

The bitumen stabilised materials engineering essay



**ASSIGN
BUSTER**

The following section looks at what bitumen stabilised materials are and how they are implemented in construction. As many aspects of bitumen emulsion and foamed bitumen overlap this section looks at them both together, with sub-sections outlining the differences between the methods.

Introduction

Bitumen Stabilised materials

Bitumen stabilized materials are materials which have been treated with either bitumen emulsion or foamed bitumen. When adding either type of bitumen the quantity of bitumen should not exceed more than 3% of the total mass of the dry aggregate, as this would mean it is more than a stabilizing agent. Furthermore in many situations an active filler in the form of cement or hydrated lime can also be added to the mix. If it is added however it should not exceed more than 1% of the bitumen stabilizer added. If it does the material is considered to be cement treated.

It is also important to note that this stabilisation agent does not turn the material into solid asphalt like material. In undergoing this treatment the material will remain in a granular state similar to how it was before stabilisation. It is only its behavioral characteristics which will change. The material will experience an increase in material strength and a reduction in moisture susceptibility as a result of the manner in which the bitumen is dispersed amongst the finer aggregate particles.

The fact that the material will remain in a granular state means that this treatment method is dramatically different from all other pavement

materials. The dispersed bitumen changes the shear properties of the material by significantly increasing the cohesion value whilst causing little change to the internal friction angle of the material. It will also have a void content similar to that of a granular layer, not like and asphalt.

Bitumen Emulsion

As the name suggest in this process bitumen is emulsified in water. This means that bitumen is dispersed in water, with the knowledge that they will not mix; due to the fact an emulsifying agent is used. The emulsifying agent will also give the bitumen emulsion a charge, making the bitumen emulsion either cationic or anionic.

This mixture is then added to the aggregate which will make up a part of the pavement structure. As the bitumen droplets are charged, they will be attracted to the aggregate particles. In attraction they will be drawn to the smaller particles as they have the greatest surface area and charge concentration features. For these reasons the type and moisture of the aggregate in the mix is crucial in efficiently dispersing the bitumen emulsion and preventing premature separation of the bitumen from the water during mixing.

Once it has been mixed the separation of the water from the bitumen needs to occur. This will allow the bitumen to act as a binder. This separation should only occur after the material has been fully compacted.

The mixing process involved with Bitumen Emulsion occurs offsite in a manufacturing plant. Here it is can be stored for several months. The diagram below shows a simplified version of the manufacturing process.

Foamed Bitumen

To produce foamed bitumen water is injected into hot bitumen, which results in instant foaming of the bitumen. In the foaming process the hot bitumen is turned into vapour, which is trapped in thousands of tiny bitumen bubbles. These bubbles dissipate in less than a minute.

When the bubbles burst they form tiny bitumen particles. These spread throughout the aggregate attaching themselves to the finer particles of the aggregate mixture. When the aggregate is compacted, the bitumen covered particles are pressed against the larger particles in the aggregate. As a resultant of this localized non-continuous bonds are formed, like spot welds.

Behaviour

As the material treated with bitumen will remain in an unbound state, it will act similar to the original material. The only difference will be an improved cohesive strength and reduced moisture sensitivity, which are both favorable outcomes. This is because the bitumen only disperses amongst the finer particles, which forms a bitumen-rich mortar between the coarse particles. This also means that opposite to the common misconception that the material will become black and sticky like a hot-mix asphalt. The material will only slightly darken in colour.

Through numerous tests around the world of bitumen stabilized pavements a number of initial observations on how the pavement will behave have been made. The following behaviours have been assumed.

Materials treated with either bitumen methods will experience an increase in cohesion.

The friction angle of the treated material will remain similar to the untreated material.

They obtain flexural strength. Which will mean the pavement is less likely to crack when subjected to tensile stresses.

Moisture sensitivity and durability are improved. This is due to the fact the finer particles are encapsulated and immobilized blocking flow channels.

The most common mode of failure is permanent deformation.

All these behaviors will depend on the following:

The local climate (Temperature, Average rainfall, likeliness of frost or snow)

The properties of the parent material

The density of the layer

The quantity of binder added

The use of any active fillers

The properties of the supporting material

It is important to note here that BSMs behave very different to asphalt and cement treated materials.

Benefits

There are a number of benefits associated with using BSMs. These include:

Increased strength

The ability to replace higher quality materials, meaning a cost saving

Improved durability

Improved moisture sensitivity

Can provide cost and time savings

Typical failure mode is permanent deformation, which requires less effort to rehabilitate when compared to a material that will fail due to full-depth cracking

They are not temperature sensitive

If the road requires rehabilitation BSMs propose little treat to the environment

They are not overly sensitive, meaning the amount of bitumen added can vary slightly

The process does not require heavy construction traffic. This limits the damage cause to newly constructed layers during construction

Limitations

When considering whether to use BSMs or not there are three main limitations. These should be carefully considered when making the decision to use BSMs. The three limitations are;

Economics - Bitumen treatment can add significant costs to a project. Its use of lower category roads should be carefully examined as it could not be worth it.

Design Expertise - as they are currently been developed and act differently from all other pavement materials careful design is required.

Construction Expertise - the construction process requires attention to detail. This means special training of the work force is required.

Along with this limitations the both bitumen emulsion and foamed bitumen have their own disadvantages

Bitumen Emulsion

With bitumen emulsion come the following disadvantages

By adding the water present in the emulsion process, the original material may go over its optimum water content. This will mean the material cannot be compacted properly.

A quick setting time is required allow the material to gain sufficient strength

the construction process must be completed with care. If the bitumen breaks prematurely it will not mix properly. If the material is too stable it can take months for the bitumen to break

Foamed Bitumen

With foamed bitumen come the following disadvantages

it requires sufficient fines. They are required to ensure the bitumen mixes thoroughly.

Foaming equipment needs to be up kept and be in correct working order. The foamed bitumen needs to be sprayed in uniform, consistent manner.

The process requires specialist equipment, as the two liquids are not compatible.

Materials Suitable for treatment

For bitumen stabilisation to work a suitable material must be selected. First of all the material must be granular. For this reason materials that are suitable for treatment include;

Crushed rock

Previously untreated natural gravels, such as basalt, granite, limestone, quartz, sandstone

Reclaimed asphalt

It can also be said that calcrete gravels can be used for bitumen emulsion; however it will not work with foamed bitumen.

Design Approach

Design Sequence

The first step in a typical design for a BSM involves an investigation of the conditions. This includes expected traffic volumes, the materials available, the climate and the pavement structure for recycling projects.

Once this has been done a laboratory investigation of the proposed material takes place. This involves determining the materials class.

The next step is to design the mix and make the final material classification.

Once all of these steps are completed the structural design is completed. In this design if it is shown that the road is not economically viable the mix design will be redone and the steps repeated.

Shown below is a flow chart of the steps involved.

Mix Design

In using a stabilizer it is important that the stabilizer meets its intended purpose. The process of design the mix will be mainly dependent of the design traffic, the material available and the cost considerations. However n creating a mix design it is also important to consider the following;

The primary failure mode - this will define the materials performance requirements.

Appropriate laboratory tests - tests need to be selected that will identify the key performance criteria and failure mechanisms.

Identifying key mix properties and intrinsic material properties.

Taking into account variability in material properties

Environmental factors - Climate and moisture conditions.

The ability to effectively compact the material.

In designing the mix it is important to note that optimum bitumen content is not always selected for the mix design. This is because although the optimum bitumen content will provide the maximum material strength, this will mean other characteristics are forfeited. For example a high strength design will often lead to brittle inflexible pavement layers that are susceptible to cracking. In designing the mix it is important that the design is balance so that it will be suitable to it requirements.

Classification of BSMs

Currently South Africa has divided Bitumen Stabilised Materials into three classes. These classes are dependent on the quality of the original material and the design traffic. The three classes include:

BSM1 - The parent material has a high shear strength, and is normally the base layer for large volumes of traffic. Source materials include well graded crushed rock or reclaimed asphalt.

BSM2 - The parent material has a moderately high shear strength and is normally the base layer for moderate traffic loads. Source materials include graded natural gravel or reclaimed asphalt.

BSM3 - The parent material is soil-gravel and/or sand, stabilized with higher bitumen contents. It is a base layer that can only handle low traffic volumes.

It is thought that Australia will have a classification system similar to this.

Mix design

BSMs behave in a very complex manner, which gives engineers a great flexibility when it comes to designing a mix that will best meet the design conditions. The mix is made up of aggregate, bitumen and sometimes an active filler where required.

In design the mix there are two fundamental failure mechanisms that need to be designed for in the mix these are;

Permanent Deformation - This is dependent on the materials shear properties as it is caused by the accumulation of shear stresses. Resistance to permanent deformation as known as rutting is improved by:

Improved aggregate angularity shape, hardness and roughness

Increased maximum particle size

Improved compaction

Reduced moisture content

Addition of limited amounts of bitumen

Addition of an active filler

Moisture Susceptibility - this is the damage caused by the exposure of a BSM to high moisture contents and pore-pressures caused by traffic. This then means a loss of adhesion between the bitumen and the aggregate. Due to water been involved in the mixing stage and the partially coated nature of the aggregate makes moisture susceptibility an important consideration in the evaluation of material performance. Moisture resistance is improved by

Increased bitumen content

Addition of an active filler

Improved compaction

Smooth continuous grading

It is interesting to note here the difference in recommended bitumen content. To help prevent deformation limited amounts of bitumen are recommended. However to improve moisture resistance increased bitumen contents are recommended. This means that a compromise must be made, by using the laboratory testing to determine a bitumen content which will meet the demands of the design.

Mix type selection

As stated in section XX the three main factors that influence the type of BSM used are:

The design traffic

The quality of aggregate available

The cost

Once the type of BSM has been selected there are three main factors that affect the bitumen and active filler selection for the mix design;

Traffic design (volumes and loadings)

Climate (particularly moisture considerations)

Supporting layers (strength)

The influence these factors have is demonstrated in the following figure. As it can be seen heavy traffic loads, a wet climate and weak supporting layers all mean an increased amount of bitumen is required to ensure design requirements are met.

Mix Design Procedure

To create the best design mix possible several procedural steps need to be done. This ensures that every criteria is met, as there are numerous variables that need to be checked.

The first step of the mix design is to test the material which will be treated. This is done to ensure that the material is appropriate for testing. These tests include standard laboratory tests to determine the materials grading curve, moisture, density and Atterberg limits.

The next tests which are undertaken are the level 1 mix design tests. These provide an indication of the application rate of bitumen and active filler required to achieve an indicated class of BSM. Level 1 starts with the preparation of samples that will be used to manufacture the specimens required for all levels of mix design testing's. testing at this level involves preparing 100mm diameter specimens which are compacted and cured for the purpose of undergoing Indirect Tensile Strength testing. These testing results are used to:

Identify the preferred bitumen stabilizing agent

Determine the optimum bitumen content

Identify if there is a need for an active filler and its type

Tests after level 1 are done depending on the design traffic. The first of these are Level 2 mix design tests. The test at this level involves making a sample which is 150mm in diameter and 127mm in length. These are manufactured using vibratory compaction and then cured at the equilibrium moisture content. This sample then undergoes Indirect Tensile Strength to optimize the required bitumen content.

The level 3 mix design test is only recommended for high capacity roads.

This test involves preparing 150mm diameter by 300mm in length
<https://assignbuster.com/the-bitumen-stabilised-materials-engineering-essay/>

specimens, which allows for a higher level of confidence. It then undergoes the same Indirect Tensile Strength test.

Mix Constituents

Aggregate

A wide range of mineral aggregates are suit for use with both types of bitumen treatment. These include aggregates ranging from sands to weathered gravels to crushed stone and can either be virgin or recycled. These must however fall into certain quality standards to ensure the road will be at it required class.

When examining a material its following properties will be checked:

Durability characteristics of the untreated aggregate

Plasticity

Grading

Spatial composition

Weathering characteristics

Aggregate source

The aggregate used can come from three different sources, Virgin Aggregate, Recycled Granular Layers and Reclaimed Asphalt

Quality of Aggregate

In using bitumen to stabilize the material it is possible to use a poorer quality of aggregate. For virgin aggregates four tests are used to identify material limits.

Soaked CBR

Grading - completing a grading will identify any deficiencies in the material

Percentage passing through the 0.075mm sieve - higher fines contents mean a higher need for bitumen

Plasticity Index - for bitumen emulsion the materials PI should be less than 7. For foamed bitumen the materials PI should be less than 10. Materials with a high PI can be treated with lime.

For recycled granular layers the materials quality will depend on:

The structure of the existing pavement

Construction variability

Depth of recycling

Age of the pavement

Degree of patching and repair on the existing pavement

Thickness and nature of old surfacing seals.

Using reclaimed asphalt needs serious consideration as some material may not meet the quality standards required. This is particular important on highly used roads, where traffic loads are going to be large.

When deciding whether the quality of the reclaimed asphalt will meet standards, the following needs to be considered.

Climatic region - if the material is going to be placed in a warm climate, shear tests must be carried out to represent that climate

Axle loads - high stresses will result in accelerated deformation of the road. This means that if the road is to carry heavy traffic its shear properties will need to be carefully considered

Reclaimed Asphalt Composition - if needed crusher dust can be added to the mix. This will provide an angular skeleton that will improve the mixes shear resistance.

Grading

The grading requirements for both types of bitumen stabilisation is different. This is due to the fact that the bitumen will disperse differently. The graph and table below give an indication of the grading required for each type of stabilisation.

XXXXXX

Bitumen Emulsion

As the above table shows a minimum filler content of 2% is required. This is because the bitumen emulsion will coat the large particles of the aggregate better than the foamed bitumen.

Foamed bitumen

Foamed bitumen requires more filler; approximately 5% filler content is required. This is because the bitumen droplets disperse through the material, only partially coating the large particles. It uses the filler to create a “ spot welds” connecting the larger particles using the fines.

Bitumen Selection

The bitumen selected plays an important part in how well the BSM works. Penetration grade bitumen is used to produce both bitumen emulsion and foamed bitumen. In the next two sections the specific bitumen requirements for each form of stabilisation is given below.

Bitumen Emulsion

For bitumen emulsion base bitumen's with a penetration value between 80 and 100 are normally selected. In saying this around the world softer and harder grades of bitumen have successfully been used.

In recent years there have been many technological advances which have allowed the bitumen emulsion to have improved stability without prolonging the break time. However sufficient testing of the bitumen mix needs to take place both in the mix design phase and during construction trials. This will ensure the correct bitumen has been chosen.

Another important consideration is the compatibility of the bitumen emulsion and the aggregate. This is because the type of bitumen chosen is influenced by the type of aggregate been treated. Certain materials are not suitable for catatonic treatment and others are not suitable for anionic treatment. The table below gives an indication of the compatibility of the emulsion with a aggregate.

Aggregate Type

Compatible with

Cationic Emulsion

Anionic Emulsion

Dolerite

Yes

Yes

Quartzite

Yes

No

Hornfels/Greywacke

Yes

Yes

Dolomite

Yes

Yes

Granite

Yes

No

Tillite

Yes

Variable

Basalt

Yes

Yes

Syenite

Yes

No

Amphibolite

Yes

Yes

Marble

Yes

Yes

Rhyolite

Yes

No

Felsite

Yes

No

Sandstone

Yes

No

Andesite

Yes

Yes

Furthermore it is normally recommended that the undiluted bitumen emulsion is heated to between 50 and 60°C. This will prevent premature breaking of the bitumen emulsion while pumping in the construction equipment. It is also important to note here that when diluting the emulsion the emulsion must be added to the water. This will prevent premature breaking.

Foamed Bitumen

When it comes to foamed bitumen a softer grade of bitumen can be used without compromising stability. This is because foamed bitumen only requires low percentages of bitumen in the mix. However like bitumen emulsion typical penetration values are between 80 and 100. Harder bitumen is normally avoided due to the poor quality of foam it produces.

There are two main properties that determine the suitability of the bitumen for foamed bitumen stabilisation. These are its Expansion Ratio and its Half-Life.

The expansion ratio is a measure of the viscosity of the foam. This is what determines how well the bitumen will disperse through the mix. It is calculated by finding the ratio between the maximum volume of foam in relationship to the original volume of bitumen.

The half-life is a measure of the stability of the foam and provides an indication of the rate of collapse of the foam during mixing. It can be calculated by determining the time it takes for the foam to collapse to half its

maximum volume. The table below shows the minimum limits of the expansion ratio and the half-life of the bitumen.

XXX

The greatest factor which will influence the foam properties is the water injected into the expansion chamber. A greater injection of water will mean a higher expansion ratio, but this is offset by the fact it will mean a short half-life as the foam will subside faster. Furthermore a higher bitumen temperature is usually recommended as it will create a better quality foam.

Active Filler

There are two types of fillers which can be used to improve the results of bitumen stabilisation; these are active and natural fillers. An active filler is a filler which will chemically alter the mix properties. There are various active fillers which can be used, examples of these are cement hydrated lime and fly ash. Natural fillers are fillers such as rock flour.

These fillers can be used either by themselves or in a combination with another filler. Their use will depend on their cost, efficacy during use and the materials availability. Research has shown that it is almost impossible to predict the effectiveness of a filler. The only way to gain an idea of their effect is to complete experiments using different mixes.

Active fillers are added to the bitumen in order to;

Increase the stiffness of the mix

Increase the rate at which the mix will gain strength

Improve the dispersion of bitumen in the mix

Improve adhesion between the bitumen and the aggregate

Improve the curing time of the compaction mix

Along with these general improvements, there are specific benefits for both treatments. For Bitumen Emulsion a filler will:

Control the breaking time of the emulsion

Improve the workability of the emulsion

For Foamed Bitumen a filler will:

Assist in dispersing the bitumen droplets

Natural fillers on the other hand only act as a supplement for a lack of fines in the material which is needed for dispersion.

It is important to note that when adding an active filler the time between the bitumen is mixed and its application is dramatically reduced. When an active filler is added the reaction begins immediately when it comes into contact with moist material. The longer the delay between mixing and application the less the filler will work.

Water

To ensure a high quality product it is important that the water used in mixing meets certain standards. Each technique requires different water qualities.

Bitumen Emulsion

For bitumen emulsion the pH levels of the water are extremely important.

For cationic bitumen the water cannot be alkaline. If it is hydrochloric acid can be used to decrease the waters pH.

For anionic bitumen emulsion the opposite applies, the water cannot be too acidic. To make the water more alkaline lime or caustic soda can be added to the water.

Foamed Bitumen

The standards for foamed bitumen aren't as high as they are for bitumen emulsion. It is acceptable for the water used to contain some impurities, however this should be avoided. This is because the water can affect the mixing machinery.

Specimen Preparation

Moisture

Moisture plays an important part in using bitumen to stabilize material. The role that moisture plays in the two types of BSM is explained in the table below.

Component

Bitumen Emulsion

Foamed Bitumen

Bitumen

Contributes to fluids for compaction

Does not effect

Moisture in aggregate

Reduces absorption of bitumen emulsion water into aggregate

Separates and suspends the fines making them available to bitumen during mixing

Prevents premature breaking

Acts as a carrier for bitumen droplets during mixing

Extends curing time and reduces early strength

Reduces early strength

Provides workability at ambient temperatures

Reduces friction angle and lubricates for compaction

Provides shelf-life for the mix

The term for the best moisture content in the material is the optimum mixing moisture content or OMMC. It is important to note that for bitumen emulsion

this moisture value is the moisture in the aggregate plus the moisture from the emulsion.

The introduction of modern rollers has allowed for high energy compaction. In the case of BSM this means a lower fluid content can be used to produce the same quality of compaction. This has the added benefit of increasing the strength of the BSM.

Material Preparation

Below is the basic procedure for the material preparation involved in the mixing design.

Determine the grading curve of the aggregate and its optimum moisture content of the natural material

Determine the materials Atterberg Limits

Determine the moisture and density relationship of natural material to obtain optimum moisture content

Determine the moisture and density relationship of the treated material to obtain optimum moisture content

Determine the moisture and density relationship using vibratory hammer compaction to obtain optimum moisture content

Mixing

It is recommended that a pugmill mixer is used in both mixes. The use of different mixers can produce up to a 25% difference in strength. Experiments have found that the pugmill mixer provides the most comprehensive mix.

Compaction

Correct compaction of the material is extremely important as it reduces the voids and improves particle contact. The use of bitumen emulsion will help improve the compatibility of the mix, while the use of foamed bitumen will promote the adhesion of the bitumen mastic to the stone.

Curing

Curing is the process where the water is removed from the compacted layer. Water can be removed from either evaporation, particle charge repulsion and pore-pressure induced flow paths. The reduction in moisture content will lead to an increased tensile and compressive strength as well as add stiffness to the mix. The curing process is different for both methods

Bitumen Emulsion

It is chemistry that controls the way bitumen emulsion treated material cures. By removing the water from the mix breaking of the emulsion occurs. To do this the water is removed by means of evaporation and migration. This curing will take longer than foamed bitumen curing, due to the higher moisture contents.

Foamed Bitumen

The curing of the foamed bitumen is a natural process. It is cured through the migration of water during compaction and continues as the water is evaporated.

Testing

There are two main tests which are used to check the various mix designs, they are the Indirect Tensile Strength test and a Triaxial Test

Indirect Tensile Strength

This test is completed to measure the flexibility of the material and give an indication of its tensile strength. The table below gives a guide for interpreting the results of the test.

Test

Specimen Diameter (mm)

BSM1

BSM2

BSM3

Purpose

ITSdry (kPa)

100

> 225

175-225

125-175

Indicates optimum bitumen content

ITSwet (kPa)

100

> 100

75-100

50-75

Indicates need for active filler

ITSequil (kPa)

150

> 175

135-175

95-135

Optimise bitumen content

ITSsoaked (kPa)

150

> 150

100-150

60-100

Check value on ITSwet

Triaxial Test

This test is completed to measure the cohesion of the material, the friction angle and the retained cohesion. The table below gives a guide for interpreting the results of the test.

Test or Indicator

BSM1

BSM2

BSM3

Cohesion (kPa)

> 250

100-250

50-100

Friction Angle (°)

> 40

30-40

<30

Retained cohesion (MIST)

> 75

60-75

50-60

Structural Design

As discussed in Section XX the structural layers purpose is to protect the subgrade by dispersing the traffic loads. This means that the pavement structure and subgrade must work together to ensure the required design capacity.

Construction

For both stabilizing methods once the material has been mixed into the material, the various construction operations are relativitively the same as those if the material wasn't treat