LABORATORY INVESTIGATION OF MOISTURE SUSCEPTIBILITY OF HOT-MIX ASPHALT CONTAINING HYDRATED LIME AS ADDITIVE

A thesis report submitted in the partial fulfillment of requirement of the award of the degree of

MASTER OF TECHNOLOGY
IN
CIVIL ENGINEERING

(With specialization in Transportation Engineering)

Submitted by

RISHI SINGH CHHABRA

REGISTRATION NO 11311265

Under the Supervision of

Mr. AJAY KUMAR

ASSISTANT PROFESSOR

DEPARTMENT OF CIVIL ENGINEERING
LOVELY PROFESSIONAL UNIVERSITY
PHAGWARA, PUNJAB (INDIA) – 144401
2013-2015

CERTIFICATE

I hereby certify that the work which is being presented in the Dissertation entitled **"Laboratory Investigation of Moisture Susceptibility of Hot-Mix Asphalt Containing Hydrated Lime as Additive"** in partial fulfillment of the requirement for the award of degree of **Master of Technology** and submitted in Department of Civil Engineering, Lovely Professional University, Punjab is an authentic record of my own work carried out during period of Dissertation under the supervision of **Mr. Ajay Kumar**, **Assistant Professor**, Department of Civil Engineering, Lovely Professional University, Punjab.

The matter presented in this Dissertation has not been submitted by me anywhere for the award of any other degree or to any other institute. .

Date: **Rishi Singh Chhabra**
11311265

This is to certify that the above statement made by the candidate is correct to best of my knowledge.

(Mr. Ajay Kumar)
Assistant Professor

(Mrs. Dolonchapa Prabhakar)

Head of Department

ACKNOWLEDGEMENT

I am very thankful to my supervisor **Mr. Ajay Kumar** for giving me this great opportunity to work under his supervision. His valuable guidance continues boosting and constant support makes confidence to my work. He always helps me when I am in any conceptual problem during my study. He enhanced my knowledge about the pavement construction to a very higher stage and make me understand that how can I do my work.

I would like to extend much appreciation and gratitude to **Mrs. Mandeep Kaur**, Head of School, for providing necessary help and academic environment during the course of study. I also would like to thank **Mrs. Dolonchapa Prabhakar,** Head of the Department, for providing her valuable advice about the Dissertation. Without the help and encouragement of my Dissertation committee, this study would not have been possible. I shall always thankful to my other faculties who have helped me in direct or indirect way.

I would especially like to thank my elder brother, my mother and father who have provided me with the strength and dedication needed for doing this thesis and also to my friends who have supported me this year and a half while I have been doing my research.

Rishi Singh Chhabra

11311265

ABSTRACT

Damage of flexible pavement due to moisture is a major problem because of the fact that repair cost is around 30-40 % of the total cost of construction of flexible pavement. There are various tries made to find out the practical solution in laboratories by testing the pavement construction materials separately and also by performing tests on their mixes to come up with the solution of reducing the stripping phenomenon and also for reducing the effect of moisture susceptibility in flexible pavement after its construction. Work performed and conducted in the previous year's towards the progress for reducing the stripping effect and moisture susceptibility is discuss in brief in this Dissertation report. Now-a-days it is a challenge for Pavement Engineers to construct a flexible pavement without having much effect of moisture on its strength due to the changing properties of construction materials and their availabilities varies from one place to another place. There is a urgent need of the best suitable method or solution to reduce the stripping effect is required to deal with the effect of moisture susceptibility on HMA. There are some methods of testing the materials which are standardized as per local basis on the procedure used and test equipment available according to the method of test used. None of the test can give 100 % satisfactorily results and make fine adjustments, so that the test can be executed worldwide. The only basic reason for the variations in test result is the absence of relationship with the performance on field as compare with the laboratories due to the difficult in performing some tests on site (field). Residual moisture from incompletely dried aggregates would most likely remain in the Warm Mix Asphalt (WMA) due to it's lower production and compaction temperature, which results in harmful effects on field performance. It's a very common phenomenon that when water penetrates into the pavement layer then damage due to moisture occurs, as a result, it may damage pavement adversely resulting in stripping of asphalt with aggregates or damage the pavement structure by detaching the aggregate and asphalt/bitumen bonding. Pour water in mixtures can cause premature failure in hot-mix asphalt pavement, primarily through loss of adhesion between the asphalt binder and the aggregates or the loss of cohesion in the asphalt binder. Hot mix asphalt or bitumen have very good binding property with aggregates but it loses its property of sticking together which can result to stripping. The removal of covering of asphalt onto the aggregate's surface is the result of poor adhesion and poor binding with aggregates and the second reason is the nature of aggregates i.e. if the aggregate is hydrophilic then it will definitely attracts the water and hence, stripping occurs because of the reason that water acts as poison if it come in contact for larger time with bitumen. The second reason is being considered as true stripping and also known as the effect of moisture susceptibility on HMA pavement. The research conducted along with the experimental work in laboratories in this dissertation for the identification of the reasons for moisture susceptibility of hot mix asphalt i.e. bitumen when hydrated lime is added to it, and to develop new procedure or methods which will reduce the moisture effect on flexible pavement structure and reduces the water to enter into the pavement structure and damage it.

Keywords: moisture, asphalt, hydrophilic aggregates, calibration, aggregates, stripping, pore.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVATIONS

HMA	Hot Mix Asphalt
NH	National Highways
SH	State Highways
MDR	Major District Road
ODR	Other District Road
VR	Village Roads
IS	Indian Standard
IRC	Indian Road Congress
ASTM	American Society For Testing And Materials
NHAI	National Highways Authority of India
NHDP	National Highway Development Programsme
MORT&H	Ministry of Road Transport And Highways
CVPD	Commercial Vehicles Per Day
WBM	Water Bound Macadam
WMM	Wet Mix Macadam
DBM	Dense Bituminous Macadam

CHAPTER 1 – INTRODUCTION

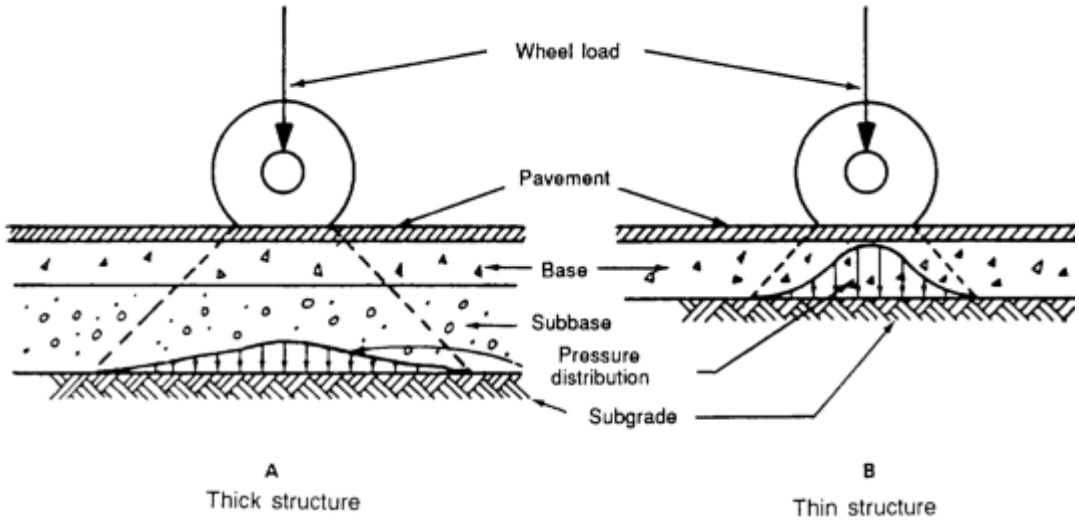
1.1 Background

Asphalt is an important binder material used in flexible pavement construction. Nearly about 80% of the asphalt is used in the construction of flexible pavement, though only 5-7% bitumen is added in the bituminous concrete, mixture. If we talk about the physical property of Asphalt, then it is a dark bituminous substance and are found in natural beds and also as a residue from petroleum distillation which is the most commonly used material used everywhere in flexible pavement construction and also sometimes used in roof construction wherever needed. In India, use of bitumen content since many year ago. Bitumen is the most commonly used material used in the road construction methods because of its availability and also because of its property of adhesion with aggregates which will results in very good bonding as a whole and can resist or withstand under heavy loading condition. As a knowledge regarding paving material expanded , need for more economical, functional and safer design criteria should require to find out optimum bitumen content in semi dense bitumen macadam. Factors such as strength, durability and economy need to be considered as the basic need for the construction of flexible pavement. The strength and durability of the mix can be increased by adding lime in it which also reduces the moisture susceptibility of Hot Mix Asphalt. To satisfy the mix design specification, number of methods have been developed. It is principally obtained as a residual product in petroleum refineries after high fractions such as diesel, kerosene, gas and petrol are removed. Bitumen is a black or dark brown non-cyrstalline soil or viscous material having adhesive properties derived from petroleum crude either by natural or by refinery processes. Bituminous mixes are designed to withstand heavy traffic loads under adverse climatic conditions and also fulfill the requirement of structural and pavement surface characteristics. The primary use (70%) of asphalt/bitumen is in road construction, where it is used as binder mixed along with the aggregate particle or as a glue to manufacture asphalt concrete. The other main uses are for bituminous water-proofing products, which includes production for sealing flat roofs. Many factors such as water, air and temperature also affects on the durability of hot mix asphalt pavement structures which will reduce the life of flexible pavement and hence, thus increase the cost of construction and maintenance of pavement. The maximum part played to decline in quality may be traffic loading. The resultant distress results simply as fatigue cracking, rutting, and stripping. In case of more

severe climate, flexible pavement with poor materials and heavy traffic, however, premature failure may result which causes heavy maintenance cost or also re-construction of pavement.

In past years construction of roads, national highways and state highways pick up a speed because roads are the major mode of connecting different cities within a country and it is also a well-known fact that flexible pavement construction requires lum-sum amount for the good quality construction. Stripping have become a big problem in the past few years in case of hot mix asphalt(HMA) on the surface of pavement which is mainly due to the stresses cause in the pavement structure. Now, in each and every year there are more and more anti-stripping agents are being used to reduce the stripping effect and also to reduce the effect of moisture susceptibility in hot mix asphalt pavement. Specific study which are based on laboratory experiments study are in need to know what the actual problem is all about and to reduce the effects of moisture susceptibility and also to reduce the stripping effect by using asphalt with adding hydrated lime as an additive . Besides this, bad subsurface drainage is also the reason which is causing excessive moisture in the pavement structure which are the result of uncommonly early stripping. Use of bad quality aggregates in construction, weak or having undesirable properties with respect to its strength and excessive dust around the aggregates, and undesirable compaction of HMA mat during construction.

If we talk about aggregates then it also affects the pavement strength due to it's bonding with Hot Mix Asphalt. So, aggregates also plays an important role in affecting moisture susceptibility of bitumen because the load is transferred from the top layer of flexible pavement structure to bottom layer and aggregates constitutes about 30-40% of the total material. So, we should give kind concern equally to test the aggregates used before taking the aggregates for construction purposes. It should also be noted that the aggregates taken for construction purposes should not only possess strong physiological effects and tough but it must have proper size and also should not be angular in shape, otherwise it may not form a proper bonding with asphalt and water can break the bond between the two easily. Test on aggregate can be performed for their hardness, the property of being physically strong, physical shape and size, amount of water absorbed by them i.e. stripping test of road aggregates.



Source : www.slidesharecdn.com/pavement

Figure 1 : Distribution of pressure under the influence of wheel load

Main properties of aggregates which aggregates should possess are as follows-

a) Toughness or resistance to impact : Aggregate impact test- Toughness is a property of aggregates which defines the aggregates as strong and durable which can't be easily cut or broken when different load apply on the surface of aggregates. Also it is defines as the resistance offered or showed by the aggregates to impact.

b) Strength or resistance to crushing : Aggregate crushing test- Strength of an aggregate to withstand great force or pressure when external load is coming from different vehicles irrespective of their weights and sizes. Because, the aggregate which we put into the service in uppermost layer will have to deal with – (i) Load from the traffic through the wheel loads coming directly on them, (ii) Crushing, (iii) Wear and tear. Therefore, it is advisable that the aggregates should possess high resistance to crushing, and to withstand with the different traffic loads and different environmental conditions.

c) Durability or resistance to weathering : Soundness test or durability test or accelerated weathering test- Soundness of aggregates maybe defined as the state which can withstand with resistance even in all type of weather conditions without any deformation in their shape or size. Because, the aggregates have to face the rain water or water present on the

surface of pavement as well as the ground water, so they should not be affected form the impurities present in the water.

d) Adhesion of bitumen : Bitumen adhesion test or stripping test of aggregates- In bituminous pavements, the aggregates used must have very few attraction with water on comparing it with the bituminous particles, reason being bitumen which is being present on the aggregates as coating will be stripped off from the bituminous mixture when coming with contact with water.
e) Freedom from deleterious particles- If the aggregates used is to be mixed as bituminous mixes then it should be usually free from impurities, hard and which can exist for a longer time should not possess dust, clay, and unwanted particles.

1.2 Need of the study

Currently many national highways built in India are under the national highway development programme (NHDP) have bituminous layer, as a surface layer which started showing premature signs of distress as early cracking, ruts formation, flushing and stripping respectively [Ref. 15]. Out of these, rutting has been the major effect on flexible pavement construction. However all these pavements were constructed strictly as per the specifications which are laid down by the MoRT&H (2001) guidelines under a very good quality control.

Some of the factors causing pavement distresses in bituminous pavements in India are:

1. Poor binder quality of both the HMA and aggregates.
2. High pavement temperatures, heavy axle loads and high tire pressures.

Hence, a detailed study is required to study the effect of both HMA and aggregates under the laboratory investigation of moisture susceptibility of Hot-Mix Asphalt containing hydrated lime as additive. Therefore, in this research there is a need to study the performance of mixes which will be prepared using modified binders considering the above mentioned factors. Effect of moisture on bituminous mixes also affects the pavement adversely, that’s why this is also cover under this research study.

It’s a well-known fact that due to moisture damage in flexible pavement (bituminous pavements), formation of pit or holes produced due to the wear or weathering, improper drainage of water, cracks may also develops. The result being it removes the aggregates chips from the bonding of asphalt from surface of flexible pavement structure. And the basic and most important reason is the lack of bonding or adhesion between the aggregate and HMA. Some aggregates are of the kind which show resistance to the action of water which are known as hydrophobic aggregates. But still, there are number of ways through which water can enters into the pavement structure-

- Aggregates having wet surface or not properly dried before making bituminous mix.
- Water taken in and comes out by the capillary action from the top layer or sub-grade of flexible pavement structure.
- When water (usually rain water) seeps through the cracks on the pavement surface, through the shoulders provided along the road side, crack, water present on the surface of flexible pavement layer which slowly enters inside the bitumen layer.

Various factors contributing to moisture damage of flexible pavements include-

- Unwanted substances such as dust or clay onto the aggregate surface.
- Inadequate drainage.
- Presence of water vapor between layers.
- Inappropriate compaction which results in high percentage of voids in material.
- Dusty aggregates.
- Mix design with less binder.

1.3 Objective

It’s a well know fact that roads are constructing at a very rapid speed in India because the Government is also focusing on infrastructure and transportation because of the reason that transportation is the main source of connectivity and any connectivity directly or indirectly are connected with the road networks only such as airports, railways all need a common mode of

connection which is only the roadways (pavement structure). But, there is a huge amount of maintenance cost needed for maintaining the flexible pavement in a good working condition for fast and efficient transportation. In India, flexible pavement structure show failures at a very early stages of pavement life. Some very common factors which are the main reason behind the failure of flexible pavement structure are the excessive loads on the vehicles, humidity, moisture susceptibility of bitumen, effect of aggregates, behavior of HMA with other bonding materials, and high temperature. It is very common to see damaged spots just after the rainy season in India, which may definitely cause stripping due to the poor properties of aggregates and also seen sometimes the removal of HMA from the pavement surface for which the reason is moisture effect on flexible pavement. Rise in water table also affects the flexible pavement by affecting the lower layer of flexible pavement structure. Hence, existing road network is in a situation which is facing various problems of durability which includes stripping, moisture susceptibility as well as from the formation of potholes.

Main points which focused mainly in this research are:

- The objective of this research is laboratory investigation of moisture susceptibility of hot-mix asphalt containing hydrated lime as additive.
- To check the performance of flexible pavement structure graphically by adding hydrated lime in the HMA for controlling the stripping and controlling the effect of moisture damage.
- To determine the workable solutions which will minimize the effect of moisture susceptibility on flexible pavement performance.
- To see the effects of aggregate quality on bituminous mixes or on HMA.

CHAPTER 2 – LITERATURE REVIEW

First a brief review of various studies on investigation of moisture susceptibility of hot-mix Asphalt and aggregates are as follows:

1. **Peter E. Sebaaly (2007)** : They presents the discussion related to the mechanical properties of HMA pavements under the influences of environmental effects and traffic conditions. The treated-lime mix will start with a better performing HMA pavement and also maintains the inferior pavement quality along the better performance.

2. **Brown & Bassett:** they conduct the test on 5 hot mix asphalt mixes with different maximum aggregate sizes. They use the crushed lime stone to preparing the specimens and they allow the air voids up to 4%.then the specimens were tested in Marshall, creep and resilient modulus tests.
3. **Abo-Qudais:** they studies on the different techniques on the predicted stripping of 24 different HMA using different mix parameters. The estimated study show that stripping is affected significantly by the method of evaluation. The reduction in indirect tensile strength & Marshall stability were found to be less sensitive to stripping than the percentage increase in creep.
4. **Roberts et. al (1996) :** They suggested that the hydrated lime as an anti-stripping agent has been used as an additive to help to address moisture susceptibility problems. According to Robert the lime reduces the potential for moisture to disrupts the adhesive bond between the aggregate and asphalt binder which binds them together.
5. **Little et al**. **(1991)** In their research paper, they said that the aggregate's upper surfaces are very rich in metallic elements for instance say calcium, that seems to improve the resistance for stripping to a greater extent. The main reason behind the resistance to stripping is mainly due to the fact that such metals strongly associated along with the bitumen acids and this results to form hydrophobic salts that are not soluble in water.
6. **Yoon et al**. (2000) also focuses on the impact of aggregates on pavement structure and it's contribution in moisture phenomenon and finds out that some physical properties of

aggregate which affects moisture damage includes mainly the shape of aggregates, roughness of it's surface, porosity and presence of adsorbed coatings. They suggested that good bonding is offered mainly by rough-textured aggregate surfaces and not by angular surfaces.

2.1 Classification of roads in India:

2.1.1 Preamble

Roads in India are classified as National Highways (NH), State Highways (SH), Major District Road (MDR), Other District Road (ODR) and also some cross drainage works such as road over bridge (ROB), bridges, culverts, and road under bridges (RUB)

Roads are broadly classified as Rural Roads and Urban Roads. For designing purposes and construction purposes of the roads both flexible pavement and rigid pavement structure, some standards prescribed in Indian Road Congress (IRC) and Ministry of Road Transport and Highways (MoRT&H) specifications are to be observed carefully [Ref 15.]. Such as,

- IRC 37:2001- for the design of flexible pavements
- IRC : SP-20:2002- Rural roads manual
- IRC 58:1974- for the design of rigid

2.1.2 Traffic

The traffic data should be counted in terms of cumulative number, of Standard axles as, (8160 k.g.) which is to be bear only by the flexible pavement structure during it's design life, which is normally 15-20 years for flexible pavement. Below provided information is of important use:

- Total initial traffic as number of commercial vehicles in each day, "CPVD"
- Estimated design life of asphalt road structure, in years.
- Growth of traffic during the design life (in %).
- Vehicle damage factor (VDF)
- Commercial traffic distribution over the carriageway.

Primary calculation of traffic: A detail evaluation for all the calculation of initial average, daily traffic flow, for any road must be on at least 7days , 24 hours study. Whereas, for newly pavement construction, rate of traffic flow counts or predictions may be guess from the existing data and from the various traffic routes available on the area.

Increment in traffic flow during the design life : Traffic growth rates should be estimated by study. If adequate data is not available, the expected twelve month increment in traffic flow at the rate of 7.5 % can be Assumed. The factor is reduced to 6% for roads designed based on IRC:SP 20-2002[Ref. 15]

2.1.3 Soil Parameter

One of the main parameter of designing pavement is the quality of soil in the roadway. For design purpose, top 500 mm portion of the roadway/embankment is formed with filling materials, immediately supporting the pavement, termed as sub grade, is considered for design purposes. Whereas in rural road the top 30 cum of cutting or embankment at the formation level is considered as sub grade.

Sub grade:
Sub grade is normally formed with natural earth
- Compacted to 97% of dry density IS 2720 (Part 8).

- Materials used for sub grade construction should have the dry density of not less than 1.75 gm/cc

- Whenever as per the details of site, original ground is to leveled so that the first layer of the embankment should be placed easily and also mixed with water and do compaction with the help of rolling to achieve maximum dry density. In some case where the difference between the subgrade level and the ground level if it's value lies below 0.5 m (0.3 m for Rural Roads) below the subgrade level watered, then it is compacted in layers so as to achieve not less than 97% dry density (clause 305.3.3 of MoRT&H)

- When the soil does not fulfill the requirements of normal subgrade soil, a stabilization technique can be used to modify and improve the same. Stabilization is of different type viz., stabilization with lime, sand, cement, coal ash, soft aggregates, gravel/moorum and mechanical stabilization etc., as stipulated in IRC SP 20:2002 and other IRC's & MoRT&H specifications.
- As far as possible a non-expansive soil should not be used for the sub grade
- The sub grade strength is assessed in terms of the CBR (California Bearing Ratio)
- The design should be based on the CBR value of the weakest soil type proposed to be used for subgrade construction or encountered extensively at subgrade level over a given section of the road.
- Pavement thickness on new road may be modified at intervals (say 1 Km) based on the CBR values.

- Where the variation in CBR test is + or – 1 and + or – 2 for soil sample having CBR value less than 5% and 5-10% respectively then the CBR value should be the average of test from atleast 6 samples.

- Where CBR value of sub grade is less than 2% a capping layer of 150 mm thickness of materials with a minimum CBR of 10% shall be provided in addition to the sub base. (normally sand would be used)

- Where embankment was formed, the CBR value of sub grade has to be tested and pavement design modified, if necessary.

2.1.4 Bituminous Surfacing

1. Comprising of either a wearing course or a binder course with wearing course depending on traffic intensity and structural requirements
2. Wearing course-open grade premix carpet, surface dressing, semi dense bituminous carpet (SDBC), Bituminous Concrete (BC)
3. Binder course - Bituminous Macadam (BM), Dense Bituminous Macadam (DBM)

4. DBM is recommended for road designed to carry more than 5 msa
5. DBM binder course may be preceded by a 75 mm thick BM layer. when this is done, the thickness of DBM layer will be suitably reduced. 10mm BM can be taken as equivalent to 7 mm DBM
6. DBM shall be constructed in two layers when it is more than 100 mm
7. Mastic asphalt maybe used at bus-stops and intersections, where Wearing course of open graded premix carpet of thickness upto 25mm, should not be counted towards the total thickness of the pavement.

2.2 Hot Mix Asphalt (HMA) or Bitumen

2.2.1 Overview and Prospect

Asphalt - A solid or sometimes semi-solid substance of color black or dark-brown having the binding properties as cement which in a gradual manner changes into liquid on heating, in which in large number there are bitumens which mostly occurs in semi-solid or in solid form in nature and can be obtained by refining petroleum products and also they can substantially soluble in carbon di sulphide.[Ref.9]

When the bitumen contains some inert material or minerals, it is then known as Asphalt. Asphalt is found as deposits in the form of natural asphalt or rock asphalt.

Bitumen-Mixtures of hydrocarbons of natural origin, frequently having comapanions by their non-metallic derivatives, which may be gaseous, liquid, semi-solid or solid. They are completely soluble in carob di sulphide. Bitumen is derived from the fractional distillation of petroleum. The components derived from fractional distillation of petroleum at various levels are gas, kerosene, diesel, naphtha, lubricating oil, bitumen, furnace oil and residue. The common bitumen used is called Penetration grade bitumen, since they are characterized by the penetration test. The two other forms are Bitumen Emulsion and Cutback Bitumen. All the three can act as binders in bitumen mix and are generally referred as bituminous binders.[Ref.9]

Bitumen is a complex organic material and occurs either naturally or may be obtained artificially during the distillation of petroleum. Bituminous materials are very commonly used in highway construction due to the reason of the bonding of asphalt or bitumen with aggregates and water resistant properties of asphalt.

Bitumen grade which we generally used in the construction of flexible pavement and airfields are called **Paving grade** bitumen while the one which we used for water proofing of building construction and floors (industrial) are known as **Industrial grade** bitumen. First one namely paving grade in India are available and are classified in the following classes :

1) Paving grade bitumen which comes from Assam petroleum is commonly represented as grades A35, A90, etc.
2) Paving bitumen from other sources denoted as S-type and designated as grade S35, S90, etc. [Ref.13]

2.2.2 Classification of Tar:

Depending upon its availability, TAR is further classified as:

- **Coal Tar**.
- **Wood Tar**
- **Mineral Tar**
- **Coal Tar Pitch**

HMA is produced at temperatures approximately 30-100°F higher than temperatures used in the production of WMA. Typically high temperature during the production of HMA is essential to drive all of the moisture away from the aggregates and to reduce asphalt binder viscosity for good aggregates coating as well as ease of placement and compaction [ref. 10]

2.2.3 Properties of Asphalt

Adhesion : It is a general and basic property of asphalt of sticking together or joining together with the surface of different composition.

Resistance shown to water : Under some conditions, it is sometimes observed that the water is being absorbed by small quantities of inorganic salts which are present in the asphalt or filler. Thus, bitumen is a water resistant.

Hardness : The property of being rigid and which shows resistance to pressure and can not be easily scratched.

Viscosity and flow of asphalt : Viscosity is the resistance of liquid to shear forces and plays an important role because it is important at high temperature at the time of processing as well as at low temperature also, when it is providing services. It is a commonly accepted fact that flow properties of asphalt is dependent on temperature and changes with the change in temperature.

2.2.4 Bituminous Mix Characteristics

- Stability
- Durability
- Impermeability
- Workability
- Flexibility
- Fatigue Resistance
- Skid Resistance

2.2.5 Stripping

Removal of covering of material at the upper surface of flexible pavement, structure is known as stripping. In stripping, there is loss of bond between bitumen or HMA and aggregates. It ha been observed that when the bond strength between aggregates and HMA weakens then there is a loss of strength in flexible pavement structure and stripping phenomenon takes place. Stripping starts from lower part in pavement structure and then travel in an upward direction.

Figure 2.1 : Stripping on flexible pavement upper surface

2.1 Use of hydrated lime in asphalt –

Use of lime (hydrated) is used as an additive in Hot mix asphalt which are generally used in road surfacing. The purpose of adding lime (hydrated) is to increase the resistance of asphalt when it comes in contact with water and thus avoid stripping phenomenon and helps the asphalt to remain in a state of good strength and also helps in showing resistance to heavy wheel load which comes directly on pavement surfaces where there is high traffic volume and repetition of loads. Besides this, hydrated lime helps the asphalt binder as a filler material which also increases properties like increasing the viscosity of asphalt binder and also increase it's stiffness, tensile strength and the resistance showed by it to water or stripping.

It's a well known fact that across the world, asphalt is used as a binder material due to it's outstanding properties for the construction of flexible pavement. Also, if we ignore the quality of the binding material then it may lead to damages of vehicles and may sometimes result in

accidents also due to inferior quality of asphalt binder. Hence, we can conclude that, infrastructure is dependent on quality of pavement construction and also comfort is dependent on quality of material used in pavement.

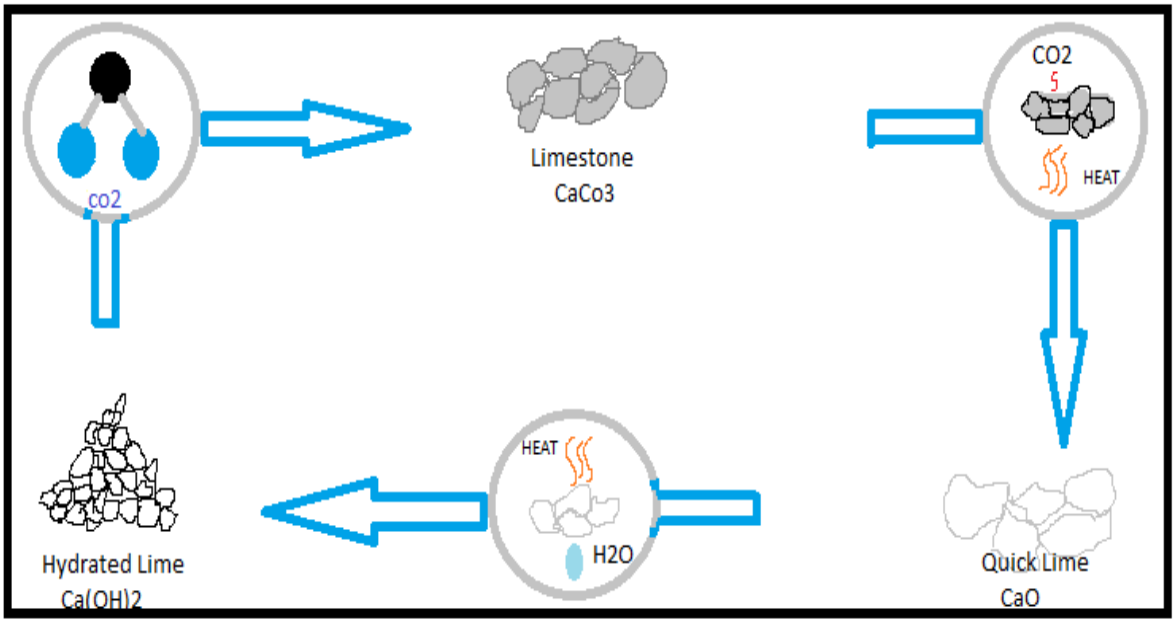


Figure 2.2 : Manufacturing of hydrated lime process

Miscellaneous uses of lime

It can be used for painting purpose, in explosives etc.

CHAPTER 3 – METHODLOGY

3.1 Laboratory Tests

- Bitumen Test - There are some standard tests like ductility, softening point of bitumen, penetration value, viscosity, specific gravity test. These tests are conducted by using appropriate apparatus.
- Aggregate Test - Some standard tests are there like, aggregate impact value test, crushing value test on aggregates, flakiness and elongation index, water absorption test, stripping test on road aggregates, grain size analysis.
- Some tests on mix – Bituminous mix should be tested for determining various properties likes marshal stability test which give us optimum bitumen content in the mix, void in mineral aggregate, stability value, flow value, etc..

3.1.1 Aggregates and Bitumen

Coarse aggregates form the major part of the pavement structure as this is one of the prime and important material used in pavement construction. Aggregates have to primarily bear load stresses occurring or coming on the road and runway pavement. Aggregate is the major component of materials used in road making. The aggregate which we use in the pavement construction process is exposed to impact because of the heavy moving loads of the vehciles. Therefore, the aggregates used in pavement construction (layers) should have resistance to toughness or impact. In case of pavement construction or road construction, aggregates are used in construction of flexible pavement layers, in granular sub-base and base course such as WBM and WMM in binder courses and in surface courses. In case of cement concrete pavement layers, R.C.C. work, masonry work, aggregates are to be used.

Affinity of aggregates to bitumen binders is an important property of coarse aggregates for use in the bituminous pavement layers. If the aggregates do not have affinity to bituminous binder, the stripping of bituminous binder is likely to take place from the coated aggregates, in case of bituminous mix or the pavement layer is in contact with water for prolonged periods.

3.1.2 Testing on Aggregates

The tests required to be conducted on representative samples of aggregates depend on the specific use in a road pavement, so as to ensure that they meet the specified requirements laid down for that specific use (Ref. 18). A laboratory sample is obtained from a bulk sample collected, either in a number of increments or in one go from a stockpile. A sample collected for testing procedures has to be reduced in size to prepare laboratory samples. The aggregates are quartered either manually or by using riffle boxes.

The commonly laboratory tests and the corresponding test methods are given below:

3.2 Aggregate Impact Test

3.2.1 Overview

Aggregate impact test is being conducted on aggregates for checking the toughness or resistance offered by the aggregates when load is being applied on it. The aggregate impact test is important to determine the resistance which is showed by the aggregates when the load applied on the surface of aggregates by heavy rollers and also due to the heavy traffic movement after the construction of flexible pavement.

3.2.2 Apparatus

- Balance
- Measuring cylinder
- Tamping rod
- Sieve of sizes 2.36 mm, 10 mm and 12.5 mm respectively along with the pan
- Impact testing machine
- Oven

3.2.3 Principle

One can determine mechanical property of coarse aggregates by aggregate impact test. Toughness is measured by aggregate impact test. Basically, the aggregates shows resistance to breaking down under repeated load application.

Figure 3.1 : Aggregate sample collection for aggregate impact test

Aggregate impact testing machine and weighing pan

Sieve of sizes, 2.36 mm, 10 mm, and 12.5 mm respectively along with the pan

Table 3.1 : Result of aggregate impact test

S. No.	**Details of the experiment**	**Trial Number**		**Average**
		1	**2**	
1.	Weight of aggregate sample = **W1g**	595 **gm**	585 **gm**	590 **gm**
2.	Weight of aggregate passing through 2.36mm sieve after the experiment = **W2g**	25 **gm**	20 **gm**	22.5 **gm**
3.	Aggregate Impact Value = **100W2/W1 %**	4.2 %	3.41 %	3.8 %

3.2.4 Result

Since our calculated value is **3.4** % i.e. less than 10. Hence, our sample of aggregates taken are exceptionally tough and strong.

3.3 Aggregate crushing value test

3.3.1 Overview

Coarse aggregates which are also known as stone aggregates or road materials such as aggregate which we use for construction of pavement must be strong. So that, it can withstand the force of the load of heavy rollers during the time of compacting the pavement layers as well as also when heavy traffic flow through them continuously.

The resistance which is being offered by coarse aggregates on the application of compressive load at a uniform rate of 4.0 tones in every minute until the load is 40 tones is applied and this resistance showed/offered by the aggregate is the strength of aggregates. Standard test method adopted for determining the crushing strength of aggregates is IS : 2386 (part 4) -1963.

3.3.2 Apparatus

- Balance
- Steel tamping rod with one end round having 16 mm diameter
- IS sieves of sizes 2.36 mm, 10 mm and 12.5 mm respectively along with the pan
- Cylindrical measure
- Steel cylinder with open ends
- Compression testing machine

3.3.3 Principle

It is a method of determining crushing strength of aggregates in which low aggregate crushing value indicates exceptionally strong aggregates. In this, load is applied through a plunger at a uniform rate of 4.0 tones in every one minute until load is 40 tones.

Figure 3.2 : Aggregates "crushing value" test apparatus

Table 3.2 : Result of Aggregate crushing value test

Serial Number	**Weight of dry sample (Total) (W)g**	**Weight of fines passing 2.36mm sieve (W2)g**	**Aggregate crushing value =100W2/W %**
1.	3985 gm	480 gm	12.04 %

3.3.4 Result

Aggregate Crushing Value = **12.04** %

3.4 PENETRATION TEST

3.4.1 Overview

In this test we examine the consistency of a sample of bitumen by determining the distance in tenths of a millimetre that a standard needle vertically penetrates the bitumen specimen under known conditions of loading, time and temperature.

Mostly all over the world, this method is used to determine the consistency of bituminous specimen or material at given temperature.

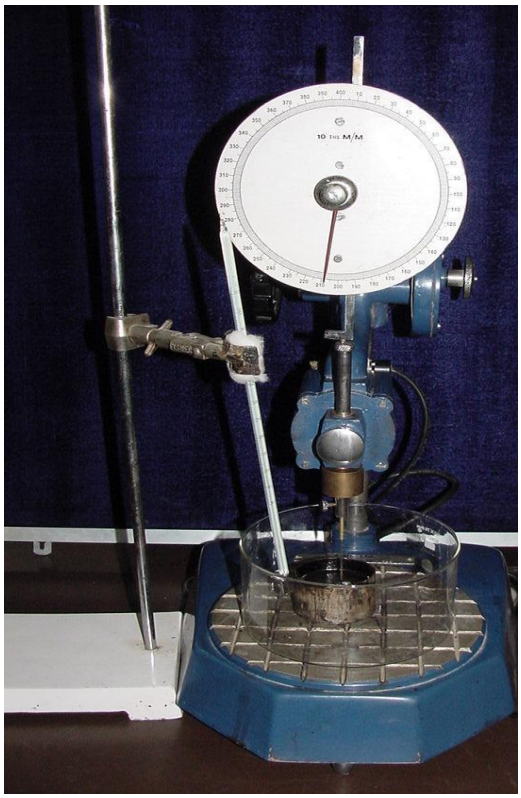


Figure 3.3 : Penetrometer

3.4.2 Apparatus Required

- Standard apparatus i.e. Penetrometer
- Container
- One needle of 100 gram weight
- Thermostatically controlled water bath
- Thermometer
- Watch to determine time (stop-watch)

3.4.3 Principle

This test is used to determine the hardness or softness of asphalt with the measurement of the depth in tenth's of milli meter to which a standard loaded needle will penetrate vertically in a time duration of 5 seconds.

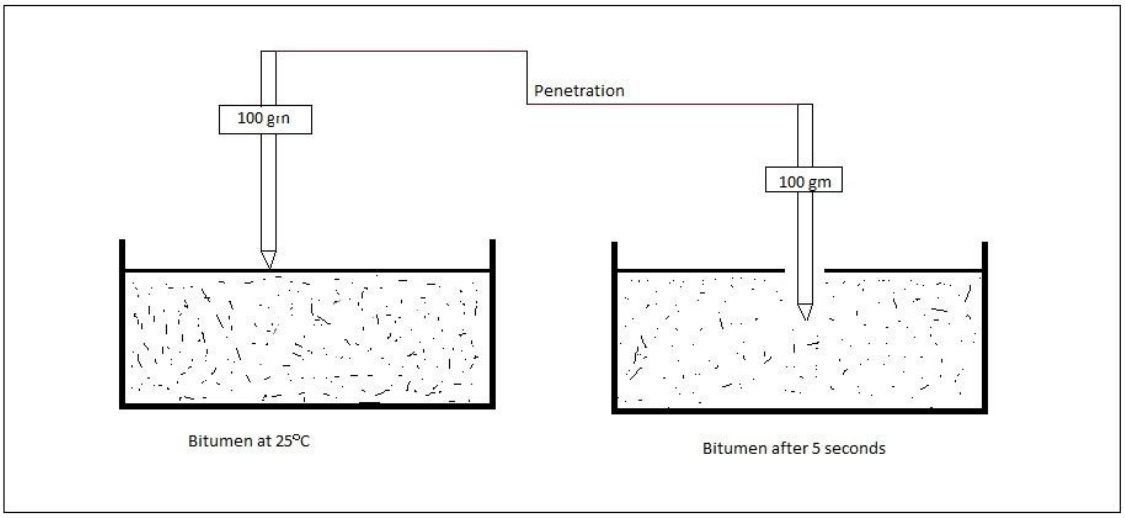


Figure 3.4: Penetration in Bitumen

Table 3.3 : Results of penetration test

Readings from dial of penetrometer	No. of test Sample				No. of test Sample			
	Sample 1	Sample 2	Sample 3	Average value	Sample 1	Sample 2	Sample 3	Average value
Initial	194	191	165	**183.33**	179	204	197	**193.33**
Final	215	216	185	**205.3**	195	220	216	**210.33**
Penetration Value	21	25	20	**22**	16	16	19	**17**

3.4.4 Result

Mean penetration value = 19.5

NOTE: Needle used for this experiment was of 100 gm.

3.5 Ductility test

3.5.1 Overview

The bitumen sample is heated to high temperature of 75 ^{0} C - 100 ^{0} C until it comes in fluid state. In this test, we determine the ductility value in distance (in cms) which is measured when the specimen of bitumen is kept in the ductility testing machine.

Figure 3.5 : Ductility testing machine (Lpu, lab)

3.5.2 Apparatus Required

- Ductility machine
- Briquette mould for keeping bitumen as a sample.
- Heater

Figure 3.6 : Preparation of bitumen specimen in Briquette Mould along with heating bitumen

3.5.3 Principle

Bitumen sample is kept in ductility testing which works on a constant temperature water bath and which also pulls the Briquette mould at a rate of pull of 50 mm per minute. The sample of bitumen specimen should be kept at a minimum of 10 mm depth under water inside the ductility testing machine. The bitumen sample is kept fixed at one end and is stretched from the other end with the help of ductility testing machine. When the specimen is break from middle that particular value must be noted which is our required ductility value.

3.5.4 Result

Grade of bitumen = VG 30

Pouring temperature = 80^0C - 90^0C

Test temperature = 27^0C

Period of cooling (in min) –

- In air = 01:40pm – 02:15pm = 35 min
- In water bath after trimming= 02:20pm – 02:50pm = 30 min at 27^0C

3.6 Stripping Value of Road Aggregates

3.6.1 Overview

Bitumen or Hot-Mix Asphalt adhere fine with road aggregates if the aggregates do not have dust or soil particles and also if the aggregates are dry. When we add binder on the surface of aggregates then after it comes into contact with water. Here, we try to find out how much quantity of binder material will be stripped off from the surface of aggregates when it comes in contact with water. This test is also known as static immersion test. It is used very commonly due to its simplicity and easy procedure of gaining the results. It's a visual test and one can get the result easily.

The problem of adhesion is not observed if there is no presence of water during the constructions of flexible pavement. Problems which are commonly observed if water is present on the surface of aggregates or on the mixture of bitumen and aggregates -

1. Somehow, if the aggregates taken for coating with HMA is cold or having water on it's surface then it becomes difficult to coat it with a bituminous binder. The solution to this problem is to remove the water from the aggregates by heating it and thus, make it dry and suitable for the bituminous mix and by gradually increasing the mixing temperature.
2. If we take wet aggregates then it is not possible to coat the bitumen on to the surface of aggregates if water particles are there. Wetness from surface of aggregates can be removed by heating the aggregate sample in electric oven upto 150° C for an hour or two.

3. Another major problem is the detachment of a bituminous binder from the surface of aggregates due to the presence of water. This phenomenon of detaching of binder from aggregates are commonly known as “Stripping”. The stripping problem is generally observed when the bituminous pavement layer is subjected under water for more time, mostly during the rains.

3.6.2 Apparatus

- Thermostatically controlled water bath.
- Heat resistance glass beaker of 500 ml capacity.
- Mixer.
- Electronic balance of capacity 10 kg and sensitivity 1 gram.
- IS-sieves, 20 mm and 12.5mm.
- Electric oven.
- Distill water (around 400 ml).

3.6.3 Principle

With the aim of reducing the influence of moisture on coarse aggregates, it becomes of extreme importance to know about the stripping and it’s displacement characteristics of asphalt binder with the road aggregates.

Total ratio of uncovered area observed visually to total area of aggregate taken for experiment which is expressed in percentage is known as the stripping value. [Ref. 17]

3.6.4 Result

I) Results of stripping test on road aggregates

OBSERVATION SHEET

• **Type of aggregate**	Dry and clean coarse aggregates, which pass through 20 mm IS sieve and retains on 12.5 mm IS sieve.
• **Binder used**	VG 30
• **Binder used (%)**	5% by weight ; bitumen binder, heated at 160° C
• **Total weight of aggregates**	200 grams
• **Weight of binder used**	10 grams
• **Heat of water – bath**	40° C

Table 3.4 : Stripping value result

Observation Digit	Uncovered area/ Stripping, percentage
1	1.6%
2	1.8%
3	1.5%

Average stripping value = **1.633 %**

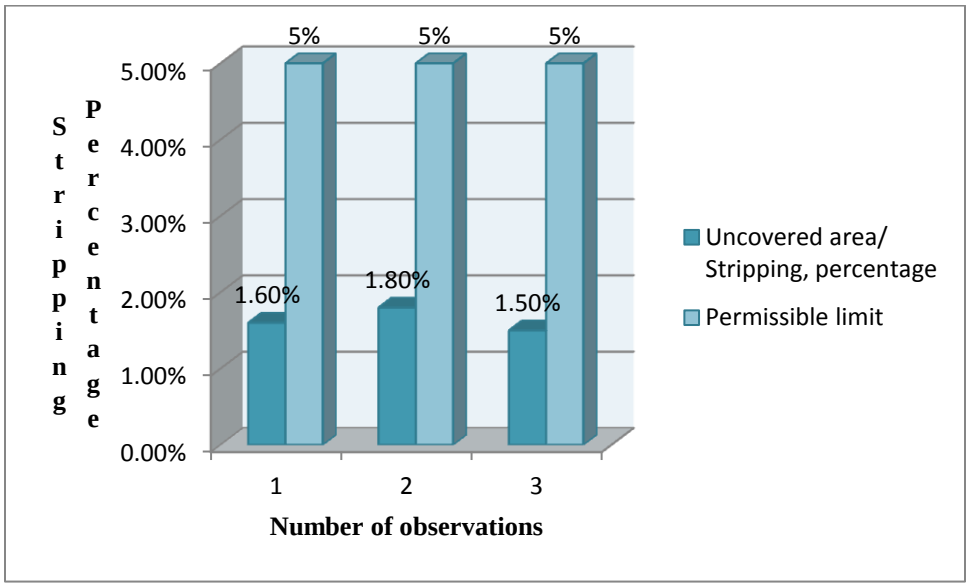


Figure 3.7 : Stripping percentage of road aggregates

Whereas, maximum permissible stripping value suggested by IRC is 5%

II) Results of stripping test on road aggregates by adding hydrated lime with bitumen-

• **Aggregate used**	Dry and clean coarse aggregates, passing through 20 mm IS sieve and retaining on 12.5 mm IS sieve
• **Binder used**	VG 30
• **Binder used (%)**	5% by total weight of bitumen binder used, heated at 160° C
• **Type of additive**	Hydrated lime
• **Percentage of additives added**	1%, 1.5%, 2% by weight of aggregates
• **Total weight of aggregates**	200 grams

• **Total weight of binder**	10 grams
• **Total weight of additives**	2grams, 3 grams, 4 grams respectively
• **Temperature of water – bath**	40° C

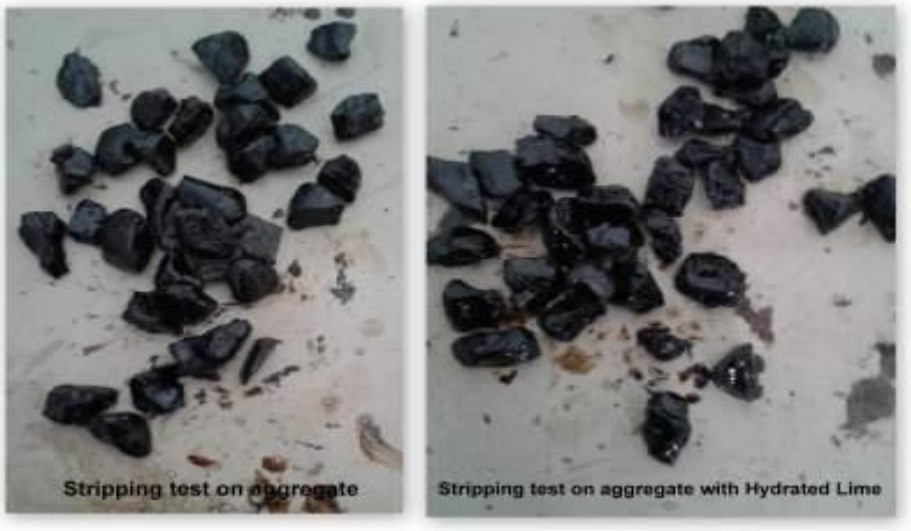


Figure 3.8 : Stripping test on aggregates (without hydrated lime and with hydrated lime)

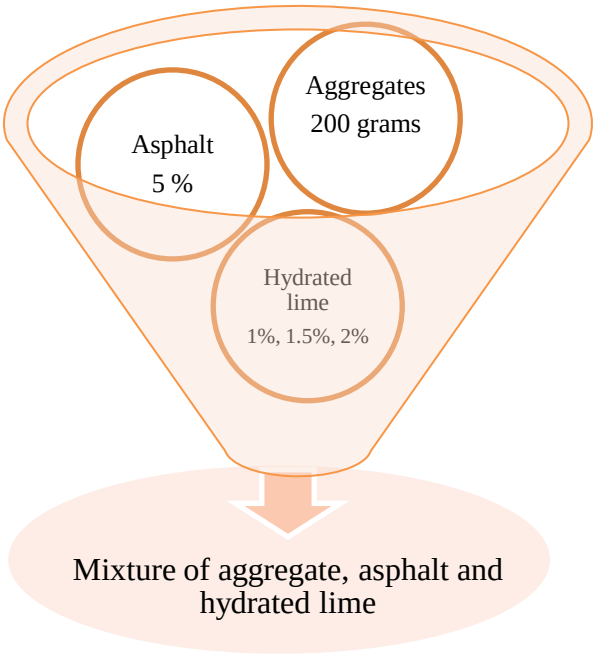


Figure 3.9 : Mixture of aggregate, asphalt and hydrated lime

Table 3.5 : Stripping value test results with hydrated lime

Observation Number	Hydrated Lime (%)	Uncovered area/ Stripping, percentage
1	1	0.9%
2	1.5	0.5%
3	2	0.3%

Average stripping value = **0.566%**

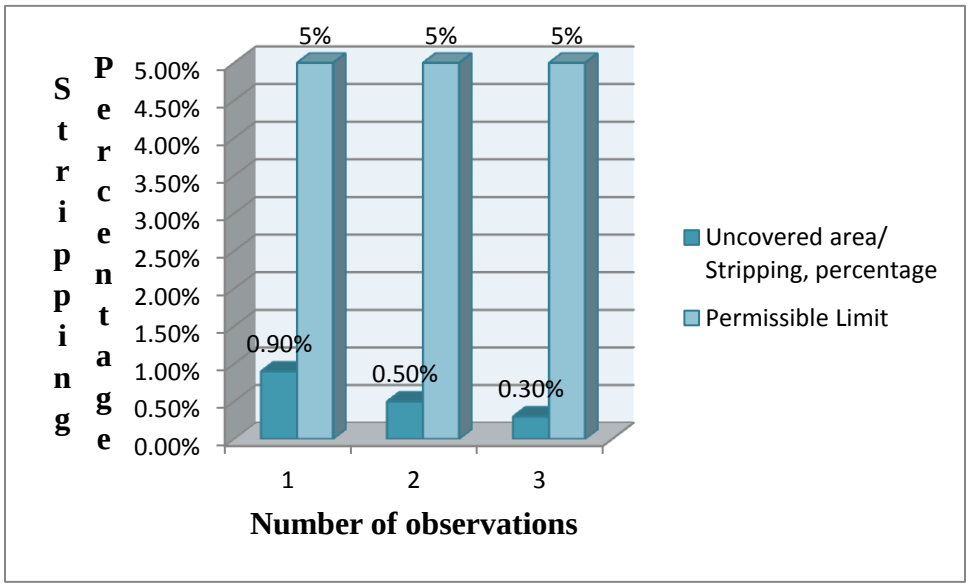


Figure 3.10 : Stripping percentage of road aggregates with addition of hydrated lime in bitumen

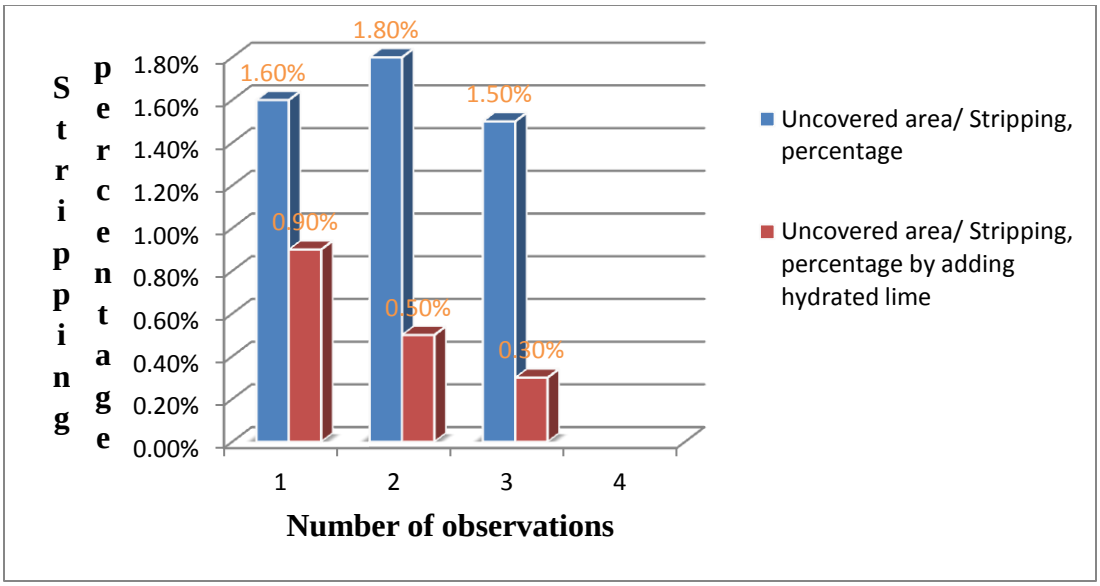


Figure 3.11: Stripping test comparison without adding hydrated lime and by adding hydrated lime

3.7 MARSHAL STABILITY TEST

3.7.1 Overview

As it is a known parameter that surface layer of flexible pavement have to bear larger load as compare to the below layers. Also, extreme climatic conditions which includes variation of temperatures as well as effect of water during the rainy seasons and moisture effect due to the retained water on the surface of flexible pavement is only to be faced by surface layer. So, it is very important to make sure of the bituminous mix we are using for the surface course of flexible pavement and the quality we used for flexible pavement construction.

Ideal bitumen content is determined by Marshall Stability test.

Figure 3.12 : Marshal Stability & Flow Value Test Apparatus

3.7.2 Apparatus required

- Compaction mould assembly
- Hammer of weight 4.5 kg
- Electric heater

- Mixing pan
- Mechanical thermometer
- Extractor to extract test specimen
- Water bath
- Thermostatically controlled oven
- Testing machine (5 tonnes capacity)
- Dial gauge to measure deformation

3.7.3 Principle

The Marshall Stability test helps in determining the maximum load which the test specimen can bear when the load of **50.8 mm/minute** is applied on it. The rate of deformation is constant, which is being applied perpendicular to the axis of specimen and the standard test temperature is **60^{o} C.**

Figure 3.13 : Marshal Test Specimen

“Maximum load which is carried by the marshal stability test specimen in kilograms at a constant temperature of **60° C** is known as the ‘Marshall Stability’ “.

“Flow Value” is the measure of deformation of marshal test specimen exactly at the time, when the maximum load is applied and is recorded in **0.25 mm**.

Figure 3.14 : Marshal test specimen after the application of load

Figure 3.15 : Marshall test specimens

3.7.4 Preparation of marshal test specimen

Here, we take aggregates of sizes 20 mm, 10 mm, 6 mm respectively as per gradation of aggregates for Dense Bituminous Macadam (DBM) layer. In this experimental study, we take cement (3%) as a filler material in normal Marshal Test and asphalt range from 4.5 % upto 7 % respectively. And, as per the present requirement of this dissertation we take Hydrated lime (1 % - 3 %) in place of filler material as an additive to reduce the moisture effect on flexible pavement.

Mixture of aggregates (both fine and coarse), filler approximately **1200 grams** is mixed properly and heated in oven at **170^{o} - 190^{o} C** for an hour, so that the aggregate can make proper binding with the binder (asphalt). It should be noted that the mould in which the mixture of aggregates, filler and asphalt is to be filled is also pre heated at a temperature of around **90^{o} - 150^{o} C.** Asphalt binder is also heated in mixing pan to a temperature of **120^{o} - 165^{o} C** mixes with the aggregates and filler mixture and then transferred in mould. Apply **75 blows** to both side of specimen form a free fall of **457 mm** with a hammer of weight **4.5 kg**. After this, keep the test specimen in thermostatically water bath at a constant temperature of **60^{o} C** for around **30-40** minutes.

To achieve the required strength and durability parameters for dense bituminous macadam as per **IRC : 94 - 1986**, it should consists of coarse aggregates, fine aggregates and filler materials along with bitumen. The standard gradation value are given in below table as :

Table 3.6 : Gradation of mineral aggregates in mix as per IRC : 94-1986

Sieve size	Grading number	
	1	2
	Percent passing	
37.5 mm	-	100
26.5 mm	100	85-100
19.0 mm	85-100	71-95
13.2 mm	63-82	58-82
9.5 mm	52-74	52-72
4.75 mm	39-54	35-50
2.36 mm	28-43	28-43
600 μm	15-27	15-27
300 μm	7-21	7-21
150 μm	5-15	5-15
75 μm	2-8	2-8

Source : Specifications for Dense bituminous macadam, IRC : 94-1986

Here, I took the aggregates by heat and trial method, and percentages of size of aggregates used are-

20 mm	10 mm	6 mm	Fine aggregates	Filler	Asphalt
20 %	25 %	27 %	25 %	3 %	4.5-6.0 %
240 gm	300gm	324gm	300gm	36gm	54-72gm

For thickness upto 50 mm grading I should be used and for thickness more than 50 mm grading II should be used. It should also noted that thickness must not increase 75 mm.

On compacted specimen which is cylindrical in shape having diameter **101.5 mm** and thickness as **63.5 mm**, Marshall test of stability is performed. Workability of the bituminous mix must be adequate at mixing, laying and compacting temperatures.

The stability values which obtained from the test specimen should be corrected by multiplying with the correction factor as given in the table below-

Table 3.7 : Marshal stability values correction factor

Volume, cm^3	Thickness, mm	Correction Factors
457 – 470	57.1	1.19
471 – 482	68.7	1.14
483 – 495	60.3	1.09
496 – 508	61.9	1.04
509 – 522	63.5	1.00
523 – 535	65.1	0.96
536 – 546	66.7	0.93
547 – 559	68.3	0.89
560 – 573	69.9	0.86

Source : Road Research Laboratory, Bituminous Materials in Road Construction, H.M.S.O., London

3.7.5 Calculations and Analysis

Table 3.8 : Observed thickness of test specimen

Bitumen Content (%)	Thickness of sample (mm)			Weight of bitumen (gram)
	Sample 1	Sample 2	Sample 3	
4.50 %	61.60	63.33	63.96	54
5.00 %	62.98	65.28	62.84	60
5.50 %	63.98	66.09	64.46	66
6.00 %	65.72	63.12	64.60	72

Table 3.9 : Observed weight of sample in air and water (in grams)

Bitumen Content (%)	Weight in Air			Weight in water		
	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
4.50 %	1248	1244.4	1252.3	729.7	728.3	732.1
5.00 %	1238.6	1258	1247	724.4	738.5	730.4
5.50 %	1247.5	1300	1260	729	762.2	738.9
6.00 %	1270.4	1257.8	1268	740.1	735.5	745

Table 3.10 : Stability of sample (kg)

Bitumen (%)	Stability (kg)					
	Sample 1	Sample 2	Sample 3	Average	Factor	Corrected
4.50 %	838.9	820.8	840.0	833.2333333	1.04	866.5626666
5.00 %	970.6	704.9	927.1	867.533	1.04	902.23432
5.50 %	890.8	975.6	949	938.4666667	1	938.4666667
6.00 %	840.2	930.5	910.9	893.8666667	1	893.8666667

Bitumen (%)	Stability (kg)
4.5%	866.56
5.0%	902.23
5.5%	938.47
6.0%	893.87

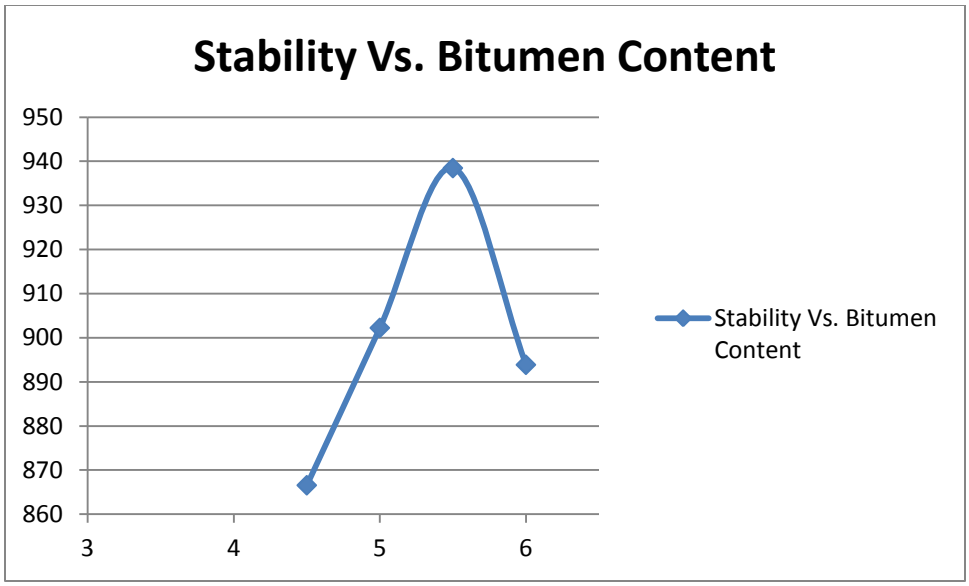


Figure 3.16 : Stability v/s Bitumen Content

Table 3.11 : Flow Value (0.25 mm)

Bitumen Content %	**Flow value (0.25 mm)**			
	Sample 1	**Sample 2**	**Sample 3**	**Average**
4.50 %	2.4	2.3	2.5	2.4
5.00 %	2.8	2.5	3	2.766
5.50 %	3.8	3.2	4.5	3.8
6.00 %	4.4	3.5	4.6	4.166

Bitumen %	Flow Value (0.25 mm)
4.5	2.4
5.0	2.77
5.5	3.8
6.0	4.17

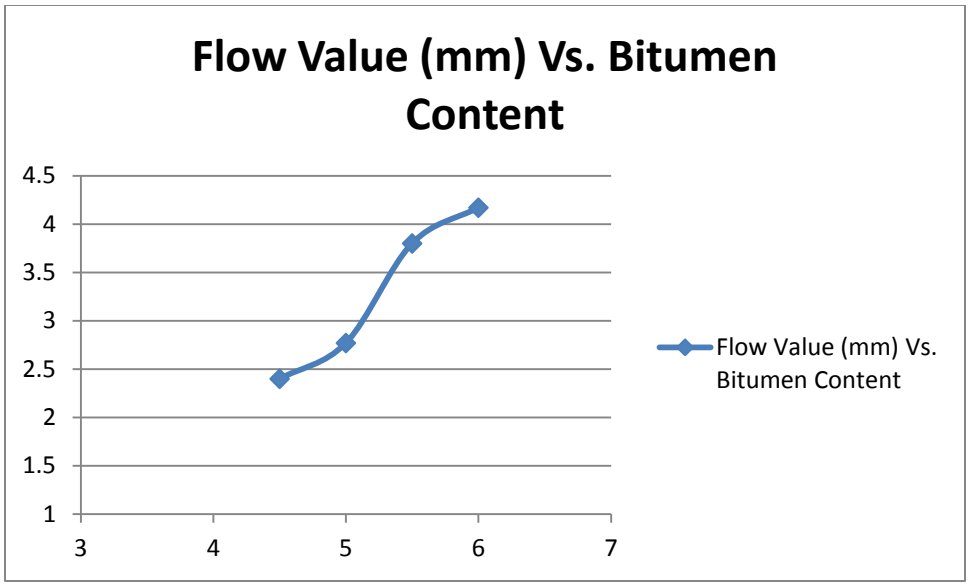


Figure 3.17 : Flow value vs. Bitumen Content

Table 3.12 : Unit weight vs. Bitumen content calculations

Bitumen Content (%)	Bulk specific gravity			$Gm = \frac{Wm}{(Wm - Ww)}$
	Sample 1	Sample 2	Sample 3	Average
4.5 %	2.307871889	2.311160628	2.347343329	2.34
5.0 %	2.408790354	2.421559192	2.413859853	2.41
5.5 %	2.305978785	2.317255485	2.207962003	2.39
6.0 %	2.305625118	2.408194524	2.324474187	2.36

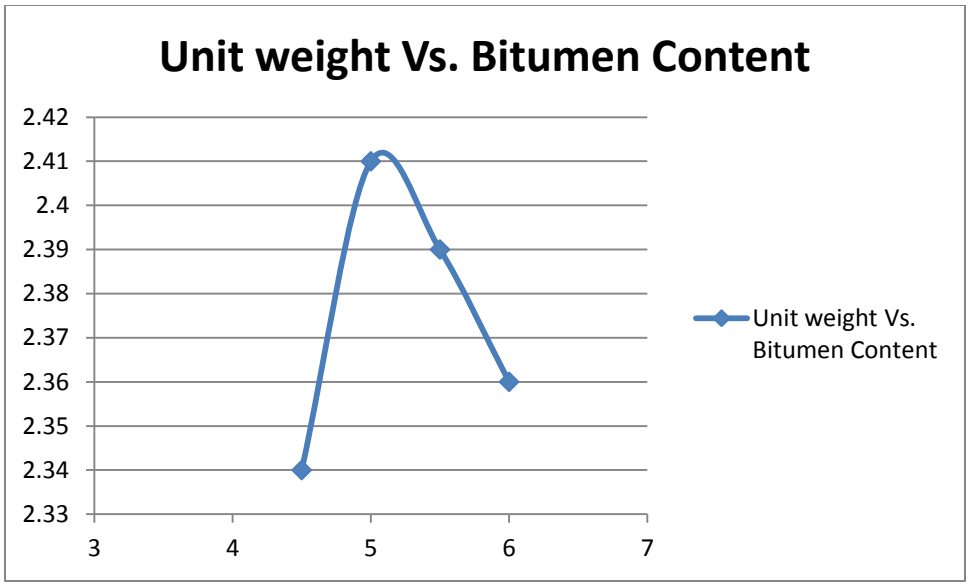


Figure 3.18 : Bulk specific gravity vs. Bitumen (%)

Table 3.13 : VFB vs. Bitumen Content

Bitumen Content (%)	$\text{VFB} = \frac{100 * (\text{VMA} - \text{Vv})}{\text{VMA}}$
4.5 %	60.14
5.0 %	65.07
5.5 %	70.74
6.0 %	75.33

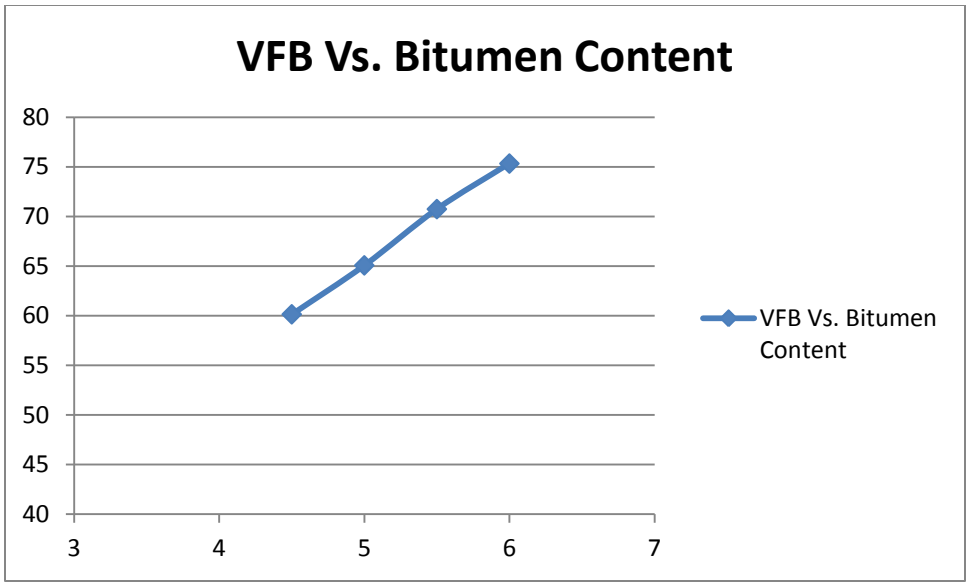


Figure 3.19: VFB vs. Bitumen Content

Table 3.14 : % voids vs. Bitumen content

Bitumen Content	Vv= Air Voids percentage
4.5	4.72
5.0	4.63
5.5	4.02
6.0	3.55

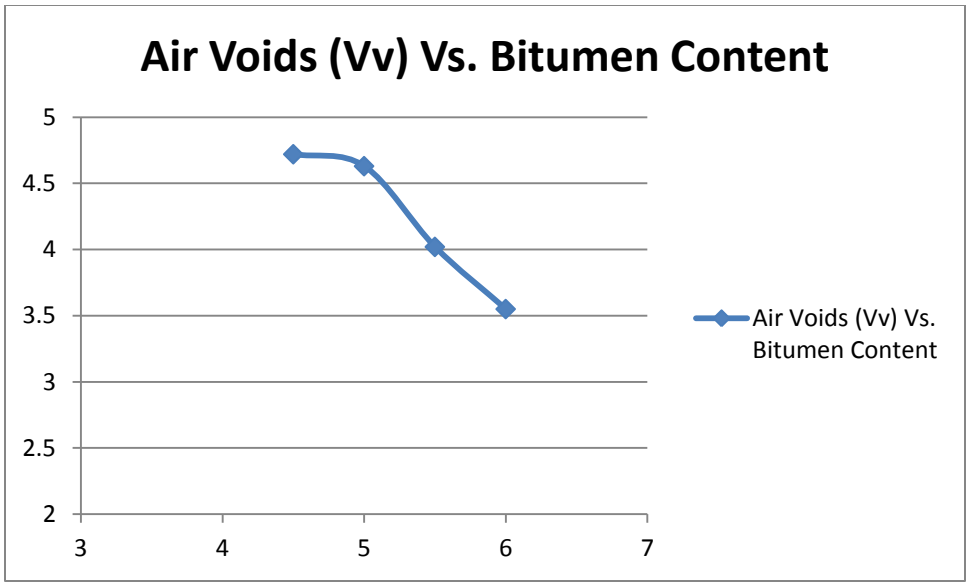


Figure 3.20 : % voids vs. Bitumen content

3.4.4 Result I

Hence optimum bitumen content form the given test results-

- Optimum bitumen content corresponding to the maximum stability = 5.5 %
- Bitumen content corresponding to maximum bulk density = 5.0 %
- Percent air voids (Vv) in the compacted mix using mean of limits = 4.0 %
  Hence, bitumen content corresponding to 4.0 % air voids = 5.20 %
- Therefore, optimum bitumen content in the mix (5.5+5.0+5.20)/3 = 5.23 %
- Value corresponding to 5.23 % bitumen content = 3.3 mm
- VFB at 5.23 % = 68 %

Now adding hydrated lime in the mix in the percentage range, 1.0, 1.5, 2.0, 2.5 percentage by weight of test specimen. As we get optimum content of bitumen is 5.5 %, so now we vary percentage of hydrated lime and take constant value of bitumen as 5.5% in the marshal test specimen. We get the following results.

Note : Calculations done by the same method as shown above for normal marshal test speciemen.

Table 3.15 : Result on addition with hydrated lime

Hydrated Lime (%)	Bitumen Content (%)	Stability (kg)	Correction factor	Corrected Stability (kg)
1.0 %	5.5 %	980	1	980
1.5 %	5.5 %	1275	1	1275
2.0 %	5.5 %	1490	1	1490
2.5%	5.5 %	1489.58	0.96	1430

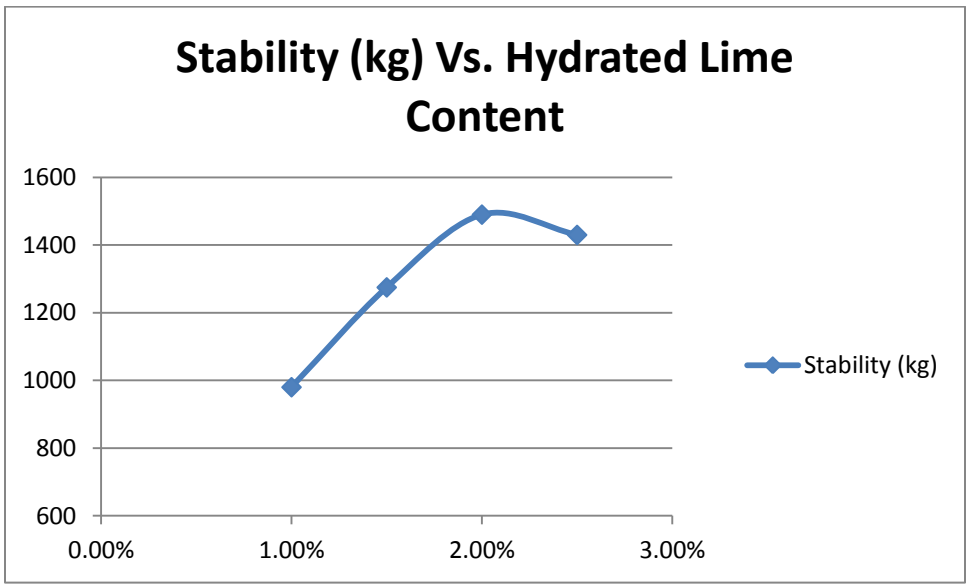


Figure 3.21 : Stability vs. Lime content (%)

Table 3.16 : Flow value on addition with hydrated lime

Hydrated Lime (%)	Flow value (0.25 mm)
1.0 %	2.72
1.5 %	3.52
2.0 %	4.30

2.5 %	4.82

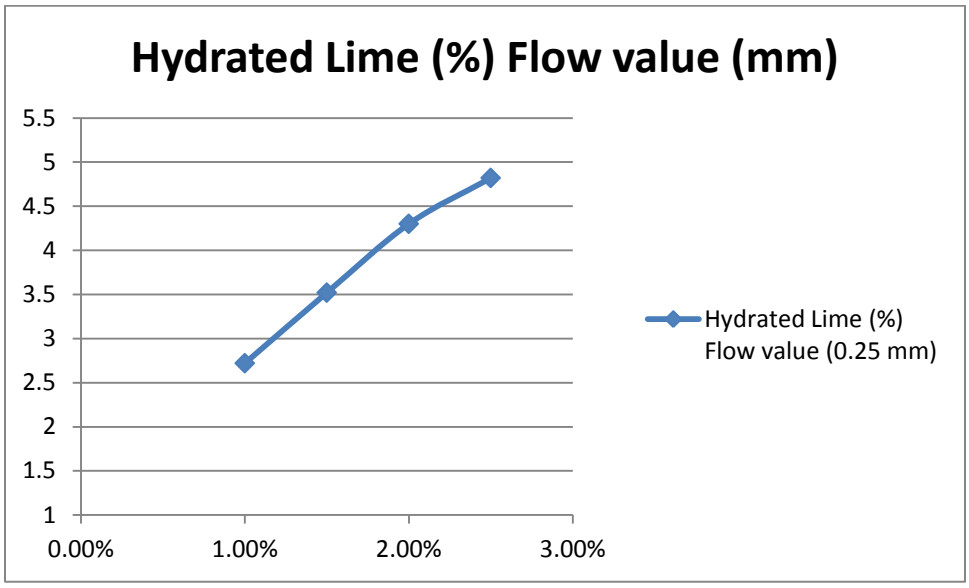


Figure 3.22 : Flow value vs. Hydrated lime (%)

CHAPTER 4 – RESULTS

After applying many theoretical concepts practically in laboratory, I found the optimum content (5.5 %) of asphalt which could be used in pavement construction along with the use of hydrated lime as an additive. A minute quantity of hydrated lime can increase the life of asphalt pavement because as shown clearly from the results, hydrated lime increase the strength between the aggregate and asphalt binder i.e. it creates very strong bond between both of them.

Results also shown that by adding hydrated lime in asphalt, it improves it's bonding with both the asphalt binder and also with the aggregates.

Following are the main points which I conclude from the laboratory experiments-

4.1 Effect of Aggregates-

As 80-90 % of the test specimen contains aggregate only, so it is important to choose the desired aggregate very appropriately. Before using the aggregates on field, one must perform the tests in laboratory to determine the physical properties of aggregates.

- Aggregates used should be dry only otherwise it will effect the mixture very badly which in turn affects the bonding between the aggregate and asphalt binder as shown in the stripping value of road aggregates.
- From the test results of experiments performed in laboratory, it is clear that aggregates used should not be angular in shape otherwise it will result in stripping, result being improper bonding between the aggregate and asphalt.
- Aggregate used before making any test specimen should be clean with water (if possible), so as to make it free from clay, dust, and other unwanted particles.
- As, from aggregate crushing value test, **3.4 %** value indicates that the aggregates taken for testing purpose are exceptionally strong and hard. So, the life of pavement will increase naturally if we use correct aggregates and choose them wisely by performing tests on them.
- Addition of hydrated lime in asphalt binder in stripping value of road aggregates also shows that hydrated lime can be used for making better bonding between the asphalt binder and aggregates and also it absorbs water or any moisture present on to the surface

of aggregates. Hence, addition of hydrated lime as an additive helps in reducing moisture sucsceptiblity.

4.2 Effect of asphalt

- After performing marshal test on so many samples and by changing the amount of bitumen content in it and also adding additive which is Hydrated Lime in it at 1, 1.5, 2.0, 2.5 % we found that hydrated lime plays very important role in marshal stability test as the stability values we get are much better than the normal values without adding hydrated lime.
- Thus, adding of hydrated lime in asphalt binder in small amount can make big differences. Stability should be minimum **340 kg** as per ASTM guidelines but here if we compare virgin asphalt marshal test with the one we get by adding hydrated lime as an additive in asphalt binder, we get outstanding results from the experiments performed in laboratory.

  Optimum bitumen binder content is **5.5%** which satisfies all the traffic conditions i.e. it can withstand the traffic load.

  Now, if we compare the addition of Hydrated Lime in stripping test then also we conclude from this dissertation work that hydrated lime proves as a very cost reducing additive if we talk about long time working durability of asphalt pavement.

4.3 Sources of errors

- **Mechanical errors.**
- **Human errors –** I tried my best during the testing of materials in laboratories but sometimes there is loss in material at the time of filling, mixing and transferring it in moulds.
- **Temperature effect-** The result of some experiments may change due to change in atmospheric conditions at site as compare to the experiments performed in laboratories.
- **Type of material available –** It is the most important factor which affect the tests results very adversely because it is not possible that each material have the same physical properties all over the globe.

CHAPTER 5 – CONCLUSION

5.1 Conclusion

From the experimental results, we conclude that the aggregates used in this project is exceptionally hard and that is a very good sign as we need this aggregate to mix with HMA for the construction of flexible pavement. Also, since the aggregates are strong, i.e. they will make good bonding with the bitumen mix.

By making use of strong and hard aggregates it is possible to construct a pavement of inferior quality which will directly increase the life of pavement and thus indirectly reduces the maintainence cost.

By using hard or good quality aggregates in bitumen mix, stripping phenomenon will also be reduced because a good quality aggregate will a tight bonding with bitumen and is able to withstand under heavy loads.

Quality of asphalt also influences the strength characteristics hence as per the guidelines of Morth, we use VG 30 grade of asphalt binder for our all tests in the laboratory.

Though initial cost will increase if we use hydrated lime as an additive in asphalt binder but there are many factors which will improve which are as follows-

- Cost of repair could be minimize by using hydrated lime as it increase it’s strength characteristics.
- Comfort of passengers will be maintained as if there will be no moisture damage in the pavement then there will be no stripping and vehicle can travel at their design speed easily.
- Also, by adding hydrated lime, moisture from the surface of aggregate (if any) can be absorbed by hydrated lime.

REFERENCES

1. ASTM D 1559, “Test procedure for carrying out Marshal test”. American Society for Testing and Materials.

2. ASTM D5, “Test method adopted to calculate penetration in bitumen”. American Society for Testing and Materials.

3. Alam, M. M. 1977. “A Test Method for Identifying Moisture Susceptible Asphalt Concrete Mixes”. M.S. thesis. Department of Civil Engineering, University of Texas at El Paso.

4. B. Sengoz, E. Agar. “Effect of Asphalt Film Thickness on the Moisture Sensitivity Characteristics of Hot-Mix Asphalt”, Build Environ, 42 (2007), pp. 3621–3628.

5. Brijesh Kumar and R.K. Yadav,Study on Marshall Retained Stability of BC Mix Used in Road Construction by Adding Cellulose fiber. September 2013, International Journal of Emerging Trends in Engineering and Development.

6. Bureau of Indian Standards, “Indian Standard Method for Determination of Stripping Value of Road Aggregates”. IS : 6241-1971 (Reaffirmed 1998).

7. Bureau of Indian Standards, “Indian Standard Method for Determination of Methods of Testing Tar and Bituminous Materials, Determination of Penetration. IS: 1203-1978 (First revision).

8. Bureau of Indian Standards, Methods for Testing Tar and Bituminous Materials : Determination of Specific Gravity, (First Revision), IS : 1202-1978

9. Bureau of Indian Standards. Paving Bitumen - Specification (Third Revision) IS 73:2006, July 2006

10. “Cause and Prevention of Stripping in Asphalt Pavements”, Educational Series No. 10, Asphalt Institute, College Park, MD, 1981.

11. Cheng, D., D. N. Little, R. L. Lytton, and J. C. Holtse. 2001. "Surface Free Energy Measurement of Aggregates and Its Application on Adhesion and Moisture Damage of Asphalt-Aggregate System." Proc., 9th International Center for Aggregate Research Symposium, Austin, Tex.

12. Gorkem C, Sengoz B, 2009. "Predicting stripping and moisture induced damage of asphalt concrete prepared with polymer modified bitumen and hydrated lime". Constr Build Mater.

13. Hossain 2009, "Evaluation of the Use of Warm Mix Asphalt as a Viable Paving Material in the United States". Federal Highway Administration.

14. Ministry of Road Transport and Highways, "Specifications for Road and Bridge Works" Fourth Revision, Published by Indian Road Congress on behalf of the Government of India, New Delhi, 2001.

15. Prajapati Harshad, Dr. P.J. Gundaliya (2014) "A study on aging behavior of paving grade bitumen using filler material" International Journal Of Scientific Research And Development. Volume 2, Issue 03.

16. Road Research Laboratory, Bituminous Materials in Road Construction, H.M.S.O., London

17. Raquel Moraes, Raul Velasquez, 2010, "Measuring Effect Of Moisture On Asphalt-Aggregate Bond With The Bitumen Bond Strength Test", Transportation Research Board Annual Meeting January 23-27, 2011 Washington, D.C.

18. Solaimanian, M., T. W. Kennedy, and W. E. Elmore. 1993. "Long-Term Evaluation of Stripping and Moisture Damage in Asphalt Pavements Treated with Lime and Antistripping Agents". Center for Transportation Research, University of Texas at Austin.

19. Specifications for Road and Bridge Work, Ministry of Surface Transport (Roads Wing) Third Revision, IRC, New Delhi 1995.

20. The Indian Road Congress, "Specifications for Dense Bituminous Macadam". IRC : 94-1986