005	1.0	97.4
Pan	0.013	2.6	100.0
Total	0.500	100.0	

BS Sieve Size (mm)	Weight Retained (g)	Percentage Retained (%)	Total Passing (%)
5	0.028	5.6	5.6
3.35	0.027	5.4	11.0
1.18	0.073	14.6	25.6
425	0.212	42.4	68.0
150	0.143	28.6	96.6
63	0.007	1.4	98.0
Pan	0.010	2.0	100.0
Total	0.500	100.0	

BS Sieve Size (mm)	Average Total Passing (%)
5	94.2
3.35	88.9
1.18	74.13
425	32.13
150	3.87
63	2.73



APPENDIX C

Marshall Mix Design for Marine Sand

Sample Designation	Height (mm)	Volume cm3		Weight (gm)		Density	Marshall Stability (kg)				Flow (mm)		Specific Gravity					Porosity (%)		Density (gm/cm3)		VMA
		Volume	Average	Air	Water		Measured	CF	Corrected	Average Stability	Flow (mm)	Average Flow	Bulk	Average Bulk	Aggregate	max	Effective Aggregate	Calculated	Average	Calculated	Average Density	
4.5A	67.30	510.500		1224.5	714.0	2.399	287	0.89	255.430		0.23		2.399		2.95	2.719	2.95	11.767		2.399		
4.5B	69.00	526.500	517.667	1253.5	727.0	2.381	246	0.86	211.560	380.123	1.56	1.113	2.381	2.375	2.95	2.719	2.95	12.422	12.620	2.381	2.375	23.100
4.5C	69.30	516.000		1211.0	695.0	2.347	783	0.86	673.380		1.55		2.347		2.95	2.719	2.95	13.670		2.347		
5.0A	70.00	464.000		1109.5	645.5	2.391	556	0.83	461.480		0.80		2.391		2.95	2.695	2.95	11.275		2.391		
5.0B	67.30	539.500	511.500	1283.0	743.5	2.378	541	0.89	481.490	491.603	1.44	1.557	2.378	2.390	2.95	2.695	2.95	11.759	11.313	2.378	2.390	23.029
5.0c	64.30	531.000		1275.0	744.0	2.401	554	0.96	531.840		2.43		2.401		2.95	2.695	2.95	10.905		2.401		
5.5A	67.60	551.000		1302.5	751.5	2.364	927	0.89	825.030		2.53		2.364		2.95	2.672	2.95	11.529		2.364		
5.5B	64.30	511.000	530.333	1232.0	721.0	2.411	211	0.96	202.560	500.483	2.53	2.267	2.411	2.386	2.69	2.466	2.69	2.239	5.729	2.411	2.386	16.132
5.5C	69.00	529.000		1260.0	731.0	2.382	551	0.86	473.860		1.74		2.382		2.69	2.466	2.69	3.420		2.382		
6.0A	66.00	530.000		1259.0	729.0	2.375	525	0.93	488.250		3.00		2.375		2.95	2.649	2.95	10.334		2.375		
6.0B	68.00	515.500	521.500	1227.5	712.0	2.381	676	0.86	581.360	489.217	2.28	2.893	2.381	2.377	2.95	2.649	2.95	10.118	10.271	2.381	2.377	24.254
6.0C	66.60	519.000		1232.5	713.5	2.375	428	0.93	398.040		3.40		2.375		2.95	2.649	2.95	10.361		2.375		
6.5A	70.60	530.000		1258.0	728.0	2.374	517	0.83	429.110		1.29		2.374		2.95	2.627	2.95	9.644		2.374		
6.5B	66.60	530.500	532.000	1258.5	728.0	2.372	209	0.93	194.370	421.587	3.06	2.120	2.372	2.371	2.95	2.627	2.95	9.693	9.732	2.372	2.371	24.843
6.5C	64.60	535.500		1268.0	732.5	2.368	668	0.96	641.280		2.01		2.368		2.95	2.627	2.95	9.861		2.368		
7.0A	68.30	528.000		1234.5	706.5	2.338	313	0.89	278.570		2.71		2.338		2.95	2.605	2.95	10.246		2.338		
7.0B	64.30	522.500	525.833	1234.0	711.5	2.362	432	0.96	414.720	368.323	4.09	3.223	2.362	2.350	2.95	2.605	2.95	9.338	9.777	2.362	2.350	25.906
7.0C	71.30	527.000		1239.0	712.0	2.351	496	0.83	411.680		2.87		2.351		2.95	2.605	2.95	9.748		2.351		

APPENDIX D

Marshall Mix Design for Marine Sand

Sample Designation	Height (mm)	Volume cm3		Weight (gm)		Density	Marshall Stability (kg)				Flow (mm)		Specific Gravity					Porosity (%)		Density (gm/cm3)		VMA
		Volume	7.000	Air	Water		Measured	CF	Corrected	Average Stability	Flow (mm)	Average Flow	Bulk	Average Bulk	Aggregate	max	Effective Aggregate	Calculated	Average	Calculated	Average Density	
4.5A	64.3	533.000		1224.0	691.0	2.296	834	0.96	800.640		2.17		2.296		2.92	2.694	2.92	14.763		2.296		
4.5B	65.6	557.000	544.333	1245.0	688.0	2.235	783	0.93	728.190	788.277	2.36	2.257	2.235	2.283	2.92	2.694	2.92	17.036	15.269	2.235	2.283	25.340
4.5C	63.0	543.000		1258.0	715.0	2.317	836	1.00	836.000		2.24		2.317		2.92	2.694	2.92	14.008		2.317		
5.0A	57.6	548.000		1241.0	693.0	2.265	928	1.14	1057.920		2.00		2.265		2.92	2.671	2.92	15.222		2.265		
5.0B	68.0	542.000	550.333	1258.0	716.0	2.321	897	0.89	798.330	877.910	2.76	2.637	2.321	2.299	2.92	2.671	2.92	13.109	13.938	2.321	2.299	25.207
5.0c	66.3	561.000		1296.5	735.5	2.311	836	0.93	777.480		3.15		2.311		2.92	2.671	2.92	13.483		2.311		
5.5A	66.3	545.500		1268.0	722.5	2.324	795	0.93	739.350		4.26		2.324		2.92	2.649	2.92	12.239		2.324		
5.5B	65.0	536.000	544.500	1245.0	709.0	2.323	1228	0.95	1166.600	920.317	2.92	3.577	2.323	2.314	2.92	2.649	2.92	12.304	12.617	2.323	2.314	25.097
5.5C	65.0	552.000		1267.5	715.5	2.296	900	0.95	855.000		3.55		2.296		2.92	2.649	2.92	13.307		2.296		
6.0A	64.3	533.500		1235.5	702.0	2.316	980	0.96	940.800		5.40		2.316		2.92	2.626	2.92	11.826		2.316		
6.0B	62.0	551.500	542.333	1276.5	725.0	2.315	921	1.04	957.840	923.040	3.18	4.607	2.315	2.319	2.92	2.626	2.92	11.874	11.718	2.315	2.319	25.357
6.0C	66.0	542.000		1260.5	718.5	2.326	936	0.93	870.480		5.24		2.326		2.92	2.626	2.92	11.453		2.326		
6.5A	65.6	557.000		1287.5	730.5	2.311	1295	0.93	1204.350		4.37		2.311		2.92	2.605	2.92	11.255		2.311		
6.5B	66.0	557.500	546.333	1284.5	727.0	2.304	806	0.93	749.580	921.010	7.98	5.927	2.304	2.317	2.92	2.605	2.92	11.541	11.054	2.304	2.317	25.818
6.5C	66.0	524.500		1224.5	700.0	2.335	870	0.93	809.100		5.43		2.335		2.92	2.605	2.92	10.367		2.335		
7.0A	64.0	573.500		1315.0	741.5	2.293	546	0.96	524.160		8.78		2.293		2.92	2.583	2.92	11.236		2.293		
7.0B	65.0	546.500	568.667	1264.0	717.5	2.313	691	0.96	663.360	634.840	5.15	7.413	2.313	2.303	2.92	2.583	2.92	10.463	10.838	2.313	2.303	26.645
7.0C	63.3	586.000		1350.0	764.0	2.304	717	1.00	717.000		8.31		2.304		2.92	2.583	2.92	10.817		2.304		

APPENDIX E

Milestone for Semester 1

No	Work Detail	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**Selection of Project Topic** ↳ Propose Topic ↳ Topic Assigned to Students	■													
2	**Preliminary Research Work** ↳ Meet Supervisor ↳ Set Weekly Meeting with Supervisor ↳ Prepare Preliminary Report		■	■											
3	**Request for Resources/Services**		■	■	■	■	■	■							
4	**Submission of Preliminary Report**				◎										
5	**Project Work** ↳ Reference/ Literature Review ↳ Practical/ Laoratory Works				■	■	■	■							
6	**Submission of Progress Report**								◎						
7	**Project Work Continue** ↳ Padical/ Laboratory Work								■	■	■	■			
8	**Submit Draft of Interim to Supervisor**										◎				
9	**Submission of Interim (Final Draft)**												◎		
10	**Oral Presentation**													◎	

Week columns 1–14.

◎ Suggested Milestone   ■ Processes

APPENDIX F

Milestone for Semester 2