Use of Crumb Rubber in the Modification of Asphalt Mix

BY
Hedi Amjad
Karwan Muhammed
Tazhan Muhammed
Is such a person (preferable or he) who is obedient, and prostrates himself in the watches of the night, stands (in Prayer), is fearful of the Hereafter, and looks forward to the mercy of His Lord? Ask them: “Are those who know equal to those who do not know?”28 Only those endowed with understanding take heed.
Dedication

Firstly, we dedicate this project to God Almighty our creator, our strong pillar, our source of inspiration, wisdom, knowledge, and understanding. It is noteworthy to mention that this research would not have been completed without the help of our adviser, friends, and participants in the research. We would like to express our heartfelt gratitude and sincere thanks to our advisor, (Mrs. Asmaa Abdulmajeed), for her continuous support and guidance, motivation, patience, and immense knowledge. She has always been available for us throughout the semester, and this is something that we never forget. Her guidance enabled us to write and finish this research. We would also like to thank our friends who directly and indirectly helped us while conducting this research. We wholeheartedly appreciate TIU- Erbil, University of Sulaimani, Sulaimanyeah Construction Laboratory’s contribution to this research by helping us to do our practical works. We declare that this research "Use of Crumb Rubber in the Modification of Asphalt Mix" is solely undertaken by us. We are the only authors of this research under the supervision of (Mrs. Asmaa Abdulmajeed). Any information related to this research including the data is provided by us; therefore, the publication of this research by the KRG TISHIK UNIVERSITY FACULTY OF ENGINEERING will not be counted as a violation of the right of any third party. This research has been submitted to none of the academic and educational institutions, and it has not been published by anyone.
Use of Crumb Rubber in the Modification of Asphalt Mix

Project Report Submitted in fulfillment of the requirement for the degree of
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in
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Supervisor
Mrs. Asmaa Abdulmajeed

by
Karwan Muhammed
Tazhan Muhammed
Hedi Amjad

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Abstract

As the rapidly growing number of vehicles in the world, the waste of tire rubber becomes a major environmental concern. The usage of crumb rubber, which is the recycled tire rubber, as a modifier in hot mix asphalt mixture is considered as a sustainable construction method. The purpose of this study was to investigate the effect of adding crumb rubber to asphalt mixture using dry process. The laboratory hot mix asphalt design tests were done by Marshall Method procedure. In this study, three different crumb rubber contents (10%, 20% and 30% by weight of bitumen) and two different crumb rubber sizes (2-4 mm) were investigated. A comparative study was done among the unmodified and modified asphalt concrete mixtures considering the Marshall Stability and Flow value and the volumetric properties. The results showed that crumb rubber is recommended as a modifier in asphalt mixture, as all the test results are within the standard requirements. The addition of crumb rubber tended to increase the strength and quality of asphalt mixture. However, it should be more concern about durability of asphalt mixture because of the lower asphalt content in crumb rubber modified asphalt mixture. The rubber content has a significant effect on the performance of resistance to permanent deformation at high temperature and cracking at low temperature.

Key Words: Crumb rubber, Optimum binder content
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Chapter One

1.1 Introduction to Highway

Highway engineering is an engineering branch from civil engineering that involves the planning, design, construction, operation, and maintenance of roads, bridges, and tunnels to ensure safe and effective transportation of people and goods. (A. Hoel, 2013)

Highway engineers must take into account future traffic flows, design of highway intersections/interchanges, geometric alignment and design, highway pavement materials and design, structural design of pavement thickness, and pavement maintenance.

Road is one of the most important part of highway engineering, that is a thoroughfare, route, or way on land between two places that has been paved or otherwise improved to allow travel by foot or some form of conveyance, including a motor vehicle, cart, bicycle, or horse.

Roads consist of one or two roadways, each with one or more lanes and any associated sidewalks and road verges. There is sometimes a bike path. Other names for roads include parkways, avenues, freeways, tollways, interstates, highways, or primary, secondary, and tertiary local roads.

1.2 Objectives

1. To learn marshal mix design and finding OBC.
2. improve asphalt behavior by using CR as an modifier in asphalt concrete mixture.
3. The rubber content has a significant effect on the performance of resistance to permanent deformation at high temperature and cracking at low temperature.
4. To minimize the wastage of tire, and reusing them in civil engineering fields.
5. The major objective of this thesis is to determine the effectiveness of crumb rubber as a modifier binder in asphalt paving mixtures.
1.3 Types of Road

Based on Traffic Volume

- **Light Traffic Roads** *(Shown figure (1.1))*

  The roads which are carrying 400 vehicles daily on an average is called light traffic roads.

- **Medium Traffic Roads** *(Shown figure (1.2))*

  If a road carrying 400 to 1000 vehicles per day then it is said to be medium traffic road.

- **High Traffic Roads** *(Shown figure (1.3))*

  If a road is carrying is more than 1000 vehicles per day then it is considered as high traffic road.

![Figure 1. 1 Light traffic](image1)
![Figure 1. 2 Medium traffic](image2)
![Figure 1. 3 Heavy Traffic](image3)

Based on Rigidity

- **Flexible Pavement (Bituminous Road)**

  A flexible, or asphalt pavement typically consists of three or four layers. For a four layer flexible pavement, there is a surface course, base course, and subbase course constructed over a compacted, natural soil subgrade. When building a three layer flexible pavement, the subbase layer is not used and the base course is placed directly on the natural subgrade, *Shown figure (1.4).* *(The Constructor - Civil Engineering Home, 2019)*
With flexible pavement, the highest stress occurs at the surface and the stress decreases as the depth of the pavement increases. Therefore, the highest quality material needs to be used for the surface, while lower quality materials can be used as the depth of the pavement increases. The term "flexible" is used because of the asphalt's ability to bend and deform slightly, then return to its original position as each traffic load is applied and removed. It is possible for these small deformations to become permanent, which can lead to rutting in the wheel path over an extended time.

![Figure 1. 4 Bituminous Road](image)

- **Rigid Pavement (Concrete Road)**

  Rigid pavements are non-flexible and cement concrete roads are come under this category. A rigid pavement is constructed from cement concrete or reinforced concrete slabs. Grouted concrete roads are in the category of semi-rigid pavements. Shown figure (1.5)

  The design of rigid pavement is based on providing a structural cement concrete slab of sufficient strength to resist the loads from traffic. The rigid pavement has rigidity and high modulus of elasticity to distribute the load over a relatively wide area of soil. (Mishra, 2014)
1.4 Bituminous Roads

Bituminous roads are very popular roads around the world. They are most used roads in the world. They are low in cost and good for driving conditions. They are flexible and thickness of bituminous roads depends upon the subgrade soil conditions. (Kisunge, 2012)

There are three main layers of road. Shown figure(1.6)

1. Surface course
2. Base course
3. Subbase course
Surface course of roads are made with asphalt. Asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties and relatively low cost.

Asphalt is used in road construction due to various properties and advantages it has over other pavement construction materials. Asphalt gain certain unique properties that are inbuilt in it during its manufacture. The asphalt as a raw material in flexible road construction and asphalt as a mix of (aggregate and bitumen).

Bituminous materials consists of bitumen which is a black or dark coloured solid or viscous cementitious substances consists chiefly high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt, has adhesive properties, and is soluble in carbon disulphide. Tars are residues from the destructive distillation of organic substances such as coal, wood, or petroleum and are temperature sensitive than bitumen. Bitumen will be dissolved in petroleum oils where unlike tar.

Bitumen is a viscoelastic material which is derived from crude petroleum or from natural deposits; its chemical composition is complex, consisting mainly of carbon (80-88%) and hydrogen atoms (8-12%). Other elements, such as Sulphur (0-9%), oxygen (0-2%) and nitrogen (0-2%) may also be present, as well as traces of vanadium, nickel and manganese. (Lesueur, 2009).

1.5 Aggregate

Aggregate is a collective term for the mineral materials such as sand, gravel and crushed stone that are used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials (such as asphalt concrete and Portland cement concrete). By volume, aggregate generally accounts for 92 to 96 percent of HMA and about 70 to 80 percent of Portland cement concrete. Aggregate is also used for base and sub base courses for both flexible and rigid pavements.
Aggregates can either be natural or manufactured. Natural aggregates are generally extracted from larger rock formations through an open excavation (quarry). Extracted rock is typically reduced to usable sizes by mechanical crushing. Manufactured aggregate is often the byproduct of other manufacturing industries. Shown figure (1.7)

![Image of aggregate](image1)

**Figure 1. 7 Aggregate**

**Coarse Aggregate**

Those particles that are predominantly retained on the 4.75 mm (No. 4) sieve and will pass through 3-inch screen, are called Coarse Aggregates coarse aggregate. The coarser the aggregate, the more economical the mix. Shown figure (1.8)

![Image of coarse aggregate](image2)

**Figure 1. 8 Coarse aggregate**
Fine Aggregate

Those particles passing the 9.5 mm (3/8 in.) sieve, almost entirely passing the 4.75 mm (No. 4) sieve, and predominantly retained on the 75 µm (No. 200) sieve are called fine aggregate. The fine aggregate should have a rounded shape. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent. Shown figure (1.9)

![Fine Aggregate](image)

Figure 1. 9 Fine aggregate

1.6 Advantages of Bituminous Pavement

- **A smooth Ride Surface**

  It does not make use of any joints; Hence provide a smooth surface to ride. It also gives less sound emission when compared with concrete pavements. The wear and tear are less in the bituminous pavement, thus maintaining the smoothness. (The Constructor - Civil Engineering Home, 2019)

- **Gradual Failure**

  The deformation and the failure in the bituminous pavement is a gradual process. The concrete pavement shows brittle failures.
• **Quick Repair**

They have an option to be repaired to be quick. They don’t consume time in reverting the path for traffic; as they set fast.

• **Staged Construction**

This helps in carrying out staged construction in a situation when problems of fund constraint or traffic estimation problems are faced.

• **Life Cost is less**

The initial cost and overall maintenance cost of bituminous pavement are less compared to concrete pavement.

• **Temperature Resistant**

They act resistant against high temperature from melting and are not affected by de-icing materials.

1.7 **Disadvantages of Bituminous Pavement**

• Bituminous pavements are less durable. (The Constructor - Civil Engineering Home, 2019)

• Low tensile strength compared to concrete pavement.

• Extreme weather and improper weather conditions tend to make bituminous pavement slick and soft.

• Bitumen with impurities can cause pollution to soil, hence ground water by their melting. These may have hydrocarbons in small amounts.

• Clogging of pores and drainage path during construction and service life.

• More salting- to prevent snow during winter season.

• Cost of construction high during extreme conditions of temperature.
The most important layer of asphalt layers is its surface layer because it faces the most problems of road, like (deformation and cracking due to temperature changing, fatigue cracking, rutting, skidding, bleeding…ect). shown figure (1.10)

Because of that reason we decided to study on that layer, by adding admixture in asphalt of that layer, which is (crumb rubber), we get it from scrap tires.

As we know that there is a huge number of wasted tires per year in the world of course it has a bad effect on environment. And nowadays the recycling process is one of the most important factors of saving environment. We reuse that scrap tires as an admixture in our project.

Figure 1. 10 Rutting

Figure 1. 11 Bleeding
Figure 1. 12 Fatigue cracking

Figure 1. 13 Skidding
Chapter Two

Literature review

2.1 History of asphalt concrete

The story of asphalt begins thousands of years ago. Asphalt occurs naturally in both asphalt lakes and in rock asphalt (a mixture of sand, limestone and asphalt). (Reserved., 2019)

The ancient Mesopotamians used it to waterproof temple baths and water tanks. The Phoenicians caulked the seams of their merchant ships with asphalt. In the days of the Pharaohs, Egyptians used the material as mortar for rocks laid along the banks of the Nile to prevent erosion, and the infant Moses' basket was waterproofed with asphalt. Shown figure (2.1)

Figure 2.1 History of Asphalt Concrete in ancient time

In 625 B.C., the first recorded use of asphalt as a road-building material in Babylon. The ancient Greeks were also familiar with asphalt. The Romans used it to seal their baths, reservoirs and aqueducts.

In today’s world, the advancements made to the asphalt and concrete paving industry have completely changed how we construct our road systems. There are so many modern advancements in the construction equipment, tools, training, materials, methods, and much more. These advancements have delivered many advantages for society in terms of safety, reliability,
efficiency, longevity, and expediency. Asphalt is the most common paving material used in the United States today. It is highly versatile, low maintenance, long-lasting, and malleable, making it a top choice for all kinds of pavements. Driveways, parking lots, roads, interstates, highways, and more are common surfaces paved with asphalt.

### 2.2 Type of asphalt concrete

Asphalt concrete is extensively used to build roads. Asphalt concrete mainly contains asphalt which is used as a binder and some other aggregate of minerals. Asphalt layer is laid upon a base of gravel layer to construct a stiff and dependable road. Asphalt can be categorized into different categories depending on the laying temperature of the asphalt. Following are the types of Asphalt-Mix that are used in roads. (Asphalt Concrete, 2012)

1. **Hot-Mix Asphalt:**

   The Asphalt which is laid with its temperature over 300F is known as Hot Mix Asphalt. HMA or Hot-Mix Asphalt is made by heating of Asphalt to a very High Degree. The heating of asphalt causes the binder to loose its viscosity. (yilmaz, 2012) Shown figure (2.2)

![Figure 2. 2 Hot-Mix Asphalt](image)
2. Warm-Mix Asphalt:

The Asphalt that is applied at 200-250 F is called Warm Mix Asphalt. Warm-Mix Asphalt or WMA is made by addition of materials like waxes or zeolites or asphalt emulsions with asphalt- binder before mixing. Thus this process provides a more work friendly environment. Moreover, the laying temperature for warm-mix asphalt is also less compared to hot mix temperature. The lower laying temperature provides more flexibility to working schedules.shown figure (2.3)

![Figure 2.3 Warm-Mix Asphalt](image)

3. Cold-Mix Asphalt:

In rural areas the lower temperature Asphalt known as the Cold Mix Asphalt is used in these processes. Cold-Mix Asphalt or CMA is made by emulsifying asphalt in water with soap before mixing. However, it is not as durable as Hot-Mix Asphalt or Warm-Mix Asphalt. They are generally used in the roads where traffic volume is low and road is not used very regularly. Shown figure (2.4)

![Figure 2.4 Cold-Mix Asphalt](image)
4. Cut Back Asphalt:

It is another type of Asphalt concrete which is made by adding kerosene or other petroleum with the binder. However, use of such petroleum products causes a lot of pollution, therefore, they are generally not a preferred material for building roads. Shown figure (2.5)

![Figure 2.5 Cut back Asphalt](image)

5. Mastic-Asphalt:

It is made by heating bitumen until it turns enough viscous. Then it is added to the aggregate mix. Polymers or other additives may also be added to increase the quality of the final product. The mix is cooked for six to eight hours and then the whole mixture structure is taken to the site of work. The whole mixture is emptied on the site where road is supposed to be built. Then the mixture is laid carefully. Shown figure (2.6)

![Figure 2.6 Mastic Asphalt](image)
6. **Natural – Asphalt:**

It constitutes bituminous rocks and sometimes used in making roads. Shown figure (2.7)

![Natural Asphalt](image)

**Figure 2.7 Natural Asphalt**

### 2.3 Scrap Tire

Car tires are a major global waste problem. Collectively we drive 1.5 billion tires to the end of their useful lives every year (make wealth history, 2017)

Just in Britain there are more than 55 million wasted tires generate every year. In the USA than in Europe. In the USA, an estimated 300 million tires are disposed of annually, In Kuwait City's Sulaibiya area every year huge holes are dug out in the sandy earth and filled with old tires - there are now over seven million in the ground. (news, 2013). Shown figure (2.8)

![Scrap Tire](image)

**Figure 2.8 Scrap Tire**
2.4 Scrap tire effects on environment

The environmental pollution is one of the most famous problems in the universe. Preventing this pollution is the wide study cases and investigating topic. Increasing of the wastes are the main factors of the environmental pollution, our case of study in crumb rubber which is a part of tire waste. Shown in figure(2.9)

![Crumb rubber waste](image)

Figure 2.9 Crumb rubber waste

A real environmental problem with the disposal of used and waste tires. Solid scrap tires management has become one of the serious problems in environment due to unavailability of large number of disposal places, large space tire void occupies, in addition of fire and diseases hazard. Many research areas were trying to use the huge quantities of waste tires in asphalt mixes and in plastic and rubber manufacturing. (Zageer, 2016).

2.5 Use of waste tire in engineering field

We can get benefits of that huge amount of scrap tires by reusing them other fields like civil engineering. Crumb rubber from waste tires has been used in pavement construction since the 1930s. The usage has currently increased due the potential it offers in improving the performance of the asphaltic mixes and the potential solution in reducing waste tires in landfills. Rubber crumbs can be mixed with aggregates within the asphaltic mix (dry process).shown figure (2.10) or blended in bitumen at a specific temperature where rubber crumbs serve as a binder modifier (wet process).
Crumb rubber modification by the wet process has been shown to have the ability to help improve the rutting resistance, resilience modulus, and fatigue cracking resistance of asphaltic mixes. This is due to the alteration to the property of the bituminous binder in terms of the viscosity, softening point, (Mohd Rasdan Ibrahim, Herda Yati Katman, Mohamed Rehan Karim, Suhana Koting, Nuha S. Mashaan, 2013).

Rising energy and material costs and increase awareness of the problem of emissions in the production of modified asphalt mixture highlighted the potential benefits of the process of reducing the temperature of asphalt mixture preparation. In this connection, the properties of the asphalt are improving by additives. There are many additives used as asphalt mixes modifiers. Among of these additives the crumb rubber is often used with regards to environmental and material costs. The process of crumb rubber interaction with asphalt affects the composition of asphalt, type of rubber, rubber particle size, temperature, time and energy of mixing (Lucia Hrušková, Elena Hájeková, Pavol Daučík, 2016).
Chapter Three
Methodology

3.1 Bitumen

Bitumen is also familiar with the word of asphalt. It's a black, clinging, viscous and very adhesive fluid or semi-solid appearance of petroleum. In real it's an engineering material and is manufactured to provide a diversity of specification originated in physical properties. As well as bitumen is the remained outcome from distillation of crude oil in petroleum refining or purifying. It can be moreover handled impacting or blowing air through it at raised temperatures to change or vary its physical properties for commercial uses. Bitumen should not be confused with coal tar or coal-tar pitches. These are manufactured with high temperature pyrolysis 800°C) of bituminous coals and differ from bitumen substantially in composition and physical characteristics. The specialty of bitumen depends on the properties of the remainder from which the bitumen is produced. (D6114, 2009)

Properties of bitumen depend on construction and the mix type. In general, bitumen should have the following desirable properties. The bitumen should not be extremely high temperature susceptible: During the hot weather the mix should not soften much or become unstable and during cold weather the mix should not brittle much in order not to cause cracks

The viscosity of the bitumen should be adequate especially at the time of mixing compaction. There should be sufficient affinity and coherence between the and bitumen and aggregates.
3.1.1 Bitumen Test

3.1.1.1 Penetration Test

Penetration is the vertical distance, which a standard needle (5cm length and 0.1cm diameter) can penetrate through asphalt under a standard situation of:

1. Load of 100 gm.
2. Temperature of 25 °C.
3. For 5 seconds.

Through the penetration value we can classify the asphalt to different grades according to ASTM. e.g. G(30-40, or 50-70, 80-100……..180-200) the higher numbers or values means more flexible asphalt. (https://civilengineerspk.com/, 2012)

Test Signfication:

1. To know the hardness of the asphalt.
2. To select the proper asphalts in fit to the work locations. Hard asphalts is suitable for warm locations.

Apparatus:

1. Penetration instrument.
2. Container has 5.5cm diameter and 3.5cm depth.
3. Transfer dish.
5. Cleveland cup.
Accuracy:

Table 3-1 The difference between three readings for each sample should be not more than

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<th>50-149</th>
<th>150-249</th>
<th>250 and more</th>
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<tbody>
<tr>
<td>Accuracy</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>

Procedure:

1. Heating asphalt to (75 – 100) °C.
2. Mix the asphalt during the heating continuously for getting a uniform and un air voids asphalt.
3. Put the container on a horizontal layer and fill it with asphalt. Shown figure (3.1.2)
4. Cooling the sample in air for (1) hr. at 18 °C.
5. Submerging the sample in 25 °C water bath for an other (1) hr.
6. Transfer the sample to the penetration test instrument and keep the needle to be in touch to the asphalt surface.
7. Start testing and take the first reading after 5 seconds.
8. Repeat the testing two times for the same sample in other location of the same sample surface not close less than (1) cm from the first test location after cleaning the needle with benzene.
9. The average of three readings within the accuracy mentioned before is the penetration value.

Figure 3.1 Container filled with bitumen for penetration test
3.1.1.2 Ductility Test

Ductility is the asphalt characteristic for ability to the elongation when it was pulling in both ends. This will provide an idea about the asphalt stability and capability to resist the external efforts. AASHTO prefer for desirable asphalts the ductility of (50 – 100) cm.

Test Signification:

1. To know the ductility of the asphalt.
2. Higher values of ductility means asphalts with higher degree of temperature susceptibility.
3. Higher values of ductility provides better bonds and resisting the impact forces.

Apparatus:

1. Ductility test instrument.
2. Electrical motor can move 5cm/min.
3. Sample form consist of base plate and four pieces from brass. Shown figure (3.3)
4. The sample cross section is (1) cm$^2$ at the midpoint.
5. Cleveland cup.
Procedure:

1. Heating asphalt to (75 – 100) °C with mixing.
2. Put the sample form on a horizontal layer and fill it with asphalt after oiling it.
3. Cooling the sample in air for (30-40) min.
4. Submerging the sample in 25 °C water bath for (30) min.
5. Cut the access asphalt from the top surface of the sample.
6. Repeat the step (4) above for another (95) min.
7. Fix the sample in the instrument for testing and remove the form. Shown figure (3.4)
8. The sample should be surrounded with water by (10)cms at 25 °C.
9. Start the machine and keep watching the asphalt elongation until cutting.
10. Write down the amount of elongation in (cm). Shown figure (3.5)
3.1.1.3 Softening Point Test

Softening point: is that degree of temperature in which the asphalt will start to change from solid to liquid state under specific situation.

**Test Signification:**

1. It will give a significant indicator regarding the temperature susceptibility, higher softening point means lower temperature susceptible asphalt.
2. To determine the capability of asphalt for maintaining the roads in filling or repairing cracks.

**Apparatus:**

1. Softening point test instrument. Ring and ball complex consist of two rings, two ball guides and two steel balls with diameter of (9.5) mm, weight is (3.5) gm. for each. Shown figure (3.6)
2. Oiled glass.
3. Heater.
4. Cleveland cup, gloves, tongues and thermometer.
Accuracy:

1. For softening higher than (80) °C Glysine will be sued instead of water. And for more than 195 °C Ethylene glycol will be replaced.
2. The difference between the two readings is not more than (1) °C.
3. The distance between the container bottom and the holder frame should not pass (20) mm.

Procedure:

1. Heating asphalt to (75 – 100) °C.
2. Mix the asphalt during the heating continuously for getting a uniform asphalt.
3. Put the oiled glass on a horizontal layer and fill the two heated rings with asphalt on it.
4. Cooling the sample in air for (1/2) hr. and cut the access asphalt by knives.
5. Collect the test instruments all together and put it in water of (5) °C for 15 minutes.
6. Put the two balls on their places on the samples.
7. Start heating the water in rate of (5) °C /min.
8. The asphalt with the two balls will start down ward to touch the frame base.
9. Write down the two temperatures of the two balls when touch the base of the frame.
10. The softening point is the average of the two temperature readings. Shown figure (3.7)
3.1.1.4 Flash and Fire Point Test

Flash point: is that point of temperature at which the asphalt will flash for one second under specific situation. Shown Figure (3.9)

Fire point: is minimum point of temperature at which the asphalt will fire (burn) for five seconds under specific situation. Shown figure (3.10)
**Test Signification:**

1. To find out the type and quantities for the availability of undesirable materials in the asphalt.
2. To find the safe point of heating the asphalt during the construction process (to protect asphalt from burning). Shown Figure( 3.8)

**Difference between Flash and Fire Points:**

<table>
<thead>
<tr>
<th>FLASH TEMPERATURE POINT</th>
<th>FIRE TEMPERATURE POINT</th>
</tr>
</thead>
<tbody>
<tr>
<td>After this point the asphalt can be used.</td>
<td>After this point the asphalt cannot be used.</td>
</tr>
<tr>
<td>Asphalt will be cleaned from undesirable materials.</td>
<td>Asphalt will be burned.</td>
</tr>
<tr>
<td>It will happen in lower temperatures and for one second.</td>
<td>It will happen in higher temperatures and for five seconds.</td>
</tr>
</tbody>
</table>

**Apparatus:**

1. Flash and fire test instrument.
2. Flame.
3. Cleveland cup, gloves, tongues and thermometers

**Accuracy:**

The difference between three readings for Flash Point should be not more than 3 °C and for Fire Point not more than 6 °C.

**Table 3-3 Spesification for Fire Point**

<table>
<thead>
<tr>
<th>ASPHALT GRADE</th>
<th>from 40-100</th>
<th>From 120-180</th>
<th>From 200 and more</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRE POINT °C</td>
<td>232</td>
<td>219</td>
<td>177</td>
</tr>
</tbody>
</table>
Procedure:

1. Heating asphalt above the softening point to able it to fill the test cup.
2. Fix the thermometer inside the sample. (don’t touch the cup bottom)
3. Start the test heater to heat in a rate of (5-6) °C/min.
4. Before the expected Flash point by about (28 °C) start to close the flame from the samples surface each (1 °C) until (104 °C).
5. Continue with step (4) after (104 °C) but in intervals of each (3 °C)
6. Compute the flash and fire points when they happened.
3.1.1.6 Specific Gravity of Asphalt Test

This test is to determine the specific gravity of semi-solid bitumen. The principle is that it is the ratio of mass of a given volume of bitumen to the mass of an equal volume of water, both taken at a recorded/specified temperature. This can be done either by balance or by using picnometer.

![Specific Gravity Bottles](image)

**Figure 3.11 Specific Gravity Test**

**Test Signification:**

1. To measure the quantities of materials in the Job Mix Formula (JMF).
2. To classify the materials according to the Sp.Gr..
3. To find the foreign material

**Apparatus:**

The apparatus needed to determine specific gravity of bitumen is

1. Specific gravity bottles of 25 ml capacity. Shown Figure(3.11)
2. Water bath with thermometer.

**Procedure:**

1. Heating asphalt to (75 – 100) °C.
2. Mix the asphalt during the heating continuously for getting a uniform and un air voids asphalt.
3. Cleaning the picnometer and weight it = (a) gm.
4. Fill the picnometer with pure water at 25 °C and weight it = (b) gm.
5. Fill half of the picnometer with asphalt then cool it for half hour in water at 25⁰C and weight it = (c) gm.
6. Fill the rest space remain from the picnometer in step (5) with water at 25⁰C and weight it = (d) gm.

**Calculation:**

\[
\text{Sp. gr.} = \frac{\text{Weight of the substance}}{\text{Weight of an equal volume of water}}
\]

Or

\[
\text{Sp. gr.} = \frac{\text{density of the substance}}{\text{Density of water}}
\]
3.2 Aggregate

Aggregate is a collaborated term for the mineral materials such as sand, gravel and crushed stone in which they are used with a binding medium (such as water, bitumen, Portland Cement, lime, etc.) in order to form compound materials (such as Asphalt Concrete and Portland Cement Concrete). Aggregates can either be natural or manufactured. Natural aggregates are generally extracted from larger rock formations through an open excavation (quarry). Extracted rock is typically reduced to usable sizes by mechanical crushing. Manufactured aggregate is often the byproduct of other manufacturing industries. Shown Figure (3.12)

![Different sizes of Aggregate](image)

Figure 3.12 Different sizes of Aggregate
3.2.1 Aggregate Test

3.2.1.1 Sieve Analysis Test

The sieve analysis, commonly known as the gradation test, is a basic essential test for all aggregate technicians. The Sieve analysis determines the gradation (the distribution of aggregate particles, by size, within a given sample) in order to determine compliance with design, production control requirements, and verification specifications. The gradation data may be used to calculate relationships between various aggregate or aggregate blends, to check compliance with such blends, and to predict trends during production by plotting gradation curves graphically, to name just a few uses. Used in conjunction with other tests, the sieve analysis is a very good quality control and quality acceptance tool. (TXDOT DESIGNATION, 2016)

![Figure 3. 13 Sieve Sets](image1)

![Figure 3. 14 Aggregate used in this study](image2)
Objective

To determine the particle size distribution of the coarse and fine aggregates, Shown Figure (3.14)

Apparatus

1. A set of is sieves Shown Figure (3.13)
2. Balance or sale with an accuracy to measure 0.1 percent of the weight of the test sample
3. Mechanical sieve shaker (optional)

Materials

1. Coarse aggregate
2. Fine aggregate

Procedure

1. The test sample is dried to a constant weight at a temperature of (110 to 150 °C) and weighed
2. The sample is sieved by using a set of is seves.
3. On completion of sieving, the material on each sieve is weighed
4. Cumulative weight passing through each sieve is calculated as a percentage of the total sample weight.
3.2.1.2 Los Angeles Abrasion Test

Abrasion value is the percentage of aggregate weights that passing sieve (No. 12 = 1.7mm) after application of standard abrasion by mechanical rotation parallel with standard iron balls for a dry aggregate Shown Figure( 3. 15).

Test Signification:

1. To choose the best type of aggregate due to abrasion value.
2. To calculate the hardness of aggregates.

Apparatus:

1. Los Angeles equipment consisting a cylindrical barrel diameter is (70)cm and height is (50)cm, handled on an horizontal axes can be rotate around this axes with a speed of (30-33) RPM.
2. Balance.
3. Sieves of No. 12, 12.5 mm and 10mm.
4. Iron or metallic balls (11) numbers, diameter is (4.8)mm and weight of each is (445)gm.
5. Oven.

Accuracy and specification:

1. For high quality projects it should be less than (30)%.
2. For normal and low quality projects it should not pass (50)%.
Procedure:

1. Put about (1000) gm is \( W_1 \) of the aggregate in the oven for drying.

2. Open the los Angeles equipment and put the dried aggregate sample with the (11) balls in it and close it again. Shown Figure( 3.16)

3. Rotate the barrel for (500) times.

4. Take out the total sample and sieve it on sieve No. 12.

5. Take the weight of passed material through sieve No. 12. and it is \( W_2 \).

![Los Angeles Abrasion balls](image)

Figure 3.16 Los Angeles Abrasion balls

3.2.1.3 Specific gravity test of fine aggregate

Specific gravity of fine aggregate (sand) is the ratio of the weight of given volume of aggregates to the weight of equal volume of water. The specific gravity of sands is considered to be around 2.65.

Apparatus for Specific Gravity Test

1. A balance of capacity not less than 3 kg, readable and accurate to 0.5 gm and of such a type as to permit the weighing of the vessel containing the aggregate and water.

2. A well ventilated oven to maintain a temperature of 100ºC to 110ºC
3. Pycnometer of about 1 litre capacity having a metal conical screw top with a 6 mm hole at its apex. The screw top shall be water tight. Shown Figure( 3. 17)

4. A means supplying a current warm air.

5. A tray of area not less than 32cm².

6. An airtight container large enough to take the sample.

7. Filter papers and funnel.

Figure 3. 17 Standard Pycnometer

Procedure :

1. Take about 500g of sample and place it in the pycnometer.
2. Pour distilled water into it until it is full.
3. Eliminate the entrapped air by rotating the pycnometer on its side, the hole in the apex of the cone being covered with a finger.
4. Wipe out the outer surface of pycnometer and weigh it (W).
5. Transfer the contents of the pycnometer into a tray, care being taken to ensure that all the aggregate is transferred.
6. Refill the pycnometer with distilled water to the same level.
7. Find out the weight (W₁).
8. Drain water from the sample through a filter paper.
9. Place the sample in oven in a tray at a temperature of 100°C to 110° C for 24±0.5 hours, during which period, it is stirred occasionally to facilitate drying.
10. Cool the sample and weigh it (W₂).
Calculations:

Apparent specific gravity = \( \frac{\text{Weight of dry sample}}{\text{Weight of equal volume of water}} \)
= \( \frac{W_2}{W_2 - (W - W_2)} \)

3.2.1.4 Specific Gravity Test of Coarse Aggregate

Specific gravity test of aggregates is done to measure the strength or quality of the material while the main objective of these test is; Shown Figure(3.18)

To measure the strength or quality of the material.

To determine the water absorption of aggregates.

![Figure 3.18 Coarse Aggregate](image)

Specific Gravity is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. It is the measure of strength or quality of the specific material. Aggregates having low specific gravity are generally weaker than those with higher specific gravity values.
**Procedure of Water Absorption and Specific Gravity Test on Aggregates**

There are three methods of testing for the determination of the specific gravity of aggregates, according to the size of the aggregates larger than 10 mm, 40 mm and smaller than 10 mm. For samples larger than 10 mm, 40 mm, the below given test method is used and for samples smaller than 10 mm Pycnometer test is done. Water absorption test determines the water holding capacity of the coarse and fine aggregates.

**Apparatus Required**

1. A balance of capacity about 3 kg, to weigh accurate 0.5 g, and of such a type and shape as to permit weighing of the sample container when suspended in water.
2. A thermostatically controlled oven to maintain temperature at 100-110° C.
3. A wire basket of not more than 6.3 mm mesh or a perforated container of convenient size with thin wire hangers for suspending it from the balance.
4. A container for filling water and suspending the basket
5. An air tight container of capacity similar to that of the basket
6. A shallow tray and two absorbent clothes, each not less than 75x45cm.

**Procedure**

1. About 2 kg of aggregate sample is washed thoroughly to remove fines, drained and placed in wire basket and immersed in distilled water at a temperature between 22 - 32° C and a cover of at least 5 cm of water above the top of basket.
2. Immediately after immersion the entrapped air is removed from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop at the rate of about one drop per second. The basket and aggregate should remain completely immersed in water for a period of 24 hour afterwards.
3. The basket and the sample are weighed while suspended in water at a temperature of 22° – 32°C. The weight while suspended in water is noted = \( W_1 \) g.
4. The basket and aggregates are removed from water and allowed to drain for a few minutes, after which the aggregates are transferred to the dry absorbent clothes. The empty basket is then returned to the tank of water jolted 25 times and weighed in water = \( W_2 \) g.
5. The aggregates placed on the absorbent clothes are surface dried till no further moisture could be removed by this cloth. Then the aggregates are transferred to the second dry cloth spread in single layer and allowed to dry for at least 10 minutes until the aggregates are completely surface dry. The surface dried aggregate is then weighed $= W_3 \, g$.

6. The aggregate is placed in a shallow tray and kept in an oven maintained at a temperature of 110° C for 24 hrs. It is then removed from the oven, cooled in an air tight container and weighted $= W_4 \, g$.

**Observations of Test**

- Weight of saturated aggregate suspended in water with basket $= W_1 \, g$
- Weight of basket suspended in water $= W_2 \, g$
- Weight of saturated surface dry aggregate in air $= W_3 \, g$
- Weight of oven dry aggregate $= W_4 \, g$
- Weight of saturated aggregate in water $= W_1 - W_2 \, g$
- Weight of water equal to the volume of the aggregate $= W_3 - (W_1 - W_2) \, g$

**Formulas:**

a. Specific gravity $= W_3 / (W_3 - (W_1 - W_2))$

b. Apparent specific gravity $= W_4 / (W_4 - (W_1 - W_2))$

c. Water Absorption $= ((W_3 - W_4) / W_4) \times 100$

**The size of the aggregate and whether it has been artificially heated should be indicated.**

**Though high specific gravity is considered as an indication of high strength, it is not possible to judge the suitability of a sample aggregate without finding the mechanical properties such as aggregate crushing, impact and abrasion values.**
3.2.1.5 Flakiness test

The type of rocks and the type of crushing machine highly determine the shape and size of the aggregates produced. Elongated and flaky stones are normally not very suitable for road works since the shape and the size make them difficult to compact. As such the flakiness and elongation test must be carried out to determine the suitability of the material Shown Figure(3.19)

To determine the flakiness Index of a given aggregates sample.

![Flakiness Index apparatus](image)

**Figure 3. 19 Flakiness Index apparatus**

**Apparatus:**

The apparatus consists of a standard thickness gauge, I.S. sieves of sizes 63, 50, 40, 31.5, 25, 20, 16, 12.5, 10 and 6.3 mm.

Balance to weigh the samples.

**Flakiness Index:**

The flakiness index of aggregates is the percentage by particles whose least dimension (thickness) is less than 3/5th (0.6) of their mean dimension. The test is not applicable to sizes smaller than 6.3 mm.
procedure:

1. The sample is sieved with the sieves mentioned in the table.
2. A minimum of 200 pieces of each fraction to be tested are taken and weighed (w1 gm).
3. In order to separate flaky materials, each fraction is then gauged for thickness on thickness gauge, or in bulk on sieve having elongated slots as specified in the table.
4. Then the amount of flaky material passing the gauge is weighed to an accuracy of at least 0.1% of test sample.
5. Let the weight of the flaky materials passing the gauge be w1 gm. Similarly the weights of the fractions passing and retained on the specified sieves be w1, w2, w3, etc. are weighed and the total weight w1+w2+w3+........ = w gm is found.
6. Also the weights of the materials passing each of the specified thickness gauges are found = W1, W2, W3... and the total weight of the material passing the different thickness gauges = W1+W2+W3+........ = W gm is found.
7. Then the flakiness index is the total weight of the flaky material passing the various thickness gauges expressed as a percentage of the total weight of the sample gauged.
3.3 Marshall Mix design

This test procedure is used in designing and evaluating bituminous paving mixes and is extensively used in routine test programmers for the paving jobs.

There are two major features of the Marshall method of designing mixes namely, density -voids analysis and stability - flow test.

Strength is measured in terms of the 'Marshall's Stability of the mix following the specification ASTM D 1559 (2004), which is defined as the maximum load carried by a compacted specimen at a standard test temperature of 60 °C. In this test compressive loading was applied on the specimen at the rate of 50.8 mm/min till it was broken. The temperature 60 °C represents the weakest condition for a bituminous pavement. (ASTM D 1559, (2004).)

The flexibility is measured in terms of the flow value which is measured by the change in diameter of the sample in the direction of load application between the start of loading and at the time of maximum load. During the loading, an attached dial gauge measures the specimen's plastic flow (deformation) due to the loading. The associated plastic flow of specimen at material failure is called flow value. The density-voids analysis is done using the volumetric properties of the mix, which will be described in the following sub sections. (BOMBAY, 2009)

3.3.1 Marshall Stability and Flow Test

The purpose of this test is to determine;

1. The all Marshall Test characteristics such as: Stability, Flow Value, Air Void Ratio, VMA, Specific Gravity and VFA.
2. The Optimum Binder Content for a specified aggregate blend and asphalt to be used.

One of the most widely used methods of bituminous mix design is the Marshall method developed by Bruce Marshall& the U.S. Corps of Engineers. Stability and flow, together with
density, voids and percentage of voids filled with binder are determined at varying binder contents to determine an 'optimum' for stability, durability, flexibility, etc

To measure the resistance to plastic flow of cylindrical specimens of a bituminous paving mixture loaded on the lateral surface by means of the Marshall Apparatus. Experience has shown that the results of Marshall Tests can be excellent guidelines to use when determining the optimum asphalt content for a given mix.

There are two major features of the Marshall method of mix design:

1. Density - Voids analysis
2. Stability - Flow tests

The Marshall Stability of the mix is defined as the maximum load carried by the specimen at a standard test temperature of 60°C. Strength is measured in terms of the "Marshall's Stability" of the mix following the specification ASTM D 1559.

The Flow value is the deformation that the test specimen undergoes during loading up to the maximum load, it is measured in 0.25 mm units. The flexibility is measured in terms of the "low value". The associated plastic flow of specimen at material failure is called flow value.

Definitions

It is essentially an unconfined compression test in which a cylindrical specimen is compressed in a special cylindrical test - head, with a constant rate of 50.8 mm/min.

This test is used for with mixtures containing asphalt cement; asphalt cut - back or tar and aggregate up to 25.4 mm maximum.

Main principles

1. The binder content is varied in steps of typically 0.5 % around an assumed optimum binder content.
2. The binder content is determined which best complies with Marshall stability, flow, void content, voids filled with binder and density requirements for the mix being investigated
Apparatus

1. Specimen mold 101.6 mm diameter and 76.2 mm height with extension collar and base plate, see Figure (3.20).

![Figure 3. 20 Marshall molds](image)

2. Specimen extractor

3. Compaction hammer 4.536 kg weight, 457.2 mm drop, see figure (3.21)

![Figure 3. 21 Compaction hammer and sample](image)

4. Specimen mold holder
5. Breaking head
6. Ring dynamometer assembly
7. Flow meter
8. Oven or hot plate
9. Mixing bowls
10. Water bath
11. Water tank balance,
12. Thermometers
13. Miscellaneous apparatus, see Figure (3.22)

Figure 3. 22 Marshall apparatus

**Steps of Marshall Mix Design**

1. Select aggregate grading to be used.
2. Determine the proportion of each aggregate size required to produce the design grading.
3. Determine the specific gravity of the aggregate combination and bitumen.
4. Prepare the trial specimens with varying asphalt contents.
5. Determine the specific gravity of each compacted specimen.
6. Perform stability tests on the specimens.
7. Calculate the percentage of voids and percent voids filled with bitumen in each specimen.
9. Select the optimum binder content from the data obtained.
10. Evaluate the design with the design requirements

**Procedure and Preparation of Marshall Specimens**

1. The dimension and specifications of the Marshall apparatus are written in ASTM D1559. The diameter of the specimen is 101.6 mm and nominal thickness 63.5 mm. Taken from ASTM D1559. 1. Placing mold, hammer, mixing dish, mixer head and temping rod in oven for 24 hours.
2. Approximately 1150 gr of aggregate containing coarse and fine placed in oven heated at a temperature 170 °C for 24 hours.
3. Bitumen is placed in oven and heated to a temperature 160 °C for 2 2 hours before starting the experiment.
4. Starting the test by adding the bitumen to aggregate, here the Optimum Binder Content assumed to be OBC 4.8 %. See figure(3.23)

![Figure 3.23 Adding Bitumen to Aggregate](image)

5. Mixing the bitumen with aggregate by mixer, for 1 % minutes then fill preheated molds in each pouring tamp it with tamping rod so the surface will be straight or leveled. See figure(3.24,25)
6. Take the mold and place it under compacting machine with 75 blows on each sides of specimen at compaction temperature (145-150) °C. See Figure (3.26)
7. Repeat these steps above by varying the bitumen content in each trial by +0.5%.
8. The molds left to cool at room temperature for 3 hours before removing the mold.
9. Take the specimen out of mold by extruder, in each specimen take the average of three heights then weigh it in air and water.
10. Test specimens, prepared according to the standard are immersed in a water bath, for 30 - 40 minutes at temperature of 60 °C. The testing heads and guide rods are thoroughly cleaned, guide rods lubricated and head maintained.
11. The specimens are removed from the water bath and placed between the lower jaw and the upper jaw of the specimen holder of Marshall testing machine. The complete assembly is then placed in the compression testing machine and the flow meter adjusted to zero.
12. The load is applied to the specimen at a constant strain rate of 50.8 mm/min until the maximum load is reached. The maximum force (called stability) and flow at that force are read and recorded. The maximum time allowed between removal of the specimen from the water bath and maximum load is 30 second.
Calculations Required

Determining the properties (Volumetric) of mix include:

A. Theoretical specific gravity \( (G_t) \)
B. Bulk specific gravity \( (G_{mb}) \)
C. Percentage of air voids \( (V_a) \)
D. Percentage volume of bitumen \( (V_b) \)
E. Percentage voids in mineral aggregate \( (VMA) \)
F. Percentage voids filled with asphalt \( (VFA) \)

A. Theoretical Specific Gravity \( (G_t) \)

\[
G_t = \frac{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_b}{G_b}}{W_1 + W_2 + W_3 + W_b}
\]

Where:

\( W_1 \): Weight of coarse aggregate in total mix
\( W_2 \): Weight of fine aggregate in total mix
\( W_3 \): Weight of filler in total mix
\( W_b \): Weight of bitumen in total mix
\( G_1 \): Apparent specific gravity of coarse aggregate
\( G_2 \): Apparent specific gravity of fine aggregate
\( G_3 \): Apparent specific gravity of filler
\( G_b \): Apparent specific gravity of bitumen
B. Bulk specific gravity \((G_m)\)

\[
G_m = \frac{W_m}{W_m - W_w}
\]

Where:
- \(W_m\): Weight of mix in air
- \(W_w\): Weight of mix in water

C. Percentage of Air Voids \((\% V_a)\)

\[
V_v = \frac{(G_t - G_m)100}{G_t}
\]

Where:
- \(G_t\): Theoretical specific gravity of mix,
- \(G_m\): Actual or bulk specific gravity,

D. Percentage volume of bitumen \((\% V_b)\)

\[
V_b = \frac{W_b}{\frac{G_b}{W_1 + W_2 + W_3 + W_b} G_m}
\]

Where:
- \(W_1\): Weight of coarse aggregate in total mix
- \(W_2\): Weight of fine aggregate in total mix
**E. Percentage voids in mineral aggregate ( % VMA )**

\[ V_{MA} = V_a + V_b \]

Where:
- \( V_a \) : Percentage of air voids
- \( V_b \) : Percentage volume of bitumen

**F. Percentage voids filled with asphalt ( % VFA) **

\[ V_{FB} = \frac{V_b \times 100}{V_{MA}} \]

Where:
- \( V_b \) : Percentage volume of bitumen
- \( VMA \) : Percentage voids in mineral aggregate
Chapter Four

Calculations

4.1 Aggregate Test

There are four main types of aggregate in this project, which are (coarse aggregate, crush sand, fine aggregate, and filler).

For each of them there are its own sieving from sieve 19.5mm to 0.075mm. shown in table (4.1).

Then by taking 9% of coarse aggregate , 38% of crush sand , 50% of fine aggregate and 3% of the filler, we will get a mix of aggregate with different sizes and properties with their own weights. (AASHTO Designation, 2018)

Table 4- 1 Aggregate gradation for surface course according to AASHTO T 11 & 27

<table>
<thead>
<tr>
<th>sieve</th>
<th>Coarse aggregate 9%</th>
<th>Crush sand 38%</th>
<th>Fine aggregate 50%</th>
<th>Filler 3%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>passing % retained %</td>
<td>passing % retained %</td>
<td>passing % retained %</td>
<td>passing % retained %</td>
</tr>
<tr>
<td>19.5</td>
<td>100 0</td>
<td>100 0</td>
<td>100 0</td>
<td>100 0</td>
</tr>
<tr>
<td>12.5</td>
<td>27.6 72.4</td>
<td>100 0</td>
<td>100 0</td>
<td>100 0</td>
</tr>
<tr>
<td>9.5</td>
<td>1.3 26.3</td>
<td>100 0</td>
<td>76 24</td>
<td>100 0</td>
</tr>
<tr>
<td>4.75</td>
<td>0.3 1</td>
<td>93.5 6.5</td>
<td>6.6 69.4</td>
<td>100 0</td>
</tr>
<tr>
<td>2.36</td>
<td>0 0.3</td>
<td>66.8 26.7</td>
<td>1 5.6</td>
<td>100 0</td>
</tr>
<tr>
<td>0.3</td>
<td>0 0</td>
<td>19.4 47.4</td>
<td>0 1</td>
<td>100 0</td>
</tr>
<tr>
<td>0.075</td>
<td>0 0</td>
<td>7.5 11.9</td>
<td>0 0</td>
<td>95.5 4.5</td>
</tr>
<tr>
<td>pan</td>
<td>0 0</td>
<td>0 7.5</td>
<td>0 0</td>
<td>0 95.5</td>
</tr>
</tbody>
</table>
Table 4-2 Physical Properties of Aggregate used in this study

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Specific gravity</th>
<th>Absorption</th>
<th>Apparent specific gravity</th>
<th>Los angeles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse</td>
<td>2.654</td>
<td>0.8</td>
<td>2.714</td>
<td></td>
</tr>
<tr>
<td>Fine</td>
<td>2.649</td>
<td>0.9</td>
<td>2.711</td>
<td>19</td>
</tr>
<tr>
<td>Crushed sand</td>
<td>2.602</td>
<td>0.6</td>
<td>2.644</td>
<td></td>
</tr>
<tr>
<td>Filler</td>
<td>2.721</td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>

Bulk specific gravity, Apprant specific gravity, Absorption, according to (ASTM C-127 & 128) (ASTM C-127 & 128, 2004)

Los Angeles according to (AASHTO T – 96)

4.2 Bitumen Test

Table 4-3 Result of Bitumen Test

<table>
<thead>
<tr>
<th>Tests</th>
<th>Results</th>
<th>Limits</th>
<th>Standards (ASTM, 2004)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ductility</td>
<td>150cm</td>
<td>&gt;100</td>
<td>ASTM D113-99</td>
</tr>
<tr>
<td>Softening point</td>
<td>52</td>
<td>51-62</td>
<td>ASTM D36-06</td>
</tr>
<tr>
<td>Penetration</td>
<td>46</td>
<td>40-50</td>
<td>ASTM D5-05a</td>
</tr>
<tr>
<td>Flash</td>
<td>281</td>
<td>&gt;232</td>
<td>ASTM D92-05a</td>
</tr>
<tr>
<td>Fire</td>
<td>287</td>
<td></td>
<td>ASTM D92-05a</td>
</tr>
</tbody>
</table>
4.3 Marshall Stability and Flow Test

4.3.1 Finding optimum binder content (OBC)

- Total weight of each sample = 1150 gm
- Bitumen content (BC)% = (4 -6)% , 0.5 increment Value ,2 replicates
- No. of Blows = 75 blows for heavy traffic
- Heating temp.before starting the test = 170°C
- Compacting temp = (150 – 160)°C
- Tem.of water Bath = 60°C
- Total 25 specimens of marshall

<table>
<thead>
<tr>
<th>Traffic Property</th>
<th>Light</th>
<th>Medium</th>
<th>Heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Blows / side</td>
<td>35</td>
<td>50</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>Stability N - (Ib)</td>
<td>3333-(750)</td>
<td>5333-(1200)</td>
<td>8000-(1800)</td>
</tr>
<tr>
<td>Flow 0.25mm - (001 in.)</td>
<td>18</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Air Voids, Va %</td>
<td>5</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>VFA %</td>
<td>75</td>
<td>65</td>
<td>78</td>
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</tbody>
</table>
### Table 4-5 Requirement for VMA

<table>
<thead>
<tr>
<th>Nominal Max. Aggregate Size</th>
<th>Min. Requirement VMA, %</th>
<th>Va, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2.36mm</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>4.75mm</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>9.5mm</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>12.5mm</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>19mm</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>25mm</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>37.5mm</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>50mm</td>
<td>9.5</td>
<td>10.5</td>
</tr>
<tr>
<td>63mm</td>
<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>

### Table 4-6 Determination of OBC results

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>2.313</td>
<td>2.309</td>
<td>8.2</td>
<td>15.7</td>
<td>2.5</td>
<td>2.5</td>
<td>1204</td>
<td>1274</td>
</tr>
<tr>
<td>2</td>
<td>4.5</td>
<td>2.31</td>
<td>2.306</td>
<td>2.3</td>
<td>2.3</td>
<td>2.4</td>
<td>2.5</td>
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<td>1309</td>
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<td>4.5</td>
<td>2.335</td>
<td>2.328</td>
<td>5.7</td>
<td>15.5</td>
<td>2.2</td>
<td>2.3</td>
<td>1440</td>
<td>1431</td>
</tr>
<tr>
<td>1</td>
<td>5.0</td>
<td>2.334</td>
<td>2.333</td>
<td>3.4</td>
<td>15.7</td>
<td>2.9</td>
<td>2.9</td>
<td>1379</td>
<td>1411</td>
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<tr>
<td>2</td>
<td>5.0</td>
<td>2.338</td>
<td>2.333</td>
<td>3.4</td>
<td>15.7</td>
<td>2.8</td>
<td>3</td>
<td>1440</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>5.0</td>
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<td></td>
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<td></td>
<td>1440</td>
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</tr>
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<td>5.5</td>
<td>2.307</td>
<td>2.305</td>
<td>3.3</td>
<td>17.2</td>
<td>2.9</td>
<td>2.9</td>
<td>1304</td>
<td>1271</td>
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<tr>
<td>2</td>
<td>5.5</td>
<td>2.302</td>
<td>2.305</td>
<td>3.3</td>
<td>17.2</td>
<td>3</td>
<td>3</td>
<td>1254</td>
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<tr>
<td>3</td>
<td>5.5</td>
<td>2.306</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1254</td>
<td></td>
</tr>
<tr>
<td>1</td>
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<td>2.282</td>
<td>2.281</td>
<td>2.5</td>
<td>18.5</td>
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<td>3.4</td>
<td>1007</td>
<td>1055</td>
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<td>6</td>
<td>2.275</td>
<td>2.281</td>
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<td>3.3</td>
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<td></td>
<td></td>
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<td></td>
<td>1055</td>
<td></td>
</tr>
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</table>
Figure 4.1 Air Voids & Bitumen Content

Figure 4.2 Marshall Stability & Bitumen Content
Figure 4.3 Flow & Bitumen Content

Figure 4.4 Specific Gravity & Bitumen Content
By using the graphs of (density, stability, AV) OBC can be found.

From the graph of density we will take the maximum density value (peak point) and by reading the bitumen content we will get first value. From the stability graph by taking the maximum value and reading the bitumen content we will get the second value. And in AV graph take 4% of air void and extend to the curve, when the line touches the curve read the bitumen content, and get the third value. Finally by taking average of these three points we will get optimum binder content.

The bitumen content of maximum density = 4.9%

The bitumen content of maximum stability = 4.7%

The bitumen content of 4% of air void = 4.8%

\[ \text{OBC} = \frac{4.9 + 4.7 + 4.8}{3} = 4.8\% \]
4.3.2 Finding Optimum CR Content.

- Total weight of each sample = 1150 gm.
- Bitumen content (BC)\% = (4-6)\% , 0.5 increment Value ,2 replicates
- No. of Blows = 75 blows for heavy traffic
- Heating temp. before starting the test = 170 °C
- Compacting temp = (150 – 160) °C
- Tem.of water Bath = 60 °C
- Total 16 specimens of marshall

There are four contents of CR used in this project to fine the most perfect value of CR to be used.

The ratio of CR contents are taken according to the bitumen content which are (0\% , 10\% , 20\% , 30\%) .

<table>
<thead>
<tr>
<th>%CR</th>
<th>CR.(gm)</th>
<th>OBC</th>
<th>Bitumen.(gm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0</td>
<td>4.8</td>
<td>55.2</td>
</tr>
<tr>
<td>10%</td>
<td>5.52</td>
<td>4.8</td>
<td>55.2</td>
</tr>
<tr>
<td>20%</td>
<td>11.04</td>
<td>4.8</td>
<td>55.2</td>
</tr>
<tr>
<td>30%</td>
<td>16.56</td>
<td>4.8</td>
<td>55.2</td>
</tr>
</tbody>
</table>
Table 4- 8 Determination of optimum modifier content

<table>
<thead>
<tr>
<th>PCr%</th>
<th>Density Avarage</th>
<th>A.V%</th>
<th>VMA% Avarage</th>
<th>Flow (mm) Avarage</th>
<th>Stability (Kg) Avarage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.37</td>
<td>2.38</td>
<td>4.41</td>
<td>13.85</td>
<td>2.15</td>
</tr>
<tr>
<td></td>
<td>2.39</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>2.43</td>
<td>2.405</td>
<td>4.18</td>
<td>12.94</td>
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<tr>
<td></td>
<td>2.38</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>2.34</td>
<td>2.355</td>
<td>3.87</td>
<td>14.75</td>
<td>4</td>
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<tr>
<td></td>
<td>2.37</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>30</td>
<td>2.35</td>
<td>2.335</td>
<td>4.9</td>
<td>15.47</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td>2.32</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4. 6 Air Voids &. CR content
Figure 4.7 Stability & CR content

Figure 4.8 Flow & CR content
Figure 4.9 Density & CR content

Figure 4.10 Void in mineral aggregate & CR content
To find the best CR content we have to follow this procedure:

From the graph of density we will take the maximum density value (peak point) and by reading the bitumen content we will get first value. From the stability graph by taking the maximum value and reading the bitumen content we will get the second value. And in AV graph take 4% of air void and extend to the curve, when the line touches the curve read the bitumen content, and get the third value. Finally by taking average of these three points we will get best modifier content.

The optimum CR of maximum density = 10%

The optimum CR content of maximum stability = 10%

The optimum CR content of 4% of air void = 14%

\[
OCRC = \frac{(10+10+14)}{3} = 11.3\% 
\]
Chapter Five

Conclusion

Based on the results of the experimental investigations conducted on normal and crumb rubber modified asphalt mixes, it may be concluded that by adding different CR percentages to HMA the mix gradually improve its property noticeably. Numerous laboratory tests conducted on asphalt, among them; (Penetration, Ductility, Softening Point, Flash and Fire, Specific gravity of Asphalt) tests. The laboratory tests conducted on aggregate are (Sieve Analysis, Los Angeles Abrasion, Specific Gravity of Fine Aggregate, and Specific Gravity of Coarse Aggregate) tests.

One of the most widely used methods of bituminous mix design is the Marshall method. Stability and flow, together with density, voids, and percentage of voids filled with binders are determined with various binder contents to determine an 'optimum' for stability, durability, flexibility, etc.

After conducting all the tests for asphalt and aggregate, the Marshall stability and flow test were done for the mix. Optimum binder content OBC found for 25 samples with different percent of bitumen of 0.5 increments (4, 4.5, 5, 5.5, 6, 6.5) %. The result of the OBC was (4.8%).

To find optimum or ideal percent of CR content in the mix, one of the two main mixing processes of Marshall mix design must be selected, which are (wet process and dry process). In this study dry process has been used. The dry process is the process that the modifier CR added to the aggregate prior to the bitumen. The dry process used to find OCRC by adding CR in the different percentages which were (0%, 10%, 20%, 30%) added to the mix and preparing 16 samples of it in two times in different places in order to find more accurate OCRC. As a result, the optimal percent of CR was found to be 11.3%. Adequate stability for providing resistance to deformation under constant or repeated loads. Also, adequate voids in the total compacted mix to provide space for additional compaction under traffic loading.
**Recommendation**

Our recommendations to who want to repeat our project are

1. To get more accurate result make tests for 0, 2, 4, _20% of crumb rubber_.
2. Make continue to our content and use 40% 50% of crumb rubber to know the affectiveness to use high amount of crumb rubber in mix.
3. Make CR into powder and use it in the tests
References

2. (2004). ASTM.

