OPTIMIZATION OF DIFFERENT ANTI STRIPPING AGENTS IN CONSTRUCTION OF FLEXIBLE PAVEMENT

A Thesis Submitted

In Partial Fulfilment of the Requirements for the Degree of

MASTER OF TECHNOLOGY

In

TRANSPORTATION ENGINEERING

(CIVIL ENGINEERING)

By

PURNIMA TRIPATHI

(1180465007)

Under the Guidance of

Prof. D. S. Ray

PROFESSOR

In

Department of Civil Engineering

BBD UNIVERSITY

BABAU BANARSI DAS UNIVERSITY, LUCKNOW

(June, 2018-2020)

CERTIFICATE

This is Certified that **PURNIMA TRIPATHI (1180465007)** has carried out the research work presented in this Thesis entitled **"OPTIMIZATION OF DIFFERENT ANTI STRIPPING AGENTS IN CONSTRUCTION OF FLEXIBLE PAVEMENT"** for the award of **Master of Technology** from Babu Banarasi Das University, Lucknow under my supervision. The thesis embodies results of original work, and studies are carried out by the student herself and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

Prof. D. S. Ray

Department of Civil Engineering

Date:

urkund

Document Information

Analyzed document	PURNIMA MTECH FINAL THESIS PDF FORM.pdf (D75876528)
Submitted	7/1/2020 12:23:00 PM
Submitted by	Mr kamal Nath Tripathi
Submitter email	kamalnt11@bbdu.ac.in
Similarity	14%
Analysis address	kamalnt11.bbduni@analysis.urkund.com

Sources included in the report

W	URL: https://www.ijert.org/a-review-of-literature-on-optimization-of-different-anti-str ... Fetched: 6/29/2020 11:32:54 AM	30
W	URL: https://docplayer.net/53521133-Experimental-study-of-bituminous-concrete-containg- ... Fetched: 7/1/2020 12:26:00 PM	1
W	URL: https://pavementinteractive.org/reference-desk/pavement-management/pavement-distre ... Fetched: 7/1/2020 12:26:00 PM	1
W	URL: https://www.worldhighways.com/wh6/feature/role-anti-stripping-agents-asphalt-perfo ... Fetched: 7/1/2020 12:26:00 PM	2
W	URL: https://www.researchgate.net/publication/245145683_Effect_of_antistripping_additiv ... Fetched: 11/26/2019 4:56:22 PM	1
W	URL: https://www.researchgate.net/publication/318462571_Investigation_on_the_Effect_of_ ... Fetched: 5/2/2020 10:27:24 AM	3
W	URL: https://dir.indiamart.com/impcat/anti-stripping-agent.html Fetched: 7/1/2020 12:26:00 PM	1
W	URL: https://www.researchgate.net/publication/302066139_Effect_of_zycotherm_on_moisture ... Fetched: 6/29/2020 11:32:53 AM	1
W	URL: https://www.researchgate.net/publication/304674379_STUDY_OF_COIR_FIBRE_REINFORCED_ ... Fetched: 7/1/2020 12:26:00 PM	4
W	URL: https://www.researchgate.net/publication/341919445_A_Study_on_Improving_Convention ... Fetched: 6/14/2020 9:24:11 AM	2
W	URL: https://www.scirp.org/html/8-1880441_62005.htm Fetched: 7/1/2020 11:19:21 AM	1
W	URL: https://www.researchgate.net/publication/322551793_Using_the_Boiling_Test_to_Evalu ... Fetched: 7/1/2020 12:26:00 PM	2

W URL: https://ir.library.oregonstate.edu/downloads/9z903270s
Fetched: 7/1/2020 12:26:00 PM

2

DECLARATION

I, hereby declare that the work which is being presented in the M. Tech. Thesis Report entitled **“OPTIMIZATION OF DIFFERENT ANTI STRIPPING AGENTS IN CONSTRUCTION OF FLEXIBLE PAVEMENT”,** in fulfilment of the requirements for the award of the Master Of Technology in **Transportation Engineering (Civil Engineering)** and submitted to the Department of Civil Engineering of Babu Banarasi Das University, Lucknow (U.P.) isanauthentic record of our own work carried out during the period from **August 2018 to June 2020** under the guidance of **Prof. D.S. Ray, Department of Civil Engineering.** The matter presented in this thesis has not submitted by me for the award pf any other degree elsewhere**.**

Purnima Tripathi

University Roll. No. (1180465007)

Date:

ACKNOWLEDGEMENT

First and foremost, I praise God, the almighty for providing me this opportunity and granting me the capability to complete my research work successfully, I would like to express my sincere appreciation and deepest gratitude to my advisor, **Prof. D. S. Ray (Department Of Civil Engineering)** for his support, help and guidance during my course work study. His guidance has made my learning experience a very special one and I am truly fortunate to have had the opportunity to work with him. I could not have finished this work without the encouragement and guidance of **Prof. Anupam Mehrotra**, Head, Department of Civil Engineering, Babu Banarasi Das University, Lucknow.

Finally, I want to express my deep gratitude to my friends who always loved, supported and encouraged me throughout this challenging process.

(Purnima Tripathi)

ABSTRACT

The aim of this research project is to improve current practice by investigating different test methods to quantify moisture damage in an effort to serve the short- and long-term needs of the agency and industry. This research deals with important concepts of stripping as, bitumen chemistry and rheology, aggregate properties (chemical and mineralogical composition, surface texture, morphology, porosity, etc), traffic, water properties, construction practices (mixing, placement and in-service drainage) and nature of antistripping additives.

This report presents the effect of anti-stripping additives in bituminous mixes. As per researches series of laboratory tests have been conducted with varying percentage of these Anti-stripping additives, added Individually and in Combinations, to determine their optimum percentages. This report presents the results of experimental investigations carried out to study the effect of **Wetbond-S, Zycotherm** and **Bitugrip** on bitumen and aggregate. Boiling water test and Stripping value test were conducted as screening tests performed on **Wetbond-S, Bitugrip** and **Zycotherm** modified bitumen. The current research shows the optimization of different anti-stripping additives to evaluate moisture susceptibilities of bituminous mixes. This report deals with the review of some previous studies that are done to improve the adhesion between bitumen and aggregate. The stripping value decreases while increasing the percentage of anti-stripping additives to the bitumen. The results indicated that the addition of anti-stripping agents increase moisture resistance of asphalt mixes to some extent. Moreover, it was concluded that mix samples prepared using anti-stripping additive imparted more correlation and greater resistance to water damage.

TABLE OF CONTENTS

CERTIFICATE	i
DECLARATION	ii
ACKNOWLEDGEMENT	iii
ABSTRACT	iv
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF GRAPHS	x
CHAPTER-1 INTRODUCTION	**1-14**
1.1 Background	1
1.2 Problem Statement	2
1.3 Pavement Failure	3
1.3.1 Rutting	3
1.3.2 Raveling	4
1.3.3 Potholes	5
1.4 Pavement Maintenance and Rehabilitation	6
1.5 Important Keywords	6
1.5.1. Moisture Susceptibility	6
1.5.2 Adhesion	7
1.5.3 Stripping	7
1.5.3.1 Mechanism of Stripping	8
1.5.3.3 Causes of Stripping	10
1.5.3.3 Factors Affecting Stripping	12
1.5.3.4. Key Factors	13
1.6 Research Objectives	14
CHAPTER-2 LITERATURE REVIEW	**15-18**
CHAPTER-3 MATERIAL USED	**19-24**
3.1 Overview	19
3.2 Aggregate	19
3.3 Bitumen	19
3.4 Anti-Stripping Agents	20
3.4.1 Zycotherm	20
3.4.2 Bitugrip	21
3.4.3 Wetbond-S	23

CHPATER-4 METHODOLOGY **25-32**

4.1 Overview 25

4.2 Tests for Bitumen 25

4.2.1 Penetration Test Setup 25

4.2.2 Softening Point Test Setup 27

4.2.3 Ductility Test Setup 28

4.3 Tests used in this Research 29

4.3.1 Boiling Water Test 29

4.3.2 Stripping Value Test 30

CHAPTER-5 EXPERIMENTAL INVESTIGATION **33-49**

CHAPTER-6 OBSERVATION **50-63**

6.1 Conventional Properties of Bitumen 50

6.2 Boiling Water Test Result 51

6.3 Stripping Value Test 52

CHPATER-7 RESULT ANALYSIS AND DISCUSSION **64 -69**

CHPATER-8 CONCLUSION AND RECOMMENDATION **70-71**

SCOPE FOR FUTURE INVESTIGATION **72**

REFERENCES **73-75**

LIST OF TABLES

Table 3.4.1: Properties of Zycotherm 20
Table 3.4.2: Properties of Bitugrip 22
Table 3.4.3: Properties of Wetbond-S 23
Table 6.1 Conventional Properties of Bitumen Used 50
Table 6.2.1 Boiling Water Test Results of Wetbond-S 51
Table 6.2.2 Stripping Value Test Results of Wetbond-S 52
Table 6.3.1 Boiling Water Test Results of Bitugrip 53
Table 6.3.2 Stripping Value Test Results of Bitugrip 54
Table 6.4.1 Boiling Water Test Results of Zycotherm 55
Table 6.4.2 Stripping Value Test Results of Zycotherm 56
Table 6.5.1 Optimum Values of ASA in Boiling Water Test 57
Table 6.5.2 Optimum Values of ASA in Stripping Value Test 57
Table 6.6.1 Boiling Water Test results of Wetbond-S+Zycotherm 58
Table 6.6.2 Stripping Value Test results of Wetbond-S+Zycotherm 59
Table 6.7.1 Boiling Water Test results of Wetbond-S+Bitugrip 60
Table 6.7.2: Stripping Value Test results of Wetbond-S+Bitugrip 61
Table 6.8.1 Boiling Water Test results of Wetbond-S+Zycotherm+Bitugrip 62
Table 6.8.2: Stripping Value Test Results of Wetbond-S+Zycotherm+Bitugrip 63
Table 7.1: Analysis of Maintenance Cost in case of Boiling Water Test 64
Table 7.2: Analysis of Maintenance Cost in case of Stripping Value Test 67

LIST OF FIGURES

Fig.1.3.2 Rutting	4
Fig.1.3.3 Ravelling	5
Fig.1.3.4 Potholes	5
Fig.1.4(a) Cracking caused by stripping at the bottom of HMA layer	8
Fig.1.4(b) Adhesion failure at the Aggregate-Bitumen interface	8
Fig 1.4.2 Conceptual diagram of stripping mechanism	9
Fig 3.4.1 Zycotherm	21
Fig 3.4.2 Bitugrip	22
Fig 3.4.3 Wetbond-S	24
Fig 4.2.1 Penetration Test Setup	25
Fig 4.2.2 Softening point test setup	27
Fig 4.2.3 Ductility test setup	28
Fig 4.3.1 Boiling Water Test	29
Fig 4.3.2 Test apparatus to mix Aggregate & Bitumen	31
Fig 5.1: Stripping without adding Anti Stripping Agent in Boiling Water Test	33
Fig 5.1.1.1: Stripping after adding 0.05% Zycotherm in Boiling Water Test	34
Fig 5.1.1.2: Stripping after adding 0.075% Zycotherm in Boiling Water Test	34
Fig 5.1.1.3: Stripping after adding 0.10% Zycotherm in Boiling Water Test	35
Fig 5.1.1.4: Stripping after adding 0.15% Zycotherm in Boiling Water Test	35
Fig 5.1.2.1: Stripping after adding 0.5% Bitugrip in Boiling Water Test	36
Fig 5.1.2.2: Stripping after adding 0.75% Bitugrip in Boiling Water Test	36
Fig 5.1.2.3: Stripping after adding 1.0% Bitugrip in Boiling Water Test	37
Fig 5.1.2.4: Stripping after adding 1.5% Bitugrip in Boiling Water Test	37
Fig 5.1.3.1: Stripping after adding 0.05% Wetbond-S in Boiling Water Test	38
Fig. 5.1.3.2 Stripping after adding 0.07% Wetbond-S in Boiling Water Test	38
Fig: 5.1.3.3 Stripping after adding 0.10% Wetbond-S in Boiling Water Test	39
Fig 5.2: Stripping without adding Anti Stripping Agent in Stripping Value Test	39
Fig 5.2.1.1: Stripping after adding 0.05% Zycotherm in Stripping Value Test	40
Fig 5.2.1.2: Stripping after adding 0.075% Zycotherm in Stripping Value Test	40
Fig 5.2.1.3: Stripping after adding 0.10% Zycotherm in Stripping Value Test	41

Fig 5.2.1.4: Stripping after adding 0.15% Zycotherm in Stripping Value Test 41
Fig 5.2.2.1: Stripping after adding 0.5 % Bitugrip in Stripping Value Test 42
Fig 5.2.2.2: Stripping after adding 0.75 % Bitugrip in Stripping Value Test 42
Fig 5.2.2.3: Stripping after adding 1.0 % Bitugrip in Stripping Value Test 43
Fig 5.2.2.4: Stripping after adding 1.5 % Bitugrip in Stripping Value Test 43
Fig 5.2.3.1: Stripping after adding 0.05% Wetbond-S in Stripping Value Test 44
Fig 5.2.3.2: Stripping after adding 0.07% Wetbond-S in Stripping Value Test 44
Fig 5.2.3.3: Stripping after adding 0.10% Wetbond-S in Stripping Value Test 45
Fig 5.3.1: Stripping after adding Optimum Values of Wetbond-S+Zycotherm in Boiling Water Test 46
Fig 5.3.2: Stripping after adding Optimum Values of Wetbond-S+Bitugrip in Boiling Water Test 47
Fig 5.3.3: Stripping after adding Optimum Values of Wetbond-S+Zycotherm+Bitugrip in Boiling Water Test 47
Fig 5.4.1: Stripping after adding Optimum Values of Wetbond-S+Zycotherm in Stripping Value Test 48
Fig 5.4.2: Stripping after adding Optimum Values of Wetbond-S+Bitugrip in Stripping Value Test 48
Fig 5.4.3: Stripping after adding Optimum Values of Wetbond-S+Zycotherm+Bitugrip in Stripping Value Test 49

LIST OF GRAPHS

Fig 6.2.1: Stripping v/s Quantity of Wetbond-S in Boiling Water Test 51

Fig 6.2.2: Stripping v/s Quantity of Wetbond-S in Striping Value Test 52

Fig 6.3.1: Stripping v/s Quantity of Bitugrip in Boiling Water Test 53

Fig 6.3.2: Stripping v/s Quantity of Bitugrip in Stripping Value Test 54

Fig 6.4.1: Stripping v/s Quantity of Zycotherm in Boiling Water Test 55

Fig 6.4.2: Stripping v/s Quantity of Zycotherm in Stripping Value Test 56

Fig 6.6.1: Stripping v/s Optimum Value of (Wetbond-S+ Zycotherm) in Boiling Water Test 58

Fig 6.6.2: Stripping v/s Optimum Values of (Wetbond-S+Zycotherm) in Stripping Value Test 59

Fig 6.7.1: Stripping v/s Optimum Values of (Wetbond-S+Bitugrip) in Boiling Water Test 60

Fig 6.7.2: Stripping v/s Optimum Values of (Wetbond-S+Bitugrip) in Stripping Value Test 61

Fig 6.8.1: Stripping v/s Optimum Values of (Wetbond-S+Zycotherm+Bitugrip) in Boiling Water Test 62

Fig 6.8.2: Stripping v/s Optimum Values of (Wetbond-S+Zycotherm+Bitugrip) in Stripping Value Test 63

Fig 7.1 (a): Maintenance Cost v/s ASA (%) adding Individually in Boiling Water Test 66

Fig 7.1(b): Maintenance Cost After v/s ASA% adding in combination in Boiling Water Test 66

Fig 7.2(a): Maintenance Cost v/s Optimum Values of ASA (%) adding individually in Stripping value Test 69

Fig 7.2(b): Maintenance Cost v/s ASA (%) adding in combination in Stripping Value Test 69

LIST OF ABBREVIATIONS

ASA- Anti Stripping Agent

HMA- Hot Mix Asphalt

AP- Adhesion Promotors

PMB- Polymer Modified Bitumen

WMA- Wet Mix Asphalt

HMP- Hot Mix Plant

ASTM- American Society of Testing and Materials

IRC- Indian Road Congress

CHAPTER-1: INTRODUCTION

1.1 BACKGROUND

Road sectors are the engines of growth for economy, employment and empowerment. Owing to increases in household income, the demands for personalized vehicles have also increased. In India 95% of roads are bituminous roads which consists approximately 93-95% of aggregate and 5-7% of binder material. Until now conventional bituminous binders were performing satisfactory results but with increase in traffic intensity there is a need of better binder material which can perform better under heavy traffic loads without compromising the performance of bituminous mix. Many mileages of roadway worldwide have been replaced prematurely, due to moisture-induced damage in form of stripping. Construction and subsequent maintenance of pavements in good condition has become quite problematic especially in areas where soft bitumen is met with. During Rainy season the natural bitumen become failure and posses serious problem. Due to the movement of vehicular traffic, treatment and strengthening of bitumen appear to be the only solution for keeping the pavement of surfaces serviceable. The pavements even when constructed according to the traditional methods are failing due to the bitumen undergoing deformations during monsoon and become unserviceable. Loss of adhesion also renders cohesive resistance of the interstitial bitumen useless.

In recent years, stripping has been a serious problem in asphalt paving mixture. The loss of bond between aggregates and asphalt binder that generally begins at the bottom of the HMA layer and progresses upward is understood to be stripping of pavement. It causes functional weakening of pavements leading to costly repairs. Water may enter the interface through diffusion across bitumen films, seepage in film micro voids, and through direct access in partially coated aggregates or may be resident in aggregate pores prior to mixing. Many roads are paved applying hot mix asphalt (HMA) that imparts flexibility, comfort and ease of application. However, poor construction practices and defects of maintenance and repair works, frequently lead to complete HMA pavement failures. Most of pavements in humid and wet climates encounter failures such as rutting, cracking and stripping which occur as a result of traffic loading, thermal variation and water damages. Water penetrates through pavement surfaces, causing failure between aggregate particles and bitumen which will finally result in stripping in pavements. The moisture damage causes loss of adhesion, and adversely affect to the strength of the asphalt mixture dramatically. It can also cause the premature pavement failures like rutting and raveling on the pavement surface. The most common technique to mitigate moisture damage is the use of additives or modifiers with the asphalt binder or the aggregate. The moisture damage of asphalt mixtures is defined as the progressive loss of functionality of the material due to loss of the adhesive bond between the asphalt binder and the aggregate surface. Penetration of moisture in asphalt mixtures reduces strength and stiffness of asphalt mixtures and prone the mixtures to develop various forms of premature pavement distress. Additional distresses provoked by moisture in asphalt mixtures are: rutting, alligator cracking and potholes. To alleviate or to regulate the deformations due to water damage, various researches were performed resulting in the use of anti-stripping additives. Anti-stripping additives are used to increase physio-chemical bond between the bitumen and aggregate and also to improve wetting by lowering the surface tension of the bitumen. Numerous studies indicate that anti-stripping additives can positively affect the binder–aggregate bonding characteristics and overall mixture performance by reducing mixtures' moisture susceptibility. In India, method of determination of stripping value of road aggregates (IS:6241-1971) is the standard describing the stripping test for the coarse aggregates. The research is done by adding the anti- stripping agents to the bitumen the stripping value test is performed to describe the property of the anti-stripping agents on the bitumen.

1.2 PROBLEM STATEMENT

In the industry of road construction, the present challenge is to develop more ecological products while maintaining asphalt mixture performance and durability. Many More highway agencies experience a reduction in asphalt pavement life due to moisture damage. Every year there is a public outcry and newspapers are full of pictures showing stripped road pavements. Unexpected hurdles on the roads may cause more accidents. One of the major reason for road accidents is Stripping according to the survey conducted by automobile association. Vehicles tend to lose balance when they come across a larger potholes. Potholes on the roads are due to many reasons like rains, oil spills, road accidents or inevitable wear and tear make the road difficult to drive upon. Unexpected hurdles on the roads may cause more accidents. In this context, the use of more sustainable technologies for asphalt production aims to reduce the working temperature, save energy, and guarantee the safety of specialized personnel. To overcome the loss of adhesion quality between bitumen and aggregate caused by the demanding reduction of the manufacturing temperature it is therefore crucial to seek and test

new organic additives are ready to improve the adhesive properties of bitumen at working conditions of warm mix asphalt technology. One of the ways in which the adhesion between bitumen and mineral stones can be improved is by the use of adhesion promoters (APs).
The following are the major disadvantages:

- Inconvenience to the vehicles running on the road.
- Time delay.
- Consumption of extra fuel.
- Excessive wear and tear of the vehicles which require frequent repairs.
- Increase in air pollution.
- Increase in road accidents.

1.3 PAVEMENT FAILURE

In the case of most of the structures, failure hardly needs defining- it happens suddenly, it is very obvious, and it marks the end of the structure's useful life. Some pavement failures happen suddenly, in most situations a pavement gradually deteriorates.

To settle on a definition, let us refer to the term "pavement failure" as when the deterioration of a section of pavement reduces its serviceability and/or future usefulness such that remedial action is necessary. Most primary failures result from weakness at one of three points in a pavement. These are:

- Surface Failure: Potholes, Ageing
- Base Failure: Crocodiles cracking
- Bond Failure

1.3.1 RUTTING

Rutting is characterized by permanent deformation in the wheel path of the pavement after repeated traffic loading. This distress is caused by either insufficient support provided by the base and sub-grade layers of the pavement structure or material deficiencies in the hot mix asphalt. In terms of moisture damage, rutting would be realized in the HMA layer due to a moisture susceptible mix losing its ability to resist repeated load due to the moisture effects.

Rutting is measured using the following severity levels:

- Slight: ¼" – ½" rut depth
- Moderate: ½" – 1" rut depth
- Severe: Rut depths greater than 1"

Fig.1.3.2: Rutting

1.3.2 RAVELING

Progressive disintegration of the pavement from the surface downward. This distress is caused by the loss of bond between the asphalt binder and aggregate particles, resulting in aggregates being dislodged from the surface of the pavement. The loss of aggregates on the pavement surface presents a safety hazard due to loss of skid resistance on affected surfaces of the road. Surface raveling is measured in severity only. Severity is defined in three levels:

- Slight: The aggregate and/or asphalt binder has worn away from the surface and the
- surface texture is slightly rough or pitted.
- Moderate: Same as definition for slight except the surface texture is moderately rough
- or pitted.
- Severe: Same as definition for slight except the surface texture is severely rough or

pitted.

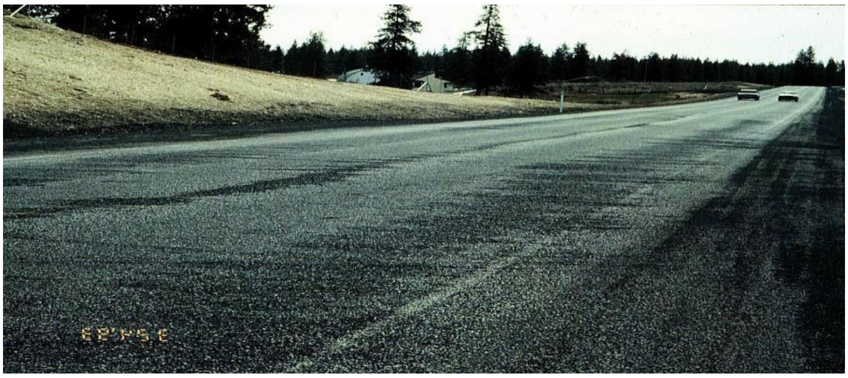

Fig. 1.3.3: Raveling

1.3.3 POTHOLES

Pothole is a structural failure in a paved surface, usually asphalt pavement, because of water with in the underlying soil structure and traffic passing over the affected area. Water first weakens the underlying soil then fatigues and breaks the poorly supported asphalt surface in the affected area. Continued traffic action ejects both asphalt and the underlying soil material to create a hole in the pavement.

Potholes are bowl shaped holes or pits of assorted sizes found on pavement surface.

1) LOW-The hole depth not exceeding 25 mm.
2) MODERATE-The hole depth ranges between 25 mm to 50 mm.
3) HIGH- Depth>50mm.

Fig.1.3.4: Potholes

1.4 PAVEMENT MAINTENANCE AND REHABILITATION

Pavement maintenance can be related to a term called "serviceability", helps us to understand how the time and traffic affects pavement performance.

Types of maintenance and rehabilitation activities the maintenance and rehabilitation of flexible pavements involves a range of activities which may be categorized as:

- Routine maintenance
- Periodic maintenance
- Rehabilitation.

Routine maintenance is concerned with minor activities required to slow down or prevent deterioration of a road pavement. It tends to be preventive as well as corrective and includes such activities as:

- Crack sealing
- Potholes repair
- Minor correction of surface texture deficiencies
- Minor shape correction.

Periodic maintenance primarily involves preservation of the asset using thin surfacing to restore texture or ride quality, protect the surface against entry of moisture, or prevent deterioration through raveling and weathering.

Rehabilitation includes major work carried out to restore structural service levels. As such, the treatments are corrective in nature and include:

- Non-structural overlays
- Structural asphalt overlays
- Reconstruction or recycling of pavement materials, etc.

1.5 IMPORTANT KEYWORDS

1.5.1 Moisture Susceptibility

Moisture susceptibility is the tendency of HMA toward stripping. The loss of integrity of an HMA mix through the weakening of the bond between the aggregate and the binder is known as stripping. Stripping usually begins at the bottom of the HMA layer, and gradually travels upward. To prevent moisture susceptibility, proper mix design is essential. However, even with a proper mix design, if the mix is not compacted properly, it may still be susceptible to moisture damage. Thus, HMA should be tested in a situation where moisture can infiltrate into the air voids of the mixture.

1.5.2 ADHESION

One of the fundamental properties for good performances of bituminous pavement is proper adhesion between aggregate and bitumen. The adhesion between mineral aggregates and bitumen is an important criterion which describes the quality of asphalt mixture, asphalt performance and resistance to distress. The lack of bonding can lead to significant asphalt pavement damage. For the evaluation of the adhesion behavior between bitumen and aggregates, used in road construction, many tests have been practiced. The adhesion is influenced by the characteristics of both the bitumen and the aggregate used in the mixture. Adhesion can be generally defined as the molecular force of attraction between two bodies of different nature in contact with each other.

1.5.3 STRIPPING

The use of bitumen is reflected in many applications and dates back to ancient times. In bituminous mixes, bitumen holds the aggregates forming a mass that supports high stresses. It is crucial that strong and durable interfacial bonds exist under all conditions. Depending on how bitumen interacts with aggregate, stripping may affect this desirable precept.

Stripping is the breaking of the adhesion bond between the aggregates and the bituminous binder. In one way or the other water gets in between the binder film and the aggregate surface and because the aggregate surface has higher attraction for water than for bituminous binder then adhesive bond is broken. It is one of the most commonly occurring distresses in asphalt pavements. Surface moisture content is most desirable factor for stripping analysis as most of the bond loss between aggregate and binder starts from pavement surface due to the moisture content from atmosphere and other outer sources.

Fig 1.4(a): Cracking caused by stripping at the bottom of HMA layer

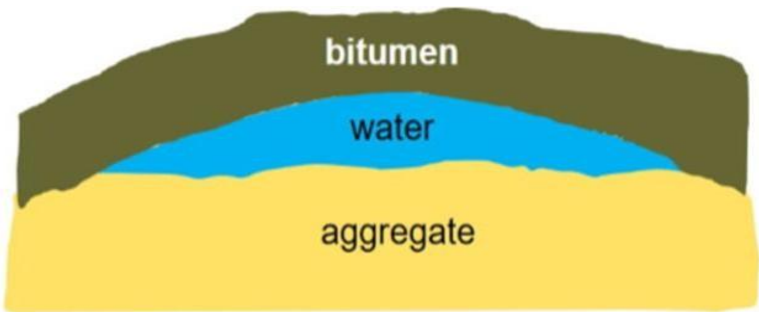

Fig 1.4(b): Adhesion failure at the Aggregate-Bitumen interface

1.5.3.1 MECHANISM OF STRIPPING

- Stripping in asphalt pavement results from the failure of the asphalt aggregate adhesion bond due to the presence of water. The location of this failure (in the interface region) is crucial to understand the mechanism of stripping. Some major mechanisms that lead to stripping are described below:
- Weak Adhesion Bond-Lack of Bonding Sites on Aggregate Surface.
- Naturally Emulsifiable Asphalt Leading to Unstable Adhesion.
- Aggregate with Weak Boundary Layers.
- Dissolution of Aggregate-Asphalt Surface Complexes.

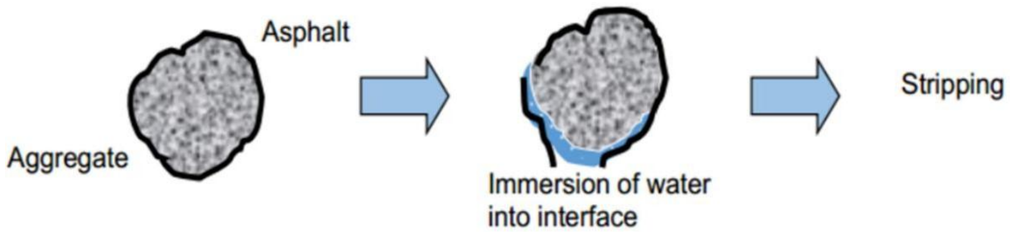

Fig 1.4.2: Conceptual diagram of stripping mechanism

There are five different mechanisms by which stripping of bitumen from an aggregate surface may occur. These five mechanisms include Detachment, Displacement, Spontaneous Emulsification, Pore Pressure & Hydraulic Scouring.

Brief description of each suggested mechanism of stripping follows:

Detachment

Detachment is defined as the separation of asphalt film from an aggregate surface by a skinny film of water with no obvious break in the asphalt film. When stripping in a mix is due to detachment, the asphalt film can be totally peeled off the aggregate, indicating a complete loss of adhesion. The effects of detachment on an asphalt mix can be mitigated by using dry aggregate and by using a less permeable asphalt binder. Both of these measures minimize the chances of water entering the asphalt aggregate system, thus reducing the probability of detachment occurring in the mix.

Displacement

Displacement is a result of penetration of water to the aggregate surface from a break in the asphalt film. To minimize the effects of displacement on an asphalt mix, the potential sources of film rupture or spaces in the asphalt aggregate interface must be minimized. Spaces in the asphalt film coating the aggregate are caused by incomplete coating of the aggregate in the mixing process, pinholes formed by dust in the binder caused by a dusty aggregate, and film rupture on sharp edges of aggregate.

Spontaneous Emulsification

In Spontaneous emulsification, water and bitumen combine to make an inverted emulsion, where bitumen represents the continuous phase and water represent the discontinuous phase. The formation of such an emulsion leads to stripping and is further aggravated by the presence of emulsifiers such as mineral clays and some bitumen additive.

Pore Pressure

The mechanism of pore pressure is a consequence of the decrease of air voids in the HMA pavement because of traffic stacking. Under loading the water present in the air voids is compressed, increasing pressure against the asphalt film. Repeated loading causes the pore pressure to reach a sufficient level to cause rupture of the asphalt film, allowing water to infiltrate the aggregate surface and begin to strip the aggregate via displacement. This mechanism is usually realized in newly placed HMA pavements. New pavements are compacted to approximately 7-8% air voids under the assumption that densification to 4% air voids will occur due to traffic loading. Therefore early in pavement life the voids are sufficiently large to be interconnected, allowing for water to freely move through the pavement. As the pavement begins to further densify the air voids close and water is trapped inside of them. This entrapped water creates pore pressures in the pavement from both traffic loading and thermal expansion/contraction.

Hydraulic Scour

Hydraulic scour may be a mechanism of stripping that only occurs in surface courses. This mechanism is due to the movement of a tire over a wet pavement. As a tire moves on a pavement the water in front of the tire is pressed down into the void spaces of the road. As the back of the tire passes the water is immediately sucked out behind the tire. This action subjects pavements to thousands of compression-tension loading cycles daily. The cumulative effect of these cycles results in stripping of the aggregate.

1.5.3.2 CAUSES OF STRIPPING

Inadequate Pavement Drainage

Inadequate surfaces or sub-surfaces produce water or moisture vapour, which is the necessary catalyst to induce stripping. Water can enter the HMA pavement in many ways. It can enter as surface runoff from cracks and other openings. It can also enter from the sides and the bottom as seepage from ditches or from a high water table. Water often moves upward by the capillary action from the bottom of the pavement.

The air voids in the HMA can become saturated with water, even from the vapour condensation from water in the sub-grade and the sub-base. A temperature rise after this saturation, and traffic stresses can cause to significant void pressure when the voids are saturated.

If the HMA is permeable, water could flow out from the voids under the pressure and relieve the developed pressure. If not, the tensile stresses developing can break the bond between the binder and the aggregate. This damage due to void water pressure is internal and the exterior sides of the specimen do not show any signs of stripping unless they are opened for visual examination.

Inadequate Compaction

Most agencies specify an air content in the HMA mat of about 8% during construction, which is further compacted by traffic to about 4-5%. Studies indicate that when the air content is about 4-5%, the pores are not interconnected, and thus almost impervious to water. However, if good compaction control is not exercised, the pavement would have a higher air content, leading to the ingress of water, causing moisture damage to the pavement. Also, if the pavement remains pervious to water for a long period of time, moisture damage can also be caused due to the hydrostatic pore pressure caused by traffic.

Excessive Dust Coating on the Aggregate

The presence of dust and clay coating on the aggregate can inhibit the intimate contact between the binder film and therefore the aggregate, thereby forming channels for penetrating water. The binder coats the dust coating and is not in contact with the aggregate surface. Some very clayey material may cause stripping by emulsifying the binder in the presence of water.

Action of the Traffic

After any rain shower, the water in the pavement is pressed into the underlying layer by truck tires. This causes tremendous hydrostatic stresses, leading to the breaking of the bond between the binder and the aggregate. This is especially severe with in the case of open graded friction courses due to the high air content.

Inadequate Drying of Aggregates

When the aggregate is coated with binder, a dry aggregate surface will better adhere to the binder than a wet surface. As the hot binder is introduced to the wet aggregate surface, the moisture on the surface of the aggregate vaporizes and does not allow the binder to coat the aggregate well.

Weak Aggregates

If weak and friable aggregates are used in the mixture, degradation takes place during rolling and later under heavy traffic loads. Degradation and delamination exposes new uncoated aggregate surfaces that can absorb moisture and initiate stripping problems.

Water Proofing Membranes and Seal Coats

If the source of moisture is from below the pavement, which is usually the case, the application of a water proofing membrane or a seal coat can be detrimental. The moisture that reaches the bottom of the pavement from ground water, shoulders, median, etc., migrates through the pavement by capillary action. Above the capillary fringe, the water moves as vapor, and if its movement is obstructed by a seal coat or a water proofing membrane, the vapour condenses under sealing layer. It is again converted to vapour, when heated by sunlight, causing significant vapour pressure and leads to stripping in the pavement.

1.5.3.3 FACTORS AFFECTING STRIPPING

The following factors were determined to affect the moisture susceptibility of the HMA:-

Aggregate Type

Aggregate shape is also an important factor. Angularity and heterogeneity promote mechanical interlocking and overall higher life cycle. Additionally, the surface texture of the it is an critical thing that relates to stripping. Rougher surfaces, allow for a stronger bond between the binder and the aggregate. This is one reason that uncrushed river gravel is not approved for asphalt in many instances – the surface is much smoother than crushed material.

Void Content

The overall performance of a pavement is also dependent on the void content of the HMA. The possibility of stripping will increase because the percentage of air voids will increase, as there is more room for moisture to enter the mix and induce hydrostatic forces with in the mix. Studies display that the Pedestal test life falls sharply as the void content inside the HMA increases.

Addition of ASA

There are many ASAs available and all of them work in another way to improve the bond between the aggregate and the binder film. Thus, the utilization of specific sort of ASA also affects stripping in HMA. Also, each ASA has a different impact on various aggregate sources. Thus, this variability also outcomes stripping in HMA relative to the form of ASA used.

Mixing Temperature

Sometimes, the aggregates are not heated for sufficient time in an asphalt plant, which may result in lower mixing temperatures. At lower mixing temperatures, the viscosity of the binder is lower, and thus, the binder will not be able to a uniform film thickness around the aggregate.

HMA Storage Time

Every time a truck is loaded, there is a clean stage that air received into the garage silos. This air oxidizes the binder, thereby making it hard and brittle. Thus, it can easily strip off the aggregate.

pH Instability

Stripping is also affected by the pH of the water coming in contact with the HMA. The pH of contact water can purpose the value of the contact angle to shift, thereby affecting the wetting traits of the interface region. The consequences indicated that coating retention decreased as the pH increased. These effects strongly suggest that stabilization of the pH sensitivity at the binder/aggregate interface would minimize the potential for bond breakage, providing strong durable bonds and hence lowering the stripping.

1.5.3.4. KEY FACTORS

These are some key factors to determine the severity of stripping potential in pavement:

- Aggregate mineralogical composition
- Asphalt chemical characteristics
- Aggregate cleanliness
- Mix design
- Construction quality
- Pavement drainage condition
- Climatic condition

1.6 RESEARCH OBJECTIVES

The following objectives have been established to define the path of this research:

1. To improve the adhesive property.
2. Enhances the service life of pavement.
3. To develop low negative effects on Hot-Mix asphalt properties such as cracking and low temperature cracking potential.
4. To make driving safer and easier and to reduce the no. of accidents.
5. Identify binder properties significant to mixture performance.
6. Examine the significance of percentage air voids and aggregate gradation on mixture performance.
7. Address the logistical and economical requirements associated with each test studied to assess possibilities for agency implementation of the test methods.

CHAPTER-2:
LITERATURE REVIEW

Cagri Gorkem, Burak Sengoz (2008)[5] This study is aimed to work out the effect of additives such as hydrated lime as well as elastomeric (SBS) and plastomeric (EVA) polymer modified bitumen (PMB) on the stripping potential and moisture susceptibility characteristics of hot mix asphalt (HMA) containing different types of aggregate (basalt–limestone aggregate mixture and limestone aggregate). The stripping properties and moisture susceptibility characteristics of the samples have been evaluated by means of captured images. As a consequence, it can be concluded that, polymer modified bitumen provides increased adhesion to the aggregate and creates a network structure within the base bitumen.

Yong-Rak Kim, Ingryd Pinto (2011)[43] This paper presents performance changes and material characteristics associated with moisture damage due to anti-stripping additives in asphalt mixtures through various laboratory tests. Two additives (hydrated lime and fly ash) are investigated by adding them into two types of mixes where different asphalt binders and aggregates are used. Two mixture constituent tests (the boiling water test and the pull-off tensile strength test) are conducted to characterize the effects of anti-stripping additives on the binder–aggregate bonding potential in mixtures. With the limited amount of test data, both hydrated lime and fly ash contribute to reducing moisture damage, which means potential significant cost savings by the use of fly ash as an alternative additive.

Erol Iskender, Atakan Aksoy (2011)[10] The aim of this study is to see the effects of SBS polymer and fatty amine anti-stripping agent additives for asphalt mixtures. The main goal of this research is to investigate rutting and moisture damage problems in asphalt mixtures. Proportional evaluation for stripping was studied and permanent deformation.

Mahmoud Ameri, Sareh Kouchaki (2013)[33] The objective of this research study was to evaluate moisture susceptibility of hot mix asphalt (HMA) with and without Zycosoil as a nano-organosilane anti-stripping additive and hydrated lime in the form of slurry. It was also observed that the effects of anti-stripping additives on specimens made by siliceous aggregate are more pronounced than those prepared with limestone aggregates. The use of Zycosoil additive will increase adhesion bond between the aggregates and asphalt binders, and in turn influences the moisture resistance of the mixture to moisture damage.

Mahmoud Nazirizad, Amir Kavussi (2015)[34] This study is aimed towards the consequences of the effects of two different anti-stripping additives, namely hydrated lime and a liquid anti-stripping agent (Iterlene In/400-S) on hot mix asphalt (HMA). Moisture susceptibilities of samples were determined by analyzing digital images taken from coated aggregate particles after performing boiling water test. Mixes containing 0.2%, 0.3% and 0.4% of liquid anti-stripping agent and mixes containing 1%, 1.5% and 2% of hydrated lime.

Gourav Goel, S.N. Sachdeva (2016)[6] This study aimed at stripping phenomenon in bituminous mixes. The contents of the paper include mechanism of moisture damage occurrence and contributing factors, as well as an introduction to the variety of methods to experimentally evaluate the stripping value.

Dae-Wook Park, Woo-Jin Seo (2017)[8] This paper studied that Evaluation of moisture susceptibility of asphalt mixture using liquid anti-stripping agents. The purposes of this study are to comprehensively evaluate the moisture susceptibility of asphalt mixtures modified with several anti-stripping additives based on laboratory tests. Boiling water test was conducted as a screening test. The addition of anti-stripping agents significantly improves asphalt mixture stripping resistance before and after stripping occurs, and rutting resistance.

Harpreet Singh, Tanuj Chopra (2017)[14] In this study, Zycotherm additive is added to neat bitumen and various comparisons were made using conventional test and rheological test on bitumen. Zycotherm gives better chemical bonding for extended moisture resistance and it ensures about 100% coating of bitumen at low temperature.

Cesare Olliviero Rossi, Bagdat Teltayev (2017)[9] conducted the study on adhesion promoters in bituminous road materials. It focuses on certain classes of organic compounds known variously with in the specific literature of asphalt as adhesion promoters, antistripping agents, wetting agents, antistrips, or adhesion agents. Their main role is to change the interfacial energy, so that the presence of water, even in trace, does not weaken the bitumen-aggregate bond and tends to favor adhesion. The review also considers the chemical functionalities that play a predominant role in bonding, also because the effects of surface modification of the aggregate due to the presence of adhesion promoters in pre-blended bituminous mixtures. The discussion is especially addressed to the development of adhesion in road materials, adhesion and wetting properties.

Hasan H. Joni, Mahmood S. Hashim (2017)[15] The main objective of this study is determining the effects of two different anti-stripping materials, namely hydrated lime and fly ash on cold bitumen emulsion mixture (CBEMs). It was found that mix samples prepared using hydrated lime additive give greater resistance to water damage, compared with control mixes and those containing fly ash. In addition, using of fly ash gives a high degree of coating and good workability.

Hamed Omrani, Ali Reza Ghanizadeh (2017)[13] The primary objective of this study is exploring the moisture susceptibility of unmodified and SBS-modified hot and warm mix asphalt mixtures.
Two different WMA additives including Aspha-min and Sasobit were employed to fabricate WMA specimens. The moisture susceptibility of warm polymer modified asphalt (WPMA) mixes was evaluated. In addition, the effect of different percentages of hydrated lime (from 0% to 2%) and Zycosoil (from 0% to 0.1%) as anti-stripping additives on the moisture susceptibility of the mixtures was explored. The test results showed that increasing moisture content decreases moisture damage resistance. Addition of hydrated lime improves moisture susceptibility. The results also showed that moisture sensitivity was affected significantly by the source of used aggregate.

Kunalkumar Vaghela, Asso. Prof. V.J. Chitaria (2018)[30] This study investigates the effects of anti-stripping agent on the microscopic strength of the mineral aggregate contact surface of mixture. The study compared the moisture susceptibility of three variations of bituminous concrete grade 1 mix: (i) Mix without anti-stripping additive (2) Mix with hydrated lime as an anti-stripping additive and (3) Mix with Zycosoil as an anti-stripping additive. The current study resulted in improved bituminous mixtures with the utilization of antistripping additives, especially in the moisture resistance property of the mixture.

Dax Patel, Pradip J. Gundaliya (2018)[9] conducted the study on the repair of raod distress and potholes with using organosilane based technologies. Since potholed roads are a common sight across rural and urban India especially during and after monsoons. Every year crores and crores of rupees are spent by the road agencies in extensive pothole patch repairs. Stripping of bitumen is one of the most commonly occurring distresses in bituminous pavements. This occurs as a result of de-bonding between aggregate particles and bitumen. Cold patch asphalt mixture (CPAM) is used to repair pavement pothole. Organosilane based technologies are important development in recent year for bituminous pavement, works for HMA and also cold mix to solve de-bonding problems. These compounds imparts surface modification at nano level. This research work includes evaluate these chemical compounds as antistripping agent for bituminous mixes for flexible pavement.

Shazi, Prof. D. S. Ray (2018)[39] This paper aims at the study of potholes on the bituminous road surface and introducing the antistripping material to the bitumen to increase the durability of the road. In this paper, the antistripping material **'**Bitugrip**'** is used to improve the adhesion properties of bitumen and aggregates. The stripping value decreases while increasing the percentage of bitugrip to the bitumen. Overall, the addition of Bitugrip has a positive influence on the adhesion properties between the aggregates and the bitumen and can be used to increase the durability of roads, thereby reduce the maintenance cost of the roads.

H. Khani Sanij, P. Afkhamy Meybodi (2018)[16] The primary goal of these efforts is to improve the durability and load-bearing performance of asphalt mixtures. In this study, glass particles were used, as aggregates in warm mix asphalt (WMA) mixtures. The objective of this study was to consequences the utilization of Zycotherm™ as an anti-stripping agent have on the mechanical properties and moisture susceptibility of glass-asphalt. Four different amounts of Zycotherm™ were used in WMA mixtures to serve as bitumen modifier and anti-stripping agent. In this study, glass particles were used, as aggregates in warm mix asphalt (WMA) mixtures. Four different amounts of Zycotherm-TM were utilized in WMA mixtures to serve as bitumen modifier and anti-stripping agent.

CHAPTER-3:
MATERIAL USED

3.1 Overview

This section describes the materials used in this research (aggregates, bitumen and three anti stripping additives). Bituminous materials are used for construction of flexible pavement. These can be either in the form of surface treatments or asphalt concrete surface courses. Properties of bituminous materials like adhesion, resistance to water, imperviousness, strength, ductility, softening point, viscosity and flow etc are helpful in constructing pavement. There are a lot of materials used in construction of flexible pavement as per requirements.

3.2 AGGREGATES

Aggregates forms the major portion of pavement structure and they form the prime materials used in pavement construction. Aggregates have to bear stresses occurring due to wheel loads on the pavement and on the surface course they also have to resist wear due to abrasive action of traffic.

Most of the road aggregates are prepared from natural rock. Aggregates are inert granular materials like sand, gravel or crushed stone. Gravel aggregates are small rounded stones of different sizes. Aggregates were used local granite rocks of such particle size obtained from **KABARAI** quarry situated in **MAHOBA** that are 100% passed from a 20 mm sieve and were retained on a 13.2 mm sieve. The aggregate was washed in distilled water to get rid of all fines dried at 105 -110℃ to constant weight and stored in airtight containers until required to be used. Crushed granite aggregates obtained from nearby quarry was used for the study and they were sufficiently strong, hard, tough, and well-shaped.

3.3 BITUMEN

Bitumen is hydrocarbon material of either natural or pyrogeneous origins, found in gaseous, liquid, semisolid or solid form and is completely soluble in Carbon disulphide and in Carbon tetra chloride. It contains 87% carbon, 11% hydrogen and 2% oxygen (a pair of oxygen). Bitumen is a complex organic material and occurs either naturally or may be obtained artificially during the distillation of petroleum. Bituminous materials are very commonly used in highway construction because of their binding and water proofing properties.

In this study **VG30** bitumen grade is used as a base binder for modification obtained from **UPPWD Research Department** on the official letter issued by **Head, Civil Department, BBDU**. The Bitumen possess excellent adhesive and bonding properties with aggregates, resists moisture to an excellent extent, resistance to mild acids and alkali too.

3.4 ANTI- STRIPPING AGENTS

Anti-Stripping agents are chemical mixtures containing active functional groups that improve adhesion of the bitumen film on the surface of the aggregates. Mixed with the binder, they lower the surface tension of the bitumen.

Anti-Stripping are chemical compounds, which renders minimum stripping(breaking) of bonds between the aggregate surface and the bitumen. To achieve good bond between aggregate and bitumen, anti-stripping agents are used. Two types of ASA are found, some are silane based and some are amine based. Currently there are various ASA used to modify bituminous layer namely Zycosoil, Bitugrip, Zycotherm, Wetbond-S, Dia Bond, Iterlene In/400-S, Tiki Tar, Supreme Bituchem etc. but here, during this research, three Anti Stripping Agents are used:-

3.4.1 ZYCOTHERM

Zycotherm additive is an odourless nano organosilane additive used for bituminous mixes. Zycotherm gives better chemical bonding for extended moisture resistance and it ensures 100% coating of bitumen at low temperature. In addition, this additive can reduce the production and compaction temperature of asphalt mixtures.

Table 3.4.1: Properties of Zycotherm

Properties	**Results**
Specific gravity	0.97 gm/cm^3
Viscosity	1-5 Pas
Flash point	>80℃
Colour	Pale yellow
Physical state	Liquid
Solubility in water	Soluble in water

Fig 3.4.1: Zycotherm

Zycotherm Features:

- Odour free additive, increase moisture resistance, lowers mixing and compaction temp, substantially enhances Salt Resistance of pavements over Hot Mix technologies.
- Resolves stripping & quick degradation of Mountain/Coastal pavements.

Zycotherm Benefits:

- Eliminates stripping.
- Reduces stickness on trucks.
- Improves field compaction.
- Reduces fuel consumption.
- Melts and mixes hardened asphalt.

Storage and Self Life: Zycotherm should be stored between -10℃ to 40℃ during a dry area, far from sunlight, heat, source of sparks, rain and standing water. The container lid should be tightly fastened after every use. Its shelf life is 48 hours.

3.4.2 BITUGRIP

Bitugrip is the product of **HINCOL** (Hindustan Colas Private Limited). HINCOL is the leading **manufacturer** and **supplier** of **Bitumen Emulsion, Modified Bitumen** catering to Road sector. Hincol bitugrip is an Amine based anti-stripping agent that changes interfacial surface tension between bitumen and aggregate, strengthening the bond for long run durability.

Bitugrip Features:

- Premature failure of flexible pavement is a widespread problem.
- The important factor contributing to this is improper adhesion between Bitumen and aggregates mostly due to non-availability of excellent quality of aggregates and improper drainage system.
- Hincol Bitugrip is specifically designed solution to tackle such problem by enhancing the adhesion of Bitumen and ensuring stability of bituminous pavements.

Table 3.4.2 : Properties of Bitugrip

Properties	**Results**
Density	1.04 gm/cm^3
Consistency	High viscosity
Drying Time@25℃	24 hours
Toxicity	Dry film non-toxic

Fig 3.4.2 Bitugrip

Bitugrip Advantages:

- Enhance the service life of the pavement
- Excellent adhesion promoter onto all kinds of aggregates
- Slow down age hardening of bitumen.
- Low dosage required.
- Stable at high process temperature of hot mix temperature.

Bitugrip Applications:

- Hincol Bitugrip is very effective while paving roads in high rainfall area and the areas with bad quality of aggregates and improper drainage system.
- It prevents bitumen against stripping action of water.

3.4.3 WETBOND-S

"Wetbond-S" is next generation Nano-technology Silicon based Anti-stripping Additive for Asphalt. This product is a low dose and extremely thermal resistive additive for use in Hot-mix and Warm-mix road constructions. This product is specially suitable for aggregates having very high and difficult to manage stripping profile. This product is suitable for production of Refinery-treated non-stripping bitumen, Hot-mix pavement constructions, Warm-mix constructions and for industrial bituminous coatings.

Table 3.4.3: Properties of Wetbond-S

Properties	**Results**
Specific Gravity	0.86-0.95
Amine Value	>200
Active Nitrogen	>7
Water Content	<1%
Active content	100%
Shelf Life	4 Years from the date of production in sealed containers.
Colour	Brownish clear liquid.
Compatibility	All grades of Road and Industrial Bitumens.

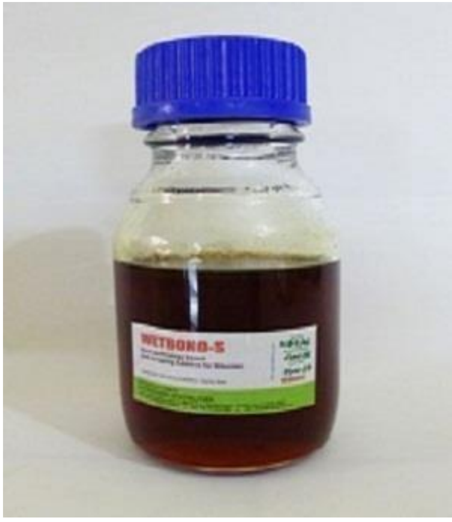

Fig 3.4.3: Wetbond-S

Advantages :

- Wetbond-S" is oily liquid product for premixing or direct injection in Bitumen. This product has several advantages over conventional Anti-stripping Agents:
- Very low dose product, no effect on bitumen properties.
- No degradation when stored in hot bitumen, saves money.
- Nano active amine and silicon based, works on molecular level.
- High amine value for active bridge formation between Bitumen and aggregates.
- High Nitrogen content gives excellent performance even with moist aggregates.
- Readily soluble in hot bitumen, so fit even for direct dosing in HMP.
- Non Hazardous product for safe handling and storage.
- Economical as compared to conventional products in dose dependent comparison.

Storage and Handling :

Wetbond-S" can be stored in HDPE or MS drums / tanks at a cool and dry place at ambient temperature. This product contains organic silicon derivatives which can cause mild irritation to skin, eyes and lungs.

CHAPTER-4:
METHODOLOGY

4.1 Overview

To enhance moisture damage resistance, it is necessary to explore techniques of improving bitumen quality. Here, in this project we focused on decreasing the stripping values of bituminous mix by using ASA like Wetbond-S, Zycotherm and Bitugrip. Hence after making samples using these ASAs we tested the sample by boiling water test and stripping value test.

4.2 TESTS FOR BITUMEN

Various tests are conducted on Bitumen to assess its consistency, garadation, viscosity, temperature susceptibility and safety.

4.2.1 PENETRATION TEST (IS:1203-1978)

OBJECTIVE:

To determine the penetration of bitumen as per IS: 1203 – 1978.

PRINCIPLE:

The principle is that the penetration of a bituminous material is the distance in tenths of a mm, that a standard needle would penetrate vertically, into a sample of the material under standard conditions of temperature, load and time.

APPARATUS REQUIRED :

1) Penetrometer
2) Water bath
3) Bath thermometer – Range 0 to 44^{o}C, Graduation 0.2^{o}C.

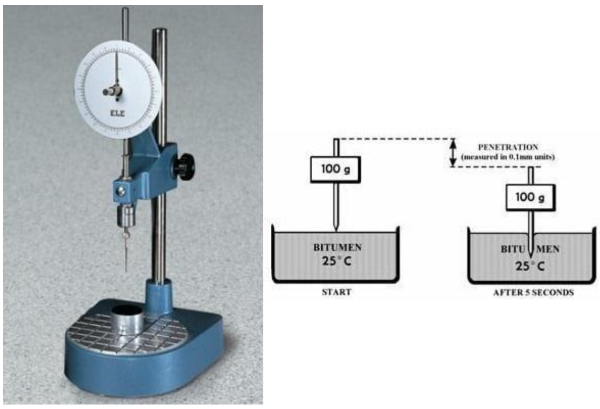

Fig 4.2.1: Penetration Test Setup

PROCEDURE:

1) Soften the bitumen above the softening point (between 75 and 100°C). Stir it thoroughly to remove air bubbles and water.
2) Pour it into a container to a depth of at least 15mm in excess of the expected penetration.
3) Cool it at an atmospheric temperature of 15 to 30°C for 90 min. Then place it in a transfer dish in the water bath at 25.0 + 0.1°C for 90 min.
4) Keep the container on the stand of the penetration apparatus.
5) Adjust the needle to make contact with the surface of the sample.
6) Adjust the dial reading to zero.
7) With the help of the timer, release the needle for exactly 5 seconds.
8) Record the dial reading.
9) Repeat the above procedure thrice.

REPORTING OF RESULTS

The value of penetration reported should be the mean of not less than three determinations expressed in tenths of a mm.

4.2.2 SOFTENING POINT TEST (IS:1205-1978)

OBJECTIVE:

To determine the softening point of asphaltic bitumen and fluxed native asphalt, road tar, coal tar pitch and blown type bitumen as per IS: 1205 – 1978.

PRINCIPLE:

The principle behind this test is that softening point is the temperature at which the substance attains a particular degree of softening under specified condition of the test.

APPARATUS REQUIRED:

1) Ring and ball apparatus
2) Thermometer – Low Range : -2 to 80°C, Graduation 0.2°C – High Range : 30 to 200oC, Graduation 0.5°C.

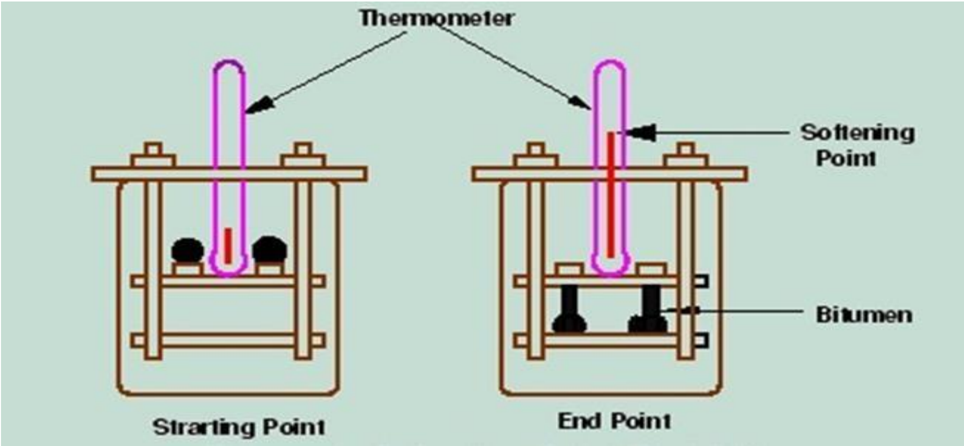

Fig 4.2.2: Softening point test setup

PREPERATION OF SAMPLE

1) The sample should be just sufficient to fill the ring. The excess sample should be cut off by a knife.

2) Heat the material between 75 and 100°C. Stir it to remove air bubbles and water, and filter it through IS Sieve 30, if necessary.

3) Heat the rings and apply glycerine. Fill the material in it and cool it for 30 minutes.

4) Remove excess material with the help of a warmed, sharp knife.

PROCEDURE:

A) Materials of softening point below 80° C:

1) Assemble the apparatus with the rings, thermometer and ball guides in position.

2) Fill the beaker with boiled distilled water at a temperature 5.0 ± 0.5°C per minute.

3) With the help of a stirrer, stir the liquid and apply heat to the beaker at a temperature of 5.0 ± 0.5°C per minute.

4) Apply heat until the material softens and allow the ball to pass through the ring.

5) Record the temperature at which the ball touches the bottom, which is nothing but the softening point of that material.

B) Materials of softening point above 80°C:

The procedure is the same as described above. The only difference is that instead of water, glycerine is used and the starting temperature of the test is 35°C.

REPORTING OF RESULTS:

Record the temperature at which the ball touches the bottom and average of both the temp will be result in ℃.

4.2.3 DUCTILITY TEST (IS: 1208-1978)

OBJECTIVE:
To determine the ductility of distillation residue of cutback bitumen, blown type bitumen and other bituminous products as per IS: 1208 – 1978.

PRINCIPLE:
The ductility of a bituminous material is measured by the distance in cm to which it will elongate before breaking when a standard briquette specimen of the material is pulled apart at a specified speed and a specified temperature.

APPARATUS REQUIRED:

1) Standard mould

2) Water bath

3)A putty knife

4) Testing machine

5) Thermometer – Range 0 to 44^{o}C, Graduation 0.2^{o}C.

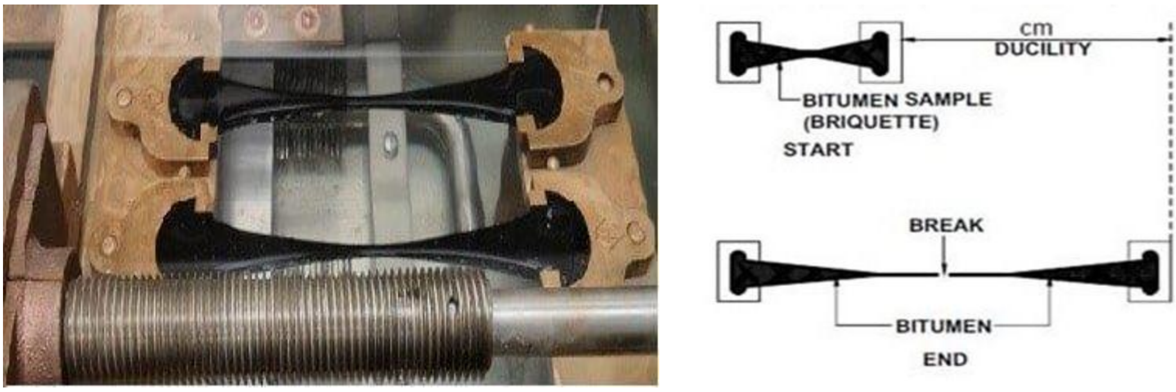

Fig 4.2.3: Ductility test setup

PROCEDURE:
1) Firstly, the bitumen sample is heated to 75-100^{o}C and melted completely.

2) This is poured into the assembled mold which is placed on brass plate. To prevent sticking the mold and plate are coated with glycerin and dextrin.

3) After filling the mold, placed it in room temperature for 30-40 minutes and then placed it in water for 30 minutes.

4) Take it out and cut the excess amount of bitumen with the help of hot knife and level the surface.

5) Place the whole assembly in water bath of ductility machine for 85 to 95 minutes.

6) Detach the brass plate and the hooks of mold are fixed to machine and operate the machine. The machine pulls the two clips of the mold horizontally and then bitumen elongates.

REPORTING OF RESULTS

The distance up to the point of breaking from the starting point is noted as ductility value of bitumen. The minimum value should be 75cm.

4.3 TESTS USED IN THIS RESEARCH

4.3.1 BOILING WATER TEST

Boiling water test (ASTM D 3625) is one of the simplest testing methods that is used to evaluate the adhesiveness characteristics of aggregate particles with bitumen (using a visual rating of the degree of stripping after test conditioning).

OBJECTIVE:

To determine the boiling water test of road aggregates by binders.

APPARATUS REQUIRED:

1. Oven to heat aggregate.
2. Sieves of sizes 20 mm and 12.5 mm.
3. Beaker of 500 ml capacity.
4. Heat source.

Fig 4.3.1. Boiling Water Test

PROCEDURE:

1. 200 g of clean and dry aggregate passing 20 mm IS sieve and retained on 12.5 mm sieve are heated up to 150°C when these are to be mixed with bitumen.
2. Bitumen binder amounting to five percent by weight of aggregate is heated to 160°C.
3. The aggregate and binder are mixed thoroughly till they are completely coated and mixture is transferred to the beaker.
4. Approximately 500 ml of water was placed in a 1000 ml beaker and was heated to boil.
5. This boiling water pour into the beaker in which mixture is already placed.
6. After this put the beaker into heat source and boiled for 10 minutes.
7. Once finished, the beaker was removed from the heat source.
8. After cooling it to room temperature, the water was removed, and the mixture was placed onto a white paper towel to be visually analyzed.
9. In an attempt to estimate the test in a more objective manner than the subjective visual rating by the investigators, a digital image analysis of photographs taken for each mixture using a digital camera was conducted.
10. Each picture was cropped to a consistent size and then transformed to a black-and-white image by applying the same level of threshold.
11. The black area represents the aggregates covered with asphalt binder, while the white portion represents aggregates or spots in the aggregates with stripping.
12. Using an image analysis software, each portion was quantified by counting the number of pixels corresponding to each color and provides the percentage of black and white pixels.

4.3.2 STRIPPING VALUE TEST

The stripping value of aggregates is determined as the ratio of the uncovered area observed visually to the total area of aggregates, expressed as a percentage. Bitumen and tar adhere well to all normal types of aggregates provided they are dry and are not exceptionally dusty. This problem of stripping is experienced only with bituminous mixtures, which are permeable to water. This test gives the procedure for determination of the stripping value of aggregates by static immersion method, when bitumen and tar binders are used. Test Specimen after and before the test.

OBJECTIVE:
To determine the stripping value of road aggregates by binders.

APPARATUS REQUIRED:
The apparatus required for this experiment are:

1. Thermostatically controlled water bath.
2. Oven to heat aggregate.
3. Sieves of sizes 20 mm and 12.5 mm.
4. Beaker of 500 ml capacity.

PROCEDURE:

- 200 g of clean and dry aggregate passing 20 mm IS sieve and retained on 12.5 mm sieve are heated up to 150°C when these are to be mixed with bitumen.
- Bitumen binder amounting to five percent by weight of aggregate is heated to 160°C.
- The aggregate and binder are mixed thoroughly till they are completely coated and mixture is transferred to the beaker and allowed to cool at room temperature for about 2 hours.
- Distilled water is then added to immerse the coated aggregates.
- The beaker is covered and kept in a water bath maintained at 40°C, for 24 hours.
- After 24 hours, the beaker is taken out, cooled at room temperature and the extent of stripping is estimated visually while the specimen is still under water.

Fig 4.3.2: Test apparatus to mix Aggregate & Bitumen

REPORT OF RESULTS:

The result is reported as the percentage of stone surface that remains coated after the specified periods, the mean value of at least three visually estimated values, being rounded off to the nearest 5 percent.

By visual estimation, stripping value of road aggregates is =________%

Specifications:

Indian Road Congress (IRC) has specified the maximum stripping value as 5 percent for aggregates to be used in bituminous construction like surface dressing penetration macadam, bituminous macadam and carpet.

Applications of Stripping Value Test:

Some types of aggregates have a lesser affinity with bitumen in comparison with water and hence stripping value of the bituminous binder is done when the mix is immersed in water. The problem of stripping in coated aggregate is not so amenable to theoretical treatment. Thus an adhesion test such as the simple stripping test would be suitable to assess whether the binder would adhere to the aggregate when immersed in water. Several anti-stripping agents are available, which when used with the bituminous mix reduce the stripping.

CHAPTER -5:
EXPERIMENTAL INVESTIGATION

Based upon the various methods involved in this research, I conducted following tests in the laboratory with varying percentages of ASA in HMA to get optimum values of ASA. Since finding the exact percentage of combination is the main key behind this research so different combinations with different percentages were tested & observations and conclusion was drawn from all these which will be discussed in the next chapter.

(A) INDIVIDUAL ADDITION OF ANTI STRIPPING AGENT

5.1 BOILING WATER TEST FOR INDIVIDUAL ADDITION

- Here, pre heated aggregates and bitumen are taken in proportion and mixed well without adding any anti-stripping additive and boiling water test was conducted. Test performed is shown in the fig shown below. Very less coating is visible on the aggregates.

Fig 5.1: Stripping without adding Anti Stripping Agent in Boiling Water Test

5.1.1 ADDITIVE: ZYCOTHERM

- In this stage, I added 0.05% Zycotherm additive in pre heated aggregate and bitumen and then performed the boiling water test. Performance of this test with this ASA is shown in the below picture. Here coating of bitumen on aggregate is better than previous pic because of ASA.

Fig 5.1.1.1: Stripping after adding 0.05% Zycotherm in Boiling Water Test

- Again Boiling water test is performed with addition of 0.075% Zycotherm additive. Thus performed test is shown in below figure. Much more coating on aggregate particles are visible here.

Fig 5.1.1.2: Stripping after adding 0.075% Zycotherm in Boiling Water Test

- Here, boiling water test is performed with addition of 0.10% of Zycotherm additive. Performance of test in shown in fig given below. Now it is seen that coating on aggregate particles are less than 0.075%.

Fig 5.1.1.3: Stripping after adding 0.10% Zycotherm in Boiling Water Test

- Now again, boiling water test is performed with 0.15% Zycotherm addition and performance of test is shown in fig mentioned below. Here coating on aggregate particles is lesser than previous.

Fig 5.1.1.4: Stripping after adding 0.15% Zycotherm in Boiling Water Test

5.1.2 ADDITIVE: BITUGRIP

- After performing the test with Zycotherm additive, now test is performed with another ASA named Bitugrip. Here boiling water test is performed with 0.5% addition and coating on the particles is shown in below figure.

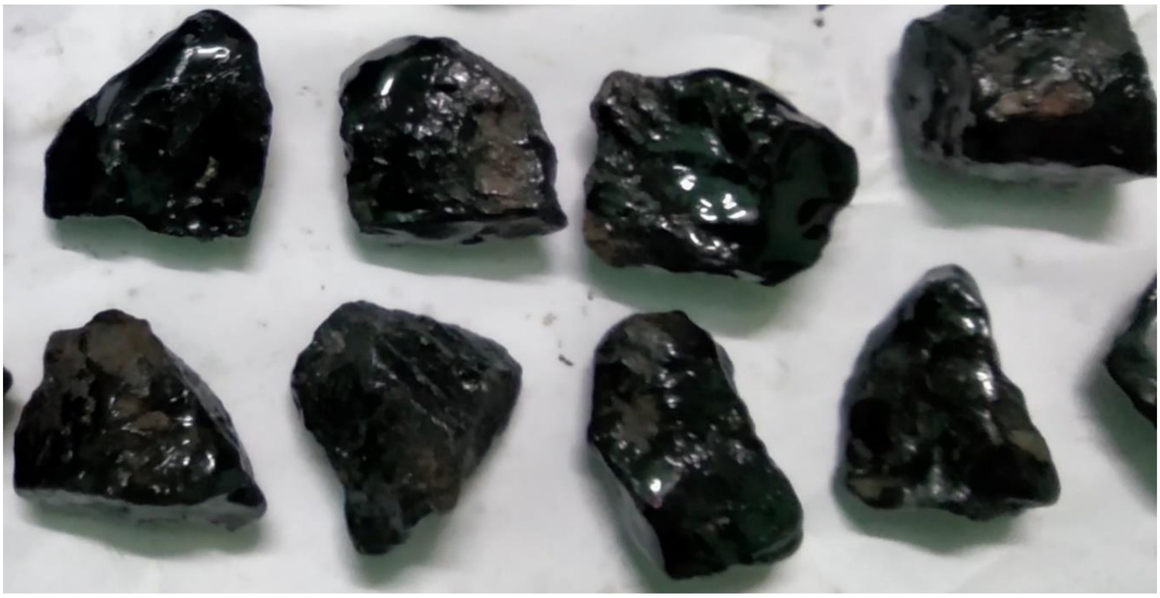

Fig 5.1.2.1 : Stripping after adding 0.5% Bitugrip in Boiling Water Test

- Again Boiling water test is performed with addition of 0.75% Bitugrip additive. Thus performed test is shown in below figure.

Fig 5.1.2.2: Stripping after adding 0.75% Bitugrip in Boiling Water Test

- Now again, boiling water test is performed with 1.0% Bitugrip addition and performance of test is shown in fig mentioned below. Here coating on aggregate particles is better than previous.

Fig 5.1.2.3 : Stripping after adding 1.0% Bitugrip in Boiling Water Test

- Here, boiling water test is performed with addition of 1.5% of Bitugrip additive. Performance of test in shown in fig given below. Now it is seen that coating on aggregate particles is very poor.

Fig 5.1.2.4: Stripping after adding 1.5% Bitugrip in Boiling Water Test

5.1.3 ADDITIVE: WETBOND-S

- After performing boiling water test with Zycotherm and Bitugrip, now perform the test with Wetbond-S(ASA). Firslty Wetbond-S is added in 0.05% and test is performed and performace is shown in given below:

Fig 5.1.3.1: Stripping after adding 0.05% Wetbond-S in Boiling Water Test

- Here, boiling water test is performed with addition of 0.07% of Wetbond-S additive. Performance of test in shown in fig given below.

Fig. 5.1.3.2 Stripping after adding 0.07% Wetbond-S in Boiling Water Test

- Now again, boiling water test is performed with 0.10% addition and performance of test is shown in fig mentioned below. Here coating on aggregate particles is much better than previous.

Fig: 5.1.3.3 Stripping after adding 0.10% Wetbond-S in Boiling Water Test

5.2 STRIPPING VALUE TEST FOR INDIVIDUAL ADDITION

Stripping value test is done to calculate the stripping of asphalt mix. Here, preheated aggregate and bitumen is taken in proportion and mixed well. Put this mix in 500 ml beaker and leave it for 2 hr at room temp. then pour distilled water in the beaker and then put it into water bath for 24 hrs maintaining temp at 40℃. After that visually seen how much bitumen is stripped from the aggregate surface. Here it is seen that too much stripping is occurred.

Fig 5.2: Stripping without adding Anti Stripping Agent in Stripping Value Test

5.2.1 ADDITIVE: ZYCOTHERM

- Now, stripping value test is done after addition of 0.05% zycotherm in the mix then visualize the aggregates and feel the difference by picture.

Fig 5.2.1.1: Stripping after adding 0.05% Zycotherm in Stripping Value Test

- In the same way stripping value test is performed with 0.075% Zycotherm and here it is seen that coating on aggregates is much better than previous.

Fig 5.2.1.2: Stripping after adding 0.075% Zycotherm in Stripping Value Test

- ❖ Again stripping values test is done with addition of 0.1% zycotherm. After adding 0.1% Zycotherm, coating is reduced.

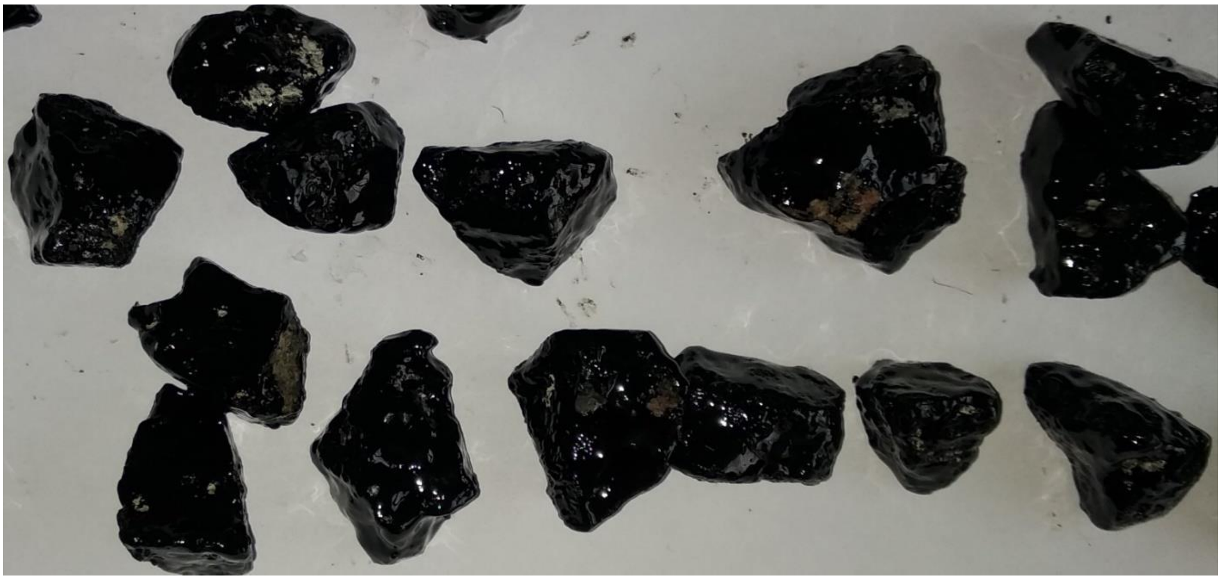

Fig 5.2.1.3: Stripping after adding 0.10% Zycotherm in Stripping Value Test

- ❖ When again after increasing % of zycotherm, too much stripping is occured as u can see in image so 0.075% is the optimum percentage.

Fig 5.2.1.4: Stripping after adding 0.15% Zycotherm in Stripping Value Test

5.2.2 ADDITIVE: BITUGRIP

- ❖ Now next additive is Bitugrip. Again in the same way stripping value test is performed with 0.5% bitugrip. Performance pic is shown below.

Fig 5.2.2.1: Stripping after adding 0.5 % Bitugrip in Stripping Value Test

- ❖ Again Bitugrip is added with 0.075% and then perform the test and difference in stripping and coating can be seen in figure.

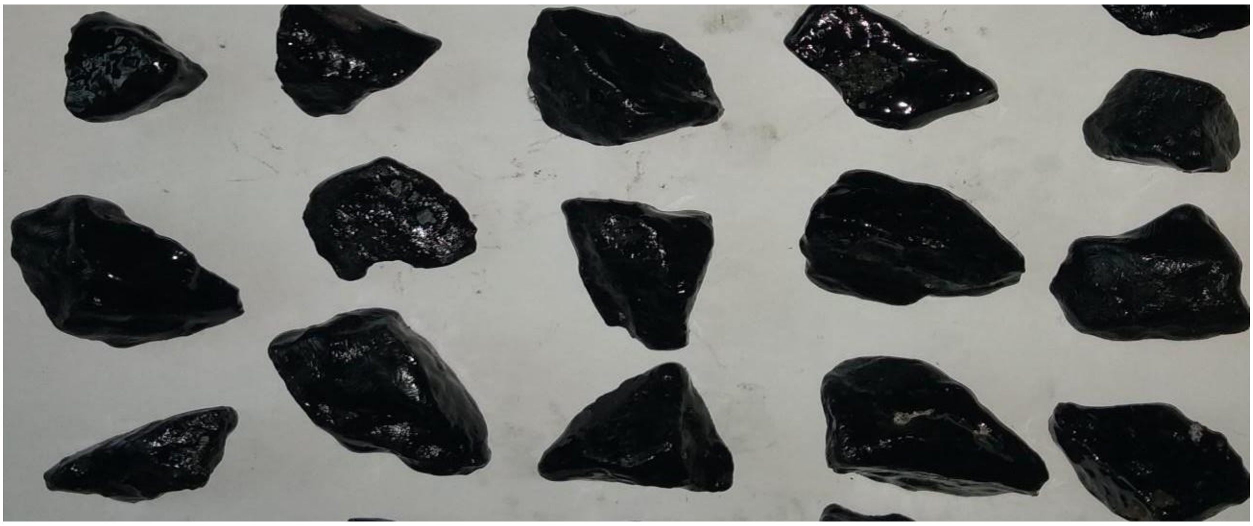

Fig 5.2.2.2: Stripping after adding 0.75 % Bitugrip in Stripping Value Test

- Next again Bitugrip is added with 1.0%. after performing the test it is clearly seen that coating on aggregate particles is much better than previous two.

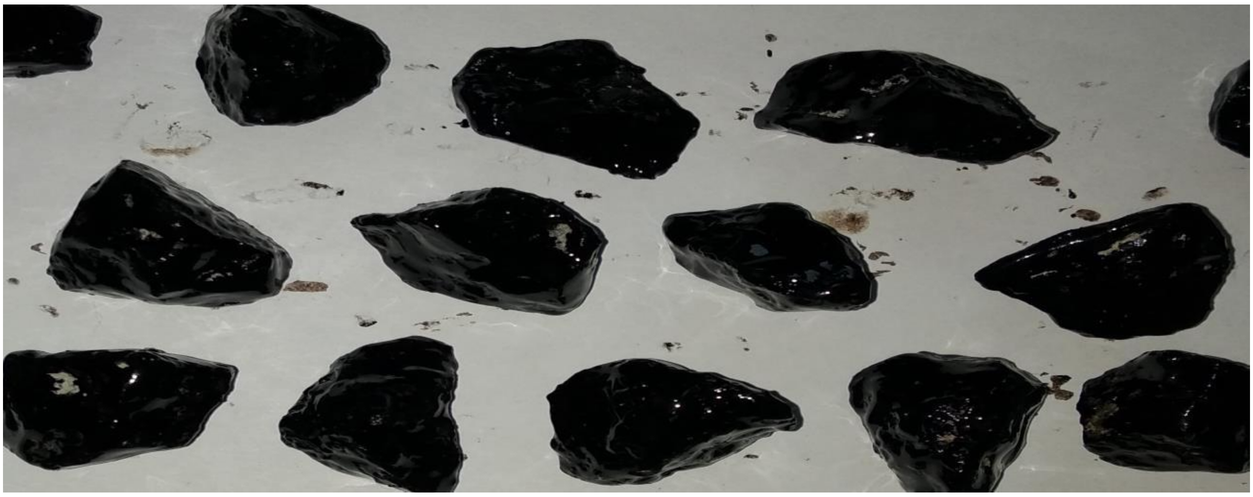

Fig 5.2.2.3: Stripping after adding 1.0 % Bitugrip in Stripping Value Test

- Again when 0.5% of bitugrip i.e 1.5% of bitugrip is added then performance of test is shown below figure.

Fig 5.2.2.4: Stripping after adding 1.5 % Bitugrip in Stripping Value Test

5.2.1 ADDITIVE: WETBOND-S

- Next additive is Wetbond-S. 1st percentage of addition of Wetbond-S is 0.05% and thus stripping value test is performed and coating can be seen in following attached picture.

Fig 5.2.3.1: Stripping after adding 0.05% Wetbond-S in Stripping Value Test

- In the same way stripping value test is performed with 0.070% Wetbond-S and here it can be seen that liile bit difference of coating on aggregate particles than previous.

Fig 5.2.3.2: Stripping after adding 0.070% Wetbond-S in Stripping Value Test

- Next again Wetbond-S is added with 0.1%. after performing the test it is clearly seen that coating on aggregate particles is much better than previous two and can say it is upto optimum level.

Fig 5.2.3.3: Stripping after adding 0.10% Wetbond-S in Stripping Value Test

(B) COMBINATIONS WITH OPTIMUM VALUES OF ANTI STRIPPING ADDITIVES:-

After performing test with all individual dosages, now perform the test with combination of optimum dosages of ASA which show minimum stripping. Combinations are made after seeing the performance of ASA dosage. 1.0% Bitugrip dose is not so effective as compared to 0.10% Wetbond-S and 0.075% Zycotherm. These two showing minimum stripping compared to Bitugrip.

5.3 BOILING WATER TEST RESULTS FOR COMBINATION

5.3.1 ADDITIVE: WETBOND-S+ZYCOTHERM

As per above figures, Wetbond-S is much effective in boiling water test.

1st combination is with optimum dose of Wetbond-S and Zycotherm. With this boiling water test is performed as per standard. Coating can be seen in below pic.

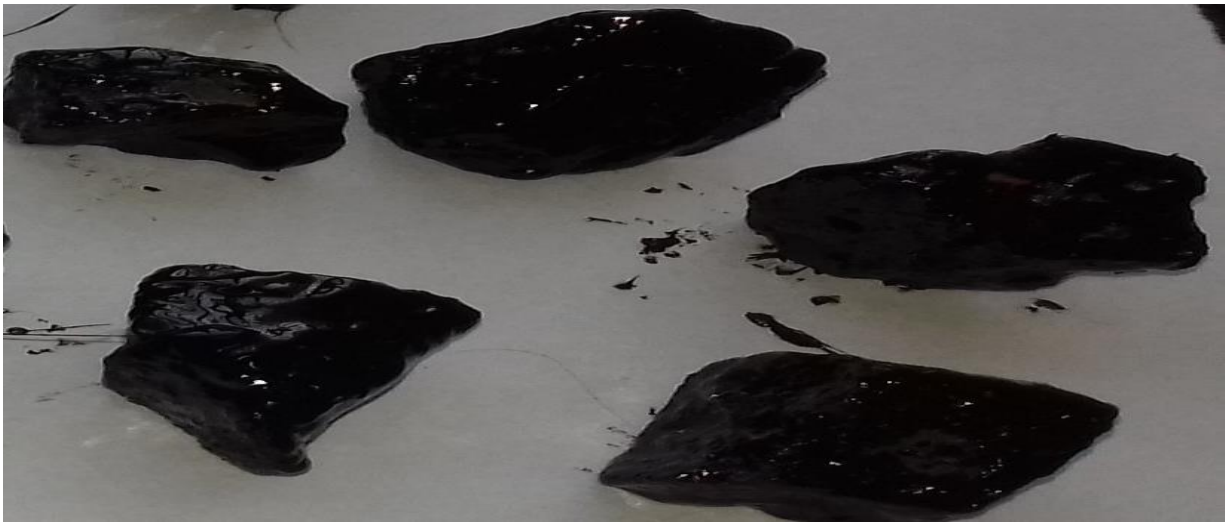

Fig 5.3.1: Stripping after adding Optimum Dose of Wetbond-S+Zycotherm in Boiling Water Test

5.3.2 ADDITIVE: WETBOND-S+BITUGRIP

- Next combination is optimum dose of Wetbond-S and Bitugrip. Performance of test is shown below

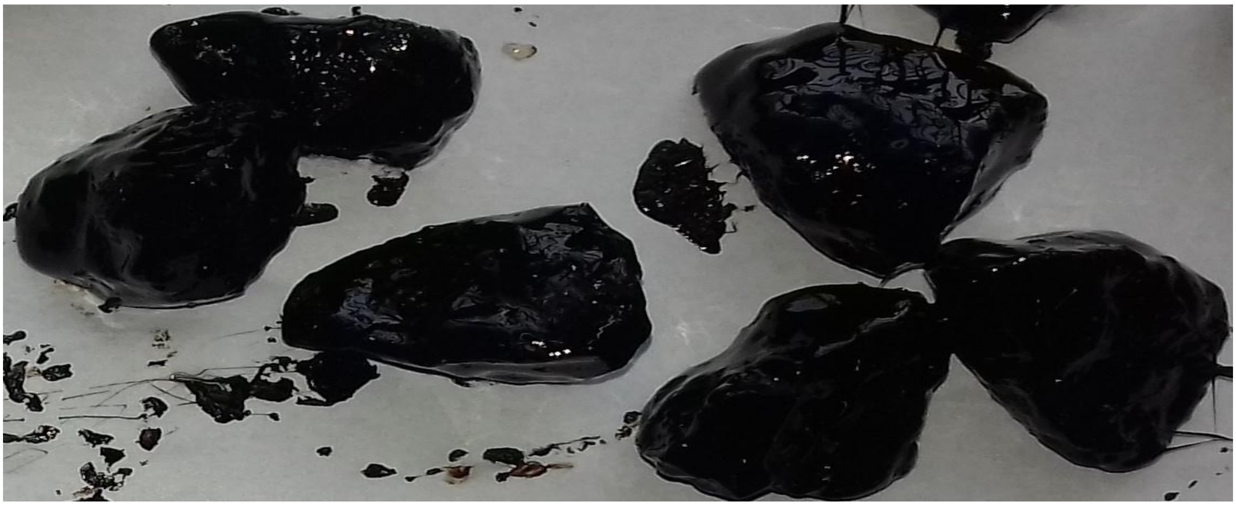

Fig 5.3.2: Stripping after adding Optimum Dose of Wetbond-S+Bitugrip in Boiling Water Test

5.3.3 ADDITIVE: WETBOND-S+ZYCOTHERM+BITUGRIP

- After combining two-two ASA, finally combine all three ASA with their optimum dosage and perform the boiling water test. Stripping can be seen in following figure.

Fig 5.3.3: Stripping after adding Optimum Dose of Wetbond-S+Zycotherm+Bitugrip in Boiling Water Test

5.4 STRIPPING VALUE TEST RESULTS FOR COMBINATION

5.4.1 ADDITIVE: WETBOND-S+ZYCOTHERM

- In the same way stripping value test is performed with combination of optimum dosage of Wetbond-S and Zycotherm.

Fig 5.4.1: Stripping after adding Optimum Dose of Wetbond-S+Zycotherm in Stripping Value Test

5.4.2 ADDITIVE: WETBOND-S+BITUGRIP

- Next combination is Wetbond-S and Bitugrip and stripping value test is performed. Experimental results can be seen in below figure.

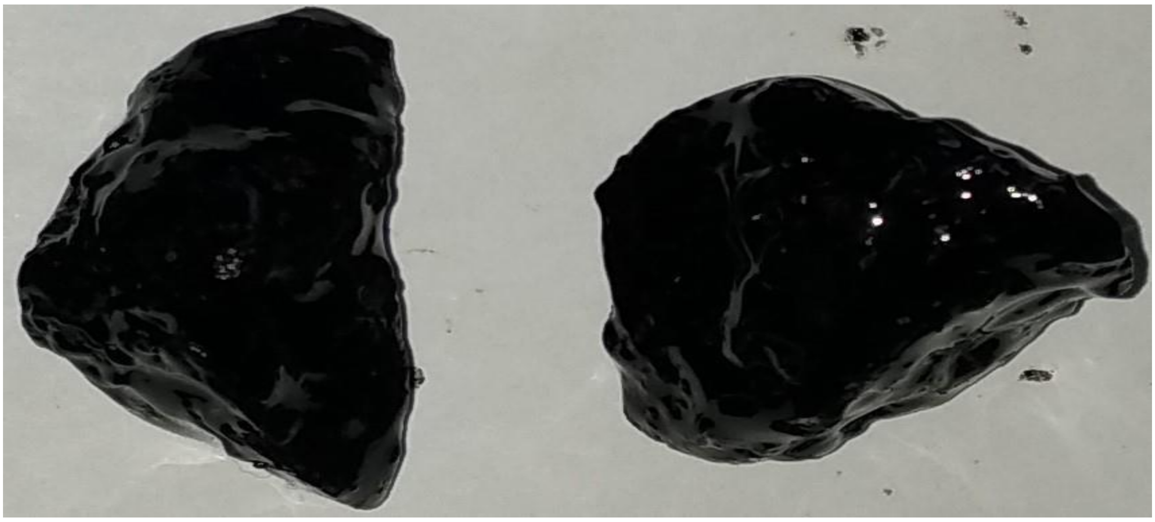

Fig 5.4.2: Stripping after adding Optimum Dose of Wetbond-S+Bitugrip in Stripping Value Test

5.4.3 ADDITIVE: WETBOND-S+ZYCOTHERM+BITUGRIP

- Finally combine all three ASA with their optimum dosage and test is performed to check the stripping.

Fig 5.4.3: Stripping after adding Optimum Dose of Wetbond-S+Zycotherm+Bitugrip in Stripping Value Test

CHAPTER-6: OBSERVATIONS

6.1 OVERVIEW

As experimental investigation is done in previous chapter, observations are going to done in this chapter. These observations will be helpful to get optimum values of ASA of bituminous mix for obtaining minimum stripping.

The standard properties of bitumen which have been used in this research work is as follow:

Table 6.1 CONVENTIONAL PROPERTIES OF BITUMEN USED

Bitumen is available in a variety of types and grades. To judge the suitability of these binders various physical tests have been specified by agencies like ASTM, British Standard Institution and ISI. These tests include penetration test, ductility test, viscosity test and softening point test. For classifying bitumen and studying the performance of bituminous pavements, penetration and ductility tests are essentials.

Here, These three basic tests of bitumen are done and obtained these values shown in table. Thus, this bitumen is categorized under **VG 30.** Thus, the standard properties of bitumen which have been used in this research work is as follow:

S. No.	TESTS OF BITUMEN	BITUMEN USED
1.	PENETRATION TEST (mm)	56
2.	SOFTENING POINT TEST (℃)	50
3.	DUCTILITY TEST (cm)	60

VG 30 bitumen is suggested for heavy density corridors having wide variety of loads. The bitumen possess excellent adhesive and bonding properties with aggregates, resist moisture to a great extent, resistance to mild acids and alkali too. It has low cost and thus this grade of bitumen is taken into consideration in this research.

(A) TEST RESULTS OF INDIVIDUAL ADDITION OF ASA

6.2 ADDITIVE: WETBOND-S

6.2.1 BOILING WATER TEST RESULTS OF WETBOND-S

Here boiling water test is performed without adding any ASA and with adding Wetbond-S in four varying percentages in bituminous mix and these results are obtained. Thus on the basis this table given below, minimum value of stripping is obtained corresponding to 0.1% Wetbond-S. Thus, 0.1% Wetbond-S is optimum percentage.

Table 6.2.1 Boiling Water Test Results of Wetbond-S

S. No.	Wt. of Aggregate (gm)	Quantity of Bitumen (%)	Wt. of Bitumen (gm)	Quantity of Wetbond-S (%)	Wt. of Sample (gm)	Wt. after Boiling Water Test (gm)	Stripping Value (%)
1.	200	5	10	0	210.00	189	10
2.	200	5	10	0.050	210.005	196	6.67
3.	200	5	10	0.070	210.007	206	1.91
4.	200	5	10	0.100	210.010	207	1.43
5.	200	5	10	0.15	210.015	205	2.39

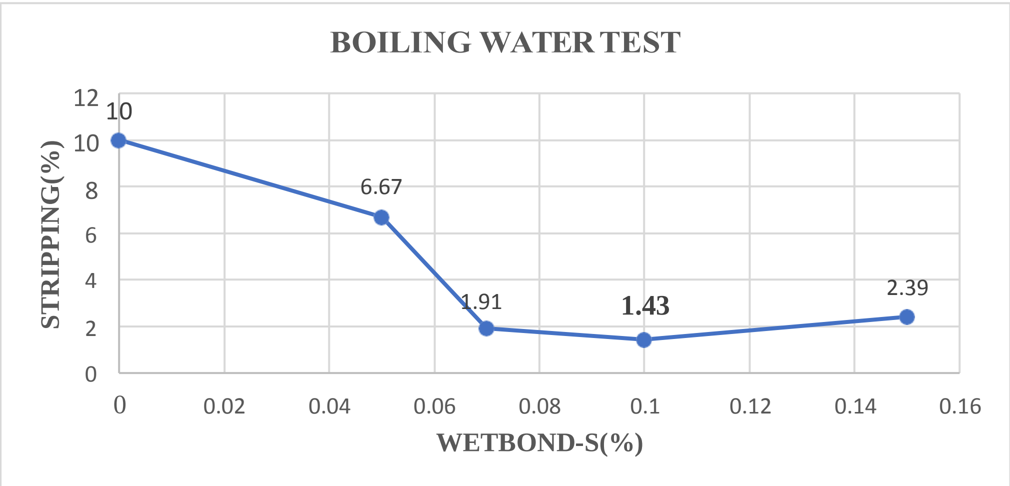

Fig 6.2.1: Stripping v/s Quantity of Wetbond-S in Boiling Water Test

6.2.2 STRIPPING VALUE TEST RESULTS OF WETBOND-S

Here stripping value test is performed without adding any ASA and with adding Wetbond-S in four varying percentages in bituminous mix and these results are obtained. Thus on the basis this table given below, minimum value of stripping is obtained corresponding to 0.1% Wetbond-S. Thus, 0.1% Wetbond-S is optimum percentage.

Table 6.2.2 Stripping Value Test Results of Wetbond-S

S. No.	Wt. of Aggregate (gm)	Quantity of Bitumen (%)	Wt. of Bitumen (gm)	Quantity of Wetbond-S (%)	Wt. of Sample (gm)	Wt. after Stripping Value Test (gm)	Stripping Value (%)
1.	200	5	10	0	210.00	193	8.1
2.	200	5	10	0.050	210.005	204	2.86
3.	200	5	10	0.070	210.007	207	1.44
4.	200	5	10	0.100	210.010	207	1.43
5.	200	5	10	0.15	210.015	206	1.91

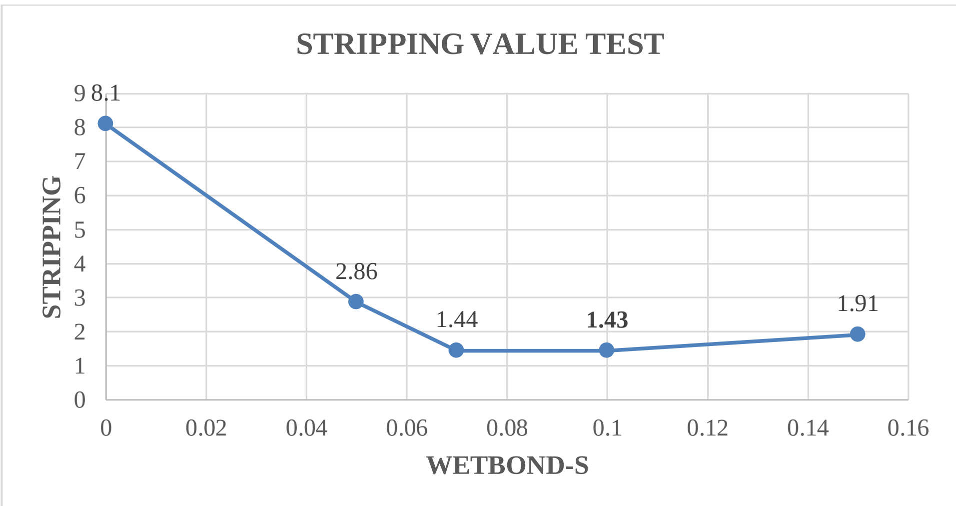

Fig 6.2.2: Stripping v/s Quantity of Wetbond-S in Striping Value Test

6.3 ADDITIVE- BITUGRIP

6.3.1 BOILING WATER TEST RESULTS OF BITUGRIP

Here, boiling water test is performed with addition of four varying percentages of Bitugrip in bituminous mix. Thus in this case, minimum stripping is obtained after addition of 1.0% of Bitugrip. So 0.1% of Bitugrip is optimum value.

Table 6.3.1 Boiling Water Test Results of Bitugrip

S. No.	Wt. of Aggregate (gm)	Quantity of Bitumen (%)	Wt. of Bitumen (gm)	Quantity of Bitugrip (%)	Wt. of Sample (gm)	Wt. after Boiling Water Test (gm)	Stripping Value (%)
1.	200	5	10	0.5	210.050	204	2.88
2.	200	5	10	0.75	210.075	204	2.29
3.	200	5	10	1.0	210.10	206	1.95
4.	200	5	10	1.5	210.15	205	2.45

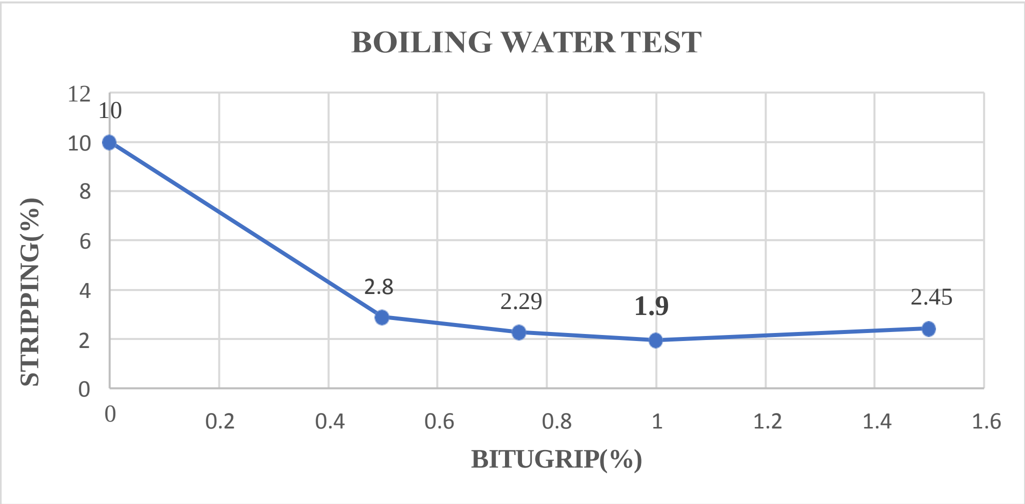

Fig 6.3.1: Stripping v/s Quantity of Bitugrip in Boiling Water Test

6.3.2 STRIPPING VALUE TEST RESULTS OF BITUGRIP

Here, stripping value test is performed with four varying percentages of Bitugrip in bituminous mix. Thus in this case, minimum stripping is obtained after addition of 1.0% of Bitugrip. So 0.1% of Bitugrip is optimum value.

Table 6.3.2 Stripping Value Test Results of Bitugrip

S. No.	Wt. of Aggregate (gm)	Quantity of Bitumen (%)	Wt. of Bitumen (gm)	Quantity of Bitugrip (%)	Wt. of Sample (gm)	Wt. after Stripping Value Test (gm)	Stripping Value (%)
1.	200	5	10	0.5	210.050	204	2.88
2.	200	5	10	0.75	210.075	204	2.29
3.	200	5	10	1.0	210.10	206	1.95
4.	200	5	10	1.5	210.15	203	3.41

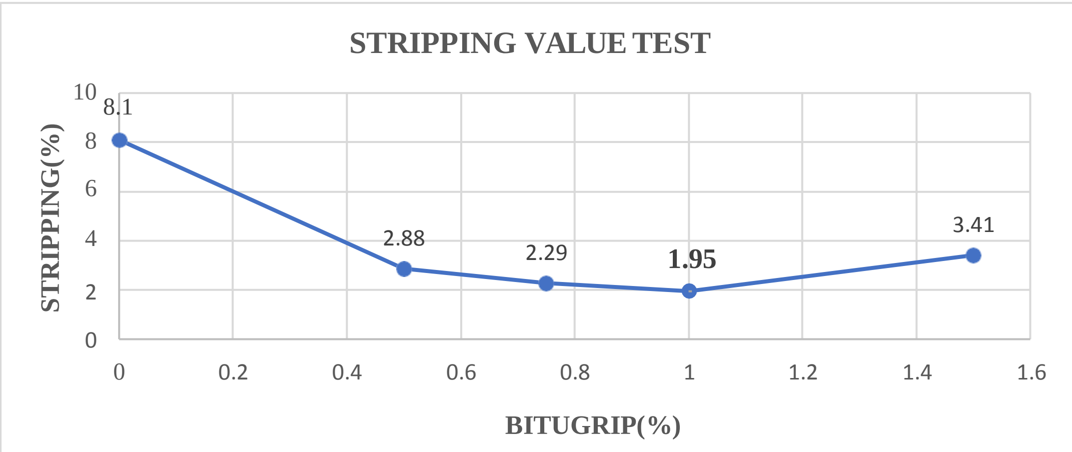

Fig 6.3.2: Stripping v/s Quantity of Bitugrip in Stripping Value Test

6.4 ADDITIVE- ZYCOTHERFM

6.4.1 BOILING WATER TEST RESULTS OF ZYCOTHERM

In the next, again boiling water test is performed with addition of four varying percentages of Zycotherm in bituminous mix. Thus in this case, minimum stripping is obtained after addition of 0.075% of Zycotherm. So 0.075% of Zycotherm is optimum value.

Table 6.4.1 Boiling Water Test Results of Zycotherm

S. No.	Wt. of Aggregate (gm)	Quantity of Bitumen (%)	Wt. of Bitumen (gm)	Quantity of Zycotherm (%)	Wt. of Sample (gm)	Wt. after Boiling Water Test (gm)	Stripping Value (%)
1.	200	5	10	0.05	210.005	206	1.91
2.	200	5	10	0.075	210.075	207	1.44
3.	200	5	10	0.10	210.010	204	2.86
4.	200	5	10	0.15	210.015	206	1.91

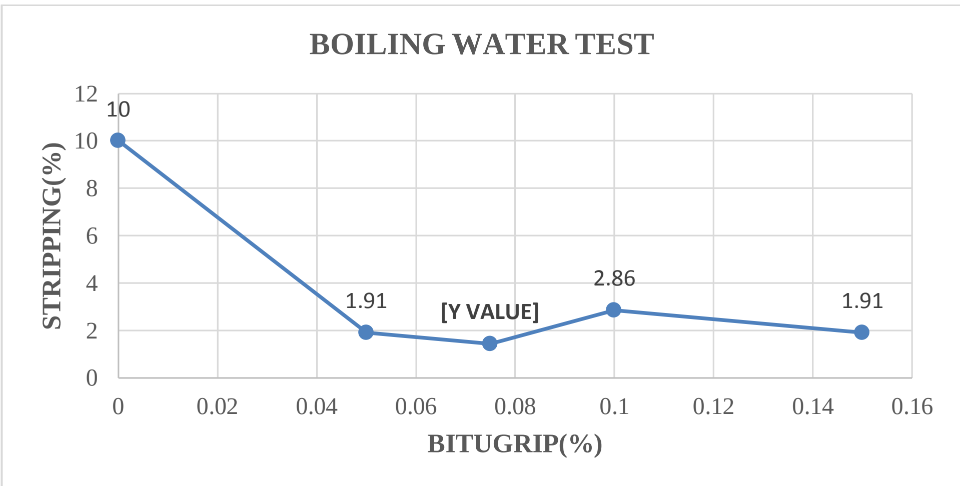

Fig 6.4.1: Stripping v/s Quantity of Zycotherm in Boiling Water Test

6.4.2 STRIPPING VALUE TEST RESULTS OF ZYCOTHERM

In the next, again stripping value test is performed with addition of four varying percentages of Zycotherm in bituminous mix. Thus in this case, minimum stripping is obtained after addition of 0.075% of Zycotherm. So 0.075% of Zycotherm is optimum value.

Table 6.4.2 Stripping Value Test Results of Zycotherm

S. No.	Wt. of Aggregate (gm)	Quantity of Bitumen (%)	Wt. of Bitumen (gm)	Quantity of Zycotherm (%)	Wt. of Sample (gm)	Wt. after Stripping Value Test (gm)	Stripping Value (%)
1.	200	5	10	0.05	210.005	204	2.86
2.	200	5	10	0.075	210.075	208	0.96
3.	200	5	10	0.10	210.010	205	2.39
4.	200	5	10	0.15	210.015	204	2.87

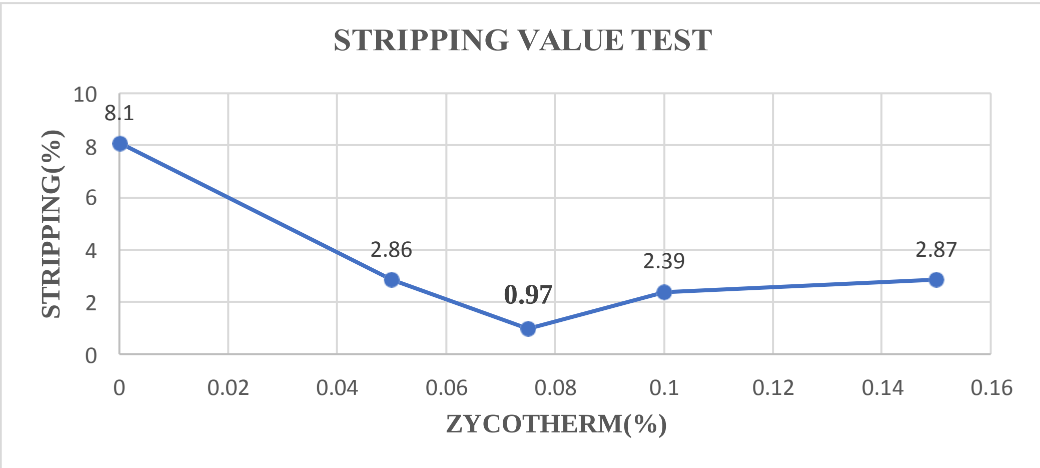

Fig 6.4.2: Stripping v/s Quantity of Zycotherm in Stripping Value Test

6.5 RESULTS OF OPTIMUM PERCENTAGES OF ASA:

6.5.1 BOILING WATER TEST RESULTS OF OPTIMUM PERCENTAGES:

This table shows the optimum percentages of these three ASA using in this research with their minimum stripping values(%) for Boiling water test.

Table 6.5.1 Optimum Values of ASA in Boiling Water Test

S. No.	Name of Anti-Stripping Agent	Optimum Quantity of Anti-Stripping Agent (%)	Stripping Value (%)
1.	Wetbond-S	0.10	1.43
2.	Zycotherm	0.075	1.44
3.	Bitugrip	1.0	1.95

6.5.2 STRIPPING VALUES TEST RESULTS OF OPTIMUM PERCENTAGES:

This table shows the optimum percentages of these three ASA using in this research with their minimum stripping values (%) for Stripping value test.

Table 6.5.2 Optimum Values of ASA in Stripping Value Test

S. No.	Name of Anti-Stripping Agent	Optimum Quantity of Anti-Stripping Agent (%)	Stripping Value (%)
1.	Wetbond-S	0.10	1.43
2.	Zycotherm	0.075	0.94
3.	Bitugrip	1.0	1.95

(C) COMBINATIONS OF OPTIMUM DOSAGE OF ASA:-

6.6 ADDITIVE: WETBOND-S + ZYCOTHERM

6.6.1 BOILING WATER TEST RESULTS OF WETBOND-S+ZYCOTHERM

This table shows stripping values of bituminous mix without adding any ASA and after addition of optimum dosage of Wetbond-S & Zycotherm in boiling water test.

Table 6.6.1 Boiling Water Test results of Wetbond-S+Zycotherm

S. No.	Wt. of Aggregate (gm)	Quantity of Bitumen (%)	Wt. of Bitumen (gm)	Quantity of Wetbond-S + Zycotherm (%)	Wt. of Sample (gm)	Wt. after Boiling Water Test (gm)	Stripping Value (%)
1.	200	5	10	0	210	189	10
2.	200	5	10	0.10+ 0.075	210.0175	207.08	1.40

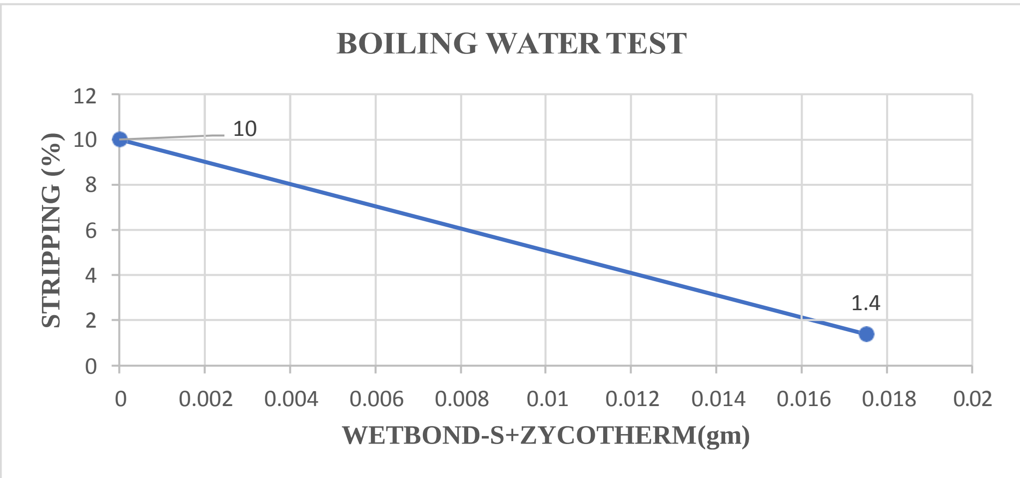

Fig 6.6.1: Stripping v/s Optimum Value of (Wetbond-S+Zycotherm) in Boiling Water Test

6.6.2 STRIPPING VALUE TEST RESULTS OF WETBOND-S+ZYCOTHERM

This table shows the stripping values of bituminous mix without adding any ASA and after addition of optimum dosage of Wetbond-S & Zycotherm in stripping value test.

Table 6.6.2 Stripping Value Test results of Wetbond-S+Zycotherm

S. No.	Wt. of Aggregate (gm)	Quantity of Bitumen (%)	Wt. of Bitumen (gm)	Quantity of Wetbond-S + Zycotherm (%)	Wt. of Sample (gm)	Wt. after Stripping Value Test (gm)	Stripping Value (%)
1.	200	5	10	0	210	193	8.1
2.	200	5	10	0.10+ 0.075	210.0175	207.12	1.38

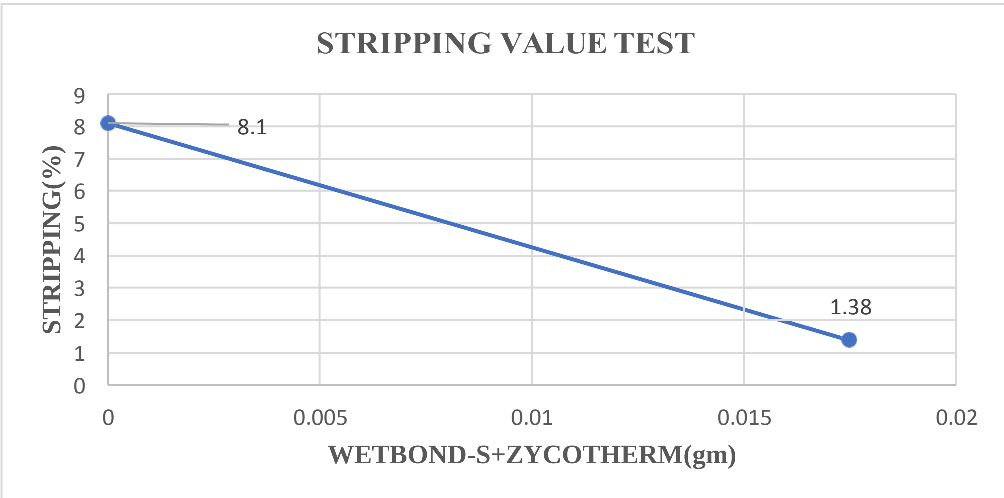

Fig 6.6.2: Stripping v/s Optimum Values of (Wetbond-S+Zycotherm) in Stripping Value Test

6.7 ADDITIVE: WETBOND-S + BITUGRIP

6.7.1 BOILING WATER TEST RESULTS OF WETBOND-S+BITUGRIP

This table shows stripping values of bituminous mix without adding any ASA and after addition of optimum dosage of Wetbond-S & Bitugrip in boiling water test.

Table 6.7.1 Boiling Water Test results of Wetbond-S+Bitugrip

S. No.	Wt. of Aggregate (gm)	Quantity of Bitumen (%)	Wt. of Bitumen (gm)	Quantity of Wetbond- S + Bitugrip (%)	Wt. of Sample (gm)	Wt. after Boiling Water Test (gm)	Stripping Value (%)
1.	200	5	10	0	210	189	10
2.	200	5	10	0.10 + 1.0	210.11	210.13	1.42

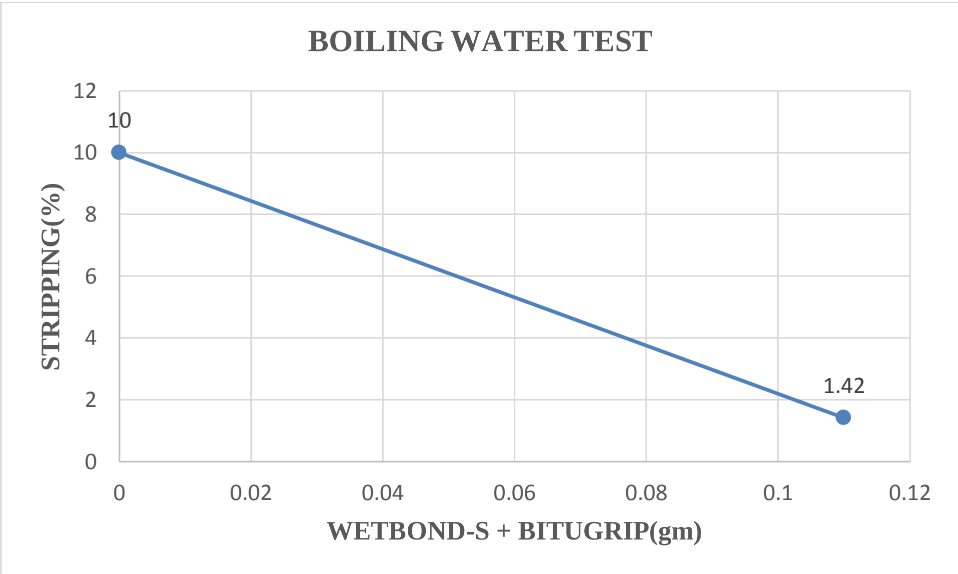

Fig 6.7.1: Stripping v/s Optimum Values of (Wetbond-S+Bitugrip) in Boiling Water Test

6.7.2 STRIPPING VALUE TEST RESULTS OF WETBOND-S+BITUGRIP

This table shows stripping values of bituminous mix without adding any ASA and after addition of optimum dosage of Wetbond-S & Bitugrip in stripping value test.

Table 6.7.2: Stripping Value Test results of Wetbond-S+Bitugrip

S. No.	Wt. of Aggregate (gm)	Quantity of Bitumen (%)	Wt. of Bitumen (gm)	Quantity of Wetbond- S + Bitugrip (%)	Wt. of Sample (gm)	Wt. after Stripping Value Test (gm)	Stripping Value (%)
1.	200	5	10	0	210	193	8.1
2.	200	5	10	0.10 + 1.0	210.11	210.13	1.41

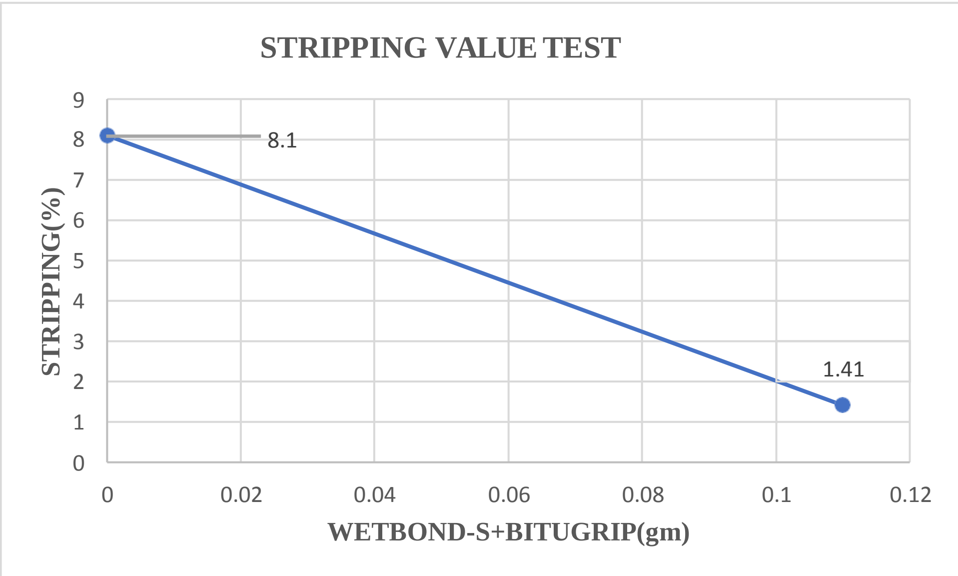

Fig 6.7.2: Stripping v/s Optimum Values of (Wetbond-S+Bitugrip) in Stripping Value Test

6.8 ADDITIVE: WETBOND-S+ ZYCOTHERM+ BITUGRIP

6.8.1 BOILING WATER TEST RESULTS OF WETBOND-S+ZYCOTHERM+BITUGRIP

This table shows stripping values of bituminous mix without adding any ASA and after addition of optimum dosage of Wetbond-S, Zycotherm & Bitugrip in boiling water test.

Table 6.8.1 Boiling Water Test results of Wetbond-S+Zycotherm+Bitugrip

S.No.	Wt. of Aggregate (gm)	Quantity of Bitumen (%)	Wt. of Bitumen (gm)	Quantity of Wetbond- S + Zycotherm + Bitugrip (%)	Wt. of Sample (gm)	Wt. after Boiling Water Test (gm)	Stripping Value (%)
1.	200	5	10	0	210	189	10
2.	200	5	10	0.10+0.075 +1.0	210.1175	207.18	1.40

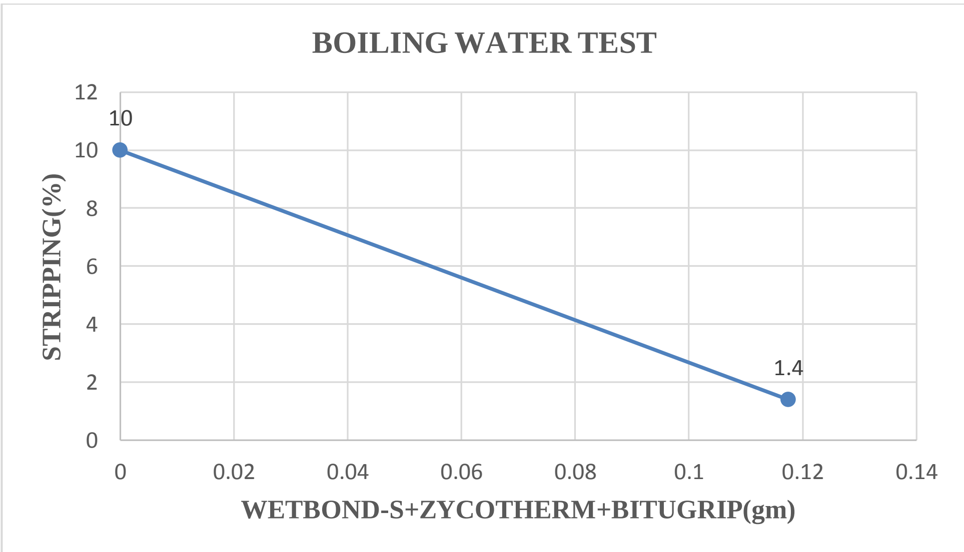

Fig 6.8.1: Stripping v/s Optimum Values of (Wetbond-S+Zycotherm+Bitugrip) in Boiling Water Test

6.8.2 STRIPPING VALUE TEST RESULTS OF WETBOND-S +ZYCOTHERM+BITUGRIP

This table shows stripping values of bituminous mix without adding any ASA and after addition of optimum dosage of Wetbond-S, Zycotherm & Bitugrip in stripping value test.

Table 6.8.2: STRIPPING VALUE TEST RESULTS OF WETBOND-S +ZYCOTHERM+BITUGRIP

S.No.	Wt. of Aggregate (gm)	Quantity of Bitumen (%)	Wt. of Bitumen (gm)	Quantity of Wetbond- S + Zycotherm + Bitugrip (%)	Wt. of Sample (gm)	Wt. after Stripping Value Test (gm)	Stripping Value (%)
1.	200	5	10	0	210	193	8.1
2.	200	5	10	0.10+0.075+1.0	210.1175	207.23	1.375

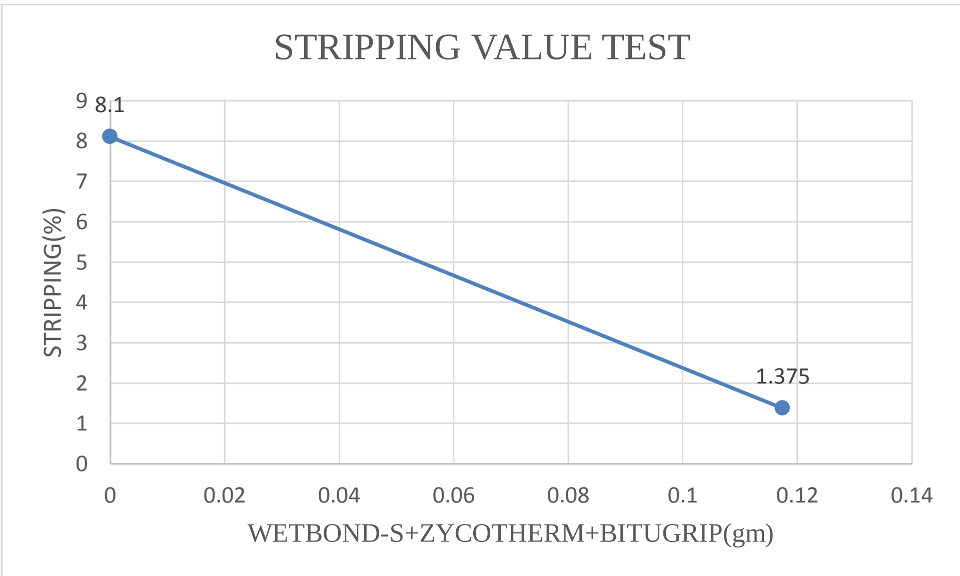

Fig 6.8.2: Stripping v/s Optimum Values of (Wetbond-S+Zycotherm+Bitugrip) in Stripping Value Test

CHPATER-7
RESULT ANALYSIS AND DISCUSSION

7.1 ANALYSIS OF MAINTENANCE COST IN CASE OF BOILING WATER TEST

Table 7.1 Analysis of Maintenance Cost in case of Boiling Water Test

S. No.	Name of ASA	ASA addition Optimum (%)	Stripping Value(%)	Damaged Area (sq.m.)	Pavement Thickness (40mm)	Damaged Quantity (cum)	Rate of BC per cum	Amount of maintenance (Rs.)	Quantity of Bitumen @ 5.4% wt. of mix	Quantity of ASA (Kg)	Rate of ASA Rs. Per kg	Cost of ASA (Rs.)	Maintenance Cost (Rs.)
1	No Agent	0	10	700	0.04	28.00	9965	279020	3.56	0	0	0	279020
2	Wetbond-S	0.1	1.43	100.1	0.04	4.00	9965	39899.86	0.51	50.94	765	38969.82	39899.86
3	Zycotherm	0.075	1.44	100.8	0.04	4.03	9965	40178.88	0.51	38.47	1350	51938.39	40178.88
4	Bitugrip	1	1.95	136.5	0.04	5.46	9965	54408.9	0.69	694.65	155	107670.63	54408.9
5	Wetbond+ Zycotherm	0.10+ 0.075	1.4	98	0.04	3.92	9965	39062.8	0.50	89.41	2115	90908.21	39062.8
6	Wetbond-S +Bitugrip	0.1+ 1	1.42	99.4	0.04	3.98	9965	39620.84	0.51	745.59	920	146640.45	39620.84
7	Wetbond-S +Zycotherm + Bitugrip	0.10+ 0.075+1	1.4	98	0.04	3.92	9965	39062.8	0.50	784.06	2270	198578.84	39062.8

- From the above table, it is seen that there is extreme reduction in damaged area and damage quantity is observed after addition of different ASA with their optimum percentages. But max variation is shown in all data is observed in case of Wetbond-S. So **Wetbond-S**(ASA) is most effective ASA in **Boiling Water Test.**

% saving in maintenance cost with reference to original mix without adding any ASA:-

After adding Wetbond-S, % saving MC= 85.7%

After adding Zycotherm, % saving MC=85.6%

After adding Bitugrip, % saving MC= 80.5%

After adding Wetbond-S+Zycotherm= 86%

After adding Wetbond-S+Bitugrip=85.8%

After adding Wetbond+Zycotherm+Bitugrip=85.6%

Here, from above table and calculation it is clearly seen that

- Addition of 0.1% Wetbond-S (individually) contributing minimum damage area and max. saving in maintenance cost.
- Although maintenance cost of Wetbond-S+Zycotherm and Wetbond-S+Zycotherm+Bitugrip is same but on the basis of overall observation and all aspects Wetbond-S+Zycotherm is most effective combination.
- After seeing, max saving in maintenance cost as 86%, Best combination is **Wetbond S+Zycotherm**.

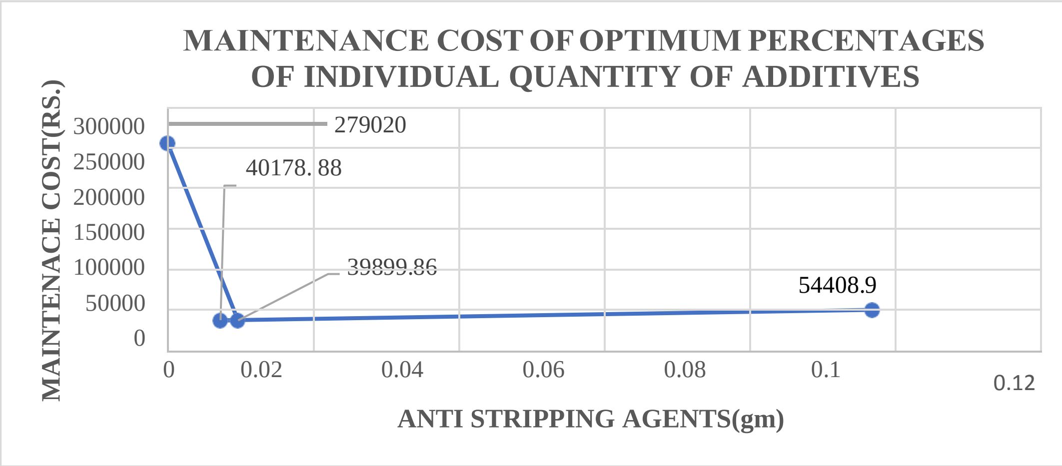

Fig 7.1 (a): Maintenance Cost v/s ASA (%) adding Individually in Boiling Water Test

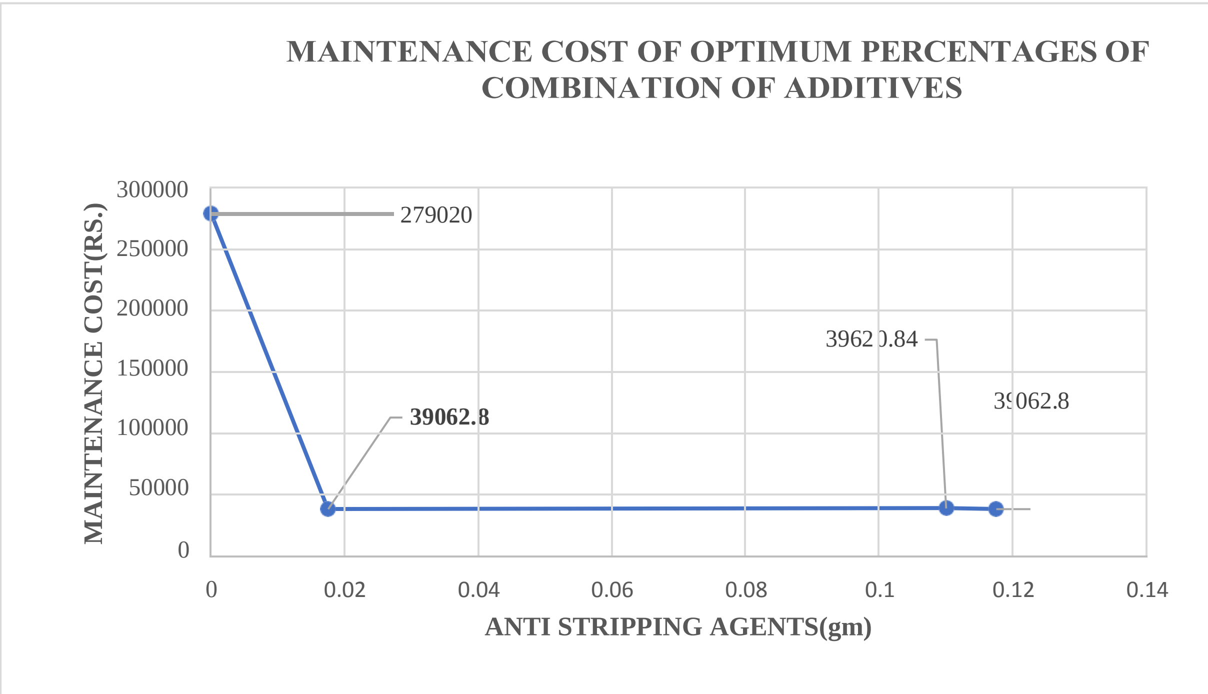

Fig 7.1(b): Maintenance Cost v/s ASA% adding in combination in Boiling Water Test

7.2 ANALYSIS OF MAINTENANCE COST IN CASE OF STRIPPING VALUE TEST

Table 7.2 Analysis of Maintenance Cost in case of Stripping Value Test

S. No.	Name of ASA	ASA addition Optimum (%)	Stripping Value(%)	Damaged Area (sq.m.)	Pavement Thickness (40mm)	Damaged Quantity (cum)	Rate of BC per cum	Amount of maintenance (Rs.)	Quantity of Bitumen @ 5.4% wt. of mix	Quantity of ASA (Kg)	Rate of ASA Rs. Per kg	Cost of ASA (Rs.)	Maintenance Cost (Rs.)
1	No Agent	0	8.1	567	0.04	22.68	9965	226006.2	2.89	0	0	0	226006.2
2	Wetbond-S	0.1	1.43	100.1	0.04	4.00	9965	39899.86	0.51	50.94	765	38969.82	39899.86
3	Zycotherm	0.075	0.96	67.2	0.04	2.69	9965	26785.92	0.34	25.65	1350	34625.59	26785.92
4	Bitugrip	1	1.95	136.5	0.04	5.46	9965	54408.9	0.69	694.65	155	107670.63	54408.9
5	Wetbond+ Zycotherm	0.10+ 0.075	1.42	99.4	0.04	3.98	9965	39620.84	0.51	76.59	2115	73595.41	39620.84
6	Zycotherm+ Bitugrip	0.075	1.44	100.8	0.04	4.03	9965	40178.88	0.51	702.30	1505	142296.22	40178.88
7	Wetbond-S +Bitugrip	0.075+ 1	1.41	98.7	0.04	3.95	9965	39341.82	0.50	745.59	920	146640.45	39341.82
8	Wetbond-S +Zycotherm+ Bitugrip	0.10+ 0.075+1	1.375	96.25	0.04	3.85	9965	38365.25	0.49	771.24	2270	181266.04	38365.25

- From the above table, it is seen that there is extreme reduction in damaged area and damage quantity after addition of different ASA with their optimum percentages. But max variation is shown in all data is observed in case of Zycotherm. So **Zycotherm**(ASA) is most effective ASA in Stripping Value Test.

% saving in maintenance cost with reference to original mix without adding any ASA:-

After adding Wetbond-S, % saving MC= 82.3%

After adding Zycotherm, % saving MC=88.1%

After adding Bitugrip, % saving MC= 75.9%

After adding Wetbond-S+Zycotherm=82.5%

After adding, Zycotherm+Bitugrip= 82.2%

After adding Wetbond-S+Bitugrip=82.6%

After adding Wetbond+Zycotherm+Bitugrip=83.0%

Here, from above table and calculation it is clearly seen that

- Addition of 0.075% ZYCOTHERM (individually) contributing minimum damage area and max. saving in maintenance cost.
- As we can see that max saving in maintenance cost is in Zycotherm+Bitugrip, but Bitugrip is not so effective ASA in this research so considering all aspects, **Wetbond-S+Zycotherm** combination is considered as best and most effective combination.

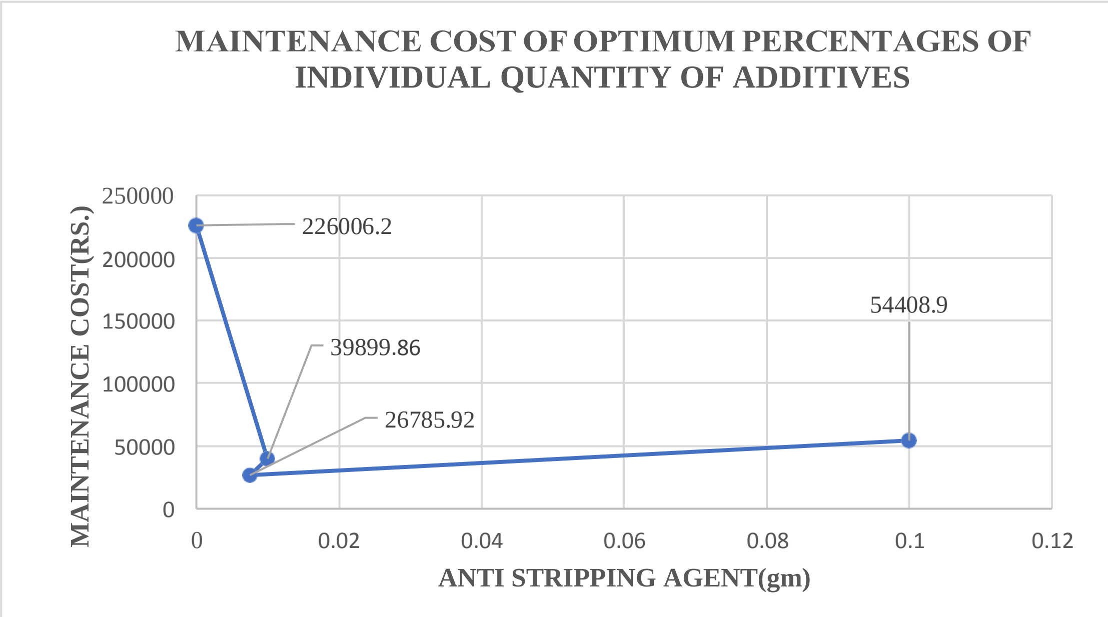

Fig 7.2(a): Maintenance Cost v/s Optimum Values of ASA(%) adding individually in Stripping Value Test

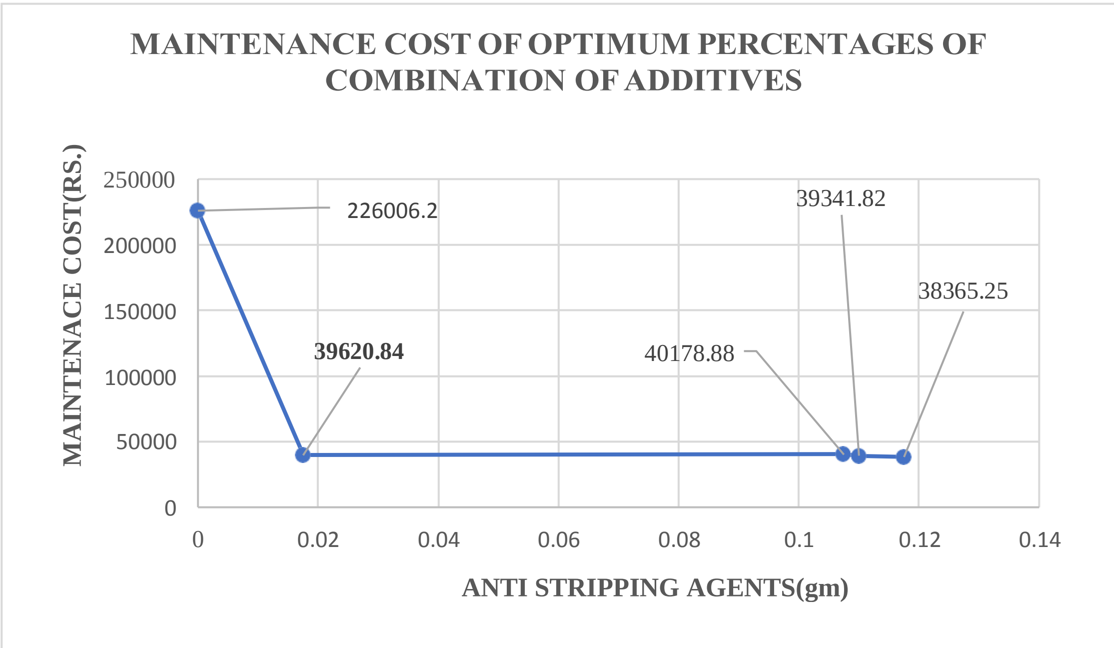

Fig 7.2(b): Maintenance Cost v/s ASA (%) adding in combination in Stripping Value Test

CHAPTER 8
CONCLUSION AND RECOMMENDATION

8.1 CONCLUSION

Following conclusions are derived based on laboratory investigations keeping in aspect procedures of codal practice:

It has been noted that there is a decrease in stripping value with the addition of different Anti-Stripping Agents as chemical with VG 30 mix as the chemistry has changed the property, as adhesion is increased, increasing the workability of bituminous mix. As bitumen is ductile and fulfills the standard criteria, the coating of aggregate is better.

The Boiling Water Test and stripping Value Test performed in this study on loose mixtures is able to detect the possibility of weak adhesion between asphalt binders and aggregates. It can also be used to identify the presence of anti-stripping additives in moisture susceptible mixes. The aggregate and binder sources have an effect on the effectiveness of a particular ASA treatment.

However, Wetbond-S is the most effective in decreasing the stripping value of mixes in case of Boiling Water Test while in same way, Zycotherm is the most effective in case of Stripping Value test.

The presence of VG 30 modification is seen with various dosages of different Anti-stripping Additives and this change is associated with Boiling Water Test and Stripping Value Test. As these additives are Silane based additives, minimize the moisture damage as a coating of bitumen is formed around the aggregate. In presence of water too, it acts as an active adhesive preventing stripping.

Proper gradation of aggregates for durable flexible pavement coupled with good compaction are of utmost importance to reduce the stripping of bituminous pavements which have been able to show repeated improvement in moisture resistance owing to packing mechanism and enhancing the adhesion of mix.

The laboratory evaluation shows that Anti-stripping agent Wetbond-S with a dosage of 0.10% by wt., Zycotherm with a dosage of 0.075% is effective in improving moisture resistance of asphalt moisture. Therefore, it is feasible to apply the anti-stripping agent to prevent moisture damages, especially potholes.

In this study, the use of Bitugrip in asphalt mixture has not shown a pronounced effect in reducing stripping value.

The addition of 0.10% Wetbond-S and 0.075% Zycotherm by wt. has greater effectiveness on stripping individually, compared with Bitugrip. Best combination of **ASAs** used in bituminous mixture to construct flexible pavement is **Wetbond-S and Zycotherm** as per observation under varying aspects as notable result has been found to reduce the stripping value.

Based on the findings, the following conclusions have been drawn:

- ASAs (Wetbond-S, Zycotherm & Bitugrip) are chemical admixtures containing active functional groups that improves the adhesion of the bitumen film on the surface of aggregate.
- It has been observed that after the addition of ASAs (Wetbond-S, Zycotherm & Bitugrip), the stripping of Bituminous Mixes reduced.
- When ASAs are mixed with the binder, lower the surface tension of the bitumen.
- As the ASAs are of low cost, therefore, it is expected to reduce the life cycle cost of the bituminous pavements.
- Using ASAs, durability of road increases as proved in the study.

8.2 RECOMMENDATIONS

1. To fully understand the moisture damage phenomenon, the physio-chemical interaction between the asphalt binder and aggregate must be investigated further.
2. The role of adhesion in this performance of the mixtures used in this study must be fully understood. The adhesion between the various asphalts and aggregate sources used in this study must be incorporated into the results of mixture testing to define the contributions of the asphalt binder to mixture performance.

SCOPE FOR FUTURE INVESTIGATION

Based on present work and findings, it is felt that further work should be pursued in the following area:

- The evaluation methods consider mainly moisture sensitivity as the main factor due to which stripping occurs.
- Damage may occur in base course. Evaluation should be carried out considering base course damage.
- Further investigation should be carried out different grades of bitumen.
- No mechanism has been developed yet to determine stripping value, observations are done visually.
- In laboratory distilled water is used in experimentation which is neutral with pH 7, but there is a large variation in pH value of water in the field.

REFERENCES

1. Aman, M.Y.; Hamzah, M.O. Effects of Anti-Stripping Additives on Moisture Sensitivity of Warm Porous Asphalt Mixtures. IJCEM 2014, 1, 10–16.
2. American Association of State Highway and Transportation Officials (2002), "Standard Specifications for Transportation Materials and Methods of Sampling and Testing," Twenty Second Edition, American Association of State Highway and Transportation Officials.
3. ASTM D3625-96, Effect of Water on Bituminous-coated Aggregate Using Boiling Water, ASTM International, West Conshohocken, PA, 2005.
4. Busching, H.W., Burati, J.L., and Amirkhanian, S.N. (1986), "An Investigation of Stripping in Asphalt Concrete in South Carolina," Report No. FHWA-SC-86-02.
5. Cagri Gorkem, Burak Sengoz (2008), "Predicting stripping and moisture induced damage of asphalt concrete prepared with polymer modified bitumen and hydrated lime". Construction and Building Materials 23 (2009) 2227–2236.
6. Cause and Prevention of Stripping in Asphalt Pavements, Educational Series, No. 10, Second Edition, The Asphalt Institute, College Park, Maryland, 1988.
7. Cesare Olliviero Rossi, Bagdat Teltayev (2017),"Adhesion Promoters in Bituminous Road Materials" Applied Science.
8. Cui, S.; Blackman, B.R.K.; Kinloch, A.J.; Ambrose, C.T. Durability of asphalt mixtures: Effect of aggregate type and adhesion promoters. Int. J. Adhe. Adhes. **2014**, 54, 100–111.
9. Dae-Wook Park, Woo-Jin Seo(2017), "Evaluation of moisture susceptibility of asphalt mixture using liquid anti-stripping agents". Construction and Building Materials 144 (2017) 399–405. Mar, 2017.
10. Dax Patel, Pradip J. Gundaliya, "Repair of Road Distress and Potholes with using Organosilane Based Technologies" (IRJET) Volume: 05 Issue: 02 | Feb-2018
11. Erol Iskender, Atakan Aksoy(2011), "Indirect performance comparison for styrene–butadiene–styrene polymer and fatty amine anti-strip modified asphalt mixtures". Construction and Building Materials 30 (2012) 117–124. Nov,2011.
12. Gourav Goel, S.N. Sachdeva, "STRIPPING PHENOMENON IN BITUMINOUS MIXES" Int. J. of Mathematical Sciences and Applications, Vol. 6, No. 2, December 2016.
13. Graf, P.E. (1986), "Factors Affecting Moisture Susceptibility of Asphalt Concrete Mixes," Association of Asphalt Paving Technologists, Vol. 55, Pg 175-204.
14. Haider Habeeb, Satish Chandra, and Yassir Nashaat, "Estimation of Moisture Damage and Permanent Deformation in Asphalt Mixture from Aggregate Gradation", KSCE Journal of Civil Engineering (2014) 18(6):1655-1663.
15. Hamed Omrani, Ali Reza Ghanizadeh (2017), "Effect of SBS Polymer and Anti-stripping Agents on the Moisture Susceptibility of Hot and Warm Mix Asphalt Mixtures" Civil Engineering Journal Vol. 3, No. 10, October, 2017.
16. Harpreet Singh, Tanuj Chopra(2017), "Effect Of Zycotherm Performance Of Neat

Bitumen And Bituminous Concrete mixes". IJCIET, Volume 8, Issue 8, August 2017.

17. Hasan H. Joni* and Mahmood S. Hashim (2017) "Evaluation of the Effects of Anti-Stripping Materials on the Performance of Cold Bitumen Emulsion Mixtures (CBEMs)". International Journal of Current Engineering and Technology. Sept, 2017.
18. Khani Sanij, P. Afkhamy Meybodi (2018), "Evaluation of performance and moisture sensitivity of glass-containing warm mix asphalt modified with zycotherm^{TM} as an anti-stripping additive". Construction and Building Materials 197 (2019) 185–194. Nov,2018.
19. Hicks, R.G. (1991), "Moisture Damage in Asphalt Concrete," NCHRP Synthesis of Highway Practice 175, Transportation Research Board, Washington, D.C.
20. Hunter, E.R., and Ksaibati, K. (2002), "Evaluating Moisture Susceptibility of Asphalt Mixes," Department of Civil and Architectural Engineering, University of Wyoming.
21. IS:1203. (1978). Methods for testing tar and bituminous materials; determination of penetration. Bureau of Indian Standards, India.
22. IS:1205. (1978). Methods for testing tar and bituminous materials; determination of softening point. Bureau of Indian Standards, India.
23. IS:1208. (1978). Methods for testing tar and bituminous materials; determination of ductility. Bureau of Indian Standards, India.
24. IS:6241. (1971). Determination of stripping value of aggregates. Bureau of Indian Standards, India.
25. Jiusu Li, Wenbo Zhang, Wenke Jia, Lubinda F Walubita and Guanlan Liu, "Quantitative evaluation and enhancement of adhesion between bitumen and aggregates", Journal of Chemical and Pharmaceutical Research, 2014, 6(6):1737-1742.
26. Kandhal, P.S. (1994), "Field and Laboratory Investigation of Stripping in Asphalt Pavements: State of the Art Report," Transportation Research Record 1454, Pg 36-47.
27. Kandhal, P.S. and Rickards, I.J. (2001), "Premature Failure of Asphalt Overlays from Stripping: Case Histories," Association of Asphalt Paving Technologists, Vol. 70: pp. 301 – 351.
28. Kanitpong, K., "Evaluation of the Roles of Adhesion and Cohesion Properties of Asphalt Binders in Moisture Damage of HMA." Dissertation, University of Wisconsin –Madison Department of Civil and Environmental Engineering, 2004.
29. Kanitpong, K., Bahia, H. "Relating Adhesion and Cohesion of Asphalts to Effect of Moisture on Asphalt Mixtures' Laboratory Performance." Transportation Research Record. Journal of the Transportation Research Board. No. 1901. Pages 33-43. Transportation Research Board, Washington DC, 2005.
30. Kennedy, T.W. and Ping, W.V. (1991), "An Evaluation of Effectiveness of Antistripping Additives in Protecting Asphalt Mixtures from Moisture Damage," Association of Asphalt Paving Technologists, Vol. 60: pp. 230 – 263.
31. Kiggundu, B.M., and Roberts, F.L. (1988), "Stripping in HMA Mixtures: State of the Art and Critical Review of Test Methods," National Center for Asphalt Technology,

Report No. 88-2.

32. Kunal kumar Vaghela, Asso. Prof. V.J. Chitaria (2018), “Evaluation of Organosilane Based Asphalt Additive For Flexible Pavement”. (IRJET) Volume: 05 Issue: 02 | Feb-2018.
33. LC 25-009. “The Evaluation of Binder Resistance to Stripping for a Given Aggregate Surface.” Quebec Department of Transportation, 2002.
34. M.A. Taylor, N.P. Khosla, Stripping of Asphalt Pavements: State of the Art,Transportation Research Board, Washington, D.C., 1983.
35. Mahmoud Ameri, Sareh Kouchaki(2013) “Laboratory evaluation of the effect of nano-organosilane anti-stripping additive on the moisture susceptibility of HMA mixtures under freeze–thaw cycles”. Construction and Building Materials 48 (2013) 1009–1016 . July,2013.
36. Mahmoud Nazirizad, Amir Kavussi (2015), “Evaluation of the effects of anti-stripping agents on the performance of asphalt mixtures”. Construction and Building Materials 84 (2015) 348–353.
37. Maupin, G.W. (2004), “Quantitative Determination of Asphalt Antistripping Additive,” Final Report VTRC 05-R3, Virginia Transportation Research Council, Charlottesville, VA.
38. Oliviero Rossi, Role of a food grade additive in the high temperature performance of modified bitumens. Colloids Surf. A: Physicochem. Eng. Aspects **2017**.
39. Roberts, F.L., Kandhal, P.S., Brown, E.R., Lee, D.Y., and Kennedy, T.W. (1996), “Hot Mix Asphalt Materials, Mixture Design, and Construction,” Second Edition, National Asphalt Pavement Association Research and Education Foundation.
40. Selim, A.A. (1997), “Cost Effective/User Friendly Anti-Stripping Additives in HMA,” Quartzite Quotes, Quartzite Rock Association, March 1997.
41. Shazi, Prof. D. S. Ray (2018), “Study and Evaluation of Disintegration of Pavement Surface”. IJSRD Vol. 6, Issue 03, 2018.
42. Strauss, F. H. and A. P. Anderson (1942), "Stripping v/s Coating of Mineral Aggregates,"Proceedings, Association of Asphalt Paving Technologists,Vol.13,pp. l-8.
43. Tunnicliff, D.G. (1997), “Performance of Antistirpping Additives,” Association of Asphalt Paving Technologists, Vol. 66: pp. 344 – 368.
44. Umaru Bagampadde, Ulf Isacsson, “Classical and Contemporary Aspects of Stripping in Bituminous Mixes” Road Materials and Pavement Design, 5:1, 7-43. Sept,2011.
45. Yong-Rak Kim, Ingryd Pinto(2011), “Experimental evaluation of anti-stripping additives in bituminous mixtures through multiple scale laboratory test results”. Construction and Building Materials 29 (2012) 386–393. Oct,2011.
46. Yoon, H.H. and R. L. Terrel (1988), "Effect of Aggregate Properties on Stripping," Transportation Research Record 1171, Transportation Research Board, National Research Council, Washington, D. C., pp. 37-43

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 01, January-2020

A Review of Literature on Optimization of Different Anti Stripping Agents in Construction of Flexible Pavement

Purnima Tripathi[1]
[1]M. Tech. Scholar, Department of Civil Engineering, BBDU, Lucknow, India

D. S. Ray[2]
[2]Professor and Head of Department, Department of Civil Engineering, BBDNITM, Lucknow, India

***Abstract*:- This paper presents the effect of anti-stripping additives in bituminous mixes. As per researches series of laboratory tests have been conducted with varying percentage of these Anti-stripping additives, added Individually and in Combinations, to determine their optimum percentages. This paper presents the results of experimental investigations carried out to study the effect of Wetbond-S, Zycotherm and Bitugrip on Bitumen and Aggregate. Boiling water test and Stripping value test were conducted as screening tests. The current research shows the optimization of different anti-stripping additives to evaluate moisture susceptibilities of bituminous mixes. This paper deals with the review of some previous studies that are done to improve the adhesion between bitumen and aggregate. The stripping value decreases while increasing the percentage of anti-stripping additives to the bitumen.**

Keywords: Bitumen, Aggregate, Antistripping, Wetbond-S, Zycotherm, Bitugrip, Boiling water test, Stripping value test.

INTRODUCTION

Road sectors are the engine of growth for economy, employment and empowerment. It is extremely essential that roads are well laid out and strong. In India 95% of roads are bituminous roads which consists approximately 93-95% of aggregate and 5- 7% of binder material. In order to cope up with the increasing trend of highly laden vehicles, new innovative materials need to be utilized for highway construction. Moisture damage in asphalt pavement has been considered to be a widespread problem all over India. The moisture damage causes loss of adhesion, and adversely affect to the strength of the asphalt mixture dramatically. It can also cause the premature pavement failures such as rutting and raveling on the pavement surface. During rainy season, the natural bitumen become failure and possess serious problem, to the movement of vehicular traffic.

Stripping is the process that results in separation of asphalt binder and aggregate due to the loss of adhesion at the interface of these materials in the presence of water. In order to control and decrease damaging effects of water, many researchers suggested to apply anti-stripping additives to increase the bond between bitumen and aggregates, leading to improved wetting resistance.

"Wetbond-S" is next generation Nano-technology Silicon based Anti-stripping Additive for Asphalt. This product is a low dose and extremely thermal resistive additive for use in Hot mix and Warm-mix road constructions. This product is specially, suitable for aggregates having very high and tough to control stripping profile. "Wetbond-S" is brownish clear liquid at room temperature with characteristic citrous odour. Acting as an adhesion promoter and water proofing agent. This product is non-miscible with water and miscible with polar & hydrocarbon solvents. The thermal stability of this product in hot bitumen (at 160°C) is over 15 days and no additional dose addition/adjustment is required on prolonged storage in hot bitumen in normal course of Hot-mix and Warm-mix pavement constructions.

Zycotherm is an odourless nano-technology based product with significant ability to improve the adhesion between bitumen and aggregates in bituminous mixtures. This additive improves the resistance of asphalt mixtures against moisture. It enables complete coating. Zycotherm allows lower mixing temp and lower compaction temp,making Zycotherm an environment friendly warm mix additive.

Bitugrip is product of HINCOAL (Hindustan Colas Private Limited). Hincol Bitugrip is very effective in high rainfall regions, areas with poor aggregate-bitumen affinity and poor drainage systems. It prevents bitumen against the stripping action of water. Hincol Bitugrip is specially designed solution to tackle such problem by enhancing the adhesion of bitumen and ensuring stability of bituminous pavements. Hincol Bitugrip is an amine based anti-stripping agent that changes interfacial tension between bitumen and aggregates, strengthening the bond for long term durability.

LITERATURE REVIEW

Cagri Gorkem, Burak Sengoz (2008)[1] This study is aimed to determine the effect of additives such as hydrated lime as well as elastomeric (SBS) and plastomeric (EVA) polymer modified bitumen (PMB) on the stripping potential and moisture susceptibility characteristics of hot mix asphalt (HMA) containing different types of aggregate

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 01, January-2020

(basalt–limestone aggregate mixture and limestone aggregate). The stripping properties and moisture susceptibility characteristics of the samples have been evaluated by means of captured images. As a consequence, it can be concluded that, polymer modified bitumen provides increased adhesion to the aggregate and creates a network structure within the base bitumen.

Yong-Rak Kim, Ingryd Pinto (2011)[2] This paper presents performance changes and material characteristics associated with moisture damage due to anti-stripping additives in asphalt mixtures through various laboratory tests. Two additives (hydrated lime and fly ash) are investigated by adding them into two types of mixes where different asphalt binders and aggregates are used. Two mixture constituent tests (the boiling water test and the pull-off tensile strength test) are conducted to characterize the effects of anti-stripping additives on the binder–aggregate bonding potential in mixtures. With the limited amount of test data, both hydrated lime and fly ash contribute to reducing moisture damage, which implies potential significant cost savings by the use of fly ash as an alternative additive.

Erol Iskender, Atakan Aksoy (2011)[3] The aim of this study is to analyze effects of SBS polymer and fatty amine anti-stripping agent additives for asphalt mixtures. The main goal of this research is to investigate rutting and moisture damage problems in asphalt mixtures. Proportional evaluation for stripping was studied and permanent deformation.

Mahmoud Ameri, Sareh Kouchaki (2013)[4] The objective of this research study was to evaluate moisture susceptibility of hot mix asphalt (HMA) with and without Zycosoil as a nano-organosilane anti-stripping additive and hydrated lime in the form of slurry. It was also observed that the effects of anti-stripping additives on specimens made by siliceous aggregate are more pronounced than those prepared with limestone aggregates. The use of Zycosoil additive will increase adhesion bond between the aggregates and asphalt binders, and in turn influences the moisture resistance of the mixture to moisture damage.

Mahmoud Nazirizad, Amir Kavussi (2015)[5] This study is aimed at determining the effects of two different anti-stripping additives, namely hydrated lime and a liquid anti-stripping agent (Iterlene In/400-S) on hot mix asphalt (HMA). Moisture susceptibilities of samples were determined by analyzing digital images taken from coated aggregate particles after performing boiling water test. Mixes containing 0.2%, 0.3% and 0.4% of liquid anti-stripping agent and mixes containing 1%, 1.5% and 2% of hydrated lime.

Dae-Wook Park, Woo-Jin Seo (2017)[6] This paper studied that Evaluation of moisture susceptibility of asphalt mixture using liquid anti-stripping agents. The purposes of this study are to comprehensively evaluate the moisture susceptibility of asphalt mixtures modified with several anti-stripping additives based on laboratory tests. Boiling water test was conducted as a screening test. The addition of anti-stripping agents significantly improves asphalt mixture stripping resistance before and after stripping occurs, and rutting resistance.

Harpreet Singh, Tanuj Chopra (2017)[7] In this study Zycotherm additive is added to neat bitumen and various comparisons were made using conventional test and rheological test on bitumen. Zycotherm gives better chemical bonding for extended moisture resistance and it ensures about 100% coating of bitumen at low temperature.

Hasan H. Joni, Mahmood S. Hashim (2017)[8] The main objective of this study is determining the effects of two different anti-stripping materials, namely hydrated lime and fly ash on cold bitumen emulsion mixture (CBEMs). It was found that mix samples prepared using hydrated lime additive give greater resistance to water damage, compared with control mixes and those containing fly ash. In addition, using of fly ash gives a high degree of coating and good workability.

Hamed Omrani, Ali Reza Ghanizadeh (2017)[9] The primary objective of this study is exploring the moisture susceptibility of unmodified and SBS-modified hot and warm mix asphalt mixtures.
Two different WMA additives including Aspha-min and Sasobit were employed to fabricate WMA specimens. The moisture susceptibility of warm polymer modified asphalt (WPMA) mixes was evaluated. In addition, the effect of different percentages of hydrated lime (from 0% to 2%) and Zycosoil (from 0% to 0.1%) as anti-stripping additives on the moisture susceptibility of the mixtures was explored. The test results showed that increasing moisture content decreases moisture damage resistance. Addition of hydrated lime improves moisture susceptibility. The results also showed that moisture sensitivity was affected significantly by the source of used aggregate.

Kunalkumar Vaghela, Asso. Prof. V.J. Chitaria (2018)[10] This study investigates the effects of anti-stripping agent on the microscopic strength of the mineral aggregate contact surface of mixture. The study compared the moisture susceptibility of three variations of bituminous concrete grade 1 mix: (i) Mix without anti-stripping additive (2) Mix with hydrated lime as an anti-stripping additive and (3) Mix with Zycosoil as an anti-stripping additive. The current study resulted in improved bituminous mixtures with the use of antistripping additives, especially in the moisture resistance property of the mixture.

Shazi, Prof. D. S. Ray (2018)[11] This paper aims at the study of potholes on the bituminous road surface and introducing the antistripping material to the bitumen to increase the durability of the road. In this paper, the antistripping material 'Bitugrip' is used to improve the adhesion properties of bitumen and aggregates. The stripping value decreases while increasing the percentage

Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 01, January-2020

of bitugrip to the bitumen. Overall, the addition of bitugrip has a positive influence on the adhesion properties between the aggregates and the bitumen and can be used to increase the durability of roads, thereby reduce the maintenance cost of the roads.

H. Khani Sanij, P. Afkhamy Meybodi (2018)[12] The primary goal of these efforts is to improve the durability and load-bearing performance of asphalt mixtures. In this study, glass particles were used, as aggregates in warm mix asphalt (WMA) mixtures. The objective of this study was to investigate the effects the use of Zycotherm^{TM} as an anti-stripping agent have on the mechanical properties and moisture susceptibility of glass-asphalt. Four different amounts of Zycotherm^{TM} were used in WMA mixtures to serve as bitumen modifier and anti-stripping agent. In this study, glass particles were used, as aggregates in warm mix asphalt (WMA) mixtures. Four different amounts of Zycotherm-TM were used in WMA mixtures to serve as bitumen modifier and anti-stripping agent.

CONCLUSIONS

From the review of literature on different antistripping additives used in bituminous pavement, the following conclusion can be drawn-

- Anti-stripping additives improve the adhesive property.
- These additives enhance the service life of pavement.
- Zycotherm additive decreases penetration value of base bitumen and there was a slight increase in softening point of bitumen with addition of Zycotherm additive.
- Zycotherm additive tends to increase conventional properties of bitumen.
- Based on bitumen test results, Zycotherm^{TM} addition increases ductility.
- Using Bitugrip increases the durability of the road as proved in the study.
- When bitugrip is mixed with the binder it lowers the surface tension of the bitumen.
- As the bitugrip is of low cost, therefore, it is expected to reduce the life cycle cost of the bituminous pavements.
- Zycosoil improves the moisture resistance and long-term performance of the asphalt mixtures compared with the hydrated lime.
- Anti-stripping additive will make driving safer and easier and to reduce the no. of accidents.
- Further studies can be done on effects of different polymers and anti-stripping agents on moisture sensitivity of WMA mixes produced with various technologies, specifically foaming or water containing ones.

REFERENCES

[1] Cagri Gorkem, Burak Sengoz (2008), "Predicting stripping and moisture induced damage of asphalt concrete prepared with polymer modified bitumen and hydrated lime". Construction and Building Materials 23 (2009) 2227–2236.

[2] Dae-Wook Park, Woo-Jin Seo(2017), "Evaluation of moisture susceptibility of asphalt mixture using liquid anti-stripping agents". Construction and Building Materials 144 (2017) 399–405. Mar, 2017.

[3] Erol Iskender, Atakan Aksoy(2011), "Indirect performance comparison for styrene–butadiene–styrene polymer and fatty amine anti-strip modified asphalt mixtures". Construction and Building Materials 30 (2012) 117–124. Nov,2011.

[4] Hamed Omrani, Ali Reza Ghanizadeh (2017), "Effect of SBS Polymer and Anti-stripping Agents on the Moisture Susceptibility of Hot and Warm Mix Asphalt Mixtures" Civil Engineering Journal Vol. 3, No. 10, October, 2017.

[5] Harpreet Singh, Tanuj Chopra(2017), "Effect Of Zycotherm Performance Of Neat Bitumen And Bituminous Concrete mixes". IJCIET, Volume 8, Issue 8, August 2017

[6] Hasan H. Joni* and Mahmood S. Hashim (2017) "Evaluation of the Effects of Anti-Stripping Materials on the Performance of Cold Bitumen Emulsion Mixtures (CBEMs)". International Journal of Current Engineering and Technology. Sept, 2017.

[7] H. Khani Sanij, P. Afkhamy Meybodi (2018), "Evaluation of performance and moisture sensitivity of glass-containing warm mix asphalt modified with zycotherm^{TM} as an anti-stripping additive". Construction and Building Materials 197 (2019) 185–194. Nov,2018.

[8] Kunal kumar Vaghela, Asso. Prof. V.J. Chitaria (2018), "Evaluation Of Organosilane Based Asphalt Additive For Flexible Pavement". (IRJET) Volume: 05 Issue: 02 | Feb-2018.

[9] Mahmoud Ameri, Sareh Kouchaki(2013) "Laboratory evaluation of the effect of nano-organosilane anti-stripping additive on the moisture susceptibility of HMA mixtures under freeze–thaw cycles". Construction and Building Materials 48 (2013) 1009–1016 . July,2013.

[10] Mahmoud Nazirizad, Amir Kavussi (2015), "Evaluation of the effects of anti-stripping agents on the performance of asphalt mixtures". Construction and Building Materials 84 (2015) 348–353.

[11] Shazi, Prof. D. S. Ray (2018), "Study and Evaluation of Disintegration of Pavement Surface". IJSRD Vol. 6, Issue 03, 2018.

[12] Yong-Rak Kim, Ingryd Pinto(2011), "Experimental evaluation of anti-stripping additives in bituminous mixtures through multiple scale laboratory test results". Construction and Building Materials 29 (2012) 386–393. Oct,2011.

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

Optimization of Different Anti Stripping Agents in Construction of Flexible Pavement

Purnima Tripathi[1], D. S. Ray[2]
[1]M. tech Scholar, Department of Civil Engineering, BBDU, Lucknow, India.
[2] Prof. and Head of Department of Civil Engineering, BBDNITM, Lucknow, India.

***Abstract*:- The aim of this research project is to improve current practice by investigating different test methods to quantify moisture damage to serve the short- and long-term needs of the agency and industry. This research deals with important concepts of stripping as, bitumen chemistry and rheology, aggregate properties (chemical and mineralogical composition, surface texture, morphology, porosity, etc.), traffic, water properties, construction practices (mixing, placement and in-service drainage) and nature of antistripping additives.**

This paper presents the effect of anti-stripping additives in bituminous mixes. As per researches series of laboratory tests have been conducted with varying percentage of these Anti-stripping additives, added Individually and in Combinations, to determine their optimum percentages. This report presents the results of experimental investigations carried out to study the effect of Wetbond-S, Zycotherm and Bitugrip on bitumen and aggregate. Boiling water test and Stripping value test were conducted as screening tests performed on Wetbond-S, Bitugrip and Zycotherm modified bitumen. The current research shows the optimization of different anti- stripping additives to evaluate moisture susceptibilities of bituminous mixes. This paper deals with the review of some previous studies that are done to improve the adhesion between bitumen and aggregate. The stripping value decreases while increasing the percentage of anti- stripping additives to the bitumen. The results indicated that the addition of anti-stripping agents increase moisture resistance of asphalt mixes to some extent. Moreover, it was concluded that mix samples prepared using anti-stripping additive imparted more correlation and greater resistance to water damage.

Keywords*: *Bitumen, Aggregate, Adhesion, Stripping, Wetbond-S, Zycotherm, Bitugrip, Boiling water test, Stripping value test.

1. INTRODUCTION

Road sectors are the engines of growth for economy, employment and empowerment. Owing to increases in household income, the demands for personalized vehicles have also increased. In India 95% of roads are bituminous roads which consists approximately 93-95% of aggregate and 5-7% of binder material. Until now conventional bituminous binders were performing satisfactory results but with increase in traffic intensity there is a need of better binder material which can perform better under heavy traffic loads without compromising the performance of bituminous mix. Many mileages of roadway worldwide have been replaced prematurely, due to moisture-induced damage in form of stripping. During Rainy season the natural bitumen become failure and possess serious problem. Due to the movement of vehicular traffic, treatment and strengthening of bitumen appear to be the only solution for keeping the pavement of surfaces serviceable. Loss of adhesion also renders cohesive resistance of the interstitial bitumen useless.

In recent years, stripping has been a serious problem in asphalt paving mixture. The loss of bond between aggregates and asphalt binder that generally begins at the bottom of the HMA layer and progresses upward is understood to be stripping of pavement. It causes functional weakening of pavements leading to costly repairs. It can also cause the premature pavement failures like rutting and raveling on the pavement surface. The most common technique to mitigate moisture damage is the use of additives or modifiers with the asphalt binder or the aggregate. To alleviate or to regulate the deformations due to water damage, various researches were performed resulting in the use of anti-stripping additives. Anti-stripping additives are used to increase physio-chemical bond between the bitumen and aggregate and to improve wetting by lowering the surface tension of the bitumen. Numerous studies indicate that anti-stripping additives can positively affect the binder–aggregate bonding characteristics and overall mixture performance by reducing mixtures moisture susceptibility. In India, method of determination of stripping value of road aggregates (IS:6241-1971) is the standard describing the stripping test for the coarse aggregates. The research is done by adding the anti- stripping agents to the bitumen the stripping value test is performed to describe the property of the anti-stripping agents on the bitumen.

1.1 ADHESION

One of the fundamental properties for good performances of bituminous pavement is proper adhesion between aggregate and bitumen. The adhesion between mineral aggregates and bitumen is an important criterion which describes the quality of asphalt mixture, asphalt performance and resistance to distress. The lack of bonding can lead to significant asphalt pavement damage. For the evaluation of the adhesion behavior between bitumen and aggregates, used in road construction, many tests have been practiced. The adhesion is influenced by the characteristics of both the bitumen and the aggregate used in the mixture. Adhesion can be generally

Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

defined as the molecular force of attraction between two bodies of different nature in contact with each other.

1.2 *STRIPPING*

The use of bitumen is reflected in many applications and dates to ancient times. In bituminous mixes, bitumen holds the aggregates forming a mass that supports high stresses. It is crucial that strong and durable interfacial bonds exist under all conditions. Depending on how bitumen interacts with aggregate, stripping may affect this desirable precept. Stripping is the breaking of the adhesion bond between the aggregates and the bituminous binder. In one way or the other water gets in between the binder film and the aggregate surface and because the aggregate surface has higher attraction for water than for bituminous binder then adhesive bond is broken. It is one of the most commonly occurring distresses in asphalt pavements. Surface moisture content is most desirable factor for stripping analysis as most of the bond loss between aggregate and binder starts from pavement surface due to the moisture content from atmosphere and other outer sources.

Fig 1: Cracking caused by stripping at the bottom of HMA layer

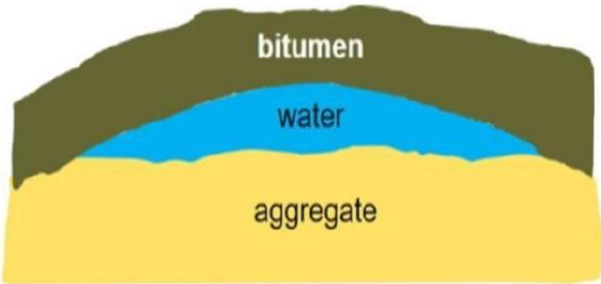

Fig 2: Adhesion failure at the Aggregate-Bitumen interface

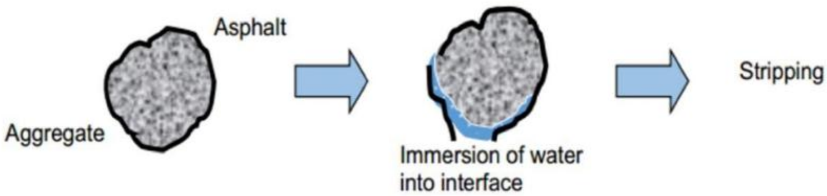

Fig 3: Conceptual diagram of stripping mechanism

2. LITERATURE REVIEW

The following literature review describes important research results regarding use of Wetbond-S, Zycotherm and Bitugrip in bituminous mix in construction of flexible pavement:

Mahmoud Ameri, Sareh Kouchaki (2013)[6] The objective of this research study was to evaluate moisture susceptibility of hot mix asphalt (HMA) with and without Zycosoil as a nano-organosilane anti-stripping additive and hydrated lime in the form of slurry. It was also observed that the effects of anti-stripping additives on specimens made by siliceous aggregate are more pronounced than those prepared with limestone aggregates. The use of Zycosoil additive will increase adhesion bond between the aggregates and asphalt binders, and in turn influences the moisture resistance of the mixture to moisture damage.

Dae-Wook Park, Woo-Jin Seo (2017)[1] This paper studied that Evaluation of moisture susceptibility of asphalt mixture using liquid anti-stripping agents. The purposes of this study are to comprehensively evaluate the moisture susceptibility of asphalt mixtures modified with several anti-stripping

Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

additives based on laboratory tests. Boiling water test was conducted as a screening test. The addition of anti-stripping agents significantly improves asphalt mixture stripping resistance before and after stripping occurs, and rutting resistance.

Harpreet Singh, Tanuj Chopra (2017)[4] In this study, Zycotherm additive is added to neat bitumen and various comparisons were made using conventional test and rheological test on bitumen. Zycotherm gives better chemical bonding for extended moisture resistance and it ensures about 100% coating of bitumen at low temperature.

Hamed Omrani, Ali Reza Ghanizadeh (2017)[3] The primary objective of this study is exploring the moisture susceptibility of unmodified and SBS-modified hot and warm mix asphalt mixtures. Two different WMA additives including Aspha-min and Sasobit were employed to fabricate WMA specimens. The moisture susceptibility of warm polymer modified asphalt (WPMA) mixes was evaluated. In addition, the effect of different percentages of hydrated lime (from 0% to 2%) and Zycosoil (from 0% to 0.1%) as anti-stripping additives on the moisture susceptibility of the mixtures was explored. The test results showed that increasing moisture content decreases moisture damage resistance. Addition of hydrated lime improves moisture susceptibility. The results also showed that moisture sensitivity was affected significantly by the source of used aggregate.

H. Khani Sanij, P. Afkhamy Meybodi (2018)[2] The primary goal of these efforts is to improve the durability and load-bearing performance of asphalt mixtures. In this study, glass particles were used, as aggregates in warm mix asphalt (WMA) mixtures. The objective of this study was to consequences the utilization of Zycotherm TM as an anti-stripping agent have on the mechanical properties and moisture susceptibility of glass-asphalt. Four different amounts of Zycotherm TM were used in WMA mixtures to serve as bitumen modifier and anti-stripping agent. In this study, glass particles were used, as aggregates in warm mix asphalt (WMA) mixtures. Four different amounts of Zycotherm-TM were utilized in WMA mixtures to serve as bitumen modifier and anti-stripping agent.

Kunalkumar Vaghela, Asso. Prof. V.J. Chitaria (2018)[5] This study investigates the effects of anti-stripping agent on the microscopic strength of the mineral aggregate contact surface of mixture. The study compared the moisture susceptibility of three variations of bituminous concrete grade 1 mix: (i) Mix without anti-stripping additive (2) Mix with hydrated lime as an anti-stripping additive and (3) Mix with Zycosoil as an anti-stripping additive. The current study resulted in improved bituminous mixtures with the utilization of antistripping additives, especially in the moisture resistance property of the mixture.

Shazi, Prof. D. S. Ray (2018)[7] This paper aims at the study of potholes on the bituminous road surface and introducing the antistripping material to the bitumen to increase the durability of the road. In this paper, the antistripping material 'Bitugrip' is used to improve the adhesion properties of bitumen and aggregates. The stripping value decreases while increasing the percentage of Bitugrip to the bitumen. Overall, the addition of Bitugrip has a positive influence on the adhesion properties between the aggregates and the bitumen and can be used to increase the durability of roads, thereby reduce the maintenance cost of the roads.

3.MATERIALS

To construct a flexible pavement, basically Bitumen and Aggregates are used. Here 3 anti stripping agents i.e. Wetbond-S, Zycotherm and Bitugrip are used to reduce mitigate the problem like stripping, rutting, raveling, potholes, cracking etc and also to reduce maintenance cost and increase service life of pavement. The details of these materials used in this research are mention below*:*

3.1 BITUMEN*:* Bitumen is hydrocarbon material, found in gaseous, liquid, semisolid or solid form and is completely soluble in Carbon di-sulphide and in Carbon tetra chloride. It contains 87% carbon, 11% hydrogen and 2% oxygen. Bitumen is a complex organic material and occurs either naturally or may be obtained artificially during the distillation of petroleum. Bituminous materials are very commonly used in highway construction because of their binding and water proofing properties. In this study, VG-30 bitumen grade is used as a base binder.

Table 1: Conventional Properties of Bitumen

S. No.	TESTS OF BITUMEN	BITUMEN USED
1.	PENETRATION TEST (mm)	56
2.	SOFTENING POINT TEST (°C)	50
3.	DUCTILITY TEST (cm)	60

3.2 AGGREGATES: Aggregates forms the major portion of pavement structure and they form the prime materials used in pavement construction. Aggregates have to bear stresses occurring due to wheel loads on the pavement and on the surface course they also have to resist wear due to abrasive action of traffic.

Aggregates are inert granular materials like sand, gravel or crushed stone. Gravel aggregates are small rounded stones of different sizes. Aggregates were used local granite rocks of such particle size obtained from KABARAI quarry situated in MAHOBA that are 100% passed from a 20 mm sieve and were retained on a 13.2 mm sieve. The aggregate was washed in distilled water to get rid of all fines dried at 105-110°C to constant weight and stored in airtight containers until required to be used. Crushed granite aggregates obtained from nearby quarry was used for the study and they were sufficiently strong, hard, tough, and well-shaped.

3.3 ZYCOTHERM: Zycotherm additive is an odourless nano-organosilane additive used for bituminous mixes. Zycotherm gives better chemical bonding for extended moisture resistance and it ensures about 100% coating of bitumen at low temperature. In addition, this additive can reduce the production and compaction temperature of asphalt mixtures.

Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

Table 2: Properties of Zycotherm

Properties	Results
Specific gravity	0.97 gm/cm3
Viscosity	1-5 Pas
Flash point	>80°C
Colour	Pale yellow
Physical state	Liquid
Solubility in water	Soluble in water

Fig 4 : Zycotherm

3.4 BITUGRIP: Bitugrip is the product of HINCOL (Hindustan Colas Private Limited). Hincol bitugrip is an Amine based anti-stripping agent that changes interfacial surface tension between bitumen and aggregate, strengthening the bond for long run durability.

Table 3: Properties of Bitugrip

Properties	Results
Density	1.04 gm/cm3
Consistency	High viscosity
Drying Time@25°C	24 hours
Toxicity	Dry film non-toxic

Fig 5: Bitugrip

Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

3.5 WETBOND-S: "Wetbond-S" is next generation Nano-technology Silicon based ASA for Asphalt. This product is a low dose and extremely thermal resistive additive for use in Hot-mix and Warm-mix road constructions. This product is especially suitable for aggregates having very high and difficult to manage stripping profile. This product is suitable for production of Refinery-treated non-stripping bitumen, Hot-mix pavement constructions, Warm-mix constructions and for industrial bituminous coatings.

Table 4: Properties of Wetbond-S

Properties	Results
Specific Gravity	0.86-0.95
Amine Value	>200
Active Nitrogen	>7
Water Content	<1%
Active content	100%
Shelf Life	4 Years from the date of production in sealed containers.
Colour	Brownish clear liquid.
Compatibility	All grades of Road and Industrial Bitumen's.

Fig 6: Wetbond-S

Advantages of Antistripping Agents:

- Enhance the service life of the pavement
- Excellent adhesion promoter onto all type of aggregates
- Slow down age hardening of bitumen
- Low dosage required
- Stable at high process temperature of hot mix temperature.

4. EXPERIMENTAL INVESTIGATION

In the first, Boiling water test and stripping value test were done without adding any ASA and calculate the stripping value. After that these three ASA were used with various percentages like **Wetbond-S** in **0.05, 0.07, 0.10 & 0.15%**, **Zycotherm** in **0.05**, **0.075**, **0.10** & **0.15%** and **Bitugrip** in **0.5, 0.75, 1.0 & 1.5%** by wt. of bitumen to check the optimum dosages of all these ASA. As **Wetbond-S** showed min stripping at **0.10%**, **Zycotherm** at **0.075%** and **Bitugrip** at **1.0%**. After getting optimum dosage, combination was made to obtain minimum value of stripping.

Table 5: Optimum Values of ASA in Boiling Water Test (adding individually)

S. No.	Name of Anti- Stripping Agent	Optimum Quantity of Anti-Stripping Agent (%)	Stripping Value (%)
1.	No ASA	0	10
2.	Wetbond-S	0.10	1.43
3.	Zycotherm	0.075	1.44
4.	Bitugrip	1.0	1.95

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

Case 1: Boiling water test is performed without adding any ASA in bituminous mix-

Fig 7: Stripping without adding any ASA in Boiling Water Test

Case 2: When 0.10% Wetbond-S is added in the mix in boiling water test

Fig 8: Stripping after adding 0.10% Wetbond-S(Optimum) in Boiling Water Test

Case 3: When 0.075%Zycotherm is added in mix in boiling water test

Fig 9: Stripping after adding 0.075% Zycotherm (Optimum) in Boiling Water Test

Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

Case 4: When 1% Bitugrip is added in mix in boiling water test

Fig 10: Stripping after adding 1.0% Bitugrip (Optimum) in Boiling Water Test

Table 6: Optimum Values of ASA in Stripping Value Test (adding individually)

S. No.	Name of Anti- Stripping Agent	Optimum Quantity of Anti-Stripping Agent (%)	Stripping Value (%)
1.	No ASA	0	8.1
2.	Wetbond-S	0.10	1.43
3.	Zycotherm	0.075	0.94
4.	Bitugrip	1.0	1.95

Case 5. Stripping Value Test performed without adding any ASA-

Fig 11: Stripping without adding any ASA in Stripping Value Test

Case 6: When 0.10% Wetbond-S added to the mix in stripping value test-

Fig 12: Stripping after adding 0.10% Wetbond-S(Optimum) in Stripping Value Test

Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

Case 7: when 0.075% Zycotherm is added to mix in stripping value test-

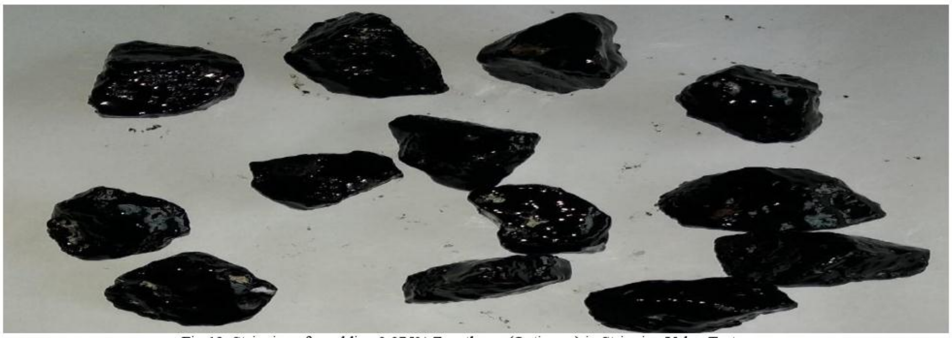

Fig 13: Stripping after adding 0.075% Zycotherm (Optimum) in Stripping Value Test

Case 8: When 1% Bitugrip added in mix in stripping value test

Fig 14: Stripping after adding 1.0% Bitugrip (Optimum) in Stripping Value Test

- As Wetbond-S & Zycotherm had given better result compared to Bitugrip so here Bitugrip was neglected.

Table 7: Combinations of ASA with optimum values in Boiling Water Test

S.No.	Combination of ASA	Stripping Value
1.	Wetbond-S + Zycotherm	1.40
2.	Wetbond-S + Bitugrip	1.42
3.	Wetbond-S + Zycotherm + Bitugrip	1.40

Case 9: When Wetbond-S+Zycotherm is added in mix in boiling water test

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

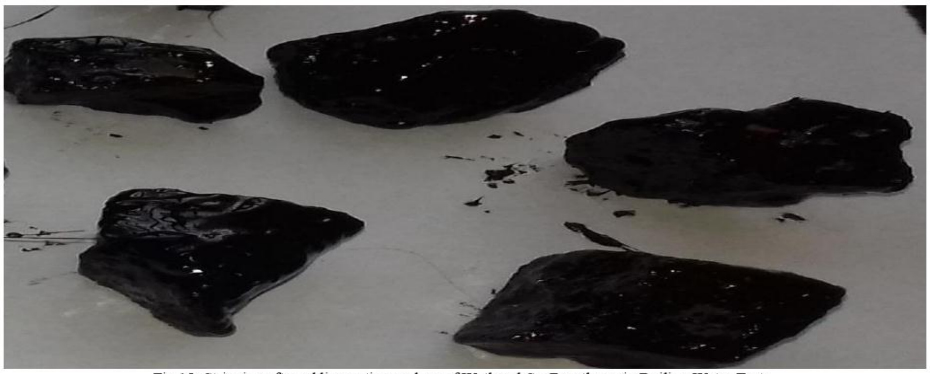

Fig 15: Stripping after adding optimum dose of Wetbond-S+ Zycotherm in Boiling Water Test

Table 8: Combinations of ASA with optimum values in Stripping Value Test

S.No.	Combination of ASA	Stripping Value
1.	Wetbond-S+Zycotherm	1.38
2.	Wetbond-S+Bitugrip	1.41
3.	Wetbond-S+Zycotherm+Bitugrip	1.375

Case 10: When Wetbond-S+Zycotherm is added in bituminous mix in stripping value test

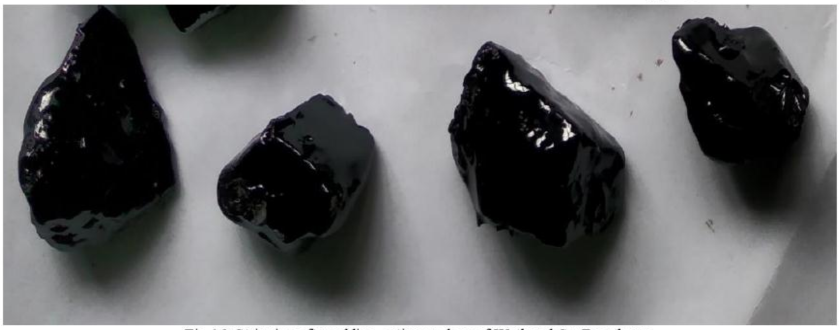

Fig 16: Stripping after adding optimum dose of Wetbond-S+ Zycotherm in Stripping Value Test

5. RESULT ANALYSIS AND DISCUSSION

Table 9: ANALYSIS OF MAINTENANCE COST IN CASE OF BOILING WATER TEST

S. No.	Name of ASA	ASA addition Optimum (%)	Stripping Value (%)	Damaged Area (sq. m.)	Pavement Thickness (40mm)	Damaged Quantity (cum)	Rate of BC per cum	Amount of maintenance (Rs.)	Quantity of Bitumen @ 5.4% wt. of mix	Quantity of ASA (Kg)	Rate of ASA Rs. Per kg	Cost of ASA (Rs.)	Maintenance Cost (Rs.)
1	No Agent	0	10	700	0.04	28.00	9965	279020	3.56	0	0	0	279020
2	Wetbond -S	0.1	1.43	100.1	0.04	4.00	9965	39899.86	0.51	50.94	765	38969.82	39899.86
3	Zycotherm	0.075	1.44	100.8	0.04	4.03	9965	40178.88	0.51	38.47	1350	51938.39	40178.88

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

4	Bitugrip	1	1.95	136.5	0.04	5.46	9965	54408.9	0.69	694.65	155	107670.63	54408.9
5	Wetbond+ Zycotherm	0.10+ 0.075	1.4	98	0.04	3.92	9965	39062.8	0.50	89.41	2115	90908.21	39062.8
6	Wetbond-S +Bitugrip	0.1+1	1.42	99.4	0.04	3.98	9965	39620.84	0.51	745.59	920	146640.45	39620.84
7	Wetbond-S +Zycotherm + Bitugrip	0.10+ 0.075+1	1.4	98	0.04	3.92	9965	39062.8	0.50	784.06	2270	198578.84	39062.8

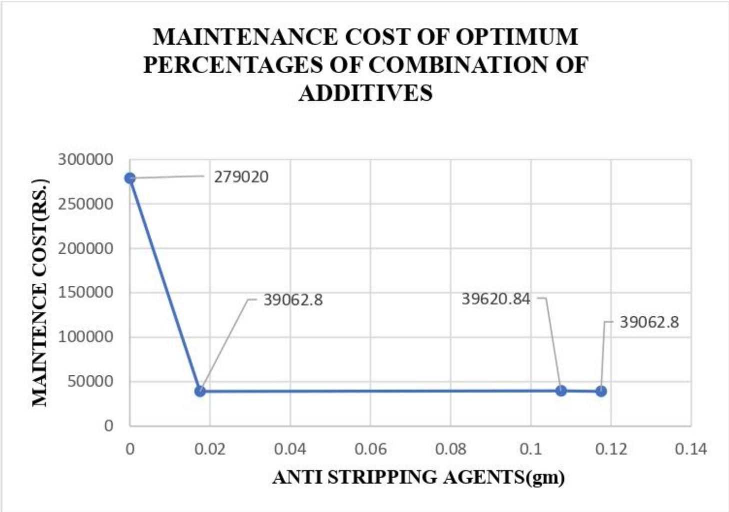

Fig 17: Maintenance Cost v/s Optimum Dose of ASA% adding in combination in Boiling Water Test

Table 10: ANALYSIS OF MAINTENANCE COST IN CASE OF STRIPPING VALUE TEST

S.No.	Name of ASA	ASA addition Optimum (%)	Stripping Value(%)	Damaged Area (sq.m.)	Pavement Thickness (40mm)	Damaged Quantity (cum)	Rate of BC per cum	Amount of maintenance (Rs.)	Quantity of Bitumen @ 5.4% wt. of mix	Quantity of ASA (Kg)	Rate of ASA Rs. Per kg	Cost of ASA (Rs.)	Maintenance Cost (Rs.)
1	No Agent	0	8.1	567	0.04	22.68	9965	226006.2	2.89	0	0	0	226006.2
2	Wetbond-S	0.1	1.43	100.1	0.04	4.00	9965	39899.86	0.51	50.94	765	38969.82	39899.86
3	Zycotherm	0.075	0.96	67.2	0.04	2.69	9965	26785.92	0.34	25.65	1350	34625.59	26785.92
4	Bitugrip	1	1.95	136.5	0.04	5.46	9965	54408.9	0.69	694.65	155	107670.63	54408.9
5	Wetbond+ Zycotherm	0.10+ 0.075	1.42	99.4	0.04	3.98	9965	39620.84	0.51	76.59	2115	73595.41	39620.84

Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

6	Zycotherm+ Bitugrip	0.075	1.44	100.8	0.04	4.03	9965	40178.88	0.51	702.30	1505	142296.22	40178.88
7	Wetbond-S +Bitugrip	0.075+1	1.41	98.7	0.04	3.95	9965	39341.82	0.50	745.59	920	146640.45	39341.82
8	Wetbond-S +Zycotherm+ Bitugrip	0.10+ 0.075+1	1.375	96.25	0.04	3.85	9965	38365.25	0.49	771.24	2270	181266.04	38365.25

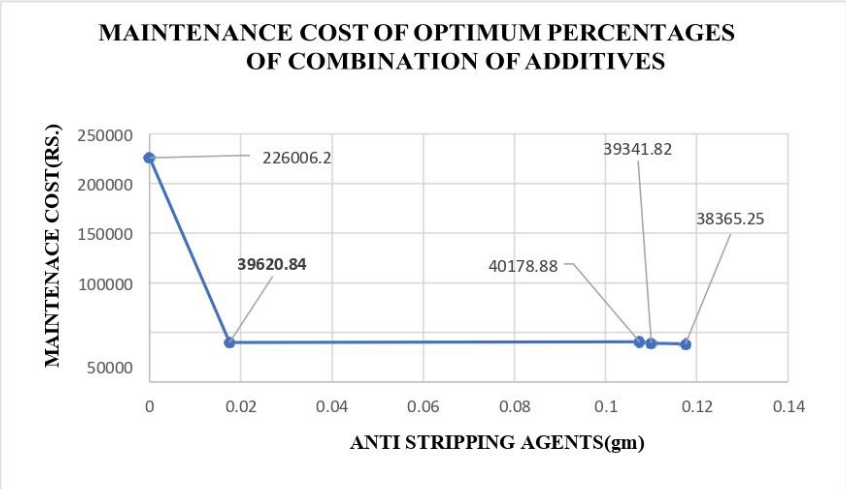

Fig 18: Maintenance Cost v/s Optimum Dose of ASA% adding in combination in Stripping Value Test

6. CONCLUSION

Following conclusions are derived based on laboratory investigations keeping in mind all aspect procedures of codal practice:

- ASAs (Wetbond-S, Zycotherm & Bitugrip) are chemical admixtures containing active functional groups that improves the adhesion of the bitumen film on the surface of aggregate.
- It has been observed that after addition of ASAs (Wetbond-S, Zycotherm & Bitugrip), the stripping of Bituminous Mixes reduced.
- Wetbond-S is the most effective in decreasing the stripping value of mixes in case of Boiling Water Test while in same way, Zycotherm is the most effective in case of Stripping Value test.
- After analyzing all the data that is collected or generated, it is found that is (Wetbond-S+ Zycotherm) is the best combination of ASAs for anti-stripping and most economical as compared to individual ASAs used.
- After adding combination of Wetbond-S & Zycotherm to bituminous mix, max. saving in Boiling Water Test and Stripping Value Test is 86% & 82.5% resp. considering all aspect. Thus, Due to the saving in maintenance cost, less quantity of material will be applicable so that, huge amount of money can be saved.
- As these additives are Silane based additives, minimize the moisture damage as a coating of bitumen is formed around the aggregate.
- When ASAs are mixed with the bituminous binder, lower the surface tension of the bitumen.
- As the ASAs are of low cost, therefore, it is expected to reduce the life cycle cost of the bituminous pavements.
- Using ASAs, durability of road increases as proved in the study.

7. FUTURE SCOPE

Based on present work and findings, it is felt that further work should be pursued in the following area:

- The evaluation methods consider mainly moisture sensitivity as the main factor due to which stripping occurs.
- Damage may occur in base course. Evaluation should be carried out considering base course damage.
- Further investigation should be carried out different grades of bitumen.
- No mechanism has been developed yet to determine stripping value, observations are done visually.

Published by : http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

- In laboratory, distilled water is used in experimentation which is neutral with pH 7, but there is a large variation in pH value of water in the field.

REFERENCES

[1] Dae-Wook Park, Woo-Jin Seo(2017), *"Evaluation of moisture susceptibility of asphalt mixture using liquid anti-stripping agents"*. Construction and Building Materials 144 (2017) 399–405. Mar, 2017.

[2] H. Khani Sanij, P. Afkhamy Meybodi (2018), *"Evaluation of performance and moisture sensitivity of glass-containing warm mix asphalt modified with zycotherm TM as an anti-stripping additive"*. Construction and Building Materials 197 (2019) 185–194. Nov,2018.

[3] Hamed Omrani, Ali Reza Ghanizadeh (2017), *"Effect of SBS Polymer and Anti- Stripping Agents on the Moisture Susceptibility of Hot and Warm Mix Asphalt Mixtures"* Civil Engineering Journal Vol. 3, No. 10, October, 2017.

[4] Harpreet Singh, Tanuj Chopra (2017), *"Effect of Zycotherm Performance Of Neat Bitumen And Bituminous Concrete mixes"*. IJCIET, Volume 8, Issue 8, August 2017

[5] Kunal kumar Vaghela, Asso. Prof. V.J. Chitaria (2018), *"Evaluation of Organosilane Based Asphalt Additive for Flexible Pavement"*. (IRJET) Volume: 05 Issue: 02 | Feb- 2018.

[6] Mahmoud Ameri, Sareh Kouchaki(2013) *"Laboratory evaluation of the effect of nano-organosilane anti-stripping additive on the moisture susceptibility of HMA mixtures under freeze–thaw cycles"*. Construction and Building Materials 48 (2013) 1009–1016. July,2013.

[7] Shazi, Prof. D. S. Ray (2018), *"Study and Evaluation of Disintegration of Pavement Surface"*. IJSRD Vol. 6, Issue 03, 2018.

[8] IS:1203. (1978). Methods for testing tar and bituminous materials; determination of penetration. Bureau of Indian Standards, India.

[9] IS:1205. (1978). Methods for testing tar and bituminous materials; determination of softening point. Bureau of Indian Standards, India.

[10] IS:1208. (1978). Methods for testing tar and bituminous materials; determination of ductility. Bureau of Indian Standards, India.

[11] IS:6241. (1971). Determination of stripping value of aggregates. Bureau of Indian Standards, India.

[12] Maupin, G.W. (2004), *"Quantitative Determination of Asphalt Antistripping Additive,"* Final Report VTRC 05-R3, Virginia Transportation Research Council, Charlottesville, VA.

BBDU-PG- FORM 01

BABU BANARASI DAS UNIVERSITY, LUCKNOW

CERTIFICATION OF FINAL THESIS SUBMISSION

(To be submitted in Duplicate**)**

1. Name:……………………………………………………………..........................……...
2. Enrollment No. ………………………………………………………......……………
3. Thesis title:…………………………………………………...……………………...

……………………………………………………………………….…………………………

………………………………………………………………………………………….

4. Degree for which the thesis is submitted: ……………………...………………………
5. Faculty of the university to which the thesis is submitted: …………………………….

…………………………………………………………………………………………….

6. Thesis Preparation Guide was referred to for preparing the thesis. [ ]YES [ ]NO
7. Specification regarding thesis format have been closely followed. [ ]YES [ ]NO
8. The contents of thesis have been organized based on the guideline. [ ]YES [ ]NO
9. The thesis has been prepared without resorting to plagiarism. [ ]YES [ ]NO
10. All sources used have been cited appropriately. [ ]YES [ ]NO
11. The thesis has not been submitted elsewhere for a degree. [ ]YES [ ]NO
12. All the corrections have been incorporated [ ]YES [ ]NO
13. Submitted 3 hard bound copies plus one CD. [ ]YES [ ]NO

(Signature of the Candidate)

Name: ………………………………..

Roll No.: ……………………………..

Enrollment No.: ……………………...

BBDU-PG- FORM 02

BABU BANARASI DAS UNIVERSITY, LUCKNOW

CERTIFICATION OF FINAL THESIS SUBMISSION

(To be submitted in Duplicate**)**

1. Name:…………………………………………………………..........................……..
2. Enrollment No. ……………………………………………………......……………
3. Thesis title:……………………………………………………...……………………...
………………………………………………………………………….…………………………
……………………………………………………………………………………….
4. Degree for which the thesis is submitted: ……………………...………………………
5. Faculty of the university to which the thesis is submitted: …………………………….
…………………………………………………………………………………………….
6. Thesis Preparation Guide was referred to for preparing the thesis. [ ]YES [ ]NO
7. Specification regarding thesis format have been closely followed. [ ]YES [ ]NO
8. The contents of thesis have been organized based on the guideline. [ ]YES [ ]NO
9. The thesis has been prepared without resorting to plagiarism. [ ]YES [ ]NO
10. All sources used have been cited appropriately. [ ]YES [ ]NO
11. The thesis has not been submitted elsewhere for a degree. [ ]YES [ ]NO
12. All the corrections have been incorporated [ ]YES [ ]NO
13. Submitted 3 hard bound copies plus one CD. [ ]YES [ ]NO

(Signature of Supervisor)
Name: …………………………….

(Signature of the Candidate)
Name: ………………………………..
Roll No.: ……………………………..
Enrollment No.: ……………………