Development of Masonry Blocks Using Bituminous Emulsions

by

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Dissertation

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
University Technology of PETRONAS
In partial fulfillment of the requirement for the
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Approved by,

(Dr. Nasir Shafiq)

UNIVERSITY TECHNOLOGY OF PETRONAS

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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 acknowledgement, and that the original work contained herein have not been undertaken or done by unspecified sources or person.

SITI ATIKAH ABDULLAH

ABSTRACT

"Development of masonry Blocks Using Bituminous Emulsions" is basically stressing about research on new material to be applied in construction technology. As widely known, concrete is brittle in nature and are prone to fragmentation. Same problem applied to glass walls. Fragmentation will cause the material to break into chips and predominantly lose its strength. Apart from that, development of this new material is also initiated due to the increase in terrorist attacks to high rise building causing major casualties as well as injuries to the occupants as well as pedestrians.

In order to fit the requirement of this research, wax emulsion is experimented to understand its behavior in terms of strength, flexural and durability. The material used is Burke Wax Emulsion White (Type II). For comparison purposes, conventional bitumen mix is also tested. The mix proportion of the bituminous material is done following the concrete proportion. Same testing method in designing bituminous mix for flexible pavement applies to this research. The specimens will be tested using Marshall Stability testing equipment which will give the optimum binder content value, Beam Fatigue equipment which will give its flexural stiffness and deflection and durability test which will give its resistance against temperature effects.

Wax emulsions produced materials with high compressive strength and durability characteristic but at low deformation rate. However, it fails instinctively under dynamics loading due to its stiffness and inflexibility to absorb loadings. Due to this factor, fiber addition is necessary to increase its flexibleness and tensile strength.

This material can be used for construction of non-load bearing partition wall, slabs or floors which experience static loadings alone. Findings from this research will open a new era for building construction technology. A more cost effective material to concrete and brick wall structures is found. Coatings of surfaces from the wax coupled with its hydrophobic nature, will sufficiently act as a moisture barrier to prevent conduction and unwanted penetration and interaction of various liqiuds in masonry blocks.

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Hopefully my final year research project will be helpful and beneficial to people who are interested to make further research in this field. Lastly, thank you very much again and certainly, it would be impossible to complete the final year research project without help from all of them.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In today's era, development and advancement in technology, give extensive benefit to the rise of skyscrapers. Criterions of most skyscrapers are concrete, brick wall or the glass curtain wall which have found growing favor in modern architectures. Aesthetically glass curtain walls will provide a better finishes compare to steel or concrete. However, in structural point of view, both glass walls and concrete are brittle material. Brittle materials fail instinctively under tension. Due to its brittleness, it is subject to fragmentation.

Fragmentation is termed as break up of the material upon detonation [*Yaakov Yerushalmi, Uzi More, Amit Seizes*] [1]. This phenomenon will cause the materials to break into small chips. In the long run, it will cause the material to lose its strength predominantly. This might lessen the fatigue life as well as the service life of the building. Due to shock load or high lateral load, the building might not be able to withstand the applied loading and causes failure.

Significance of these behaviors of material gives advantages to terrorist attacks. Nowadays, terrorist attacks are common in high rise buildings. Terrorists attacks has been populating in this world way back since 1990's. Skyscrapers or important building in a nation is always their target. This will cause major casualties for the occupants, pedestrians as well as the economic condition of the country. For instance, WTC attack causes thousands of death, injuries, and 100 nearby buildings experience severe cracking due to the massive collapse of the tower. The table below list down some cases of terrorist attacks on building from 1990 up to 2005 as well as the casualties involved.

Table 1.1 : Building's bombed down subject to terrorism from 1990 - 2005.

YEAR	DATE	BUILDING	CASUALTIES
1990	April 10	Baltic Exchange, London	- 3 killed - 91 injured
1995	April 19	Alfred P. Murrah Federal building, Oklahoma	- 166 killed - Hundreds more injured
1996	June 25	Khobar Towers, Saudi Arabia	
	December 24	Worchester Mall, Cape Town	- 4 killed - Dozens injured
1998	August 7	US Embassy in Nairobi, Kenya, Dar-es-Salem	- 247 killed - 4000 injured
1999	April 27	Intercontinental Hotel, Athens, Greece.	- 1 death
	November 3	US Embassy, Us Cultural Center, UN Islamabad Pakistan	- No injuries
2000	October 1	Church in Dushanbe, Tajikistan	- 7 death - 70 injuries
	October 13	British embassy in Sanna, Yemen	- minor damage
	December 25	US Embassy, Manila, Philippines	
2001	January 3	El Air Airlines Office, Zurich	- minor damage
	September 11	World Trade Center, New York Pentagon, Washington D.C Airplane crashes in Pennsylvania	- 3000 death - 189 death - 86 injuries - 44 killed
2003	April 2	Dawao Airport, Philippines	- 16 killed
2005	January 19	Australia Embassy, Iraq	- 25 death - Dozens of injuries

As mention earlier, concrete and glass walls are brittle materials which are subject to fragmentation. Fragmentation will cause the material to predominantly lose its strength in time. If it is impacted by shock load such as heavy explosions or blast, it will fail instinctively. Failures usually occur due to the impact of air-blast shock wave which is the primary damage mechanism in explosions [*Yaakov Yerushalmi, Uzi More, Amit Seizes*] [1].

In the case of buildings with glass wall façade, the glass itself is often the weakest part of a building, breaking at low pressure compared to other components such as floors, walls or columns. Glass breakage may extend for miles in large external explosions. The high velocity glass fragments are the major contributor to injuries of occupants in a building. Falling glasses on the other hand, poses a major hazard to passerby, pedestrians, and prolongs post-incident rescue and cleanup efforts by leaving tons of glass debris on the street [*Yaakov Yerushalmi, Uzi More, Amit Seizes*] [1].

In concrete case, the air-blast shock wave will act at the exterior envelope of a building which is in the closest vicinity to the explosions. This will cause wall failure and window breakage. As the shock wave expanding, it enters the structures and will push upward and downward on the floors. Floor structures have typically large surface areas for pressure to act and small thickness. Due to this, as the wave is propagating it will cause failures.

Apart from that, blast can also cause other significant damage to occupants. Severity and type of injury patterns incurred in explosive events may be related to the level of structural damage. The high pressure air-blast that enters through broken windows can cause eardrum damage and lung collapse. Airborne glass fragments will cause penetration or laceration-type injuries where else the larger fragments will cause non-penetrating injuries. Finally, the air-blast pressures can cause occupants to be bodily thrown against object or to fall [*Yaakov Yerushalmi, Uzi More, Amit Seizes*] [1]. Pictures below show some of the major casualties experienced by building subject to shock load.

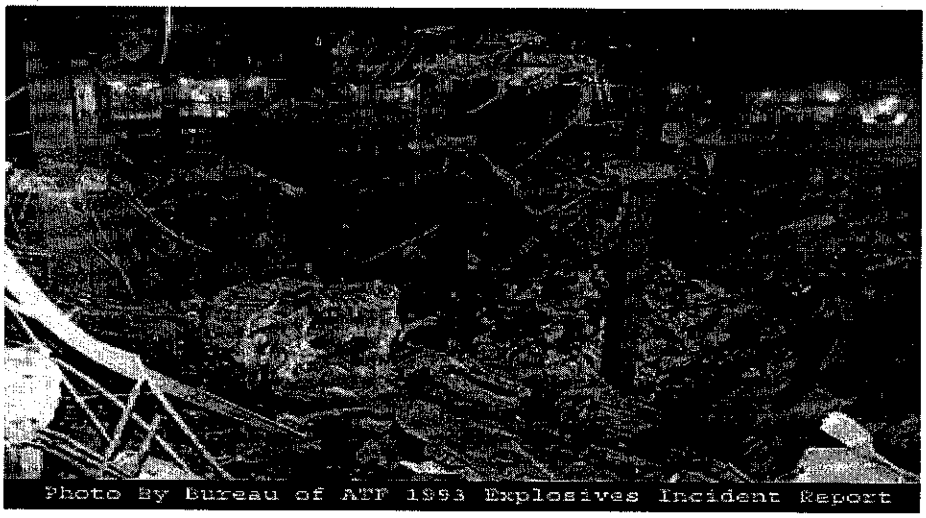


Figure 1.1: World Trade Center Blast.

Figure 1.2: Damages experience by Alfred P. Murrah Federal Building, Oklahoma.

Due to the scenario above, the need to find new materials that will diminished or at least lessen the effect of fragmentation and terrorism is crucial. Research of new flexible material will come in handy in overcoming this problem.

1.2 Problem Statement

As mention above, fragmentation problem in brittle materials such as concrete and glass walls have many significant damages to a building. It will cause the materials to break into chips which cause the structure to lose its strength. Predominantly in the long run, it will lessen its fatigue life and shorten its design service life. The effect will be more dominant when subjected to shock loading such as heavy explosions or air-blast shock wave impact [*Yaakov Yerushalmi, Uzi More, Amit Seizes*] [1].

The act of terrorism made the situation worse. In today's world, news about terrorist attacks to buildings is of normal occurrence. As the materials experiencing fragmentation, it is understood that it has lost some of its design capacity. As mention earlier, it will fail instinctively under shock loading. For instance, in glass walls, once it is impacted with heavy explosions and blast, it will cause the glass traveling at a very high velocity and hitting anyone or anything along its pathway. Looking at table 1.1 above, for some cases the damage is not significant but most of the time it will cause major casualties to the occupants as well as the passerby and will effect the country's economic condition.

Looking at the major problem noted that is fragmentation faced by brittle materials as well as terrorist attacks on the structures itself, the need for a findings of new technologies or materials to counter these problem are important. Basically the idea of developing masonry blocks using bituminous emulsions is initiated to overcome or at least lessen the impact caused by terrorism act. The idea is that for us to find new material which is flexible in nature that will sufficiently absorb the energy and dissipate the pressure from the shock loading imposed to a structure. This material will act as a non - load bearing partition walls in building specially designed to counter shock loading.

Out of the ordinary uses of bituminous materials in highways construction and maintenance, here this material will be researched to be used as masonry block for building constructions. Bituminous materials are adapted in this research based on understanding on how flexible pavement withstands enormous traffic loading throughout its entire life. Credits are given to its flexible behavior apart from other benefits which is considered significant in this research project. The emulsion chosen is *BURKE WHITE TYPE II (WAX EMULSIONS)* which will be explained later in the next section.

1.3 Objective

This research project focused on the behavior and strength achieved of the emulsions from experimental data and observation. For comparison purposes, conventional bitumen is also tested.

The research project objectives to be achieved are as stated below:

- To study the basic behavior of Burke Wax Emulsion White (Type II)
- To determine the optimum binder content that will sufficiently coat aggregate thus resulting in high strength blocks.
- To determine the maximum strength value that wax emulsions can achieve through experiments.
- To determine the bending behavior of the bituminous emulsions mix.
- To conclude whether the strength value achieved is adequate to carry its intended engineering purpose or fiber addition is necessary.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 What is Emulsion?

Bituminous emulsions or widely known as cold bitumen is generally a by product of petroleum distillation process. In this distillation process, firstly, separation of materials occur in the distillation tower where the lighter fraction of the evaporated materials collect on top tray, and the heavier fractions collect in successive trays, with the heaviest residue containing asphalt remaining at the bottom of the tower. The product obtained in this separation process is gasoline, kerosene, diesel fuel, lubricating oil, and asphalt (see Figure 1.1). Further processing of the heavy residue will gives many types of asphalt that is asphalt bitumen, cutbacks and emulsions. [*Nicholas J. Garber, Lester A. Hoes, 2002*][2]

Gasoline Kerosene Lt. Gas Oil Diesel Motor Oils Asphalt/Bitumen

Figure 2.1: Barrel of Crude Oil.

Emulsified asphalt is normally produced by breaking asphalt cement, usually of 100 - 250 penetration range, into minute particles and dispersing them in water with an emulsifier. These minute particle have like electrical charges and therefore do not coalesce. They remain in suspension in liquid as long as the water does not evaporate or the emulsifiers do not break. Asphalt emulsions therefore consists of asphalt, which makes up about 55 – 70 percent by weigh, water and an emulsifying agent, which in some cases may contain a stabilizer. [*Nicholas J. Garber, Lester A. Hoes, 2002*][2]

Asphalt emulsions are classified into 3 types that are anionic, cationic and neutral. Anionic are emulsions containing negative charged particles which are most effective in treating aggregates of positive charges such as limestone. Cationic on the other hand are positive charged particles which perform best with electronegative charged aggregates such as silica gravels. The anionic and cationic emulsions are generally used in highway maintenance and construction, while the natural/nonionic emulsions may be used in the future as emulsion technology advances. [*Nicholas J. Garber, Lester A. Hoel, 2002*][2].

2.1.1 Wax Emulsions

Wax emulsion is also one of the major discoveries from the technology advances of crude oil refining process. It is derived from the refining of lubricating oil. Wax emulsions that are derived from petroleum waxes can be formulated into numerous hot melt adhesive systems to modify viscosity, flow, set time and moisture resistance properties. Waxes can also influence adhesive's bond strength and flexibility. In this case, petroleum waxes are incorporated into asphalt blends and emulsions to modify flow, increase moisture resistance of the substance and reduce unwanted penetrations and interactions of various liquids due to their hydrophobic nature. The properties of wax emulsion mention above are the material analyzed in this research project. [*www.igiwax.com*][3].

Wax is an organic, plastic-like substance that is solid at ambient temperature and becomes liquid when melted. Because wax is plastic in nature, it usually deforms under pressure without the application of heat. The following summarizes the general features of wax: [*www.igiwax.com*][3]

- Solid at ambient temperature
- Thermoplastic in nature
- Combustible
- Liquid at 110 to 200°F
- Insoluble in water

There are three general categories of petroleum wax that is paraffin, microcrystalline and petrolatum. Paraffin waxes are derived from the light lubricating oil distillates. It contains predominantly straight-chain hydrocarbons with an average chain length of 20-30 atoms. Microcrystalline waxes on the other hand are produced from a combination of heavy lube distillates and residual oils. It contrasts from paraffin wax in the sense that it has poor crystalline structures, darker color and higher viscosity and melting point. The last category of wax is referred as petrolatum or petroleum waxes which is derived from heavy residual oils and are separated by a dilution and filtering process. It is microcrystalline in nature and semi-solid at room temperature. In general it refers to the amount of oil contained in the product. Slack wax refers to wax containing anywhere from 3-50 % oil content where else scale wax refers to 1-3 % oil. [*www.igiwax.com*][3]

Knowing the benefits wax emulsions provide for new technologies on construction purposes, it has been adopted and researched in this project. Here, we are using BURKE WAX WHITE EMULSION (TYPE II) as the binder for the mix instead of conventional bitumen.

2.2 Burke Wax Emulsion White (Type II)

Burke wax emulsion white (type II) is basically a high solid white pigmented wax based concrete curing compound which is formulated to retain moisture in freshly poured concrete. The selected white pigments will reflect the heat of the sun, keeping the concrete surface cooler. Wax Emulsion White us a membrane forming wax based material that seals the necessary moisture for proper cement hydration. It is formulated to comply with V.O.C content limits as required by Air Pollution Control Regulations of Kansas. This emulsion is of petrolatum type which contains 10-25% of slack wax along with some other chemical components.

It is specially designed for use on interior commercial projects, such as highways, residential paving, airport runways, concrete lined canals, dams, parking lots, engineering projects and other as specified aspects. Although it is basically useful for concrete curing, we are trying to research the use of this emulsion for developing of the masonry blocks. Since in the mix proportions design for this research also include cement as fillers, theoretically it will aid in the cement hydration process resulting into a high strength blocks. The behaviors, strength and adaptability of the mix using emulsions are the main focus of this research project where it will be discussed in the next section. Pictures below shows the physical features and structures of the wax emulsion. Physical and chemical characteristic of the wax is describe in Chapter 3 and included in the *Appendix 1.1*.

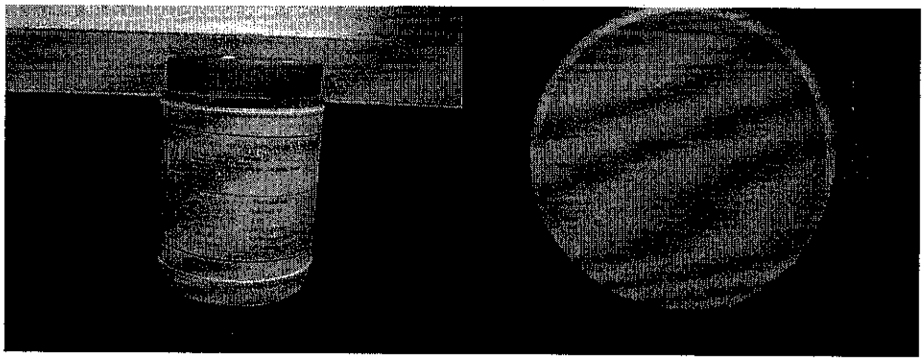


Figure 2.2: Physical Characteristic of Burke Wax Emulsion White (Type II)

2.3 Emulsion Behavior

Almost all asphaltic material obtained from the distillation process exhibit the same behavior. Since *Burke Wax Emulsion White (Type II)* that we are using is also petroleum based, theoretically it exhibits the same characteristics as other asphaltic materials. Based on the understanding of these behaviors, the idea of using emulsions to develop masonry blocks came along. Some of the properties that are considered in this research are; *[Nicholas J. Garber, Lester A. Hoes, 2002]*[2]

i. Flexibility
ii. Durability
iii. Impermeability
iv. Adhesive nature

As mention before, we are adopting the concept of how flexible pavement can carry enormous traffic loading throughout its design life into this design. Although the magnitude and type of loading a pavement experience is somewhat different from lateral and gravity loading experience by a building, however its ability to absorb the load transferred to it and to be able to perform its intended engineering purpose throughout its service life are taken into consideration in adopting this concept in developing masonry blocks using emulsions. In a flexible pavement, strength came from aggregate interlocking as well as the stiffness of the binder. Looking into this fact as well, we believe there is a future for usage of masonry blocks using bituminous emulsions.

i. Flexibility

Flexibility is one of the important properties of bituminous material analyze in adopting this research. In order to overcome brittle nature and fragmentation effect to concrete structures as well as glass wall, we need an alternative material that will be able to absorb the load flexibly and will not deform or fail in performing its intended purpose.

Wax emulsion exhibit flexible behavior because of its elastic nature where it will experience elastic deformation when subject to loading. Since it is petroleum based, the viscosity of the petroleum in the wax allows it to behave flexibly. Looking at the stress-strain relationship curve in Figure 1.2 below, elastic material does not have a limit. When subjected to tension (load applied by stretching the material), it will elongate throughout the time load is applied on it and when the load is removed, it will return back to its original shape and condition, maintaining same behavior throughout. This elastic phenomenon is explained through Hooke's law and Young's modulus where; [*William D. Callister, Jr 1997*][4]

$$\sigma = E\epsilon$$

σ	=	Stress
E	=	Young's Modulus
ϵ	=	Strain

This modulus represents the resistance to elastic deformation or stiffness of the material itself. The greater the modulus, the stiffer the material and the greater resistance against permanent deformation. In elastic deformation, the stretching of inter-atomic bonds will not cause the bond to break. That is why the material can return back to its original condition after load is removed. [*William D. Callister, Jr 1997*][4]

On the other hand, comparing to plastic material, it will not return to its original state when the load is removed because the bonds between particles that breaks during applied loading reformed new bonds with other particles relative to one another. [*William D. Callister, Jr 1997*][4]

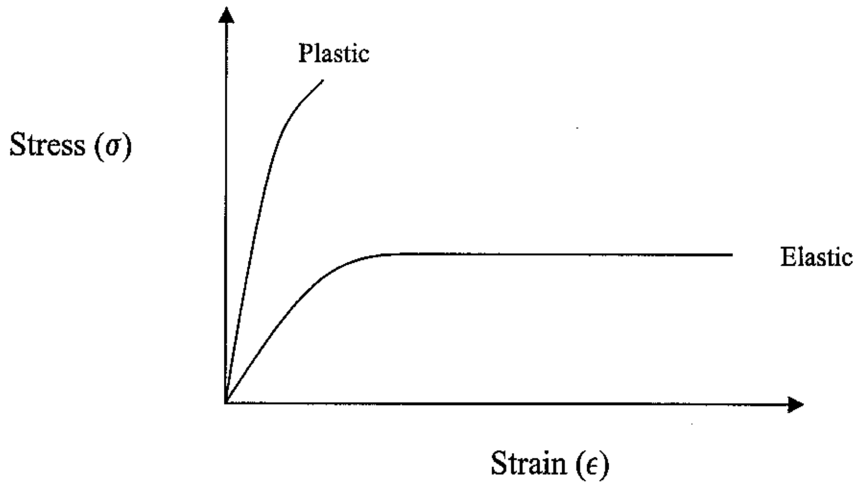


Figure 2.3: Typical Stress-strain relationship for plastic and elastic material.

Based on this elastic behavior, theoretically, it will eliminate problem of brittle failure in concrete structures and fragmentation. If this masonry block is used as a non-load bearing partition wall in a building with glass wall façade, it will lessen the injuries and death to occupants in case of shock loading such as heavy explosions or air-blast shock wave. As we know, airborne glass fragments causes by the shock loading are the major contribution of injuries of occupants in a building while air-blast pressure on the other hand will cause occupants to be thrown away or fall. In the worst cases, these can let to serious injuries as well as death of occupants or pedestrians.

By adopting this wall, which exhibit flexible behavior, theoretically, the elastic bond of the material binding the wall will absorb the external pressure imposed on it, dissipate the energy the explosion carries and at the same time will act as a barrier in protecting the occupants from the broken glasses. Even if the explosion causes the wall to break or crumble, its elastic behavior will prevent the material from hitting the occupants and lessen the injuries and other casualties.

ii Durability

Durability is termed as the ability of an asphaltic material to resist weathering. When asphaltic material is exposed to environmental elements, natural graduation takes place and causing the material to lose their adhesiveness and become brittle. However, in order for an asphaltic material to act successfully as a binder, it must possessed high resistance against weathering. *[Nicholas J. Garber, Lester A. Hoes, 2002]*[2]

Some of the factors that influence weathering are oxidation, volatilization, temperature, surface area and age hardening. In pavement, too much voids can cause oxidation of the aggregates, resulting in binder hardening that will cause the material to be brittle. Temperature has significant effects on rate of oxidation and volatilization. The higher the temperature, the greater the rate of oxidation and volatilization which in return will increase the binder hardening rate. *[Nicholas J. Garber, Lester A. Hoes, 2002]*[2]

That is why in pavement design, we only allow for sufficient amount of voids and optimum binder content to prevent bleeding in hot season and brittleness. This concept is also applied in this research. We will minimize the amount of voids and optimize the binder content to make sure that the block will be as durable as the pavement itself.

iii. Impermeability

In many structures, water will always be the main cause triggering the failures of the structures itself. Even in concrete blocks, the amount of voids should be low enough to prevent water from penetrating through and corroding the steel reinforcement. Same goes to the pavement design; the pavement must be waterproof to prevent water from penetrating through the entire pavement layer and weaken the pavement *[Nicholas J. Garber, Lester A. Hoes, 2002]*[2]. In this research, the blocks we are developing also must be impermeability to water action because we do not want the block to lose its strength. This emulsion which basically contains wax will sufficiently act as a waterproof lining protecting the blocks from water action, thus eliminating the loss of strength and failures.

iv. Adhesive

In a bituminous mix of a well graded aggregate, the strength of the material comes from aggregate interlocking. The adhesive property of the emulsions will make coat the coarse aggregates, fine aggregates and filler together which determines the interlocking behavior of the mix. This interlocking behavior gives excellent strength characteristic to the pavement in absorbing the loading applied to it. For gap graded aggregates, the strength comes from the stiffness of the binder itself [*Nicholas J. Garber, Lester A. Hoes, 2002*][2].

Effectiveness of the adhesive nature of bitumen in coating aggregates depends on nature of the surface and state of the bitumen. Better interlocking is achieved between rougher aggregates compared to round aggregates. In order for it to coat aggregate, it has to be in fluid state and resulting in good adhesion. However, presence of water will prevent adhesion. Thus this property relates closely to the waterproof nature of emulsions [*Nicholas J. Garber, Lester A. Hoes, 2002*][2]. This adhesive nature of bituminous emulsions in interlocking aggregates is one of the important properties that are taken into consideration in this research.

2.4 Advantages of Wax Emulsion

Since the objective of this research project is to identify new materials available to be used for future construction technology, experiments were proceeded with wax emulsion. As mention earlier, *BURKE WAX EMULSION WHITE (TYPE II)* is chosen in this research. Some of the benefits of this material are explained in the paragraph below. All of the benefits listed are more or less dependent of one another.

Wax emulsion will reduce shrinkage in materials. Since it resembles candle like substance once mix and harden, it will retain moisture in the mix and to successfully reduce plastic shrinkage cracks. Its hydrophobic nature will prevent excessive moisture loss due to heat generated from sun or surrounding environment.

It also accelerates strength gain for materials because strength will continuously increase as long as sufficient moisture is available for cement hydration. Basically the purpose of curing done in material such as concrete or highways mix are to make sure that sufficient amount of moisture is available for maturity. Since evaporation from surrounding environment will reduce the available moisture for the hydration of cement. By applying wax emulsions, it will sufficiently coat the material prevent evaporation of moisture from direct heat or surrounding environment thus allowing for complete maturing of cement hydration process.

Apart from that, it also enhances performance in term of durability and compressive strength. As mention above, since wax displays hydrophobic behavior, it will provide sufficient moisture for hydration of cement which resulting in higher strength material achieved. Moisture resistance of the material also increases thus providing better resistant against weathering due to environmental factors. This in return will increase the material durability. It also increases wear resistance and add a quality appearance since it will resulted in candle like material once the mix hardens.

2.5 Design Concept

In development of masonry blocks using bituminous emulsions, the weight of the design mix proportion is done following Marshall Mix requirement that is 1200g. In normal mix, 46% of coarse aggregates, 44% of fine aggregates and 9% of filler is used giving the total weight of the mix proportion 1200g. However in this research project, the percentage of coarse aggregates, fines and fillers used is changed to suit its requirement. In proportion, 2 : 1 :1 is applied where 50% of coarse aggregate, 25% of fines and 25% of filler is used which also gives the total weight of 1200g.

Here, we are trying to develop masonry blocks using emulsions. In developing the blocks, the same proportion like concrete mix are adopted where at 2 : 1 : 1, it gives the highest 7 and 28 days compressive strength compared to the other concrete proportion. The same concept and proportion is adopted in this emulsion blocks. The percent of bitumen and emulsion used in each mix is also varying from 5.0%, 5.5%, 6.0%, 6.5%, 7.0% and 7.5% by weight.

Two types of material are involved that is wax emulsion and conventional bitumen in this research. We are interested to understand the behavior of wax emulsions wherelse conventional bitumen mix is done for comparison purposes. We do trial and error to get the optimum binder content that will sufficiently coat the aggregate and provide excellent strength characteristic

CHAPTER 3

METHODOLOGY

3.1 Objective

Mainly, the objective of this experiment is to determine the optimum binder content which will be sufficient to develop masonry blocks that exhibit high strength. Apart from that, we will also determine the bending behavior of the blocks. In performing the experiment, we will also study and understand the behavior of the emulsions block. After that, we will conclude whether the strength value obtained is adequate enough to carry its intended purpose.

3.2 Experimental Procedure

In this research project, following the requirement of objective, two experiments are performed that is Marshall Stability and Porosity to determine strength and Beam Fatigue test to determine flexural stiffness and deflection of the material (refer figure 3.1 and 3.2). Apart from that, durability test against temperature effects are also performed. By right, Permeability test should also be done. However, the equipment to test for permeability is not available. All the experimental analysis will be done in Highway Lab.

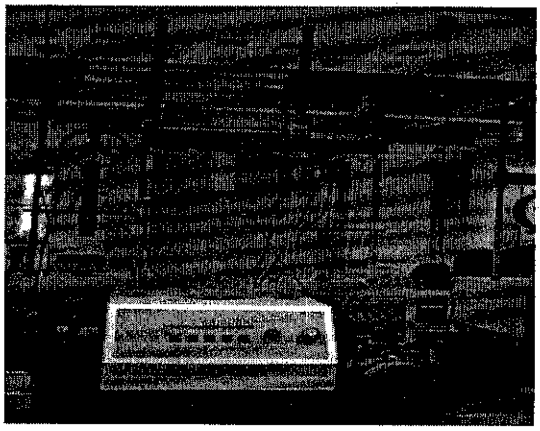


Figure 3.1: Marshall Stability Testing Equipment

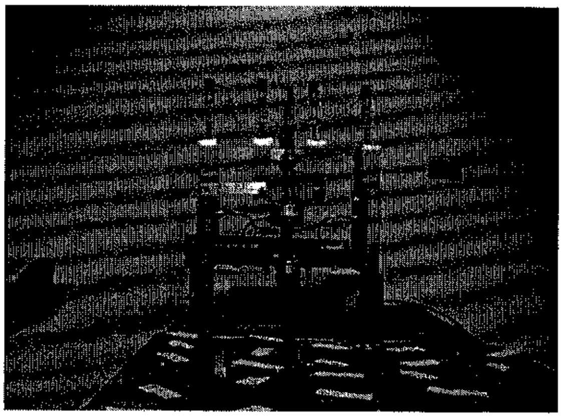


Figure 3.2: Beam Fatigue Testing Equipment

Two material are to be tested that is wax emulsion mix and conventional bitumen mix. The bitumen grade used in this research is 80 – 100 penetration. The proportion of the sample is 2 : 1 : 1 where it consist of 50% coarse aggregates (600g), 25% fines (300g) and 25% filler (300g) giving a total weight of 1200g. The bitumen percentage use is varied from 5.0%, 5.5%, 6.0%, 6.5%, 7.0% and 7.5%. From there, optimum binder content will be determined. This optimum binder content will then be used to cast a beam shape bitumen sample to test for its flexural strength (bending behavior). The result obtained will then be analyzed whether the strength value obtained is adequate or fiber addition is appropriate to alter some of the parameters of the masonry blocks.

3.2.1 Marshall Stability

3.2.1.1 Equipment used

- Gyratory Testing Machine
- Mechanical Mixer
- Thermometer
- Water Bath
- Electronic Balance
- Buoyancy Balance
- Oven
- Marshall Testing Machine

3.2.1.2 Procedures

A: Preparation of Asphalt Specimens

1 All the material are batched and kept in an oven at 150 C. The mixer is also heated up to the same level of temperature. This is because when using hot bitumen, all mixing has to be done in a hot environment.

2 The batched granular material (plus filter) should be placed in the mixer and mixed dry for about 1 minute, then the appropriate amount of bitumen should be added to the aggregate. Mixing should continue until all particles are coated with bitumen.

3 The material should be compacted in 100 mm steel moulds (which are also kept at 150°C – 160°C). Make sure that the sample filling the mould to be evenly distributed. This is done by tamping the material (using steel rod) 15 times around the edge and 5 times in the centre. At this stage, the sample is ready to be compacted using the Gyratory Testing Machine sets following the standard conditions:

Axial load	=	0.7 MPa
Rate of Gyration	=	60 gyration/min
No. of revolutions	=	150

4 When the specimens have cooled down to room temperature, they are then extruded from the mould. The weight of specimen in air and water are recorded.

5 Three specimens are to be prepared for each bitumen content.

B: Testing Asphalt Specimens

1 Heat the specimens in a water bath to a temperature of 60°C for 30 minutes.

2 Place the specimens in the Marshall Testing rig. The breaking head of Marshall Testing apparatus is also conditioned at 60°C.

3 Load the specimens radially at a constant rate of strain of 50.8mm/min.

4 Determine the stability of each specimen as the maximum load that the specimen could withstand.

5 Correct the stability value obtained above by the appropriate coefficient

6 Read also deformation at failure.

7 From the data, 4 graphs to be plotted;

    Density vs Bitumen Content

    Stability vs Bitumen Content

    Flow vs Bitumen Content

    Porosity vs. bitumen content

8 The value of optimum binder content in mixes will be obtained form the graphs mentioned above.

3.2.2 Beam Fatigue

3.2.2.1 Equipment Used

- UTM Machine
- Beam Fatigue Test mould
- Asphalt concrete mixer
- Oven
- Grease
- Brush

3.2.2.2 Procedures

1. The beam will be constructed using the optimum binder content value of conventional and emulsion mix obtained from the Marshall Testing. The required beam sample size to be prepared is 63.5mm x 50mm x 400mm. The mass of mix materials to be prepared will be calculated based on the size of the beam which requires two mixes to be done concurrently to fix the mould.
2. Upon placement the mix material into the mix, tamping using steel rod is necessary to provide even distribution.
3. The mix materials were then compacted in the mould by using the special mould's lid designed for compaction purposes. To ensure better compaction is achieved, the mould lid is then compacted using a hand compactor.
4. Beams were then cured in room temperature before tested with the beam fatigue test equipment in UTM machine.
5. The test will be conducted in control sinusoidal strain mode of loading.
6. The controlling parameter of the test is either sinusoidal strain or sinusoidal stress. Here it will be tested by controlling strain where the strain level is between 200 to 450 micro strains.
7. Graph of maximum tensile stress (kPa) and Flexural stiffness (MPa) is plotted against cycles of failures by the software.

3.2.3 Durability of Conventional and Emulsion Mix

3.2.3.1 Equipment Used

- Oven
- Marshall Stability Machine

3.2.3.2 Procedures

1 Tests were done for both conventional and emulsion mix using the optimum binder content value obtained from the Marshall Testing.

2 Mix was done using the exact same procedure as the requirement of the Marshall test. Circular mould it use in this case.

3 Upon completion of the mix, it was placed in cold water for half an hour before being put into oven for 24 hours (1 cycle). The temperature of the oven has been set to 40 C.

4 The material will be tested for 3, 6, 12 and 24 cycles. After completion of the required cycles, Marshall Test will be conducted to determine the strength and deformation value with respect to adverse condition placed.

5 Results obtained analyzed and graph of stability and flows versus number of cycles are to be plotted.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Determining the Optimum Binder Content

In order for us to determine the optimum binder contained, all the values obtained are compiled in table form so it will be easier for us to see the differences clearly. The bitumen used in this experiment is 80-100 penetration grades (specific gravity 1.03) while wax emulsion has the specific gravity of 1.00. From the experiments done, the only values obtained are height of specimens, mass of specimen in air and water, flow and stability. Some calculation has to be done to determine the bulk and theoretical specific gravity, voids percent and corrected stability values. Calculation of bulk specific gravity, theoretical specific gravity and voids for both the samples are shown below in section 4.2.1. Stability values obtained directly from Marshall Testing equipment must be corrected using the coefficient factor. The coefficient factor is also included in the appendix in Figure 4.4. With all the values calculated, graph then will be constructed to determine the optimum binder content.

Three graphs have to be constructed in order for us to determine its optimum binder content and one graph is required to determine its deformation rate. The parameters that are crucial in constructing the graphs are bulk specific gravity, porosity and stability. These parameters will be the y-axis where binder percentage content will be the x-axis. The maximum point in the graph for both bulk specific gravity and stability will be noted as well as the minimum value obtained for porosity. The average of all these bitumen content will then give the optimum binder content for this mix proportion.

4.2 Experimental and Calculation Result

4.2.1 Wax Emulsion

Table 4.1: Experimental and Calculation result for Wax Emulsions samples

Sample no.	Binder content by Mass of Mix (%)	Height (mm)	Mass of specimen		Volume (cm^3)	Specific Gravity		Air void (%)	Flow (mm)	Stability (kN)		
			In Air (g)	In Water (g)		Bulk	Theory	VMA		Measured	C.F	Corrected
1	5.0	67.31	1246.9	676.7	570.2	2.19	2.56	14.45	2.81	25.00	0.90	22.50
		68.84	1260.3	676.8	583.5	2.16	2.56	15.63	1.20	24.89	0.88	21.90
		68.81	1259.8	679.6	580.2	2.17	2.56	15.23	2.98	24.93	0.88	21.94
average		***68.32***			***577.97***	***2.17***	***2.56***	***15.23***	***2.33***			***22.11***
2	5.5	67.39	1257.6	687.6	570.0	2.21	2.54	12.99	1.89	24.94	0.91	22.70
		65.51	1262.1	688.8	574.1	2.20	2.54	13.39	1.24	22.28	0.95	21.17
		64.62	1244.8	676.5	568.3	2.19	2.54	13.78	2.61	20.62	0.97	20.00
average		***65.84***			***570.8***	***2.20***	***2.54***	***13.39***	***1.91***			***21.29***
3	6.0	67.02	1228.1	672.7	555.4	2.21	2.52	12.30	5.52	24.91	0.92	22.92
		68.47	1255.9	685.9	570.0	2.20	2.52	13.39	3.58	24.94	0.89	22.20
		68.89	1252.9	686.3	566.6	2.21	2.52	12.30	2.05	24.84	0.88	21.86
average		***68.13***			***570.7***	***2.21***	***2.52***	***12.30***	***3.72***			***22.33***
4	6.5	67.08	1220.5	654.9	565.6	2.16	2.50	13.60	2.35	24.93	0.92	22.94
		70.93	1270.3	673.7	596.6	2.13	2.50	14.80	2.24	25.00	0.84	21.00
		69.34	1252.3	666.6	585.7	2.14	2.50	14.40	2.80	24.90	0.87	21.66
average		***69.12***			***582.6***	***2.14***	***2.50***	***14.27***	***2.46***			***21.87***
5	7.0	69.94	1258.1	666.9	591.2	2.13	2.48	14.11	4.25	24.96	0.86	21.47
		69.79	1258.1	672.1	586.0	2.15	2.48	13.31	1.34	25.00	0.86	21.50
		71.47	1269.9	671.3	598.6	2.12	2.48	14.52	1.52	24.89	0.83	20.66
average		***70.40***			***591.9***	***2.13***	***2.48***	***13.98***	***2.37***			***21.21***
6	7.5	71.93	1281.2	680.9	600.3	2.13	2.46	13.41	2.07	25.00	0.82	20.50
		73.23	1276.0	674.8	601.2	2.12	2.46	13.82	2.44	24.87	0.81	20.14
		69.94	1268.4	668.9	599.5	2.12	2.46	11.79	5.04	25.00	0.86	21.50
average		***71.70***			***600.3***	***2.12***	***2.46***	***13.01***	***3.18***			***20.71***

4.2.1.1 Sample Calculation for Values Obtained

For 5% bitumen content,

Amount of bitumen used $= \frac{\% \text{ Bitumen}}{(100 - \% \text{ Bitumen})} \times 1200\text{g}$

$= \frac{5}{95} \times 1200\text{g}$

$= 63\text{g}$

Weight of total mix = Coarse + Fines + Filler + Bitumen

= (600 + 300 + 300 + 63)g

= 1263g

Volume of specimens = Mass in Air – Mass in Water

= 1246.9 – 676.7

= 670.2 cm^3

Bulk Specific Gravity $= \frac{\text{Mass in Air}}{\text{Volume}}$

$= \frac{1246.9}{570.2}$

= 2.19

$$\text{SG Mix Aggregates} = \frac{100}{\frac{\%CA}{SG\ CA} + \frac{\%FA}{SG\ FA} + \frac{\%C}{SG\ C}}$$

$$= \frac{100}{\frac{50}{2.71} + \frac{25}{2.68} + \frac{25}{3.1}}$$

$$= 2.79$$

$$\text{Theoretical SG} = \frac{100}{\frac{\%B}{SG\ Bit.} + \frac{(100-B)}{SG\ Mix.\ Agg}}$$

$$= \frac{100}{\frac{5}{1.00} + \frac{95}{2.79}}$$

$$= 2.56$$

$$\text{Void} = (1 - \text{SG Bulk/SG Theory}) \times 100$$

$$= (1 - 2.19/2.56) \times 100$$

$$= 14.45\%$$

4.2.2 Conventional Bitumen

Table 4.2: Experimental and Calculation for Conventional Bitumen Samples

Sample no.	Binder content by Mass of Mix (%)	Height (mm)	Mass of specimen		Volume (cm^3)	Specific Gravity		Air void (%)	Flow (mm)	Stability (kN)		
			In Air (g)	In Water (g)		Bulk	Theory	VMA		Measured	C.F	Corrected
1	5.0	65.25	1251.8	701.9	549.9	2.28	2.57	11.28	3.20	23.95	0.96	22.99
		65.08	1249.7	697.3	552.4	2.26	2.57	12.06	3.13	24.00	0.96	23.04
		65.32	1253.2	700.3	552.9	2.27	2.57	11.67	3.18	23.90	0.96	22.94
average		***65.22***			***551.7***	***2.27***	***2.57***	***11.67***	***3.19***			***22.96***
2	5.5	67.35	1249.9	694.8	555.1	2.25	2.55	11.76	2.58	24.84	0.95	23.60
		67.00	1251.7	697.2	554.5	2.27	2.55	11.37	2.54	24.81	0.92	22.83
		66.99	1248.1	693.5	554.6	2.25	2.55	11.76	2.57	24.86	0.92	22.87
average		***67.11***			***554.7***	***2.25***	***2.55***	***11.63***	***2.56***			***23.10***
3	6.0	66.67	1284.8	724.3	560.5	2.29	2.53	9.49	4.69	24.97	0.93	23.22
		66.35	1278.2	719.2	559.0	2.29	2.53	9.49	4.62	24.96	0.98	23.46
		66.50	1280.1	720.4	559.7	2.29	2.53	9.49	4.65	24.98	0.99	23.73
average		***66.51***			***559.7***	***2.29***	***2.53***	***9.49***	***4.65***			***23.47***
4	6.5	64.79	1262.7	700.1	562.6	2.24	2.51	10.75	3.25	23.94	0.97	23.23
		64.43	1270.4	705.2	565.2	2.25	2.51	10.36	3.20	23.90	0.98	23.42
		64.67	1266.1	699.9	566.6	2.23	2.51	11.16	3.27	23.97	0.97	23.21
average		***64.63***			***564.8***	***2.24***	***2.51***	***10.76***	***3.24***			***23.29***
	7.0	64.87	1289.5	710.6	578.9	2.23	2.49	10.44	2.07	23.86	0.97	23.14
		65.87	1286.2	712.0	574.2	2.24	2.49	10.40	2.15	24.00	0.95	22.80
		64.30	1289.3	711.8	577.5	2.23	2.49	10.44	2.04	23.90	0.98	23.42
		65.01			***576.9***	***2.23***	***2.49***	***10.43***	***2.09***			***23.12***
5	7.5	63.78	1299.3	713.5	585.8	2.22	2.47	10.12	5.08	23.25	0.99	22.02
		63.81	1300.2	717.0	583.2	2.23	2.47	9.72	5.10	23.20	0.99	22.97
		63.62	1296.3	708.6	587.7	2.21	2.47	10.53	5.07	23.17	1.00	23.17
average		***63.74***			***592.0***	***2.22***	***2.47***	***10.12***	***5.09***			***23.05***

4.2.2.1 Sample Calculation for Values Obtained

For 5% bitumen content,

$$\text{Amount of bitumen used} = \frac{\%\ \text{Bitumen}}{(100 - \%\ \text{Bitumen})} \times 1200\text{g}$$

$$= \frac{5}{95} \times 1200\text{g}$$

$$= 63\text{g}$$

$$\text{Weight of total mix} = \text{Coarse} + \text{Fines} + \text{Filler} + \text{Bitumen}$$

$$= (600 + 300 + 300 + 63)\text{g}$$

$$= 1263\text{g}$$

$$\text{Volume of specimens} = \text{Mass in Air} - \text{Mass in Water}$$

$$= 1251.8 - 701.9$$

$$= 549.9\ \text{cm}^3$$

$$\text{Bulk Specific Gravity} = \frac{\text{Mass in Air}}{\text{Volume}}$$

$$= \frac{1251.8}{549.9}$$

$$= 2.28$$

$$\text{SG Mix Aggregates} = \frac{100}{\frac{\%CA}{SG\ CA} + \frac{\%FA}{SG\ FA} + \frac{\%C}{SG\ C}}$$

$$= \frac{100}{\frac{50}{2.71} + \frac{25}{2.68} + \frac{25}{3.1}}$$

$$= 2.79$$

$$\text{Theoretical SG} = \frac{100}{\frac{\%B}{SG\ Bit.} + \frac{(100-B)}{SG\ Mix.\ Agg}}$$

$$= \frac{100}{\frac{5}{1.03} + \frac{95}{2.79}}$$

$$= 2.57$$

$$\text{Void} = (1 - \text{SG Bulk/SG Theory}) \times 100$$

$$= (1 - 2.28/2.57) \times 100$$

$$= 11.28\ \%$$

4.3 Graphs Constructed

4.3.1 Stability versus Bitumen Content

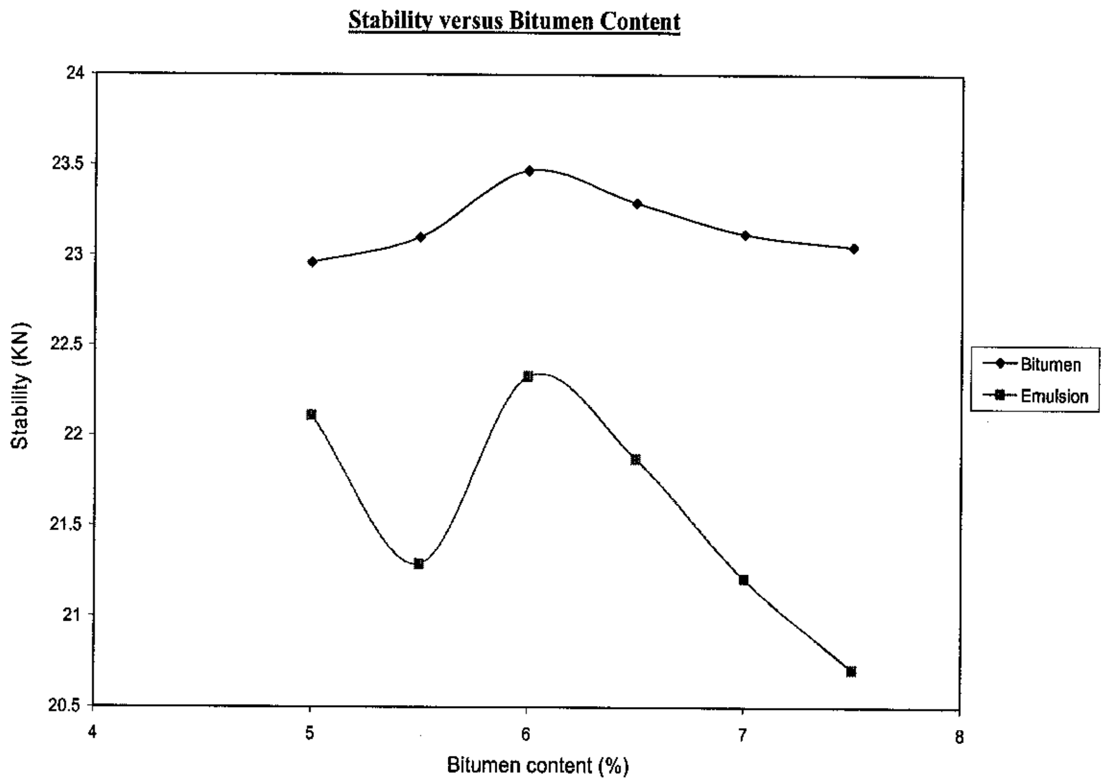


Figure 4.1: Graph of Stability versus Bitumen Content

4.3.2 Bulk Density versus Bitumen Content

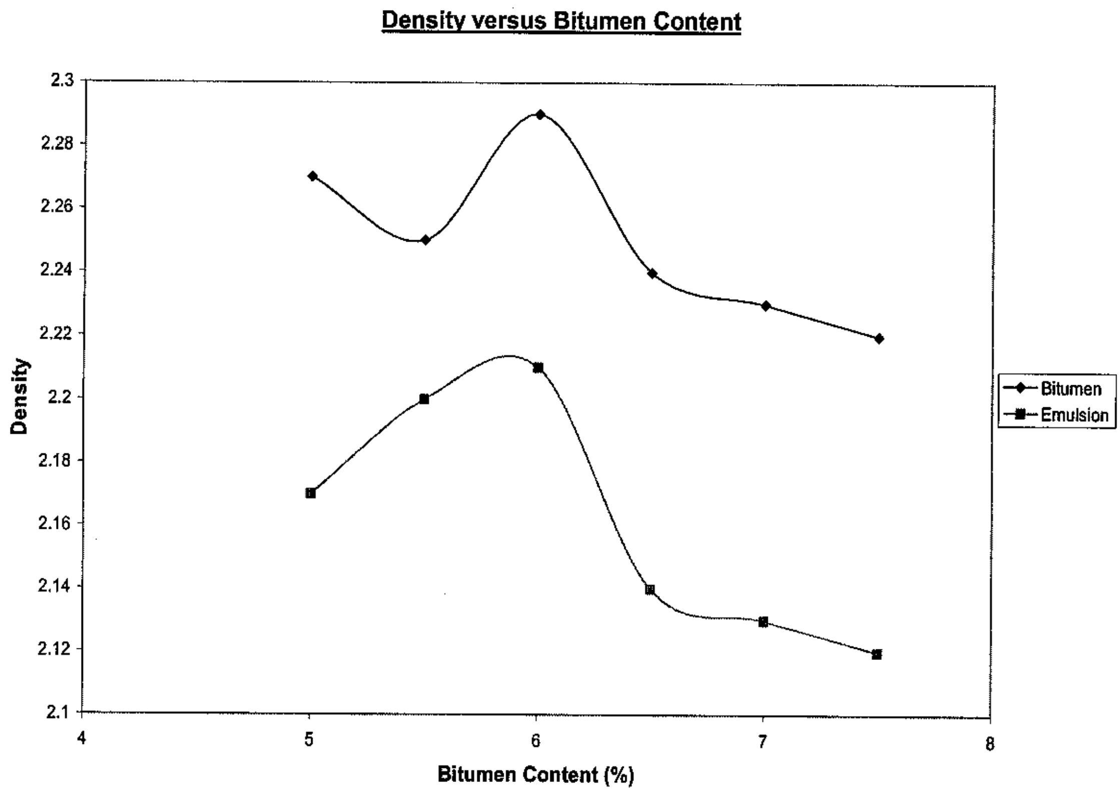


Figure 4.2: Graph of Bulk Density versus Bitumen Content

4.3.3 Porosity versus Bitumen Content

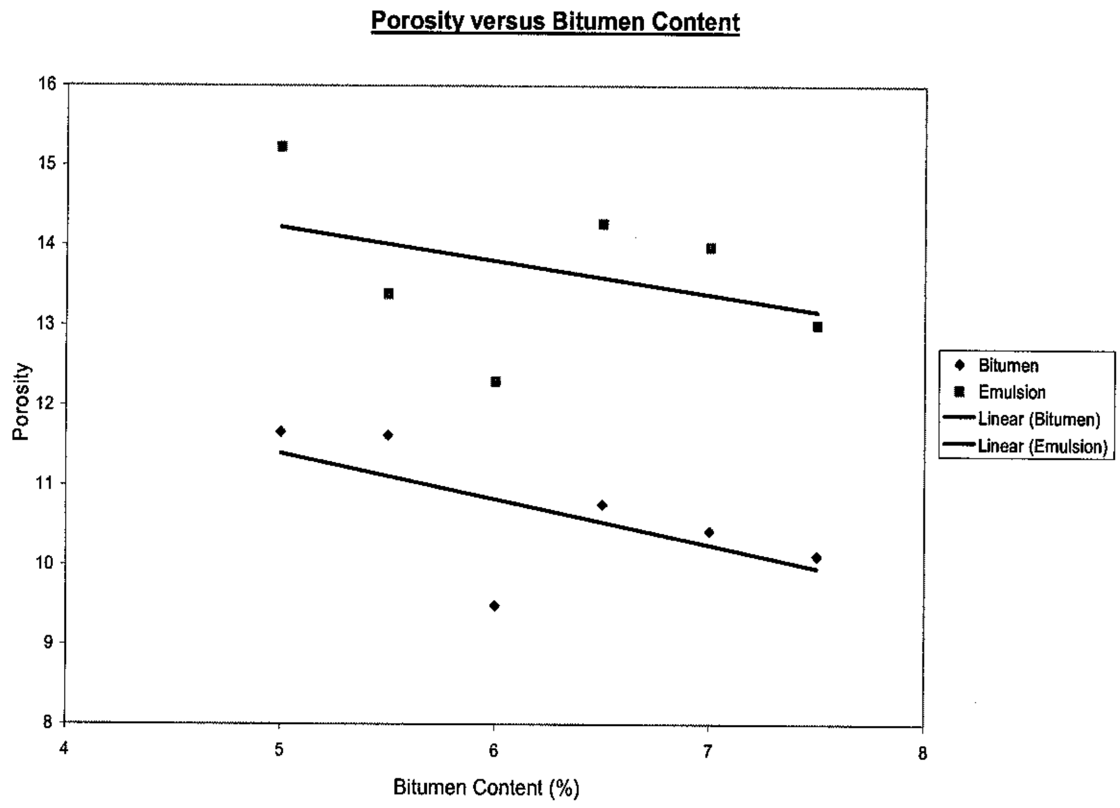


Figure 4.3: Graph of Porosity versus Bitumen Content

4.3.4 Flow versus Bitumen Content

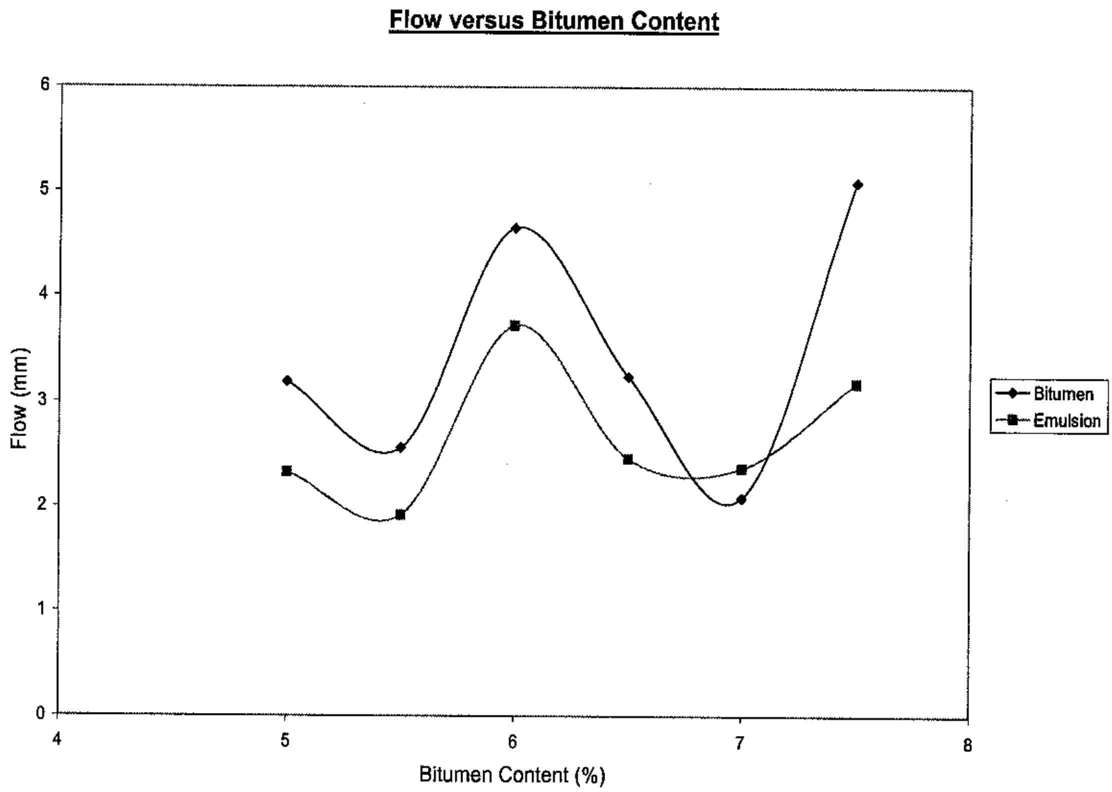


Figure 4.4: Graph of Flow versus Bitumen Content

4.4 Optimum Binder Content

As mention previously, the highest point in the curve for both density and stability graph will be noted. The lowest point in the porosity graph value will also be noted. All the bitumen content values obtained from these 3 graphs will determine its optimum binder content for the mix proportion of 2 : 1 :1. Looking at the graphs above, we can see that the highest point in stability and density curve as well as the lowest point for both emulsion and conventional value are the same. Thus the optimum binder content for both materials are;

Highest point in the stability curve = 6.0%

Highest point in the density curve = 6.0%

Lowest point in the porosity graph = 6.0%

Optimum Binder Content = (6.0 + 6.0 + 6.0) / 3

= 6.0%

4.5 Discussion

In this experiment, for every bitumen and wax emulsion content percentage, 3 samples are done. Testing were done for sample using 5.0%, 5.5%, 6.0%, 6.5%, 7.0% and 7.5% which resulting in 30 samples done that is 15 for emulsion and another 15 for conventional mix. This is to make sure the values obtained are more accurate and reliable. Gyratory compaction machine is used in this experiment instead of Marshall Compactor. This is because it compact the specimens by rolling, which symbolize how the traffic loading is distributed on a pavement during its service life.

Initially, the percentage of bitumen suggested for this experiment is 5%, 6%, 7.5%, 9% and 10%. However, at 9%, bleeding occurs where the sample is too watery and become too soft even after compaction and does not give desired strength value. Due to that, the percentage of bitumen used is changed to 5.0%, 5.5%, 6.0%, 6.5%, 7.0% and 7.5%.

From the results obtained above (Table 4.1 and 4.2), wax emulsion mix give significantly higher height values compare to conventional bitumen. The height value plays a very important role for the stability calculation of the samples. The height of the specimen obtained from the experiment is not uniform throughout each sample. This is because, when placing the mix sample into the mould before compaction, tamping with steel rod is necessary to make it evenly distributed thus resulting in uniform thickness of the sample height. However, some due to some human errors occurring while performing the experiment, not all samples are being tamped.

Volume also increases as the bitumen percent increases. It might due to the amount of bitumen added in each mix increase the total weight of the samples. Since volume is mass in air – mass in water, the increases in mass resulting in increases in volume as well. However, for emulsion mix, at 6.0 and 6.5% of bitumen content, the volume is reduced. This is because some technical errors occurring while performing the experiment which will be explained later. Wax emulsion is highly sensitive to temperature, since it is solid at room temperature appropriate heat are to be applied for it to melt. Mixing is done in temperature about 150°C. If time for mixing is too short, the mix will break upon simple touch after the compaction. On the other hand, if the mixing time is too long, it will case the mix to bleed. During compaction, many of the wax will be lost due to the bleed and the temperature of the mould itself which resulting in reducing of the volume.

Looking at Figure 4.2 in section 4.3.2, the graph shows that density increases as both the bitumen and wax content increases. This is because additional mass of the sample due to increase in bitumen content, making the sample heavier and more compacted. The maximum density is attained at 6.0% bitumen content. This means that at 6.0% bitumen content, it will give the optimum density due to binder effectively coat aggregates, lessen the voids and resulting in good compaction [*Nicholas J. Garber, Lester A. Hoes, 2002*][2]. However, density attained by emulsion is lesser compared to conventional although optimum binder content for wax is noted at 6.0% as well. This shows that at 2:1:1 mix percentage, conventional bitumen will give higher density compared to wax emulsion.

Looking at Figure 4.3 in section 4.3.3, the porosity decreases as bitumen content increases. Same condition applied to both conventional and wax mixes. This is because as the amount of bitumen added increases, it will effectively coat the aggregates and hold them together. Bitumen will then filled up the voids spaces in the sample and giving better aggregates packing that allows good compaction thus resulting in higher strength characteristic. From the graph, we can see that the lowest porosity value is attained at 6.0% bitumen content. This means that, 6% bitumen content that provides good aggregates coating which in return lessen the amount of voids in the sample. Although both porosity is attained at 6.0%, however overall performance result of conventional bitumen gives lesser porosity value compared to wax emulsions. This shows that conventional bitumen produce better aggregate interlocking characteristic.

By right, the porosity value should be taken at 4% (extend line from 4% in y-axis to the graph line) because in pavement design we allow for 4% porosity to permit a small amount of compaction when traffic load is applied onto it [*Nicholas J. Garber, Lester A. Hoes, 2002*][2]. However, in this experiment, since we are symbolizing the concrete block and using the same mix proportion as the concrete itself, that 4% value is neglected.

In brick wall, the amount of porosity is 15 – 20% where else in concrete it is 10 – 15%. At 6.0% bitumen content, the amount of porosity obtained for wax is 12.30% where for conventional is 9.49%. This value is considered good enough in masonry blocks construction. In building construction, low porosity is encouraged since it can lower the conduction rate. It will sufficiently act as a moisture barrier and will not permit the hot temperature outside the building to enter through conduction. Though wax emulsion gives higher porosity values, it will also sufficiently act as a moisture barrier since its wax surfaces reduce unwanted penetrations and interactions of various liquids due to their hydrophobic nature.

Stability test is done using the Marshall Stability Equipment, and loaded at a rate of deformation of 2 in. (5mm) per minute until failure occurs. The total load that causes failure is noted as the Marshall Stability value of the specimen. In other words, stability gives the strength value of the sample to resist failure [*Nicholas J. Garber, Lester A. Hoes, 2002*][1]. Looking at Figure 4.1 in section 4.3.1, the curve shows that the maximum stability value is obtained at 6.0% bitumen content for both wax and conventional mix. This is because of the optimum binder content that binds the aggregates together and lessens the voids volume which resulting in good aggregate packing and compaction thus increasing its strength value. All of the three properties; density, porosity and stability are inter-related to each other.

The stability values obtained from the testing equipment have to be corrected by a coefficient value. The coefficient table is included in the *Appendix 1.2*. In order to get the coefficient factor for each stability value, height of specimen is needed. The coefficient factor (CF) is then multiplied by the original stability value. The new stability value will be the adjusted stability value. Some of the height values are not available in the table, this interpolation method is used. As mention earlier, height of wax mix attained is higher compare to conventional mix. In the coefficient factor table, as the height increases the C.F value decreases. Thus, although performance of wax in term of stability value is higher to conventional, after correction with C.F, it results in lower strength to conventional.

From visible observation, wax mix either does not display any cracks or experience minor cracking compared to conventional mix. The stability values obtained are close to the load limit of the Marshall equipment which is 25 kN. This implies that wax emulsion mixes can produce higher strength value than the stated limit of the testing equipment. However due to the capacity of equipment, the strength capacity of the emulsion is limited.

After compaction using Gyratory machine, the wax emulsion are susceptible to breakage if imposed to heavy loading, insufficient or over mixing time which causes too stiff mix or bleeding. Too stiff mix will not sufficiently coat the aggregate and will not hold them progressively against loading action where else bleeding will cause the mix to be too watery and loss of wax and bonding capacity if the mix. Due to that, adequate care has to be practiced for removing of mix sample after compaction. It might be sensitive during its early state (after compaction), however after being exposed to room temperature for quite some time, it will be sufficiently hard and stiff. This agrees with the benefits of wax emulsion as explained in section 2.4. wax material will prevent any moisture losses due to temperature effect, and provide sufficient moisture needed for hydration of cement which in return resulting in higher strength material (increase in compressive strength).

Flow is termed as the amount of deformation faced by material before failure [*Nicholas J. Garber, Lester A. Hoes, 2002*][1]. According to JKR Standards, optimum binder content value should have flow more than 2.0 mm [*Nicholas J. Garber, Lester A. Hoes, 2002*][1]. overall values obtained form both conventional and wax mix produce flow greater than 2.0 mm. Looking at figure 4.4 in section 4.3.4, conventional mix experiences bigger deformation before failure compare to wax. Since wax mixes is stiffer, it lose it flexibleness. Thus, although it will result in higher compressive strength it fails al low deformation rate. In other words, it provides high strength but only for small scale of deformation. Comparing to conventional, it is more flexible thus less stiff allowing it to experience larger deformation before failure.

In performing these experiments, there are some technical and human errors occurring resulting in some discrepancies in the results obtained. Before doing the hot mix, the mix proportion has to be heated up fist because in for hot mixing to take place it requires a hot environment to achieve good workability. The total weight of the mix proportion before being heated up is 1200g. However, after heating, the weight decreases by 0.01-0.03g. This is because some of the moisture of the mix proportion has been evaporated.

As mention earlier, tamping of mix material in the mould using steel rod is necessary to produce evenly distributed mix and thus giving lesser height values. However, due to some human errors nit all samples are being tamped. Apart from that, over mixing of the wax samples will cause bleeding which resulting in loss of moisture and bonding capacity of material. Experiments are basically trial and error to get the best result for each case. Due to some mistakes in over mixing of materials, the appropriate structures and features of the right time for mixing is understood.

Porosity values obtained for both the cases are acceptable for masonry blocks constructions. However, lesser amount of porosity by both samples is probably achievable if the amount of pressure exerted by the Gyratory compaction machine is higher. By right, the suitable pressure for compaction is 600 kPa however only 400 kPa is obtained in the lab. This is because of lower central pressure send from the GDC.

4.6 Beam Fatigue

Results from Beam Fatigue test are articulated in its software. Thus the overall result of the experiments done is included in the *Appendix 1.3 – 1.6.* Since the parameters that are crucial to determine beam behavior for both conventional and wax emulsions are flexural stiffness, tensile stress, deflection, loading time and number of cycles count before failure, thus that values are extracted from the result and displayed in the table below.

Table 4.3: Crucial Parameters for Determining Beam Behavior towards Fatigue

Conditioning parameter	Conventional Bitumen		Wax Emulsions	
	450 $\mu\epsilon$	200 $\mu\epsilon$	200 $\mu\epsilon$	100 $\mu\epsilon$
Initial Flexural Stiffness (MPa)	507	871	1060	-
Flexural Stiffness (MPa)	246	670	1060	-
Termination Stiffness (MPa)	253	436	436	9709
Maximum Tensile Stress (kPa)	111	134	3767	28
Deflection (mm)	0.227	0.100	2.003	-
Loading Time	00:06:31	02:52:16	00:00:01	00:00:01
Cycle to Failure (out of 1 000 000)	3910	103360	10	10

4.6.1 Discussion

Since we are trying to adopt this wax emulsion into a non-load bearing partition wall to counter heavy explosions or air-blast shock wave, it has to be tested for fatigue. Fatigue is one of the essential structural properties apart from strength, deformation, hardness, uniformity, creep, shrinkage and temperature effects. Fatigue is termed as the number of cycles the material can undergo during its service life before failure. It is not desirable for the structure to loss its strength in time, experiences fracture or shape changes with time [A*nil K. Chopra, 2001*][5].

From the results shown above, it is clearly defined that conventional bitumen beam are more flexible in withstanding fatigue loading comparing to wax emulsion *(refer Appendix 1.3 and 1.4)*. This is because wax beam once it's harden it becomes very stiff and hard, just like a normal wax or candle that we can see it gift shops. With small amount of loading, it will break instinctively. It symbolizes concrete behavior which is high compressive but low in tensile and brittle in nature. The controlling parameter chosen for this test, as mention earlier in Chapter 3, is sinusoidal strain.

Conditioning cycle chosen for this test is 50cycles. The initial flexural stiffness obtained is the amount of continuous 50 cycles of peak-to-peak micro strain at the initial stages of the experiment. However, for wax emulsion beam, it fails after 10 cycles count, not even made it to the conditioning cycles *(refer Appendix 1.5 and 1.6)*. Apart from that, at 10 cycles count, it deflects for amount of 2.0 mm *(refer Appendix 1.5 and 1.6)*. Figure below shows wax emulsion beam before and after testing.

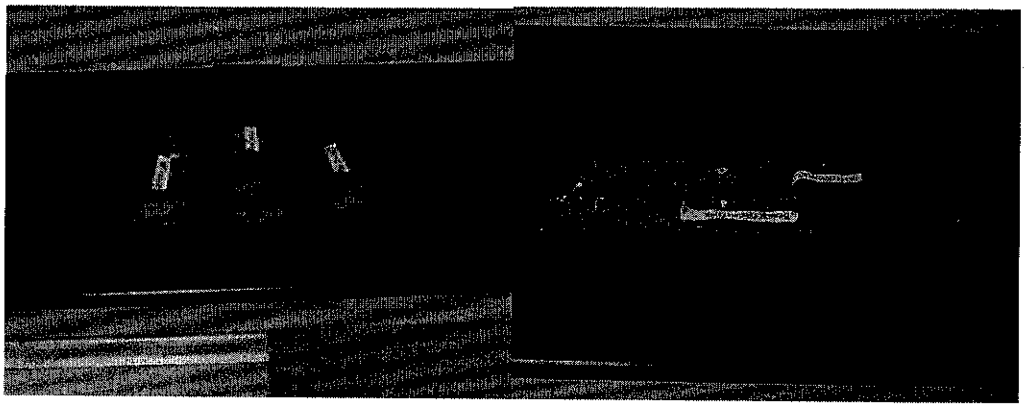


Figure 4.5: Wax Emulsion beam; Before and After Testing

By right, sufficient testing should be done by varying the value of sinusoidal strain in order that more values are available for graph plotting. Graph to be constructed is strain against number of cycles. With these graph, then prediction of material behavior under different amount of strain is possible. The graph that has been plotted by the software is maximum tensile stress and flexural stiffness against number of cycles *(refer Appendix 1.3 and 1.4)*. Practically, the graph follows the pattern below [A*nil K. Chopra, 2001*][5].

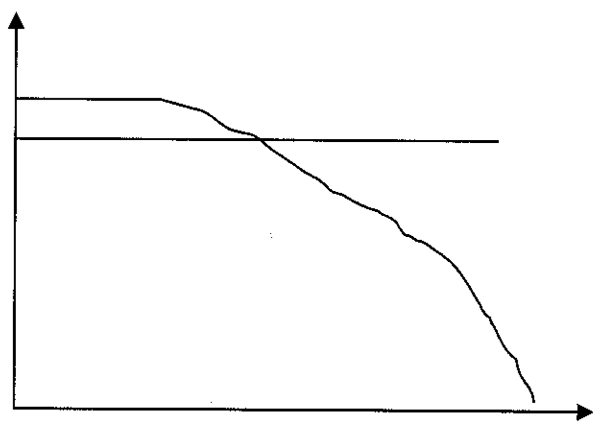


Figure 4.6: Typical Curve obtained From Beam Fatigue Test by Controlling Strain

By using controlling strain mode test, the flexural stiffness of the material obtained will be half of the initial flexural determined by the conditioning cycles. Typical figure of the flexural stiffness graph with respect to strain behavior is shown below [A*nil K. Chopra, 2001*][5].

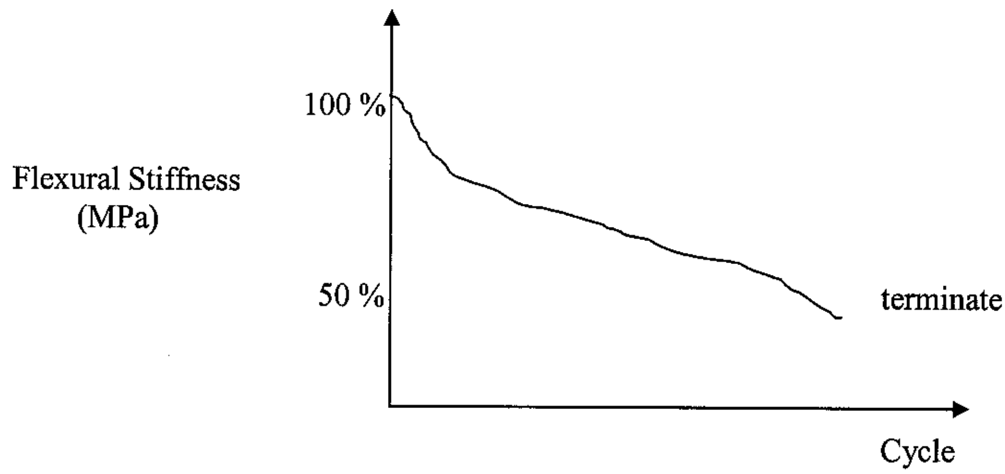


Figure 4.7: Typical Curve obtained for Flexural Stiffness from Controlling Strain

As mention earlier, wax emulsion fails instinctively under cyclic loading. It thus implies that it does not display flexibility characteristics theoretically like other petroleum distillation process product is, or in this cases the conventional bitumen. This material displays high stiffness and is very brittle. Wax emulsion thus is not suitable to counter dynamic loading caused by heavy explosions or air-blast shock wave, for that matter. Thus, fiber addition is necessary to increase its flexibleness in countering cyclic loading.

In performing this experiment, there are also some technical and human errors occurring which results in some discrepancies in the values obtained. Initially, 3 samples of wax and conventional beam are prepared. However, due to some defects in the beam fatigue testing machine, 2 of them break which is 1 conventional and 1 wax beam. Due to time constraints, constructing another beam is impossible. Thus, the results obtained are only by 2 beams which have been successfully tested.

Apart from that, the beam and the testing equipment should be condition in the chamber until the skin and core temperature are the same with the desired temperature.

However, one of the beams was tested when the chamber's temperature has not yet reached its desired value that is 27°C. As temperature increases, the material become softer thus more susceptible to fatigue. However, as temperature decreases, beam becomes harder and stiffer; resulting in higher amount of fatigue loading required to cause failures. That is why for the case of beam tested with controlling parameter of 200 micro strain, flexural stiffness increases once the core and skin temperature are the almost the same with the desired temperature (refer Figure 1.2 in appendix).

4.7. Durability

As mention in Chapter 3, durability test is done by soaking the samples in cold water for half an hour and left in the oven preset to 40°C for 24 hours. The soaking and putting in oven for 24 hours is considered one cycle. Testing of the samples by Marshall Equipment is to be done for 3, 6, 12 and 24 cycles. Results obtained are tabulated below. Graph of stability and flow versus cycle are constructed.

Table 4.4: Durability test for both Wax and Conventional Mix

Parameters	Conventional			Emulsion		
	0 cycle	7 cycles	14 cycles	0 cycle	7 cycles	14 cycles
Height (mm)	66.51	66.51	66.50	68.02	68.02	68.02
Measured Stability (kN)	24.97	20.21	17.91	24.94	24.03	22.90
C.F	0.93	0.93	0.93	0.90	0.90	0.90
Stability (kN)	23.22	18.80	16.66	22.45	21.63	20.61
Flow (mm)	4.65	3.78	4.06	4.20	2.72	3.69

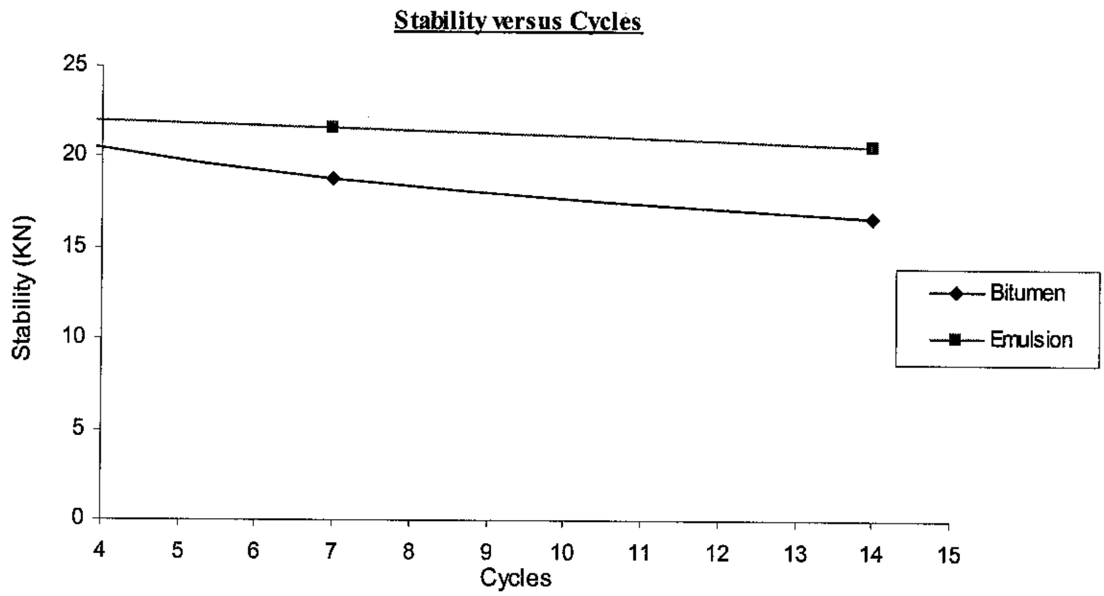


Figure 4.8: Graph of Stability versus Cycles

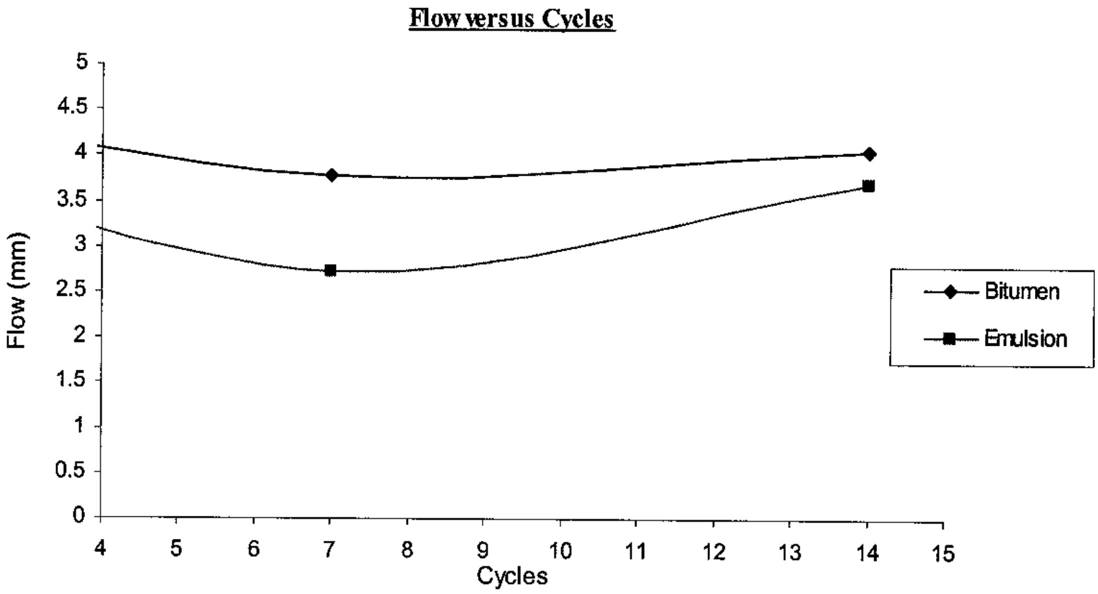


Figure 4.9: Graph of Flow versus Cycles

4.7.1 Discussion

From figure 4.8, stability versus cycle graph, wax emulsion produce better strength value compared to conventional. However, looking at figure 4.9, conventional allow bigger deformation before failure compare to wax. This implies that, wax emulsion mix shows higher strength and durability characteristic against temperature effect better than conventional but at a lower deformation rate.

For wax samples, only minor cracking experience during placement in oven for 7 and 14 cycles as well as during Marshall Test compared to conventional. Figure below shows the deformation experience by sample using conventional (left) and wax (right). It is clearly noted that, conventional sample deforms and experience a great amount of cracks compared to wax.

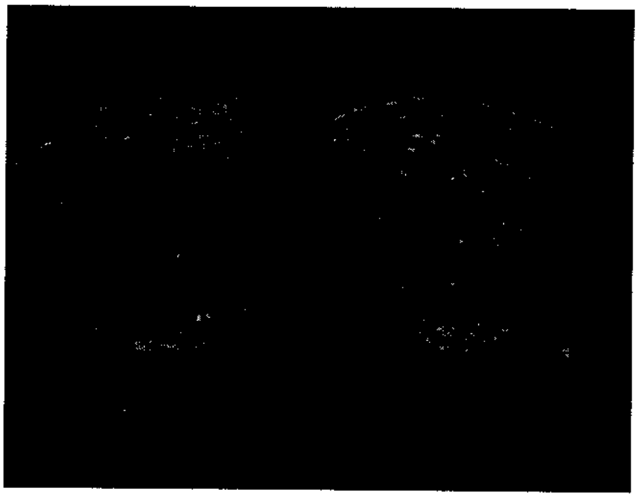


Figure 4.10: Deformation Experience by Sample using Conventional (left) and wax (right)

By right, the samples should be tested for 3, 6, 12 and 24 cycles. However, due to time constraints, only 7 and 14 cycles sample testing are made. For accuracies purposes, 3 samples are required for each cycle. Again, due to time constraint only data of one sample of each cycle is available.

There are some human errors encountered while performing this experiment. Following the requirement of the experiment, each sample has to be soaked in cold water for 30 minutes and then placed in oven for 24 hours at temperature of 40°C. This is considered one cycle. Meaning that, the samples should be soaked in cold water everyday until the desired cycle is obtained. However, due to public holiday, some of the samples are left in the oven without being soaked in cold water. This may cause the result to differ from the actual value.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The optimum binder content obtained for both conventional and wax emulsion mix is 6.0%. Although in overall performance, it is noted that conventional produce better result, however, emulsion do provide quite a challenge to conventional. Wax emulsion displays high strength and durability characteristic but at low deformation rate compared to conventional mix. These prove of the advantages of wax emulsion, where it provides sufficient moisture for cement hydration, which causes the compressive strength continue to increase. Apart from that, it also reduces plastic shrinkage of material due to its hydrophobic nature which in turn helps in gaining its strength characteristic. The advantages of wax emulsion are dependent on one another.

In contrast for beam test, wax emulsion displays a very low resistance against fatigue. This is because the material is hard and stiff, which renders it not flexible in countering dynamic loading. This contradicts the basic behavior of asphaltic materials obtained from crude oil distillation process. Conventional bitumen shows a great flexibility in fatigue. Thus, fiber addition is needed to improve its flexibleness.

Wax emulsion mix is suitable to be used as non-load bearing partition wall, slabs or platform which experience static loading. This is because it has high compressive strength and low tensile strength, representing the character of concrete block. It thus is not suitable for this research project that is to be used to counter heavy explosions or air-blast shock wave since it fails instinctively under dynamic loading.

Findings from this research will lead to a new are in building construction technology. The masonry block using emulsion will be a cost effective alternative to concrete and brick wall. Coatings of surfaces from the wax coupled with its hydrophobic nature, will sufficiently act as a moisture barrier to prevent conduction in masonry blocks.

5.1 Recommendation

In developing masonry blocks using bituminous emulsion, a lot factors has to be given great consideration. Although it is aimed to be a non-load bearing partition wall, properties such as porosity, permeability and strength are important. As we know, water is always the fault of failure for many structures. Concrete for example, water penetration will cause the steel reinforcement to corrode thus reducing strength and might cause failure.

That is why permeability test is needed in this research in order for us to determine it behavior in that sense. We do not want the block to have excellent strength and porosity but fails in water action. However, in the Highway lab, the equipment for permeability test is not yet available. With the aid of the result from permeability test, more accurate and reliable result will be obtained. From there, we can see whether this research is a fantasy or reality in the construction world.

There are also some limitations in the testing equipment available in the lab. Marshall Stability Testing equipment is very critical in determining the strength, flow and porosity of the materials tested. However, in the lab, the load limit for Marshall Test is 25 kN. Since wax emulsion either experience small cracks or none, and majority of the value obtained are so close to 25 kN, higher load limit for Marshall Testing equipment is desirable to obtained better results.

Apart from that, the porosity values obtained for both conventional and wax mix although is acceptable, obtaining lower porosity values is not impossible. This is because Gyratory Compaction Machine compact the material with 400 kPa where by right, 600 kPa is required for compaction purposes. This is due to the lower central pressure distributed by GDC. Thus, external air pressure is required to obtain more reliable results.

Since wax emulsion display low flexibility in countering dynamic loading, fiber addition is necessary to improve its behavior. Appropriate fiber will be needed to perform in equilibrium with wax emulsion thus increases its flexibleness.

Since this wax emulsion block behaves quite similarly to concrete; high compressive strength, low in tensile and brittle in nature, further comparison of this material with concrete proportion is recommended. From the result obtained, the wax samples does produces high compressive strength at low deformation rate and suitable for static loading application. After all, this entire research project is about development of masonry blocks using bituminous emulsions. By comparing its properties to concrete, further understanding of its behaviors and limitations are possible.

Apart from that, cost evaluation of wax blocks to concrete blocks is also necessary. As we know, cost is one of the important factors in construction. therefore, using material that is cost effective yet performed excellent structurally are more favorable compared to material high cost material which also exhibit structurally desirable properties. As mention earlier, wax emulsion samples produced high compressive strength blocks and will fit for static loading structures. This in a way can replaced concrete to counter static loading alone. Thus, cost evaluation will finally set the limit whether this material will make it into construction industry or not.

CHAPTER 6

REFERENCES

[1] Yaakov Yerushalmi, P.E and Uzi More MYY Ltd.; Amit Reizes, P.E, SCIENTECH, Inc., Paper on Design Techniques to Strengthen 'Soft Building' Against Act Of Terror and Car Bombs, Security-related Research and Methodology, Israel.

[2] www.igiwax.com

[3] Nicolas J. Garber, Lester A. Hoel, Traffic and Highway Engineering, Third Edition, BROOKS/COLE, 2002.

[4] William D. Callister, Jr., Materials Science And Engineering; An Introduction, Fourth edition, Wiley, 1997.

[5] Anil K. Chopra, Dynamics Of Structures; Theory and applications to Earthquake Engineering, Second Edition, Prentice Hall, 2001.

Some other related research materials which are quite useful in this research project are;

- Notes on Building Design and Construction, complied by Dr. Nasir Shafiq.
- Davtack K1-40 & K1-60 Bitumen Emulsions; Cationic bituminous highway emulsions
- Canadian Building Digest, Institute for Research in Contruction, National Research Council Canada.
- Industrial Coating & emulsions; PermaSeal™ Pavement Maintenance Product
- www.yahoo.com
- www.google.com
- www.sciencedirect.com

APPENDICES

APPENDIX 1.1 : Brief Description of Burke Wax Emulsion White (Type II); Physical and Chemical Characteristics

Burke Wax Emulsion White

(Type II)

Description

A high solids white pigmented wax based concrete curing compound. Formulated to retain moisture in freshly poured concrete. The selected white pigments reflect the heat of the sun, keeping the concrete surface cooler. Wax Emulsion White is a membrane forming wax based material that seals the necessary moisture for proper cement hydration. Wax Emulsion White is formulated to comply with V.O.C. content limits, as required by Air Pollution Control Regulations.*

Manufacturer

Edoco
4226 Kansas Ave.
Kansas City, KS 66106
(877) 416-3439
Long Beach (888) 287-5387

Use

Specially designed for use on exterior commercial projects, such as highways, residential paving, airport runways, concrete lined canals, dams, parking lots, engineering projects and as specified.

Benefits

- Reduces shrinkage; retains moisture to reduce "plastic shrinkage cracks"
- Accelerates strength gain; strength of concrete continues to increase as long as moisture is present for hydration of cement
- Improves durability; proper curing will increase the long life of concrete
- Enhances performance; increases the compressive strength over improperly cured concrete and adds a quality appearance
- Easy to spray
- V.O.C. Compliant
- High reflectively
- Increases wear resistance

Applicable Standards

ASTM C-309, Type II, Class A.
AASHTO-M-148, Type II, Class A.

Architectural Specifications

Wax Based, White Pigmented Curing Compound: Immediately after final trowel or finish, apply an approved white-pigmented curing compound to exterior surfaces. Material must comply with ASTM C-309, Type II, Class A. Approved Product: Burke by Edoco Wax Emulsion White or approved equal.

Application

Agitate prior to using. Application equipment must be clean and free of foreign materials. Apply with brush, roller or sprayer. For best results, a spray application is the preferred method. Application temperatures above 40°F are recommended. Areas that are to be caulked should be masked. Do not pond or puddle. Coverage will vary depending on the texture and porosity of the concrete. Apply at a rate of 200 - 300 sq. ft./gallon as soon as the surface moisture from the final trowel has disappeared.

On vertical surfaces apply immediately after removal of forms.

Packaging

Bulk containers
55 gallon drums (208.2 L)
5 gallon pails (18.9 L)
1 gallon cans (4 to a case)(3.8 L)

Specification Compliance
Complies with all specification requirements of ASTM C-309, Type II, Class A and AASHTO M-148, Type II, Class A

Moisture Loss:

Applied at 200 sq. ft. per gallon	.180 kg/m²	
Test Requirement	.55 kg/m² max.	
Reflectivity		Greater than 65%

* Independently tested

EDOCO CONSTRUCTION CHEMICALS

Limitations/Precautions

Do not allow to freeze. If freezing takes place, consult Burke by Edoco. Do not mix or contaminate with solvent, diesel fuel or other thinning agents.

Do not over agitate with compressed air or recirculating pump.

Keep out of reach of children. Do not take internally. Do not breathe vapors. Avoid prolonged contact with skin. If swallowed, do not induce vomiting - call physician. Wear rubber gloves, goggles and protective clothing.

Do not use on concrete that is to accept a secondary topping without first consulting the manufacturer.

Avoid hazards by following all precautions found in the Material Safety Data Sheet (MSDS), product labels and technical literature. Please read this information prior to using the product.

V.O.C. Content

Less than 350 g/l. Complies with Federal V.O.C. standards for Curing Compounds. Do not thin or dilute.

Warranty

Edoco warrants, for 12 months from the date of manufacture or for the duration of the published product shelf life, whichever is less, that at the time of shipment by Edoco, the product is free of manufacturing defects and conforms to Edoco's published specifications in force on the date of acceptance by Edoco of the order. Edoco shall only be liable under this warranty if the material has been applied, used, and stored in accordance with Edoco's instructions in this technical data sheet. The purchaser must examine the product when received and promptly notify Edoco in writing of any non-conformity before the product is used, or no later than 30 days after such non-conformity is first discovered. If Edoco, in its sole discretion, determines that the product breached the above warranty, it will, in its sole discretion, replace the non-conforming product, refund the purchase price or issue a credit in the amount of the purchase price. This is the sole and exclusive remedy for breach of this warranty. Only an Edoco officer is authorized to modify this warranty. The sales information on the Edoco website and received by the customer during the sales process does not supersede this warranty and the specifications of the product in force on the date of sale. THE FOREGOING WARRANTY SHALL BE EXCLUSIVE AND IN LIEU OF ANY OTHER WARRANTY, EXPRESS OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE AND ALL OTHER WARRANTIES OTHERWISE ARISING BY OPERATION OF LAW, COURSE OF DEALING, CUSTOM, TRADE OR OTHERWISE.

Limitation of Liability

Edoco shall not be liable in contract or in tort (including, without limitation, negligence, strict liability or otherwise) for loss of sales, revenues or profits; cost of capital or funds; business interruption or cost of downtime, loss of use, damage to or loss of use of other property (real or personal); failure to realize expected savings; frustration of economic or business expectations; claims by third parties (other than for bodily injury), or economic losses of any kind; or for any special, incidental, indirect, consequential, punitive or exemplary damages arising in any way out of the performance of, or failure to perform, this Agreement, even if Edoco could foresee or has been advised of the possibility of such damages. The Parties expressly agree that these limitations on damages are allocations of risk constituting, in part, the consideration for this agreement, and also that such limitations shall survive the determination of any court of competent jurisdiction that any remedy provided in these terms or available at law fails of its essential purpose.

Clean up

Tools and equipment should be flushed and cleaned with water immediately after use. Use 1018 Eposolvent or cleaning solvent for sprayers to remove cured or residual material then thoroughly flush with water to remove all solvent residue. Protect plastic or rubber parts from solvent.

Storage

Wax Emulsion White should be stored in tightly sealed original factory containers. Store in a horizontal position to prevent moisture accumulation on the drum head. Avoid prolonged exposure to constant heat in excess of 100°F.

Technical Services

Complete technical and specification assistance services are available from the manufacturer and their authorized representatives and distributors.

Filing System

Additional literature and the Material Safety Data Sheet can be obtained from Edoco upon request.

EDOCO
CONSTRUCTION CHEMICALS

Material Safety Data Sheet
acc. to ISO/DIS 11014

Printing date 01/08/2004

Reviewed on 01/08/2004

[illegible]

· **Product details**

· **Trade name:** Wax Emulsion Cure White

· **Article number:** 83-303309

· **Application of the substance / the preparation**

Manufacturer/Supplier:
Eddco
4226 Kansas Avenue
Kansas City, KS 66106

Tel.: (888) 287-5387

Emergency Telephone Number: Use only in the event of an emergency involving a spill, leak, fire, exposure, or accident involving chemicals. Within the U.S., Canada, or the U.S. Virgin Islands, call ChemTrec at (800) 424-9300, 24 hours a day. Or, outside these areas, call (703) 527-3887. Collect calls are accepted.

· **Information department:** Environmental, Health, and Safety department.

[illegible]

· **Chemical characterization**

· **Description:** Mixture of the substances listed below with nonhazardous additions.

· **Dangerous components:**

64742-61-6	Slack wax (petroleum)	
61790-12-3	Distilled Tall Oil Fatty Acids	10-25%
		≤ 2.5%

· **Additional information:** For the wording of the listed risk phrases refer to section 16.

[illegible]

· **Hazard description:**
Toxic

· **Information pertaining to particular dangers for man and environment:**
The product has to be labelled due to internationally acknowledged calculation procedures using the latest valid versions.
May cause cancer.
May cause sensitisation by skin contact.

· **Classification system:**
The classification was made according to the latest editions of international substances lists, and expanded upon from company and literature data.

· **NFPA ratings (scale 0 - 4)**

Health = 0
Fire = 1
Reactivity = 0

(Contd. on page 2)

USA

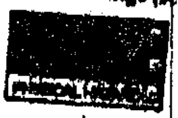
Material Safety Data Sheet
acc. to ISO/DIS 11014

Printing date 01/08/2004 *Reviewed on 01/08/2004*

Trade name: Wax Emulsion Care White

(Contd. of page 1)

· ***HMIS-ratings (scale 0 - 4)***



*Health = *0*
Fire = 1
Reactivity = 0

[illegible]

· ***After inhalation:***
Supply fresh air and to be sure call for a doctor.
In case of unconsciousness place patient stably in side position for transportation.
· ***After skin contact:***
Immediately wash with water and soap and rinse thoroughly.
If skin irritation continues, consult a doctor.
· ***After eye contact:***
Rinse opened eye for several minutes under running water. Then consult a doctor.
Rinse opened eye for several minutes under running water. If symptoms persist, consult a doctor.
· ***After swallowing:*** *If symptoms persist consult doctor.*

[illegible]

· ***Suitable extinguishing agents:*** *Use fire fighting measures that suit the environment.*
· ***Protective equipment:***
Because fire may produce thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full face piece operated in pressure-demand or positive-pressure mode.

[illegible]

· ***Person-related safety precautions:*** *Not required.*
· ***Measures for environmental protection:***
Do not allow product to reach sewage system or any water course.
Inform respective authorities in case of seepage into water course or sewage system.
Dilute with plenty of water.
Do not allow to enter sewers/ surface or ground water.
· ***Measures for cleaning/collecting:***
Absorb with liquid-binding material (sand, diatomite, acid binders, universal binders, sawdust).
Dispose contaminated material as waste according to item 13.

[illegible]

· ***Handling:***
· ***Information for safe handling:*** *No special precautions are necessary if used correctly.*
· ***Information about protection against explosions and fires:*** *No special measures required.*

· ***Storage:***
· ***Requirements to be met by storerooms and receptacles:*** *No special requirements.*
· ***Information about storage in one common storage facility:*** *Not required.*

(Contd. on page 3)

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Trade name: Wax Emulsion Cure White

(Contd. of page 2)

· **Further information about storage conditions:** None.

[illegible]

· **Additional information about design of technical systems:** No further data; see item 7.

· **Components with limit values that require monitoring at the workplace:**
The product does not contain any relevant quantities of materials with critical values that have to be monitored at the workplace.
· **Additional information:** The lists that were valid during the creation were used as basis.

· **Personal protective equipment:**
· **General protective and hygienic measures:**
Keep away from foodstuffs, beverages and feed.
Immediately remove all soiled and contaminated clothing.
Wash hands before breaks and at the end of work.
Store protective clothing separately.
· **Breathing equipment:**
In case of brief exposure or low pollution use respiratory filter device. In case of intensive or longer exposure use respiratory protective device that is independent of circulating air.
· **Protection of hands:**

Protective gloves

The glove material has to be impermeable and resistant to the product/ the substance/ the preparation.
Due to missing tests no recommendation to the glove material can be given for the product.
Select the glove material upon consideration of the penetration times, rates of diffusion and the degradation.
· **Material of gloves**
The selection of the suitable gloves does not only depend on the material, but also on further marks of quality and varies from manufacturer to manufacturer. As the product is a preparation of several substances, the resistance of the glove material can not be calculated in advance and has therefore to be checked prior to the application.
· **Penetration time of glove material**
The exact break trough time has to be found out by the manufacturer of the protective gloves and has to be observed.
· **Eye protection:**

Tightly sealed goggles

[illegible]

· **General Information**

Form:	Fluid
Color:	According to product specification
Odor:	Characteristic

(Contd. on page 4)

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Trade name: Wax Emulsion Cure White

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· Change in condition	
Melting point/Melting range:	*Undetermined.*
Boiling point/Boiling range:	*100°C (212°F)*
· Flash point:	*232°C (450°F)*
· Auto igniting:	*Product is not selfigniting.*
· Danger of explosion:	*Product does not present an explosion hazard.*
· Vapor pressure at 20°C (68°F):	*23.0 hPa (17 mm Hg)*
· Density at 20°C (68°F):	*1.010 g/cm³*
· Solubility in / Miscibility with	
Water:	*Fully miscible.*
· Solvent content:	
Organic solvents:	*0.8 %*
Water:	*76.2 %*
· Solids content:	*4.3 %*

[illegible]

· **Thermal decomposition / conditions to be avoided:** *No decomposition if used according to specifications.*
· **Dangerous reactions** *No dangerous reactions known.*
· **Dangerous products of decomposition:** *No dangerous decomposition products known.*

[illegible]

· **Acute toxicity:**
· **Primary irritant effect:**
· **on the skin:** *No irritant effect.*
· **on the eye:** *No irritating effect.*
· **Sensitization:** *Sensitization possible through skin contact.*
· **Additional toxicological information:**
The product shows the following dangers according to internally approved calculation methods for preparations:
Irritant
Carcinogenic.

[illegible]

· **General notes:**
Water hazard class 3 (Self-assessment): extremely hazardous for water
Do not allow product to reach ground water, water course or sewage system, even in small quantities.
Danger to drinking water if even extremely small quantities leak into the ground.

(Contd. on page 5)

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(Contd. of page 4)

Disposal considerations

· **Product:**
· **Recommendation:** *Must not be disposed of as normal garbage. Do not allow product to reach sewage system.*
· **Uncleaned packagings:**
· **Recommendation:** *Disposal must be made according to Federal, State, and Local regulations.*
· **Recommended cleansing agent:** *Water, if necessary with cleansing agents.*

Transport information

· **DOT regulations:**	
· **Hazard class:**	-
· **Limited Quantity Exemption:**	
· **U.S. Domestic Ground Shipments:**	*No Limited Quantity exemption applies for this shipping class.*
· **U.S. Domestic Ground Non-Bulk (119 gal or less per container) Shipments:**	*Same as listed for Standard Shipments above.*
	Same as listed for Standard Shipments above.
· **Land transport ADR/RID (cross-border):**	
· **ADR/RID class:**	-
· **Maritime transport IMDG:**	
· **IMDG Class:**	-
· **Marine pollutant:**	*No*
· **Air transport ICAO-TI and IATA-DGR:**	
· **ICAO/IATA Class:**	-

[illegible]

· **Sara**

· **Section 355 (extremely hazardous substances):**

107-15-3 | ethylenediamine

· **Section 313 (Specific toxic chemical listings):**

This product may contain 1 or more toxic chemicals subject to the reporting requirements of Section 313 of Title III of the Superfund Amendments and Reauthorization Act (SARA) of 1986 and 40 CFR part 372. If so, the chemicals are listed below.

None of the ingredients is listed.

· **TSCA (Toxic Substances Control Act):**

All ingredients are listed.

· **Proposition 65**

· **Chemicals known to the State of California (Prop. 65) to cause cancer:**

None of the ingredients is listed.

· **Chemicals known to the State of California (Prop. 65) to cause reproductive toxicity:**

None of the ingredients is listed.

(Contd. on page 6)

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Trade name: Wax Emulsion Cure White

(Contd. of page 5)

· **Cancerogenity categories**

· **EPA (Environmental Protection Agency)**		
107-15-3	ethylenediamine	D
· **IARC (International Agency for Research on Cancer)**		
13463-67-7	titanium dioxide	3
110-91-8	morpholine	3
128-37-0	2,6-di-tert-butyl-p-cresol	3
· **NTP (National Toxicology Program)**		
None of the ingredients is listed.		
· **TLV (Threshold Limit Value established by ACGIH)**		
13463-67-7	titanium dioxide	A4
110-91-8	morpholine	A4
107-15-3	ethylenediamine	A4
128-37-0	2,6-di-tert-butyl-p-cresol	A4
· **MAK (German Maximum Workplace Concentration)**		
None of the ingredients is listed.		
· **NIOSH-Ca (National Institute for Occupational Safety and Health)**		
13463-67-7	titanium dioxide	
· **OSHA-Ca (Occupational Safety & Health Administration)**		
None of the ingredients is listed.		

· **Product related hazard informations:**
The product has been classified and marked in accordance with directives on hazardous materials.

· **Hazard symbols:**
Toxic

· **Hazard-determining components of labelling:**
Slack wax (petroleum)
Distilled Tall Oil Fatty Acids

· **Risk phrases:**
May cause cancer.
May cause sensitisation by skin contact.

· **Safety phrases:**
Keep out of the reach of children.
Keep away from food, drink and animal feedingstuffs.
When using do not eat or drink.
Avoid contact with skin and eyes.
In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.
After contact with skin, wash immediately with plenty of soap and water.
Do not empty into drains.
Wear suitable gloves and eye/face protection.
In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).

(Contd. on page 7)

USA

Material Safety Data Sheet
acc. to ISO/DIS 11014

Printing date 01/08/2004 *Reviewed on 01/08/2004*

Trade name: Wax Emulsion Cure White

(Contd. of page 6)

· ***National regulations:***

· ***Water hazard class:*** *Water hazard class 3 (Self-assessment): extremely hazardous for water.*

[illegible]

· *This information is based on our present knowledge. However, this shall not constitute a guarantee for any specific product features and shall not establish a legally valid contractual relationship.*

· ***Department issuing MSDS:*** *Environmental, Health and Safety department*

· ***Contact:*** *Matthew Paquette*

>> C309 Curing Compounds Water Base

5GAL WHITE WAX EMULSION TYPE II
Prod# 25025305

$33.15 /PAL

1

* Quantity Discount Available!

Manufacturer:
BURKE BY EDOCO
Description:
BURKE WAX EMULSION WHITE (TYPE II) - A high solids white pigmented wax based concrete curing compound. Formulated to retain moisture in freshly poured concrete. The selected white pigments reflect the heat of the sun, keeping the concrete surface cooler. Wax Emulsion White is a member forming wax based material that seals the necessary moisture for proper cement hydration. Wax Emulsion White is formulated to comply with V.O.C. content limits, as required by Air Pollution Control Regulations. Applicable Standards ASTM C-309, Type II, Class A. AASH-TOM-M-148, Type II, Class A.

Subtotal-
$0.00

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webmaster@whitecapdirect.com

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AKELAND ABORATORIES IMITED

WAX EMULSION

1. IDENTIFICATION OF PRODUCT AND COMPANY

Product Code	LAKEWAX 52
Trade Name	Lakewax 52
Manufacturer/Supplier	Lakeland Laboratories Limited
Address	Peel Lane, Astley Green, Tyldesley, Manchester M29 7FE, England
Phone Number	+44 (0) 1942 873 555
Fax Number	+ 44 (0) 1942 884409
Emergency Phone Number	+44 (0) 1942 873 555

2. COMPOSITION / INFORMATION ON INGREDIENTS

Hazardous ingredients in product

Component::-	**Min. %**	**Max. %**	**Cas Number**
Slack wax (petroleum)	10	25	9010-77-9
Distilled Tall Oil Fatty Acid	--	<25%	61790-12-3

3. HAZARDS IDENTIFICATION

Health effects – Skin	Minor irritation.
Health effects – Eyes	Minor irritation.
Health effects – Inhalation	Irritation to nose, throat, respiratory tract.
Health effects – Ingestion	No adverse effects.

4. FIRST AID MEASURES

Skin contact	Immediately flush the affected area with plenty of water. Remove contaminated clothing.
Eyes contact	Immediately flush the eyes with plenty of water for at least 15 minutes, holding the eyelids open. Seek medical attention if necessary.
Inhalation	Remove to fresh air area.
Ingestion	Wash out mouth with plenty of water. Seek medical attention.

5. FIRE FIGHTING MEASURES

Extinguishing media	Not combustible. Use water spray, foam, dry chemical or carbon dioxide.
Unsuitable extinguishing media	None known.
Special hazards of product	This product may give rise to hazardous fumes in a fire.
Protective equipment for fire-fighting	Wear full protective clothing and self-contained breathing apparatus.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions	Wear appropriate protective clothing. Wear respiratory protection.
Environmental precautions	Try to prevent the material from entering drains or watercourses.
Spillage	Contain and clean with absorbent material. Transfer into suitable containers for recovery or disposal.

7. HANDLING AND STORAGE

Handling	Use in well ventilated area. Avoid inhaling vapour. Avoid contact with eyes, skin and clothing.

WAX EMULSION

Storage	Storage area should be dry, well ventilated, away from incompatible materials. Store in original containers. Do not store in metal drums.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Respiratory protection	Respiratory protection is not normally required. Respiratory protection if there is a risk of exposure to high vapour concentrations.
Eyes protection	Chemical goggles must be worn during all handling operations.
Hand protection	PVC or rubber gloves.
Body protection	Normal work clothing.
Protection during application	Mix in a well-ventilated area. If ventilation is poor, wear respiratory protection.

9. PHYSICAL AND CHEMICAL PROPERTIES

Form		Crystal
Colour		Clear
Odour		Characteristic
pH value		11.0 - 12.0
Melting temperature (°C)		N/A
Boiling temperature (°F)		212 – 220° F
Specific gravity (H_2O=1)		1.00
Ignition temperature (°C)		N.A
Flash point (°C)		> 212°F
Explosion limits	lower	N.A
	upper	N.A
Vapour pressure (Air=1)		> 1
Density (at 20°C)		8
Solubility in water (at 20°C)		100%
Evaporation Rate (butyl acetate=1)		<1

10. STABILITY AND REACTIVITY

Stability	Stable under normal conditions.
Conditions to avoid	No information available.
Material to avoid	Acid and oxidising agents.
Hazardous decomposition products	Carbon dioxide, nitrogen oxide.

11. TOXICOLOGICAL INFORMATION

Acute toxicity	Cause irritations.
Eyes contact	Irritation to the eye.
Skin contact	Irritation to the skin.

12. ECOLOGICAL INFORMATION

Persistence/degradability	N.A
Ecotoxicity	Minor marine pollutant. Do not release into the environment.

WAX EMULSION

13. DISPOSAL CONSIDERATIONS

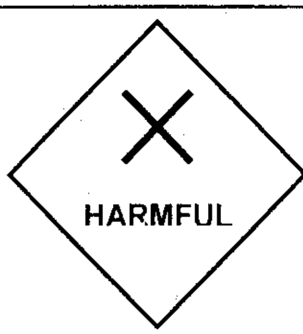
Product	Neutralise with dilute sulphuric acid. Dispose of in accordance with all applicable local and national regulations.
Container	Labels should not be removed from containers until they have been cleaned. Empty containers may contain hazardous residues.

14. TRANSPORT INFORMATION

UN Number	-
UN Proper Shipping Name	-
UN Class	-
UN Packaging Group	-
IATA - Proper Shipping Name	-
IATA - Packaging Group	-
IATA - Class	-
IATA - Subsidiary Risks	-
CAS Number	-
Shelf Life	24 months

15. REGULATORY INFORMATION

Labelling information



R-phrases	May cause sensitisation by skin contact.
S-phrases	In case of contact with eyes, rinse immediately with plenty of water and seek medical advice. Wear suitable protective clothing and apparatus.

16. OTHER INFORMATION

Date of issue	5 January 1995
Revised	6 July 1999

APPENDIX 1.2 : Coefficient Factor (C.F) for Correcting Stability Values

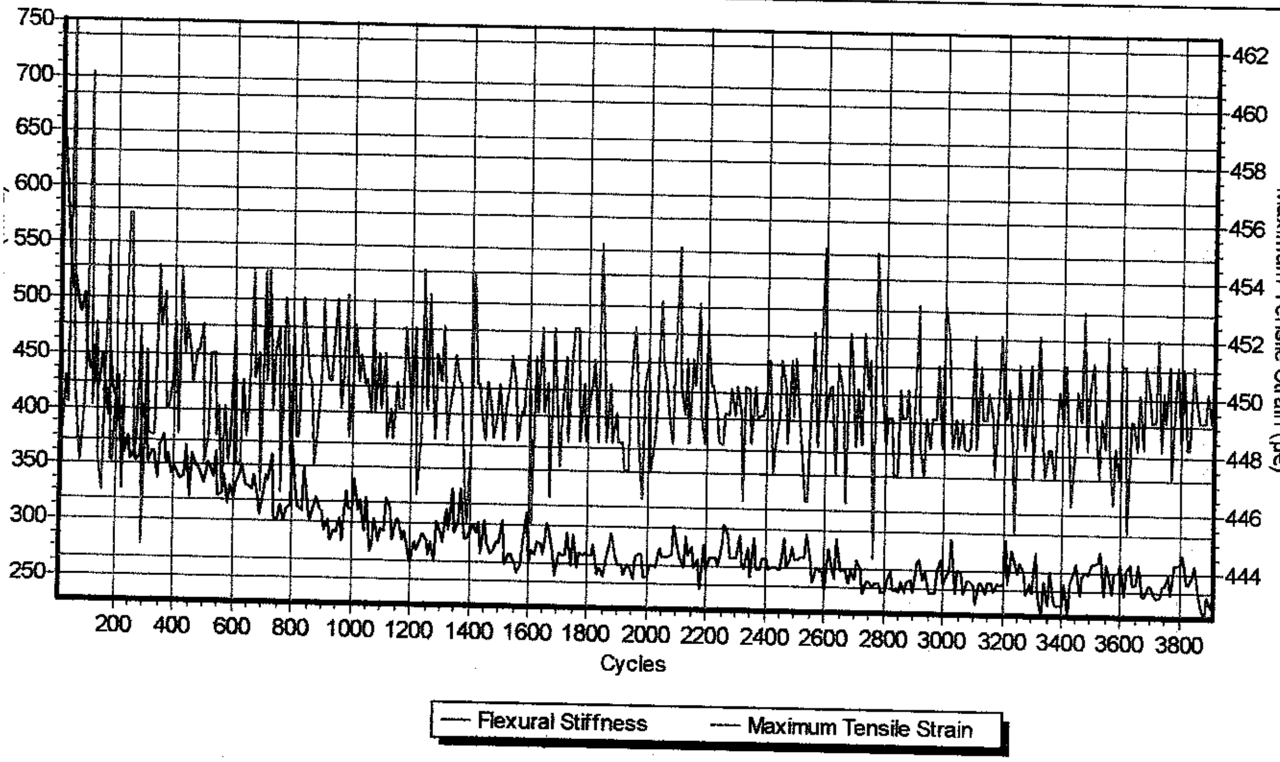
Coefficient Factor (C.F) for adjusting Stability Values.

Volume of Specimen (cm^3)	Approximate Thickness of Specimen (cm)	Correction Coefficient
200-213	2.54	5.56
214-225	5.70	5.00
226-237	2.86	4.55
238-250	3.02	4.17
251-264	3.18	3.85
265-276	3.34	3.57
277-289	3.49	3.33
290-301	3.65	3.03
302-316	3.81	2.78
317-328	3.947	2.50
329-340	4.13	2.27
341-353	4.29	2.08
354-367	4.45	1.92
368-379	4.60	1.79
380-392	4.76	1.67
393-405	4.92	1.56
406-420	5.08	1.47
421-431	5.24	1.39
432-443	5.40	1.32
444-456	5.56	1.25
457-470	5.72	1.19
471-482	5.88	1.14
483-495	6.03	1.09
496-508	6.19	1.04
509-522	6.35	1.00
523-535	6.51	0.96
536-546	6.67	0.93
547-559	6.83	0.89

560-573	6.99	0.86
574-585	7.14	0.83
586-598	7.30	0.81
599-610	7.46	0.78
611-625	7.62	0.76

APPENDIX 1.3 : Result for Conventional Beam (1)

ame: C:\UTM4\UTM_21\atikah-beamhot.B21



st start date and time: Friday, April 15, 2005, at 12:00 PM

Cycle count: 3910 of 100000

ding time (hh:mm:ss): 00:06:31
Applied Load (kN): 0.057
Maximum load (kN): 0.097
Minimum load (kN): 0.040
eam deflection (mm): 0.227
laximum LVDT (mm): 0.062
linimum LVDT (mm): -0.051

Maximum tensile stress (kPa): 111
Maximum tensile micro-strain: 451
Initial flexural stiffness (MPa): 507
Flexural stiffness (MPa): 246
Termination stiffness (MPa): 253
Modulus of elasticity (MPa): 264
Phase angle (deg): -77.0

Initial dissipated energy (kPa):0.071
Dissipated energy (kPa):0.023
Cumulative dissipated energy (MPa):0.108
Initial core temperature (deg.C):27.6
Initial skin temperature (deg.C):27.6
Core temperature (deg.C):27.7
Skin temperature (deg.C):27.6

Operator: Atikah

Notes/comments:

nen Information

ication: bfa2

sions	Point 1	Point 2	Point 3	Point 4	Point 5	Average	Std Dev.
(mm)	64.11					64.11	
t (mm)	53.47					53.47	
h (mm)	400					400	

Core/Sample Number: 2

Cross-Sectional Area: 25644
Volume: 1371185

ents/Properties:

arameters

Gauge lengths

side clamps (mm): 118.5
side clamps (mm): 355.5

fault Poisson ratio: 0.4

Loading conditions

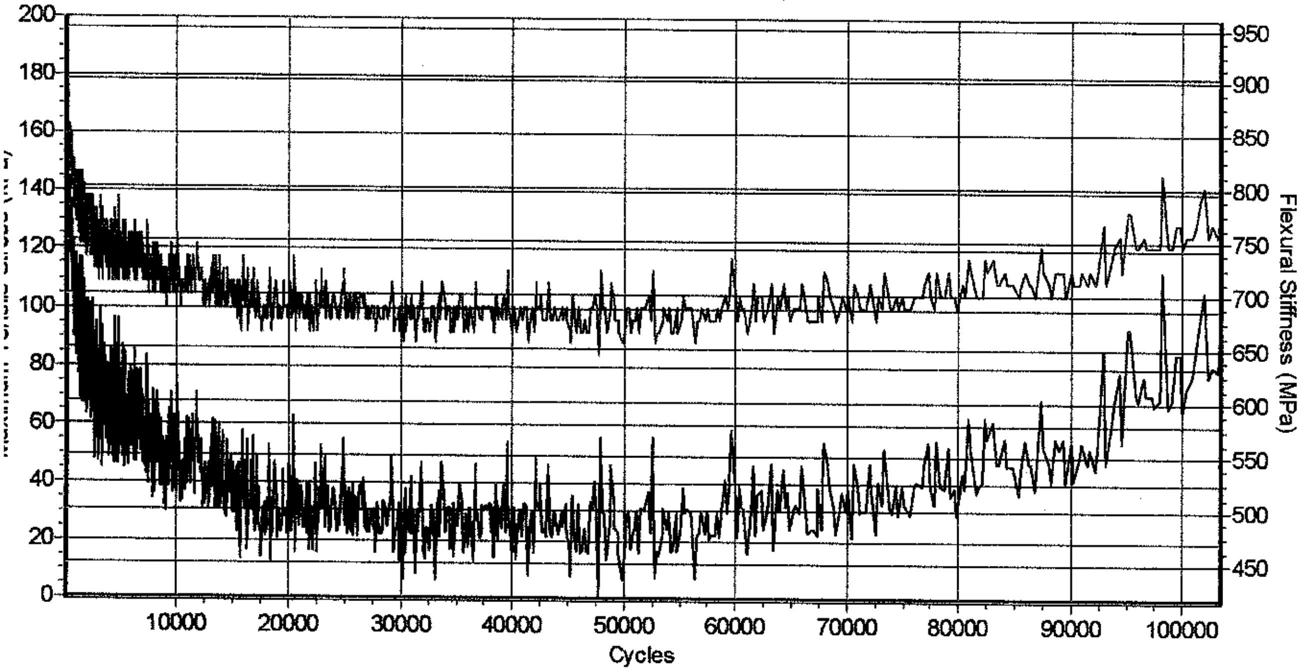
Control Mode: Sinusiodal strain
Pulse width (ms): 100
Peak to peak micro-strain: 450
Conditioning cycles: 50

Termination conditions

Termination stiffness (MPa): 253
Stop test after cycle: 100000

APPENDIX 1.4 : Result for Conventional Beam (2)

lame: C:\UTM4\UTM_21\beamhot2 2.B21



est start date and time: Thursday, May 19, 2005, at 1:10 PM

Cycle count: 103360 of 1000000

ading time (hh:mm:ss): 02:52:16
Applied Load (kN): 0.070
Maximum load (kN): 0.105
Minimum load (kN): 0.035
Beam deflection (mm): 0.100
Maximum LVDT (mm): 0.038
Minimum LVDT (mm): -0.011

Maximum tensile stress (kPa): 134
Maximum tensile micro-strain: 200
Initial flexural stiffness (MPa): 871
Flexural stiffness (MPa): 670
Termination stiffness (MPa): 436
Modulus of elasticity (MPa): 721
Phase angle (deg): 47.3

Initial dissipated energy (kPa):0.023
Dissipated energy (kPa):0.016
Cumulative dissipated energy (MPa):1.280
Initial core temperature (deg.C):31.2
Initial skin temperature (deg.C):31.4
Core temperature (deg.C):26.9
Skin temperature (deg.C):26.8

Operator: ct

Notes/comments:

imen Information

tification: beamhot2

Core/Sample Number: 2

ensions	Point 1	Point 2	Point 3	Point 4	Point 5	Average	Std Dev.
th (mm)	64					64	
ght (mm)	54					54	
gth (mm)	380					380	

Cross-Sectional Area: 24320
Volume: 1313280

ments/Properties:

p Parameters

Gauge lengths

Inside clamps (mm): 118.5
utside clamps (mm): 355.5

Default Poisson ratio: 0.4

Loading conditions

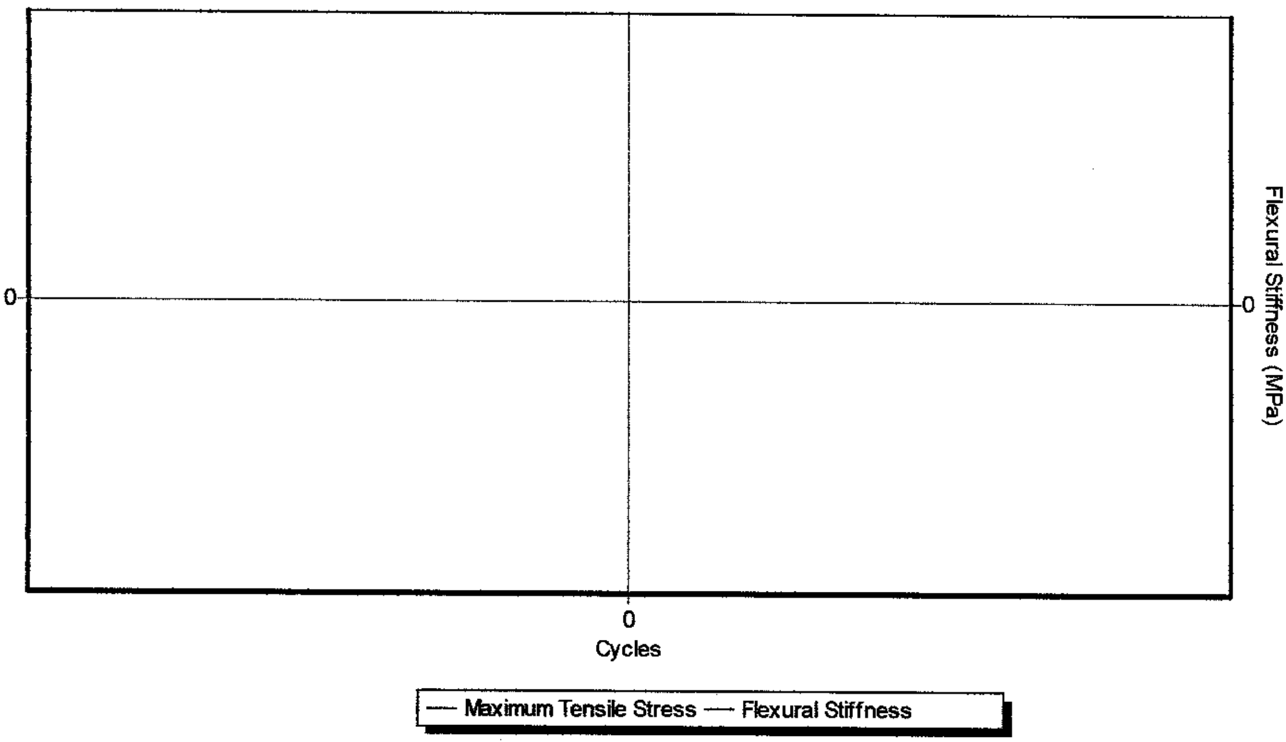
Control Mode: Sinusiodal strain
Pulse width (ms): 100
Peak to peak micro-strain: 200
Conditioning cycles: 50

Termination conditions

Termination stiffness (MPa): 436
Stop test after cycle: 1000000

APPENDIX 1.5 : Result for Wax Emulsion Beam (1)

me: C:\UTM4\UTM_21\Data\beamwax-1.B21



st start date and time:

Cycle count: 0 of 1000000

ding time (hh:mm:ss): 00:00:00
Applied Load (kN): 0.000
Maximum load (kN): 0.000
Minimum load (kN): 0.000
eam deflection (mm): 0.000
laximum LVDT (mm): 0.000
Minimum LVDT (mm): 0.000

Maximum tensile stress (kPa): 0
Maximum tensile micro-strain: 0
Initial flexural stiffness (MPa): 0
Flexural stiffness (MPa): 0
Termination stiffness (MPa): 436
Modulus of elasticity (MPa): 0
Phase angle (deg): 0.0

Initial dissipated energy (kPa):0.000
Dissipated energy (kPa):0.000
Cumulative dissipated energy (MPa):0.000
Initial core temperature (deg.C):29.4
Initial skin temperature (deg.C):29.4
Core temperature (deg.C):29.4
Skin temperature (deg.C):29.4

Operator: ct

Notes/comments:

men Information

ication: beamhot2

Core/Sample Number: 2

isions	Point 1	Point 2	Point 3	Point 4	Point 5	Average	Std Dev.
ı (mm)	64.86					64.86	
ıt (mm)	47.75					47.75	
th (mm)	380					380	

Cross-Sectional Area: 24646.8
Volume: 1176885

ıents/Properties:

Parameters

Gauge lengths
nside clamps (mm): 118.5
ıtside clamps (mm): 355.5

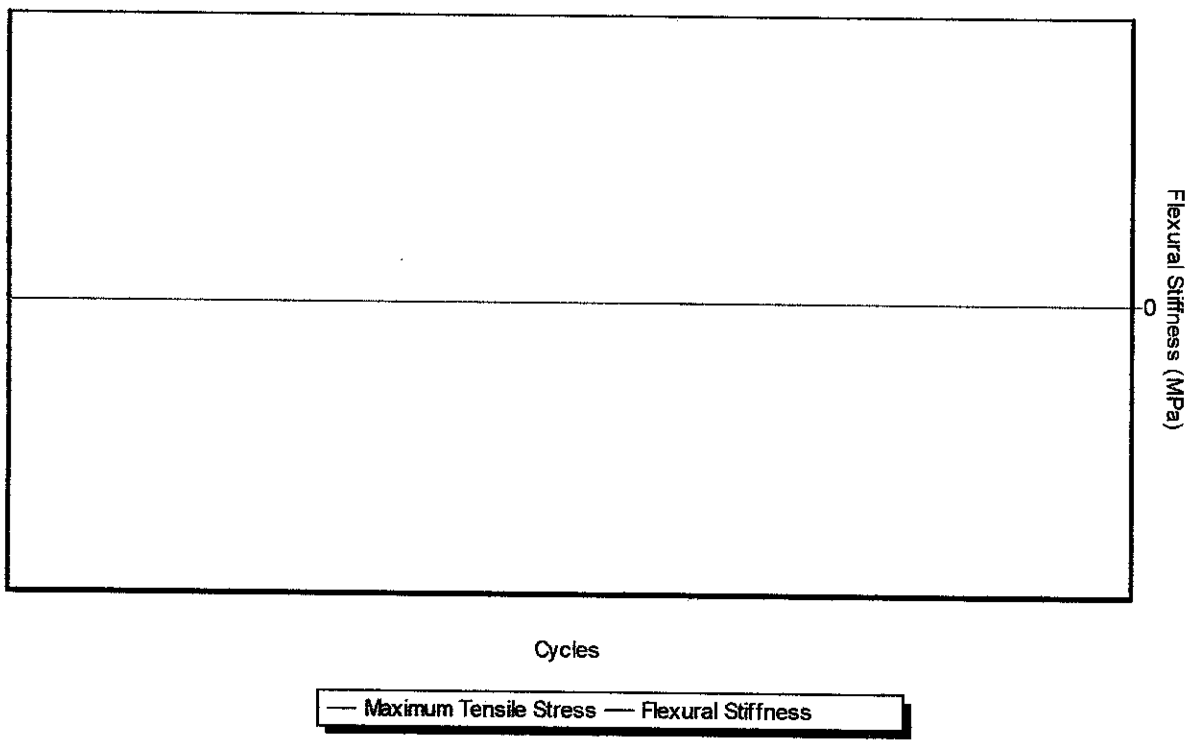
efault Poisson ratio: 0.4

Loading conditions
Control Mode: Sinusiodal strain
Pulse width (ms): 100
Peak to peak micro-strain: 200
Conditioning cycles: 50

Termination conditions
Termination stiffness (MPa): 436
Stop test after cycle: 1000000

APPENDIX 1.6 : Result for Wax Emulsion Beam (2)

ıme: C:\UTM4\UTM_21\Data\beamwax2 2.B21



st start date and time: Thursday, May 19, 2005, at 4:52 PM

Cycle count: 10 of 1000000

ding time (hh:mm:ss): 00:00:01
Applied Load (kN): 0.011
Maximum load (kN): 0.042
Minimum load (kN): 0.031
eam deflection (mm): 0.000
laximum LVDT (mm): -0.500
linimum LVDT (mm): -0.500

Maximum tensile stress (kPa): 28
Maximum tensile micro-strain: 0
Initial flexural stiffness (MPa): 0
Flexural stiffness (MPa): 0
Termination stiffness (MPa): 9709
Modulus of elasticity (MPa): 0
Phase angle (deg): 89.4

Initial dissipated energy (kPa):0.000
Dissipated energy (kPa):0.000
Cumulative dissipated energy (MPa):0.000
Initial core temperature (deg.C):27.2
Initial skin temperature (deg.C):27.7
Core temperature (deg.C):27.2
Skin temperature (deg.C):27.7

Operator: ct

Notes/comments:

nen Information

ication: beamwax2

ısions	Point 1	Point 2	Point 3	Point 4	Point 5	Average	Std Dev.
ı (mm)	63.99					63.99	
ıt (mm)	47.01					47.01	
h (mm)	380					380	

Core/Sample Number: 2

Cross-Sectional Area: 24316.2
Volume: 1143105

ıents/Properties:

Parameters

Gauge lengths
ıside clamps (mm): 118.5
tside clamps (mm): 355.5

efault Poisson ratio: 0.4

Loading conditions
Control Mode: Sinusiodal strain
Pulse width (ms): 100
Peak to peak micro-strain: 100
Conditioning cycles: 50

Termination conditions
Termination stiffness (MPa): 9709
Stop test after cycle: 1000000