“UTILIZATION OF WASTE PLASTIC IN BITUMINOUS PAVEMENT”

A Project Work submitted to

Visvesvaraya Technological University

in partial fulfillment of the requirements

for the award of degree of

Bachelor of Engineering

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This is to certify that the project work entitled **"Utilization of waste plastic in bituminous pavement"** is a Bonafide work carried out by

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The students of eighth semester B.E (Civil Engineering) declare that the project entitled **"Utilization of waste plastic in bituminous pavement"** is carried out by me at K.S School of Engineering and Management as a partial fulfillment of academic requirement of B.E in Civil Engineering under Visvesvaraya Technological University. The content in the thesis are original and are free from plagiarism and other academic dishonesty and are not submitted to any other University either partially or wholly for the award of any other degree.

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ACKNOWLEDGEMENT

We take this occasion to express my heartfelt thankfulness to everyone who made this project success.

We want to bear our most heartfelt thanks to **Er. Veerendra Kumar M, Associate Professor, Department of Civil Engineering, KSSEM, Bengaluru,** for taking out time from hectic schedule and guiding us in the most warm and friendly manner.

We would also extent our sincere thanks to **Dr. Vijayalakshmi Akella, Prof & HoD, Department of Civil Engineering, KSSEM, Bengaluru,** who with inspiration encouragement and support, has rendered meticulous guidance throughout the research work.

We express our sincere gratitude to **Dr. K Rama Narasimha, Principal, KSSEM, Bengaluru,** for providing the necessary infrastructure and his kind encouragement during the project.

We would like to grateful to all the **Teaching, Non-Teaching Staff** and **Supporting Members** of our department for their livelihood support and co-operation during our research work. We would like to thank **K. S. School of Engineering and Management** for giving us the opportunity to use their resources and for their encouragement with such a vibrant and learning atmosphere.

Last but not the least we feel short of words to express our sincere thanks to our **Parents** and **Friends** who have been there and extending the moral support, source of continuous inspiration, encouragement and support during our course and research work.

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Contents

List of figures

List of Tables

ABSTRACT

Conventional Bituminous materials have tended to perform satisfactorily in most highway pavement and airfield runway applications. However, in recent years, Increased traffic levels, Larger and heavier loads, New axle designs and Tires pressures have added to the already severe demands of load on pavement system. This has facilitated the need to enhance the properties of existing bituminous pavement. Use of waste plastic in bituminous pavement is one of the solution which has been currently investigated in worldwide to overcome the limitation of bituminous Pavement. Hence the current investigation focuses on utilization of waste plastic in bituminous pavement by dry blending. The experimental investigation is made to determine the properties of locally available aggregates and bitumen, after which dense graded bituminous mix is design as per MORTH specifications. The optimum binder content is determined initially for the conventional bituminous mix. For this mix, Waste plastic is added as percentage by weight of optimum binder in ranges from 6% to 16% at interval of 2%. Marshall stability test are performed for this samples to determine the best possible blending of waste plastic to get an improved bituminous mix. Dense graded bituminous mix with 5% bitumen content and 12% waste plastic was most efficient mix which had improved Marshall stability value by 21.36%, Decreased Marshall flow value by 10.86% and considerable decreased percentage volume of voids by 5.16%, as compared to conventional dense graded bituminous mix.

KEYWORDS: Waste plastic, Pavement, Stability and Flow value.

Chapter 1

Introduction

1. Introduction to highway.

Highways are major road systems designed to facilitate fast, long-distance travel and the efficient transport of goods. They are critical components of a country's infrastructure, connecting cities, towns, and rural areas to each other and promoting economic and social development.

Historically, the concept of highways dates back to ancient civilizations such as the Roman Empire, which built extensive road networks to maintain control over its territories and facilitate trade. In modern times, highways have evolved into sophisticated roadways with multiple lanes, advanced engineering techniques, and safety features to accommodate high-speed traffic and heavy vehicles.

Highways serve various purposes beyond transportation. They are crucial for:

- Economic Growth: Highways enable quick access to markets, raw materials, and labor forces, enhancing trade and industrial development.
- Connectivity: They provide a seamless network linking urban centers, rural areas, and regions, supporting social mobility and cohesion.
- Tourism and Culture: By making distant destinations accessible, highways promote tourism and cultural exchange, enriching national unity.

As nations continue to urbanize and industrialize, the development and expansion of highways remain critical in supporting economic activities, ensuring regional balance, and improving the overall quality of life for citizens. The introduction of highways signifies progress, and they continue to be vital drivers of a country's modernization.

1.1 IMPORTANCE OF HIGHWAY:

Highways play a crucial role in modern infrastructure, offering several important benefits as listed below:

- Economic Growth

  Highways facilitate the efficient movement of goods and services across regions, boosting trade and commerce. They connect rural areas to urban markets, enhancing business opportunities and job creation.

- Connectivity

Highways provide a seamless connection between cities, towns, and even countries. They enable people to travel long distances quickly, promoting social interactions, tourism, and access to services like healthcare and education.

- Time and Cost Efficiency

Well-constructed highways reduce travel time, leading to savings in fuel and vehicle maintenance costs. They also decrease the overall transportation costs for businesses, making them more competitive.

- Safety

Modern highways are designed with safety in mind, featuring proper signage, lanes, and safety barriers. This helps reduce the risk of accidents, compared to poorly maintained roads or those not designed for high-speed traffic.

- Rural Development

By connecting remote areas, highways stimulate development in rural regions, improving access to essential services and promoting economic activities like agriculture and local industries.

- Tourism and Cultural Exchange

Highways make tourist destinations more accessible, helping local economies thrive through tourism. They also promote cultural exchange by connecting diverse regions and encouraging travel.

- National Security

Highways are critical for national defense, allowing the rapid movement of military personnel and equipment. They also provide crucial evacuation routes during natural disasters or emergencies.

1.2 ROLE OF HIGHWAYS IN THE DEVELOPMENT OF COUNTRY:

Highways play a pivotal role in the development of a country, acting as the arteries of economic, social, and industrial growth. Here are the key ways in which highways contribute to national development:

- Economic Development

Highways facilitate the efficient transport of goods and services, reducing travel time and costs for businesses. This leads to enhanced trade, increased productivity, and better integration of markets across regions, boosting the overall economy.

- Industrial Growth

Industries rely on the quick and reliable movement of raw materials and finished products. Highways connect industrial hubs, enabling supply chains to function smoothly and making it easier for businesses to expand operations, leading to job creation and investment.

- Urbanization and Infrastructure Expansion

Highways promote the expansion of cities by providing easy access to nearby towns and rural areas. This contributes to the development of housing, educational institutions, healthcare facilities, and commercial enterprises along major routes, leading to the growth of new urban centers.

- Agricultural Development

Highways are critical for connecting rural agricultural areas with urban markets. Farmers can transport their produce quickly, ensuring better prices and reducing wastage. This helps improve rural economies and promotes the modernization of agriculture.

- Tourism and Cultural Exchange

A well-developed highway network opens up remote and scenic regions to tourists, boosting local economies through tourism. Highways make it easier for travelers to explore different parts of the country, promoting cultural exchange and enhancing national unity.

- Balanced Regional Development

Highways ensure that development is not concentrated only in major cities. By improving connectivity in less-developed or remote areas, highways encourage investment, infrastructure development, and job opportunities, helping to balance regional growth.

- Access to Services

Highways make it easier for people in rural or underserved areas to access essential services like healthcare, education, and government facilities. This helps in improving the quality of life and contributes to social development.

- Employment Generation

The construction, maintenance, and operation of highways create thousands of jobs, from skilled engineers to laborers. Additionally, industries like hospitality, transportation, and logistics flourish along highways, further boosting employment opportunities.

- National Security

Highways play a strategic role in national defense by allowing the quick mobilization of military forces and the transportation of essential goods during times of crisis. They also serve as evacuation routes during natural disasters and emergencies.

- Environmental Considerations

With well-planned highways, there is the potential for developing environmentally sustainable transportation systems. This includes the promotion of fuel-efficient transport, reduced traffic congestion, and better management of transport-related emissions.

1.3 TYPES OF PAVEMENTS USED IN HIGHWAYS

There are various type of pavements mainly flexible pavements and rigid pavements depending upon the materials used. A briefs description of all types is givenhere.

1.3.1 FLEXIBLE PAVEMENTS

A typical formation of a flexible pavement as shown in figure 1. Flexible pavements are constructed using layers of materials that distribute the load gradually. They are called flexible because they can bend or "flex" under the load of traffic without cracking.

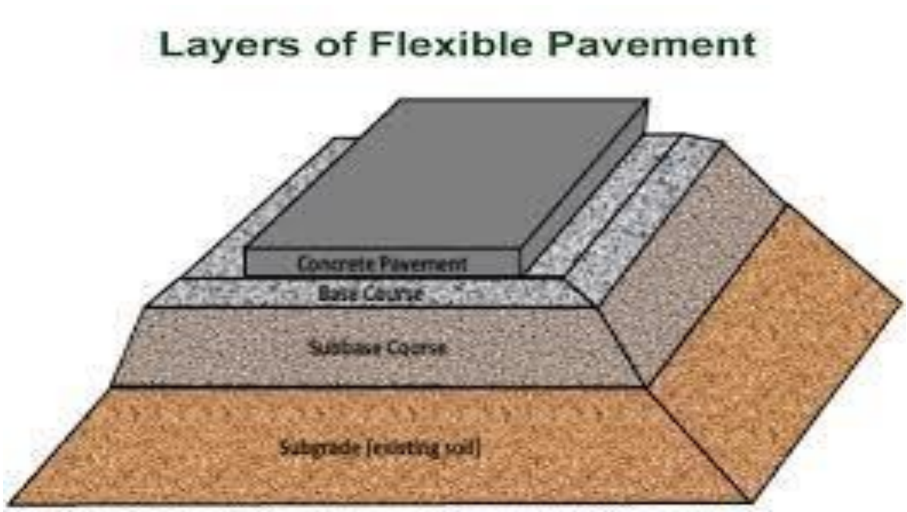

Figure 1 Flexible pavement (Source-www.theconstrutor.org)

Composition of flexible pavement: They are typically made from bituminous (asphalt) materials, which give them flexibility.

Load Distribution: The load is transferred from the surface to the lower layers through grain-to-grain contact, gradually dispersing it over a wide area.

Lifespan and Maintenance: These pavements have a shorter lifespan and may require frequent maintenance but are easier and less expensive to repair.

1.3.2 RIGID PAVEMENTS

A typical formation of the rigid pavement is as shown in figure 2. Rigid pavements are made primarily of concrete, giving them a more rigid structure that distributes loads over a wider area.

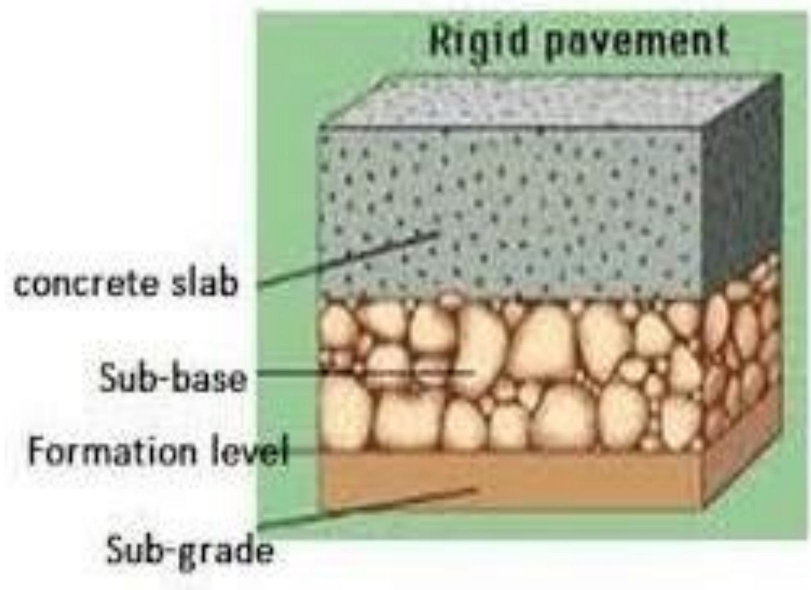

Figure 2 Rigid Pavement (Source- www.theconstrutor.org)

Composition: Constructed from Portland cement concrete (PCC), rigid pavements offer high strength and durability.

Load Distribution: The stiffness of the concrete allows the pavement to distribute loads evenly over a large area, reducing stress on the subgrade.

Lifespan and Maintenance: Rigid pavements have a longer lifespan than flexible pavements but are more expensive to construct. They are also more durable, requiring less frequent maintenance but more complex and costly repairs.

1.4 PROBLEM ENCOUNTED IN FLEXIBLE PAVEMENTS

With heavy rainfall during rainy season is one of the main causes for degradation of flexible pavement. The various types of deterioration and deterioration of the flexible pavement is as shown below.

1.4.1 POTHOLES

A typical pothole in a flexible pavement is as shown in fig.3

Figure 3 Pothole (Source- -www.meonok.com)

Potholes: - Potholes are small to large depressions or holes in the pavement surface, often caused by localized failures.

Causes: Water infiltration through cracks that softens the underlying layers.
Freezing and thawing cycles that cause expansion and contraction of water, breaking up the pavement surface. Poor maintenance of minor cracks or weak spots.

Effects: Potholes pose significant safety hazards to vehicles, causing tire damage, loss of control, and increased repair costs.

1.4.2 DEPRESSIONS

A typical depression in a road is as shown in figure 4. Depressions are localized low areas on the pavement surface, often referred to as “sags” or “bowls.”

Figure 4 Depression (Source-www.in.gov)

Cause of depression: Poor compaction of the subgrade or base layers. Settling of the underlying layers due to weak soil or subbase. Water infiltration causing erosion of the supporting layers.

Effects: Water accumulation in depressions can lead to further deterioration, reducing ride quality and increasing the risk of hydroplaning.

1.4.3 RUTTING

A typical rutting in a road is as shown in figure 5. Rutting refers to the permanent deformation or depression that forms in the wheel paths of the pavement surface.

Figure 5 Rutting (Source- www.pavementinteractive,org)

Causes of rutting: Insufficient thickness or strength of the asphalt layers. Poor compaction during construction. Weak or inadequately compacted subgrade. Excessive traffic loads, particularly from heavy vehicles.

Effects: Ruts cause water to accumulate, increasing the risk of hydroplaning for vehicles. Deep ruts can also affect ride quality and cause structural damage over time.

1.4.4 CRACKING

A typical shoving in a road is as shown in fig-6. cracking, also known as alligator cracking, appears as interconnected cracks resembling the pattern of an alligator's skin. It is one of the most common types of failure in flexible pavements.

Causes of cracking: Repeated heavy traffic loads causing the pavement to fatigue over time. Insufficient pavement thickness or subgrade strength. Poor drainage, leading to the weakening of the pavement base and subgrade.

Effects: Leads to potholes, water ingress, and further deterioration of the pavement if left untreated.

Figure 6 Cracking (Source- www.sidenote.news)

1.4.5 UPHEAVAL

A typical upheaval in a road is as shown in figure-7**.** It is a localized upward moment in the pavement due to swelling of subgrade.

Figure 7 Upheaval (Source-www.superiorasphaltlc.com)

Causes of upheavel : Asphalt upheaval is caused when elements below the asphalt surface cause the soil underneath it to expand

Effects: - uneven road surface, vehicle stability, cracking, moisture and freezing safety hazards

1.5 WASTE PLASTIC AND ITS IMPACT ON ENVIRONMENT

Plastic pollution causes harm to humans, animals and plants through toxic pollutants. It can take hundreds or even thousands of years for plastic to break down so the environmental damage is long-lasting. It affects all organisms in the food chain from tiny species like plankton through to humans and whales. The most visible and disturbing impacts of marine plastics are the ingestion, suffocation andentanglement of hundreds of marine species. Marine wildlife such as seabirds, whales,fishes and turtles, mistake plastic waste for prey, and most die of starvation as their stomachs are filled with plastic debris.

Hence utilizing and recycling the waste plastic is the only solution to minimize the effect of waste plastic and its impact on the environment it is shown in the figure 8.

Figure 8 Waste Plastic Dumping Site

(Source- www.plasticpollutioncoalition.org)

1.6 METHODS TO IMPROVE PERFORMANCE OF BITUMINOUS PAVEMENTS

Researchers around the world have found out that bituminous road have blended with waste plastic will give better results and performance compared to conventional bituminous roads. Hence in our current investigation we would like to utilize waste plastic by blending with bitumen pavements for improving its performance after studying the literature survey in this field .

CHAPTER 2

LITERATURE REVIEW

In this chapter, information is collected with respect to blending of waste plastic in bituminous pavements to be used in roads and highways.

2.1 WASTE PLASTIC SCENARIO IN BANGALORE CITY

Rubbish dumping in Bangalore is reaching crisis levels as rapid economic growth, overcrowding and poor urban planning combine.

India's Silicon Valley produces some 5,000 tonnes of waste a day, of which 1,500 tonnes are plastic. Only 25% goes for recycling and the rest is dumped in land fill or burnt, generating greenhouse gas emissions.

As the local authorities sit on their hands, local businessman Ahmad Khan has taken it on himself to rid the city of its stinking garbage menace.

Khan runs a firm named KK Plastic Waste Management that aims to "create eternal scarcity of garbage" in the city.

KK Plastic has been building roads using waste plastic for a decade. It has been working with Bruhat Bengaluru Mahanagara Palike (BBMP) since 2002. Though using plastic waste increases the cost of road construction by Rs 500 per cubic meter (nearly 7% more than bitumen road), it helps the civic body cut on cost of waste management and reduces emissions.

2.2 USE OF PLASTIC WASTE IN BITUMINOUS ROAD CONSTRUCTION

Investigations carried out by **Azmat shaikh et.al.,** mainly focused on utilizing waste plastic for improving the performance of the bituminous pavement. The bituminous content in the bituminous mix was varied from **4%, 5%, 6%** by the mass of the mix.

The shredded waste plastics was blended with bituminous concrete as a partial replacement of bitumen by **0%, 5%** of bituminous mix having **4%** bituminous content, **10%** of bituminous mix having 5% of bituminous content & **15%** of bituminous mix having **6%** of bituminous content. the marshal stability test results are as presented in the table 1:

From the test results it is seen that marshal stability value increase exceptionally by **64%, 47% & 59%** by varying waste plastic content by **5%, 10% & 15%** respectively. Marshal flow value gradually increases by **25%,36% & 38%** was waste plastic content by **5%, 10% & 15%**

Table 1 Research details by Azmat shaikh et.al

Sample No.	Bitumen content (%)	Plastic content (% by weight)	Marshall stability(kg)	Flow value (mm)
1	4	0	950	3.1
2	5	0	1170	3.3
3	6	0	1240	3.6
4	4	5	1560	3.9
5	5	10	1720	4.5
6	6	15	1980	5

respectively.

From these results, it is concluded that blending **5%** waste plastic has considerable increase in marshal stability value and marginal increase in marshal flow value which are within the acceptable limits.

Investigations carried out by **Amit Kumar das et.al.,** mainly focused on utilizing waste plastic for improving the properties of the pavement.

Initially, the bituminous content in the bituminous mix were varied from **4%** to **7%** at intervals of **0.5%** and marshal test were conducted on the samples. From these tests, optimum bitumen content for the mix was obtained **as 5.0%,** which had marshal stability value 9.34 KN and marshal flow value of 3.7 mm.

In the next experiment trial, bituminous content was fixed as standard percentage of **5.0%** of the mass of bitumen mix. For this, shredded waste plastic was blended by partial replacement of optimum bituminous mass by **4%** to **7%** with interval of **0.**5%.

From the marshal stability test results, it was seen that optimum binder mix with **4%** waste plastic content had marshal stability value of 9.7KN, an increase by **4%** and marshal flow value **37%.** Even though there is slight increase in marshal stability flow value, it is within the acceptable limits of IRC standards.

Investigations carried out by **Utibe J.N kanga et.al,** mainly focused on utilizing low density polyethylene (LDPE) waste plastic for improving the performance of the flexible bituminous pavement and repair of bituminous works.

In this project various proportion of polymeric materials (LDPE waste plastic) as **(5%,10%,15%)** were blended with the bituminous mix and were characterized for strength and performance of bitumen/plastic blends, tested by marshal stability test.

The test results showed that the waste plastic blends which had **10%** waste plastic had higher marshal stability (M.S) value in the range of 14.02 KN to 14.08 KN compared to the conventional bituminous mix sample which M.S value of around 11.35 KN and marshal flow value range from 3 to 4 mm. Hence by blending 10% LDPE waste plastic, percentage increase in the M.S value compared to conventional mix is by around **23.5%.**

This project proves that waste plastic can be used efficiently for road repairs & construction results in more sustainable and better road with the high performance and durability.

Investigation carried out by **Dr. S.L HAKE et. al.,** In the present research work focused on utilize plastic waste for developing and improving the properties of asphalt pavement.

In the experimental investigation, bitumen content was varied from **4.50% 5.75%** at intervals of **0.25%.** For each range of bitumen content, the waste plastic comprising of PET (Polyethylene terephthalate) which is a type of polyester plastic that's transparent, durable, and lightweight, which is commonly used for packaging food and beverages, is blended as the percentage by mass of bitumen content, in the ranges of **0%** to **15%,** at interval of **2.50%.** Marshall stability tests were conducted for determining the performance of the bituminous mixes.

From the test results, it is seen that the optimum waste plastic blended bituminous mix had bituminous content of **5.5 %** and waste plastic of **10%** by mass of the bitumen, which had M.S value of 995 kg (9.76 KN) compared to conventional bituminous mix which had M.S value of 980 kg (9.61 KN) resulting an increase M.s value by 1.56%.

Hence, finally it is concluded that PET waste plastic can be used as a blend for bituminous concrete.

Investigations carried out by **Taher baghee Moghaddam et.al.,** mainly focused on utilization of waste plastic for improving the structure characteristic of bituminous pavement such as resist against cracking, fatigue, rutting etc. The type of waste plastic used in this investigation is the waste PET (Polyethylene terephthalate) bottles. Which were shredded into small particles of size less than 2.36 mm.

The ranges of waste plastic considered in this investigation is from **0%** to **1%** at intervals of **0.20%** as percentage by mass of aggregate particles. The bitumen content was varied from **5%** to **7%** at intervals of **0.50%** by mass of the total aggregates. Marshall stability tests were conducted for determining the performance of bituminous concrete.

Result shows that the optimum waste plastic blended bituminous concrete had bitumen content of **5%** and waste plastic content of **0.60%** by mass of aggregates, had a M.S value of 9.50 KN whereas conventional bituminous mix having 5% bituminous mix had M.S value of 8.50 KN, resulting to increase in M.S value by 11.76%.How ever, flow value increased with respect to conventional mix by **25%,** the flow value were within the acceptable limits.

Hence, finally it is concluded that PET waste plastic can be effectively used for blending with bituminous pavement foe improving its properties.

2.3 GAP IN LITERATURE SURVEY AND SCOPE OF PRESENT INVESTIGATION

From the literature survey it is seen that there is considerable improvement in the properties of bituminous pavement with addition of waste plastic in terms of strength and stability. however, the optimum dosage of bituminous binder and corresponding dosage of waste plastic varied between different investigators.

Hence in the current investigation we are determining the optimum binder content, by using VG30-(60/70) grade bitumen. For the determined optimum bitumen content, it is partially replaced with milk sachet plastic waste in the starting range of 3% at increasing interval of 1% to reach the optimum blended mix with the locally available aggregates and determine the optimum mix which has good strength and stability.

2.4 AIM OF THE PRESENT INVESTIGATION

To improve the performance of bituminous pavements with local aggregates by partial replacement of bitumen with waste plastic by dry blending thereby obtaining dual advantage of improving the properties of highway pavement and also to reduce the environmental pollution by preventing dumping of waste plastic at solid waste landfills.

2.5 OBJECTIVES

- To determine the engineering properties of the various materials which are locally available, used in highway pavement.
- To design the mix of bituminous mix as per the MORTH specification using conventional bitumen.
- To determine the optimum binder content for conventional bituminous mix.
- To modify the above designed mix by partially replacing the bitumen with waste plastic, which is carried out by dry blending with the local aggregates.
- To compare the test results of conventional bituminous mix with modified bituminous mix with waste plastic in terms of marshal stability tests for obtaining the best bituminous mix which can be used in highway pavements.

2.6 METHODOLODY

Methodology for objective 1

Engineering properties of fine aggregates, coarse aggregates and bitumen is determined as per IRC, MORTH and IS standards.

Methodology for objective 2

Mix design of dense graded bituminous mix is done as per MORTH specifications.

Methodology for objective 3

Casting of test specimens is done and marshal stability-flow along with density tests are determined. Determination of optimum bitumen content for conventional dense bituminous mix is initially obtained.

Methodology for objective 4

For the determined optimum bituminous content for the conventional dense graded bituminous mix is partially replaced with waste plastic in percentage fraction of 3%,4%,5% and 6% waste plastic. The testing of specimens will be done as per specifications of marshal stability, flow and density tests.

Methodology for objective 5

The performance study on the addition of waste plastic in the dense graded bituminous mix is made by detailed discussion of test results with respect to conventional dense graded bituminous mix and final conclusions are arrived at for determining the best dense graded plastic waste blended bituminous mix.

CHAPTER 3

3 EXPERIMENTAL INVESTIGATION

In this chapter, the experimental work is carried out by determining the engineering property of the various materials such as fine aggregate, coarse aggregate, bitumen and waste plastic and the same is reported in section 3.1. Section 3.2 comprisesof mix design of dense graded bituminous mix as per MORTHS specifications. Section 3.3 presents detailed experimental investigation carried on dense graded bituminous mix.

3.1 TO DETERMINE THE ENGINEERING PROPERTIES OF THE MATERIALS

The engineering properties of various materials such as fine aggregate, coarse aggregate, conventional bitumen and waste plastic are presented in section 3.1.1, 3.1.2, 3.1.3, 3.1.4 respectively.

3.1.1 TESTS FOR FINE AGGREGATE

The various test conducted for fine aggregates are specific gravity and sieve analysis. The same is described below

3.1.1.1 SPECIFIC GRAVITY

The Specific gravity of the material is defined as the ratio of mass of a given volume of fine aggregate to the mass of an equal volume of water, both taken at a standard temperature of 27^0C. The specific gravity of fine aggregate is determined as per IS:2386 Part-3 (1963).

The main significance of specific gravity is its usage in the design of bituminous mix. This value is used in calculating air voids, voids in mineral aggregate (VMA), and voids filled by asphalt (VFA). All of these properties are important for good performance of a durable bituminous mix. The standard range of specific gravity for fine aggregate is generally considered in the rangeof 2.5-2.7. Specific gravity of fine aggregates is considered as an indication of strength. Material having higher Specific Gravity is generally considered as having higher strength.

The specific gravity of the fine aggregate was found to be 2.64 which is within the permissible range.

3.1.1.2 SIEVE ANALYSIS FOR FINE AGGREGATE

Grading of fine aggregate was done according to IS-2386-(1963).The sieve analysis determines the gradation (the distribution of aggregate particles, by size, within a given sample) in order todetermine compliance with design, production control requirements, and verification specifications. The sieve analysis report is presented in table 2.

Table 2 SIEVE ANALYSIS OF FINE AGGREGATE

Sl.no	**I.S Sieve Size**	**% Passing**	**Cumulative %retained**	**%Fineness**
1	4.75 mm	100	0.00	100
2	2.36mm	91.65	8.35	91.6
3	1.18mm	67.90	32.10	67.9
4	600micron	46.00	54.00	46.0
5	300micron	18.70	81.30	18.7
6	150microns	4.60	95.40	4.6
7	pan		100.0	$\sum = 328.8$

F= $\sum$ (%Fineness) / 100 = 328.8/100 = **3.28**

The fineness modules of fine aggregate was found to be 3.28 which is within the permissible range of (3 to 3.9) and falls on zone II.

The consolidated test report of fine aggregate is presented in table-3.

Table 3 Final test results of fine aggregate

Tests Performed	Test Results	Specifications	Range
Specific gravity test	2.64	IS-2386(1963)	2.5-2.7
Sieve Analysis (F.A) Fineness modulus	3.28	IS-2386(1963)	3-3.9

3.1.2 TESTS FOR COARSE AGGREGATE

The various test conducted for coarse aggregates are specific gravity, sieve analysis, water absorption test, impact test, aggregate crushing test, Los Angeles abrasion test and shape test. the same is described below:

3.1.2.1 SPECIFIC GRAVITY TEST ON COARSE AGGREGATE

Grading of coarse aggregate was done according to IS-2386- 3 (1963) methods of test for specific gravity of coarse aggregates. Specific Gravity of coarse aggregate is important for the design of bituminous mix. This value is used in calculating air voids, voids in mineral aggregate (VMA), and voids filled by asphalt (VFA).

The specific gravity of aggregates normally used in construction ranges from about 2.5 to 2.7. The specific gravity of the coarse aggregate is found to be 2.54 which is within the permissible limits.

3.1.2.2 AGGREGATE IMPACT TEST ON COARSE AGGREGATE

The testing of the coarse aggregate for impact test done as per IS 2386-1963 PART-4. The aggregate impact value is to measure the resistance due to sudden impact or shock, which may differ from its resistance to gradually applied compressive load.

The aggregate impact value was found to be 12.2% which is in the range below 30% and hence can be used for road pavements.

The standard range of classification of aggregate impact value is as described below.

Less than 10 % is ‘Exceptionally strong’.
Between 10-20% is ‘Strong’.
Between 20-30% is ‘Satisfactory for road

3.1.2.3 AGGREGATE CRUSHING TEST ON COARSE AGGREGATE

The testing of the coarse aggregate for crushing test done as per IS 2386-PART4-1963. The aggregate crushing is due to static compression due to heavily loaded trucks.

The aggregate impact value was found to be 19.17% which is in the range below 30% andhence can be used for road pavements.

According to IS:2386-Part 4-1963 the aggregate crushing strength should not exceed 30% the obtained value is below 30% hence it can be used as road aggregates.

3.1.2.4 LOS ANGELES ABRASION TEST ON COARSE AGGREGATE

The testing of the coarse aggregate for Los Angles abrasion test done as per IS 2386-PART4-1963. The aggregate abrasion is caused due to moving wheel loads on the bituminous pavement.

The aggregate Los Angles abrasion value was found to be 23.16%, A LOS Angeles abrasion value of less than 30%, Indicates that the aggregates are having good wearing resistance and hence it is suitable for use in highway pavement and cement concrete.

3.1.2.5 SHAPE TEST ON COARSE AGGREGATE

The testing of the coarse aggregate for flakiness and elongation test was done as per IS-2386-PART1-1963 and the same is shown in table-4.

This test is used to determine the particle shape of the aggregate and each particle shape being preferred under specific conditions. Due to high surface area to volume ratio, the flaky and elongated particles lower the workability of concrete mixes.

Elongation index = (($\sum W_2$) / W) 100 = (139/564) 100 = 12.0%

Flakiness index= (($\sum W_1$) / W) 100 = (106/564) 100 = 21.83%

The aggregate elongation index value was found to be 12.0% , Between 10% & 15% marginally acceptable, the tested value fell within 10%-15% which is marginally acceptable for pavement works.

The aggregate flakiness index value was found to be 21.83% which is less than maximum permitted value of 25% and hence can be used for road pavements.

3.1.2.6 SHAPE TEST ON COARSE AGGREGATE

The testing of the coarse aggregate for flakiness and elongation test was done as per IS-2386-PART1-1963.

This test is used to determine the particle shape of the aggregate and each particle shape being preferred under specific conditions. Due to high surface area to volume ratio, the flaky and elongated particles lower the workability of concrete mixes.

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The aggregate flakiness index value was found to be 21.83% which is less than maximum permitted value of 25% and hence can be used for road pavements.

Final test results of the coarse aggregate are presented in Table 4

Table 4 Final test results of coarse aggregates

Tests Performed	Test Results	Specifications	Range
Specific gravity test(C.A)	2.54	IS-2386(1963)	2.5-2.7
Water Absorptiontest (C.A)	1.78%	IS-1124-1974	0.3-2.5%
Impact test (C.A)	12.2%	IS-2386(1963)	20-30%
Crushing test (C.A)	19.17%	IS-2386(1963)	20-30%
Los Angeles Abrasion Test (C.A)	23.16%	IS-2386(1963)	<40%
Shape test	Flakiness index wasfound as= 21.83% Elongation index wasfound as=12%	IS-2386(1963)	Flakiness I < 25% Elongation I <25%

3.1.3 TEST CONDUCTED ON BITUMEN

The various test conducted for bitumen are specific gravity, penetration test, softening point and ductility. the same is described below:

3.1.3.1 PENETRATION TEST ON BITUMEN

The testing of the penetration of the bitumen was done as per IS 1203-1978.
Penetration test of bitumen determines the hardness or softness of bitumen by measuring the

depth in millimeter to which a standard loaded needle will penetrate vertically in five seconds while the temperature of the bitumen sample is maintained at 25^0 C. This test is applied almost exclusively to bitumen.

The penetration test value of the bitumen is found to be Grade 60.

3.1.3.2 SOFTENING POINT TEST ON BITUMEN

The testing of the softening point of the bitumen is done as per IS 1205-1978.
The determination of softening point helps to know the temperature up to which a bituminous binder should be heated for various road use applications. Softening point is determined by ring and ball apparatus.

The softening value of the bitumen was found to be 59.7^0 C.

3.1.3.3 DUCTILITY TEST ON BITUMEN

The ductility test of the bitumen was done as per IS 1208-1978.The ductility test of bitumen sample is one of the important tests of bitumen to be conducted before road construction.

Ductility measures the adhesive property of the bitumen along with its elasticity.

The ductility value of the bitumen was found to be 95.8cm is well above the minimum requirements for all standard grades, it indicates that the bitumen is likely of high quality and could be suitable for various applications, particularly those requiring flexibility & resentence to cracking.
The minimum ductility value for 60/70 grade is 100 cm.

Final test results of bitumen are presented in Table 5.

Table 5 Final test results of Bitumen

Tests Performed	Test Results	Specifications	Range
Penetration Test (Bitumen)	Grade 60	IS-1203(1978)	Can be used in warm & cold climates
Softening Point Test (Bitumen)	59.7^0 C	IS-1205(1978)	$40\text{-}65^0$ C
Ductility Test (Bitumen)	95.8cm	IS-1208(1978)	>50cm

3.1.4 To determine the Properties of Waste Plastic:

The waste plastic used in current investigation is from "Nandhini milk sachet" which is characterized as low-density polyethylene. The properties of this plastic is as described in table 6.

Source (http://images.app.goo.gl/cxev5g3tcvz78km36)

Table 6 Properties of waste plastic

SL NO	NATURAL PROPERTIES
1	DENSITY=0.940 g/cm^3
2	TENSILE STRENGTH = 10.50 M Pa

3.2 MARSHALL STABILTY METHOD FOR DESIGING AND TESTING OF BITUMINOUS PAVEMENT (ASTM D6927-2006)

Marshall Method of Designing bituminous mixes is a test applicable to hot mix design of dense graded bituminous mixes using bitumen and aggregates up to a maximum size of 20mm. The test procedure is used for designing and evaluating properties of bituminous mixes and it routinely used for testing bituminous mixes to be used for paving jobs.

This method carries a compression test on a cylindrical specimen prepared of a known quantity of aggregates and bitumen, of 100mm diameter and 131mm Height. It measures the resistance or the stability value to plastic deformation of the specimen of a bituminous mixture measured as the load taken at 50mm/min till its failure. The deformation is also recorded as the flow value in units of 0.25mm. This repeated for a number of specimens with the same grade of aggregates but different asphalt contents.

The Marshall method of Designing analyses two features of pavement bituminous mixes:

1. Stability Flow Analysis
2. Density- Voids Analysis.

The stability and flow values are directly recorded during the test. These will inform the maximum load which the mix can take deforming to failure. Higher the load taken, the mix is suitable to use in heavy trafficked while a high flow value is undesirable because the mix will rut easily under the rolling wheels upon applying on the pavement Lower the bitumen content is also detrimental to the performance of the mix on field, which easily leads to segregation of the bituminous mix under variation of climate and rolling of wheels.

TIR density voids analysis is studied on air voids content, voids in mineral aggregates (VMA), voids filled with asphalt (VFA) and unit weight or density of the mix dependences on the asphalt contentof the bituminous mix. These analyses are studied with the help of graph plotting as shown in figure 9.

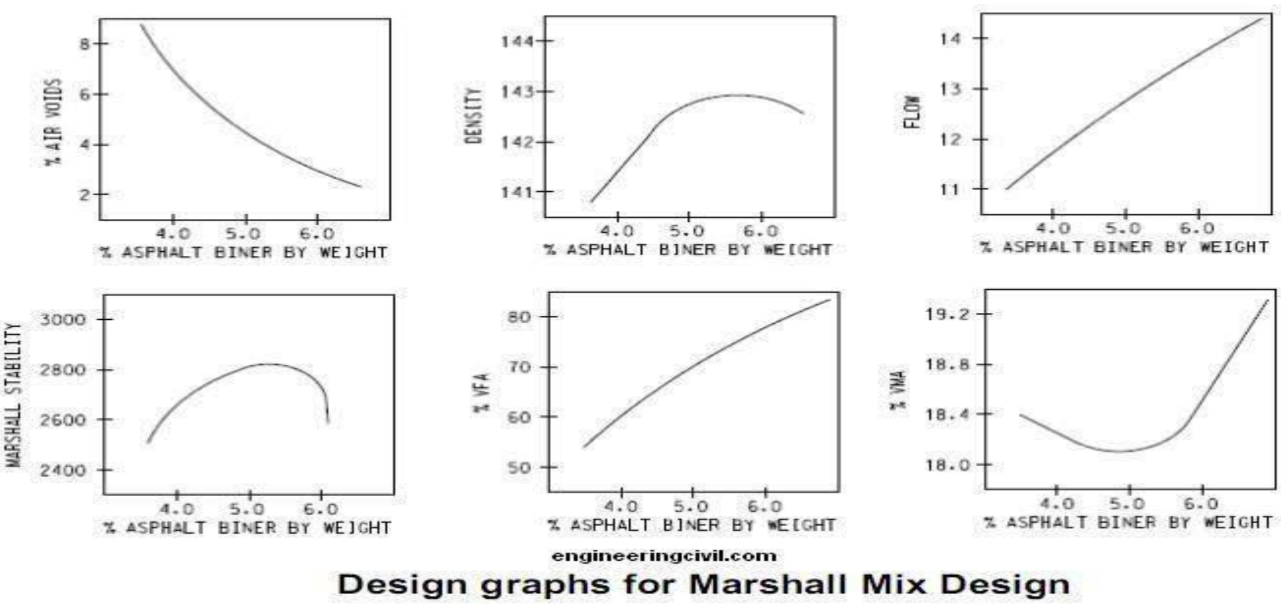

Figure 9 Design graphs for marshall mix design

As shown in Fig 9 the air void content decreases and being replaced with the increase in asphalt Content. The flow value and the percentage of Voids Filled with Asphalt increase with the asphalt Content. TIR density of the mix increases initially due to the sliding of the aggregates leading to Densification of the mix, reduction in Void in Mineral Aggregates and eventually to an increase in load carrying capacity. If the asphalt content Es further increased beyond the minimum voids filled, the mixes start to expand, the total void content of the aggregates increases, density reduces and the weak bitumen Starts taking the leading to a reduction in load carrying capacity of the mix. Based on

the graphs and the behavior of the bituminous mix to loading at different asphalt Content, the mostefficient asphalt content can determine which will compromise to balance all the mix properties.

For this lab activity mixture specification is adopted from the Morth Table No.500-16 The same is shown in Table below

Table 7 MORTH SPECIFICATION

Minimum stability (KN at 60 c)	10
Minimum flow (mm)	2
Maximum flow (mm)	4
Compaction level (Number of blows)	75 blows on each of the two faces of the specimen
Per cent voids in mineral aggregate (VMA) (Minimum)	14
Percent air voids	3-5
Percent voids filled with bitumen (VFB)	65-78

3.2.3 PREPARATION OF MARSHALL SAMPLE

- Measure out aggregates required for 1200g of mix in the desired proportions. Heat theaggregates in the oven to the mixing temperature.
- Measure out aggregates required for 1200g of mix in the desired proportions. Heat theaggregates in the oven to the mixing temperature.
- Add the required quantity of bitumen at mixing temperature to produce viscosity of 170±20 centistokes at various percentages both above and below the expected optimum content.
- Mix the materials in a heated pan with the help of mixing tools.
- Return the mixture to the oven and reheat it to the compacting temperature to produce a viscosity of 280±30 centistokes.

- Place the mixture in a heated Marshall mould with a collar and a base. Spade the mixture around the sides of the mould. Place filter paper on top and bottom of the sample.
- Place the mould in a Marshall Compaction pedestal.
- Compact the materials with a specified number of blows by the hammer. Invert the sample and give the same number of blows to reduce the size of the compacted mix to 64mmhigh and 102mm diameter.
- After compaction, invert the mould. With the collar on the bottom, remove the base and extractthe sample by pushing it out by the extractor.
- Allow the sample to cool. Obtain the sample's mass in air and submerged to measuredensity of specimen so as to allow calculations of the void's properties.
- Preferably, five specimens are required with two specimens having a bitumen contentabove and two the expected optimum content.
- Specimens are heated to 60±1 C, either in a water bath for 20 min or in an oven for 2hours.
- Remove the specimen from the water bath and place in the lower segment of thebreaking head on the specimen and place the complete assembly in position on the testing machine.
- Place the flow meter over one of the posts and adjust it to real zero.
- Apply a load at a rate of 50mm/ min until the maximum load reading is obtained.
- Record the maximum load reading in Newtons and obtain the flow as recorded on the flow Meter in units of 0.25 mm.

3.3 Determination of optimum binder content for the dense graded bituminous mix with local aggregates

The optimum binder content for the dense bound bituminous mix with local aggregates is determined by considering the MORTH specification and varying the bitumen content with a starting value of 4.5% with increasing interval of 0.50%. The calculations of materials required for casting the Marshall stability specimen is as shown in table 8, for the bitumen content of 4.5%, 5%, 5.5%, and 6% respectively.

Table 8 Materials calculations for conventional Dense Graded Bituminous Mix

Materials →	Bitumen (gms)	Aggregate content in different sieve sizes in millimeter (quantity in gm)					
% Bituminous Content ↓		20-12.5	12.5-10	10-4.75	4.75-.075	<0.075 (Filler)	Total quantity (gms)
4.5	54	264	276	240	320	46	1200
5	60	264	276	240	320	40	1200
5.5	66	264	276	240	320	34	1200
6	72	264	276	240	320	28	1200

The marshall stability and flow test for the specimens of the conventional dense graded bituminous mix with varying bitumen content is as shown in table 9.

Table 9 Marshall stability test for conventional dense graded bituminous mix

SL no.	**% Bitumen content**	**Marshall stability value (KN)**	**Marshal flow in (mm)**	**% volu me of voids**	**Bulk specific gravity (Gm)**	**% voids filled with bitumen**
1	4.5	30.68	8.2	5.01	2.460	72.28
2	5	33.38	4.6	4.65	2.460	72.28
3	5.5	26.93	8.3	4.65	2.460	72.28
4	6	28.68	11.4	4.28	2.460	72.28

Final tested values of the specific gravity, percentage air voids, %voids filled with bitumen , corrected marshall stability value and flow value is as shown in table 10

Table 10 Data sheet for calculation of marshall parameters for conventional dense graded bituminous mix

①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	①①	①②
1	4.5	61.9	1.230	0.730	2.460	5.01	29.5	1.04	30.68	8.2	72.28
2	5	61.9	1.230	0.730	2.460	4.61	32.1	1.04	33.33	4.6	72.28
3	5.5	61.9	1.230	0.730	2.460	4.65	25.9	1.04	26.93	8.3	72.28
4	6	61.9	1.230	0.730	2.460	4.28	29.5	1.04	28.68	11.4	72.28

Nomenclature	Details	Nomenclature	Details
①	Serial number	⑦	Percentage volume of air voids (Vv)
②	% Bitumen content	⑧	Marshall stability value (kN)
③	Average height of specimen(mm)	⑨	Marshall correction factor
④	Weight in air (kgs)	⑩	Marshall corrected stability value in (kN)
⑤	Submerged weight in water(kgs)	①①	Marshall flow value (mm)
⑥	Specific gravity (Gm)	①②	Percentage voids filled with bitumen %

The graphical plot of percentage bitumen content versus Marshall stability, flow value and % voids is shown in figure 10,11& 12respectively.

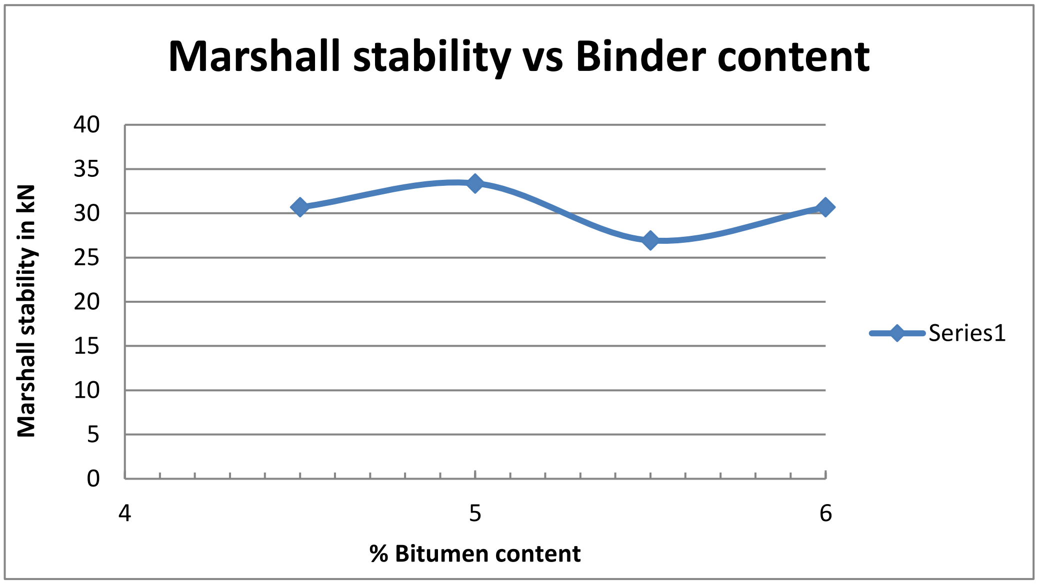

Figure 10 Graphical plot of % bitumen content vs Marshall Stability

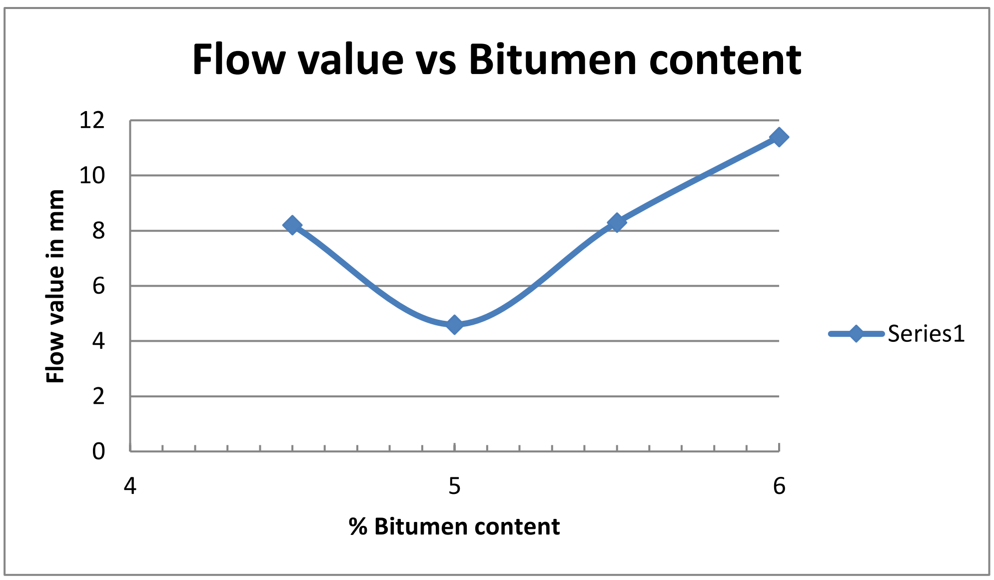

Figure 11 Graphical plot of % bitumen content vs Marshall Flow Value

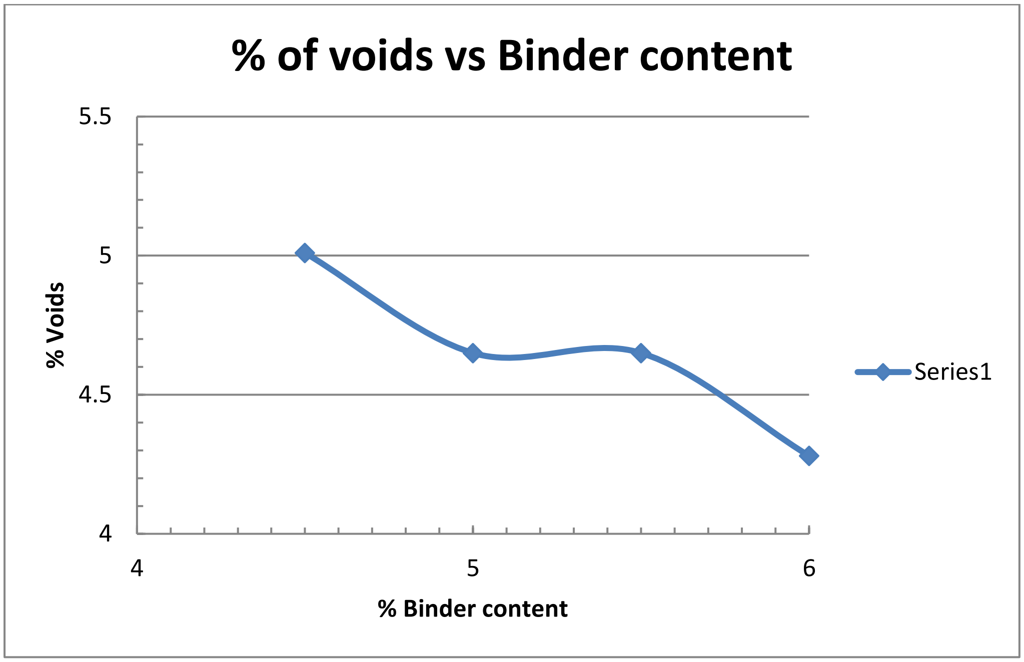

Figure 12 Graphical plot of % bitumen content vs % of voids

3.4 Determination of optimum binder (bitumen) content for Dense graded bituminous Mix.

From the marshall stability it is seen that conventional bituminous mix which had 5% bitumen content developed the following characteristics:

- It had highest Marshall stability value of 33.38 kN
- It had lowest Marshall flow value of 4.60 mm,
- It also had considerable lowest value of % volume of voids of 4.65%

Hence based on the Marshall stability test, the optimum bitumen content for the Dense graded bituminous conventional mix is 5%.

3.5 Determination of optimum blend of dense graded bituminous mix with waste plastic by dry blending.

After determining the optimum bitumen content for the conventional dense graded bituminous mix with local aggregates which found to be 5%, this mix is modified by adding waste plastic as percentage by weight of bitumen in the range of 6%,8%,10%,12%,14% & 16%.the materials calculation for the same is as shown in table 11.

Table 11 The materials calculation for waste plastic blended dense graded bituminous mix with 5% bitumen content

materials →	Bitumen (gm)	Waste plastic	Aggregate content in different sieve sizes in millimeter (quantity in gm)					
% waste plastic ↓			20-12.5	12.5-10	10-4.75	4.75-.075	<.075 (Filler)	Total quantity
6	60	3.6	264	276	240	320	36.4	1200
8	60	4.8	264	276	240	320	35.2	1200
10	60	6.0	264	276	240	320	34	1200
12	60	7.2	264	276	240	320	32.8	1200
14	60	8.4	264	276	240	320	31.6	1200
16	60	9.6	264	276	240	320	30.4	1200

The marshall stability and flow test for the specimens of the waste plastic blended dense graded bituminous mix with 5% bitumen content is as shown in table 12.

Table 12 Marshall stability test for dense graded bituminous mix with waste plastic blending.

SL no.	% Waste Plastic	Mass of sample inair (gm) (Wm)	Mass of sample in submergedin water (kg) (Ww)	Marshall stability value (KN)	Marshal flow in (mm)
1	6	1228.5	710	18.60	9.80
2	8	1259.0	740	27.02	8.50
3	10	1252.5	740	38.10	9.00
4	12	1256.0	730	42.20	4.10
5	14	1249.0	720	36.60	6.30
6	16	1260.5	720	28.20	5.30

Final tested values of the specific gravity, percentage air voids, %voids filled with bitumen, corrected marshall stability value and flow value is as shown in table 13.

Table 13 DATA SHEET FOR CALCULATION OF MARSHAL PARAMETERS FOR WASTE PLASTIC BLENDED DENSE GRADED BITUMINOUS MIX WITH 5% BITUMEN CONTENT

①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	①①	①②
1	6	63.50	1228.5	710.0	2.36	5.22	18.60	1	18.60	9.80	76.36
2	8	63.50	1259.0	740.0	2.42	2.81	27.20	1	27.02	8.50	86.0
3	10	63.50	1252.5	740.0	2.44	2.00	38.10	1	38.10	9.00	46.75
4	12	65.10	1256.0	730.0	2.38	4.41	42.20	.96	40.51	4.10	80.47
5	14	65.10	1249.0	720.0	2.36	5.22	36.60	.96	35.14	6.30	76.36
6	16	66.70	1260.5	720.0	2.33	6.42	28.20	.93	26.23	5.30	75.0

Nomenclature	Details	Nomenclature	Details
①	Serial number	⑦	Percentage volume of air voids (Vv)
②	% Waste plastic content	⑧	Marshall stability value (kN)
③	Average height of specimen(mm)	⑨	Marshall correction factor
④	Weight in air (kgs)	⑩	Marshall corrected stability value in (kN)
⑤	Submerged weight in water(kgs)	①①	Marshall flow value (mm)
⑥	Specific gravity (Gm)	①②	Percentage voids filled with bitumen %

The graphical plot of partial replacement of optimum bitumen content of 5% with waste plastic by dry blending with percentage replacing fraction of 6%,8%,10%,12%,14% &16% is asshownin figure 13,14 & 15 for percentage fraction of waste plastic versus Marshall flow value, Marshall stability value and % voids.

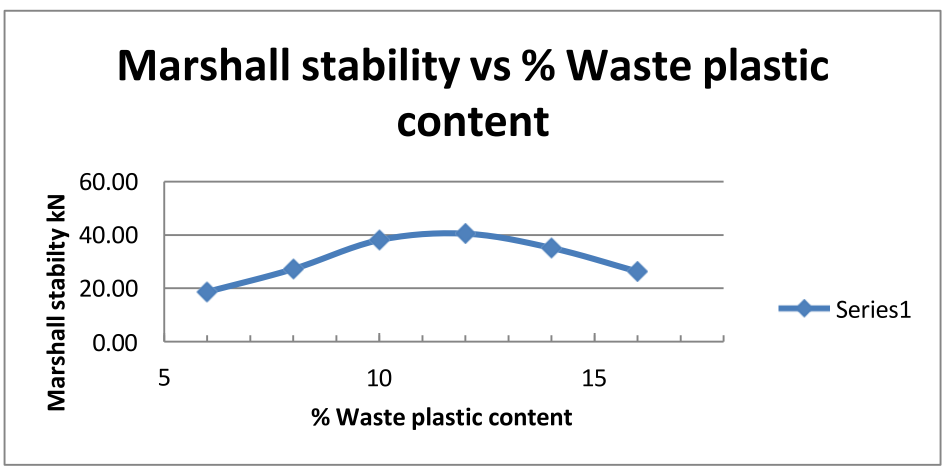

Figure 13 Graphical Plot of Stability vs Replacing Waste Plastic%

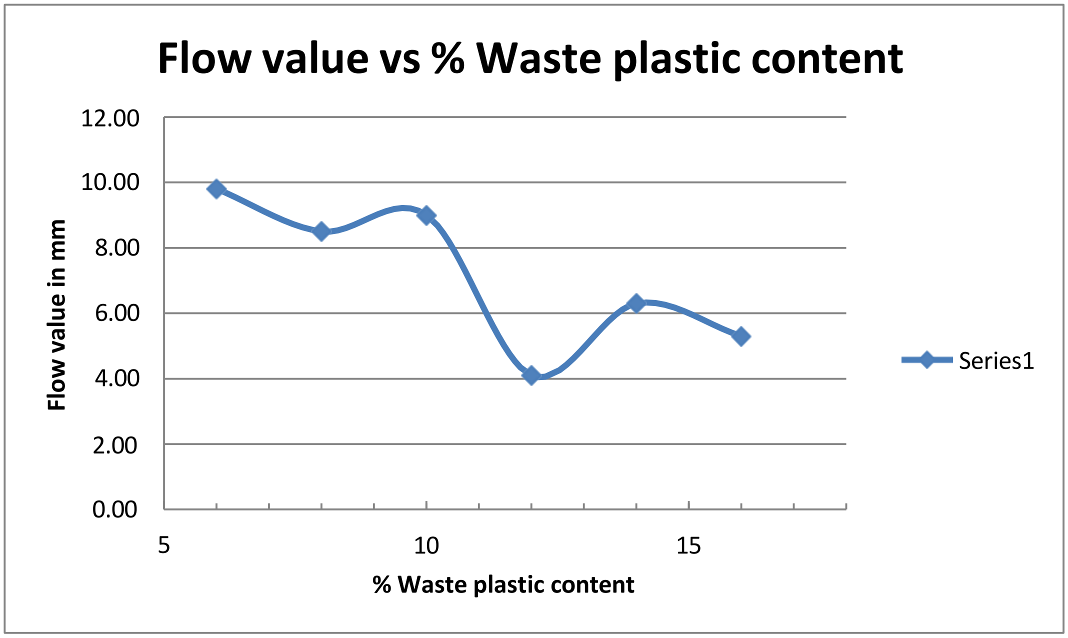

Figure 14 Graphical Plot of Flow vs Replacing

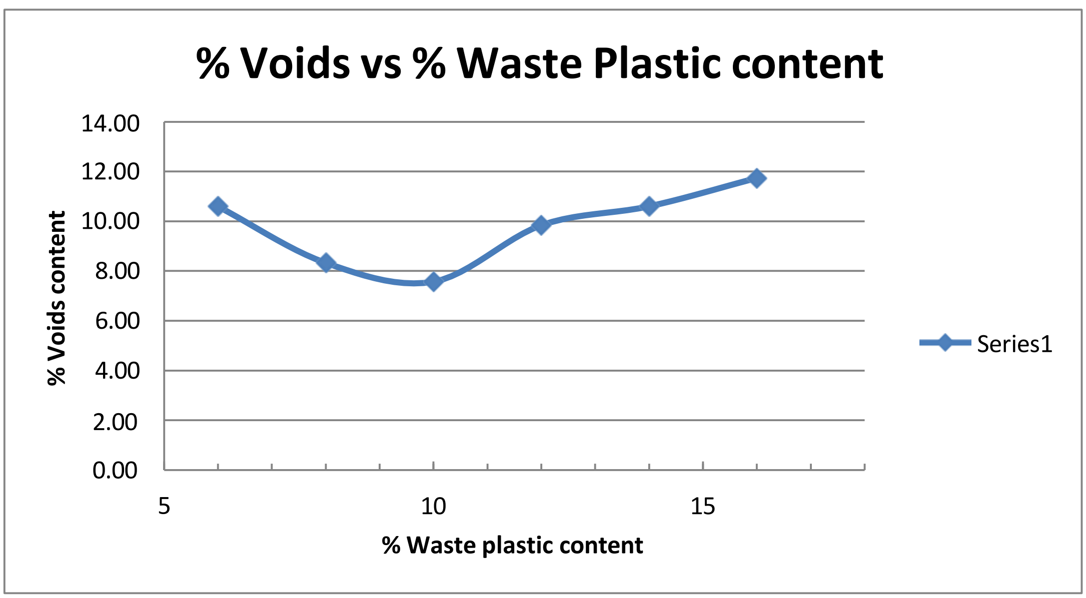

Figure 15 Graphical Plot of % voids vs Replacing Waste plastic %

Chapter 4

DISCUSSION OF TEST RESULTS

4.1 Determination of Optimum Bitumen Content for Conventional Dense Graded Bituminous Mix

From the test results as shown in table 8,9 & 10 and figure 10,11,& 12 it is seen that highest Marshall stability value, lowest flow value and considerable lowest value %volume of voids is seen at 5% bitumen content.

Hence optimum bitumen content for conventional dense graded bituminous mix is obtained as 5%.

4.2 Determination of Optimum Waste plastic Blended Dense Graded Bituminous Mix by Dry Blending

From the test results as shown in table 11,12 &13 and figure 13,14 & 15 it is seen that bituminous mix having 5% bitumen content and blended with waste plastic as 12% by weight bitumen content was the optimum waste plastic blended bituminous mix from the rest of mix combinations as it had following properties.

- Highest Marshall stability value of **40.51 KN.**
- Least Marshall flow value of **4.10 mm.**
- Considerable low values of % volume of voids as 4.41%.
- Highest value of % voids filled with bitumen as 80.47%.

Hence in this investigation the optimum blend of waste plastic by dry mixing for the dense graded bituminous mix having 5% bitumen content was found to be 12% by the weight of bitumen content.

CHAPTER 5

CONCLUSIONS

Based on this experimental investigation, it has been found that blending waste plastic with dense graded bituminous mix has various advantages which is as listed below

1. Use of waste plastic is one of the solutions for reducing the burden on solid waste disposal.
2. Dry blending of 12% waste plastic by weight of 5% binder content in dense graded bituminous mix has improved the properties of the dense graded bituminous mix which are as listed below:
    - Marshall stability value increased by 21.36%
    - Marshall flow value decreased by 10.86%.
    - % volume of voids decreased by 5.16%
3. Hence dry blending of waste plastic is advantageous as it improves the strength and stiffness of dense graded bituminous mix.

Scope for further studies

In the present investigation, the waste plastic has been used for improving the properties of dense graded bituminous mix.

Hence use of other waste materials such as waste rubber can be investigated.

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[7] ASTM (D6927-2006) Method to perform Marshall stability test.

[8] IS-1203- Method for penetration testing of bitumen.

[9] IS-1208-Method for ductility test for bitumen.

[10] IS-1205-Method for softening test for bitumen.

[11] IS-2386-Method for Flakiness and Elongation test for aggregates.

STUDIOS

(Source- KSSEM CONCRETE AND HIGHWAY MATERIALS TESTING LAB)

Aggregates coating with waste plastic aggregates

Heating of bitumen

Pouring of heated bitumen

Tamping 75 times on both sides on mould

Checking temperature of aggregates mix

Marshall sample moulds

Submerged weight in water

Mold setup in UTM

Loading Dial gauge

Deformation dial gauge