# Performance of Bituminous Mix Blended with Waste Plastic and Sodium Lignosulphonate

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***Abstract*- Flexible pavements with bituminous are widely used in India. Flexible pavements are often subjected to earlier development of failure due to high traffic intensity, over loading of trucks, significant variations in daily and seasonal temperature. The use of the innovative technology not only strengthen the road construction but also increase the road life as well as will help to improve the environment. In this project, study on the methodology of using plastic waste and Sodium lignosulphonate in bituminous mix. Different percentages of bitumen, plastic and Sodium lignosulphonate have been taken in each sample of bituminous mix and conducted various tests. The present study has been suggested the optimum percentage of bitumen that can be replaced by 19% of plastic waste and 10% of Sodium lignosulphonate gives the reduction of cost of construction, makes flexible pavements eco-friendly and increases the life time of the pavements**

**Index Terms- Flexible pavements, bituminous, plastic waste, Sodium lignosulphonate, Eco-friendly.**

## I. INTRODUCTION

The soil whose CBR value is greater than 4 is more suitable for flexible pavements. In India, the soil is more suitable for flexible pavements. Mostly flexible pavements are constructed with bitumen. Bitumen is petroleum product obtained from fractional distillation of crude oil. The roads that are constructed with bitumen gets deteriorated upon the application of heavy traffic loads. The increase in population resulted in increase in number of vehicles on road. Thus, the lifetime bituminous roads have been reducing. To increase the lifetime of these roads bitumen is partially replaced with some waste materials.

Plastic is everywhere in today's lifestyle. It is used for packaging, protecting, serving, and even disposing of all kinds of consumer goods. With the industrial revolution, mass production of goods started, and plastic seemed to be a cheaper and effective raw material. Today, every vital sector of the economy starting from agriculture to packaging, automobile, building construction, communication or InfoTech has been virtually revolutionized by the applications of plastics. Use of this non-biodegradable (according to recent studies, plastics can stay unchanged for as long as 4500 years on earth) product is growing rapidly and the problem is what to do with plastic-waste. Studies have linked the improper disposal of plastic to problems as distant as breast cancer, reproductive problems in humans and animals, genital abnormalities and even a decline in human sperm count and quality. If a ban is put on the use of plastics on emotional grounds, the real cost would be much higher, the inconvenience much more, the chances of damage or contamination much greater. The risks to the family health and safety would increase and, above all the environmental burden would be manifold. Hence, the question is not 'plastics Vs no plastics' but it is more concerned with the judicious use and re-use of plastic-waste.

Sodium lignosulphonate is a complex organic polymer that forms important structural materials in the support tissues of vascular plants. It is more important in the formation of cell walls, especially in wood and bark, because they lend rigidity and do not rot easily. It constitutes 30% of non-fossil natural carbon and 20 to 35% of the dry mass of wood. The soil humus, which is obtained, holds the nutrients on to it surface and hence increases the cation exchange capacity and moisture retention they are by increases the productivity of soil. Its composition varies from species to species. The composition from an aspen sample is 63.4% carbon, 5.9% hydrogen, 0.7% ash and 30% oxygen.

The paper depicts the methodology of using plastic waste and Sodium lignosulphonate, as substitution or fractional substitution of bitumen without losing its usefulness. In this study, Different percentages of bitumen, plastic and Sodium lignosulphonate have been taken in each sample of bituminous mix and conducted various tests to suggest optimum percentage to reduce cost of construction and to increase lifetime of the pavement.

## II. OBJECTIVE OF THE PROJECT

Basic intention is to efficiently utilize the waste plastic and Sodium lignosulphonate in constructive way so that it can be beneficial to society.

The following are main objectives of the present study,

- To identify the optimum proportion of waste plastic and Sodium lignosulphonate to be added in the bituminous mix for getting the required strength
- To compare the experimented results with the conventional pavement details and perform the economic analysis
- To prepare statistical model for optimum utilization of plastic waste and Sodium lignosulphonate
- To utilize waste plastic and Sodium lignosulphonate in bituminous mixes
- To make eco-friendly flexible pavements with high strength
- To increase the lifetime of the pavements

## III. SCOPE OF THE PRESENT STUDY

This study will be conducted to explore the idea about use of waste material in bituminous concrete with detailed laboratory Investigation will be carry out to find whether it is viable to use or not in terms of suitability, economically and environmentally. The present study will focus basically are as follows

- To study the basic physical and mechanical properties of waste plastic and Sodium lignosulphonate in order to contribute a better knowledge of its properties.
- To study the effect on Marshall Stability of bituminous mix with the addition of waste plastic and Sodium lignosulphonate.
- To reduce the bitumen content by the addition of Waste plastic and Sodium lignosulphonate in bituminous mix.

The laboratory investigations on the bituminous mix have been carried out as per the Indian Standards used for the road construction.

## IV. MATERIALS

The materials used in this study are as follows

### *A. Bitumen*

Bitumen acts as a binding agent to the aggregates, fines and stabilizers in bituminous mixtures. The material obtained from the fractional distillation of crude oil is referred as refined bitumen. Bitumen must be treated as a visco-elastic material as it exhibits both viscous as well as elastic properties at the normal pavement temperature. At low temperature, it behaves like an elastic material and at high temperatures; its behavior is like a viscous fluid. Grade of bitumen[2]& [3] used in the pavements should be selected based on climatic conditions and their performance in past. It fills the voids, cause particle adhesion and offers impermeability. In this study, to determine properties of bitumen various tests[6] are conducted and VG30 grade considered as per IS 73:2013.

Figure 1: Bitumen sample

### *B. Aggregate*

There are various types of mineral aggregates used to manufacture bituminous mixes can be obtained from different natural sources such as glacial deposits or mines and can be used with or without further processing. The aggregates can be further processed and finished to achieve good performance characteristics. Industrial by-products such as steel slag, blast furnace slag, fly ash etc. sometimes used by replacing natural aggregates to enhance the

performance characteristics of the mix. Aggregate contributes up to 90-95 % of the mixture weight and contributes to most of the load bearing & strength characteristics of the mixture. Hence, the quality and physical properties of the aggregates should be controlled to ensure a good pavement

Figure 2: Aggregates

Various tests[1] are conducted on aggregate; the following are the properties of aggregates

Table 1: Properties of aggregates

| S .No | Experiment | Standard Values | Obtained Values |
|---|---|---|---|
| 1 | Crushing value | <30% | 13.08% |
| 2 | Impact value | <30% | 12.57% |
| 3 | Specific gravity | 2.6 to 2.9 | 2.74 |
| 4 | Los angle absorption | 40% | 17.6% |
| 5 | Elongation test | - | 73.08% |
| 6 | Flakiness index | - | 25.07% |

*C. Plastic*

Plastics[10] are natural substances shaped by macro cells called polymers. These polymers are extensive gatherings of monomers connected by a compound procedure called polymerization. Plastics give the fundamental adjust of properties that cannot be accomplished with different materials, for example, shading, lightweight, delicate touch and imperviousness to ecological and natural debasement. In this project, HDPE (High Density Poly Ethylene) of 50 micron as replacement material used.

Figure 3: High Density Poly Ethylene

*D. Sodium lignosulphonate*

Lignosulphonates are by-products from the sulphite pulping process for the manufacture of specialty dissolving pulps and paper. During the liberation of the cellulose, the lignin is fractionated and solubilized through covalent addition of sulphonic acid groups at various positions in the structure. The formed sulphonated lignin, lignosulphonate is then further isolated and refined. Sodium lignosulphonate is yellow brown powder completely water soluble and it is naturally anionic surfactant of high molecular polymer, rich in sulfo and carboxyl group and has better water-solubility, surf-activity and dispersion capacity. It could be used for construction, ceramics, mineral powder, chemical industry, textile industry (leather), metallurgical industry, petroleum industry, fire-retardant materials, rubber vulcanization, organic polymerization ,also could used as animal feed additives due to its antimicrobial and preservative properties.

Figure 4: Sodium lignosulphonate sample

## V. METHODOLOGY

The research methodology for present study has adopted various tests to investigate the results on aggregate, bitumen, plastic, Sodium lignosulphonate & aggregate-bitumen-plastic-Sodium lignosulphonate mix. Plastic and Sodium lignosulphonate are added in different percentages to get optimum percentage value of bitumen. The results are obtained for different percentages of plastic & Sodium lignosulphonate by weight of bitumen indicated in graphs. The behavior of specimens for different percentage of plastic & Sodium lignosulphonate are shown in graphs.

## VI. EXPERIMENTAL INVESTIGATION

Several tests are conducted on aggregate, bitumen, plastic, Sodium lignosulphonate to determine properties. Marshall Stability Test conducted for different combinations of aggregate, bitumen, plastic, Sodium lignosulphonate at various percentages. The following are various tests

### *A. Bitumen*[5]& [6]

There are many tests to assess the properties of bituminous materials. The following tests are conducted in the present study to evaluate different properties of bituminous materials

1. Penetration test
2. Ductility test
3. Softening point test
4. Flash and fire point test

### *B. Aggregate*[7]to[9]

To determine the suitability of the aggregate for use in pavement construction, following tests are carried out

1. Shape test
2. Specific gravity and water absorption test
3. Crushing Strength test
4. Impact Strength test
5. Devil's Attrition test
6. Los Angle Abrasion test

### *A. Plastic (High Density Poly Ethylene)* [10]

To determine properties of Sodium lignosulphonate physical and chemical tests are conducted

### *B. Sodium lignosulphonate*[12]

To determine properties of Sodium lignosulphonate physical and chemical tests are conducted

### D. Bituminous mix[11]

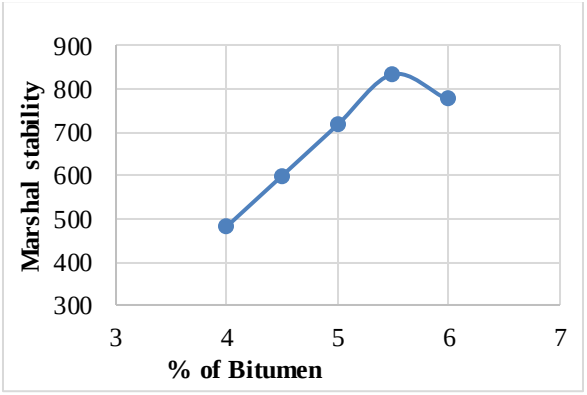
Several combinations of plastic and Sodium lignosulphonate at various percentages are added to bituminous mix and Marshall Stability Test[11] conducted for every combination of specimen. Marshal stability is the load at which the specimen fills when it is subjected a gradual compressive load. Marshal flow value is the deformation sustained by the specimen exactly at the failure load.

Figure 5: Marshall Stability Test apparatus

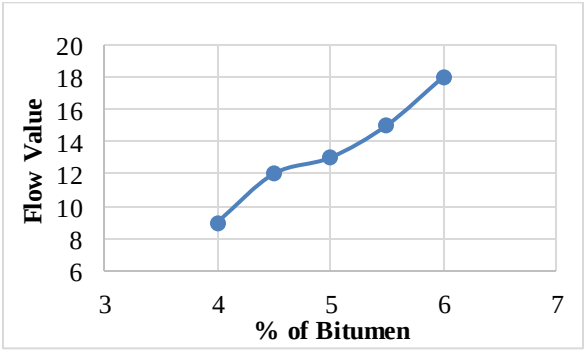
## VII. RESULTS AND DISCUSSIONS

### *A. BEHAVIOUR OF SPECIMEN FOR BITUMEN MIX:*

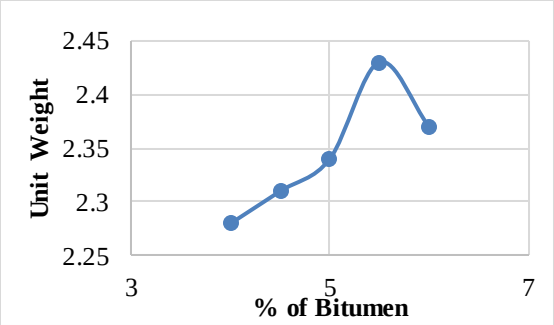
The following are the graphs (1) to (5) indicated the behavior of the specimen for bitumen mix at different percentages are casted as 4%, 4.5%,5%,5.5%,6% by weight of aggregate.



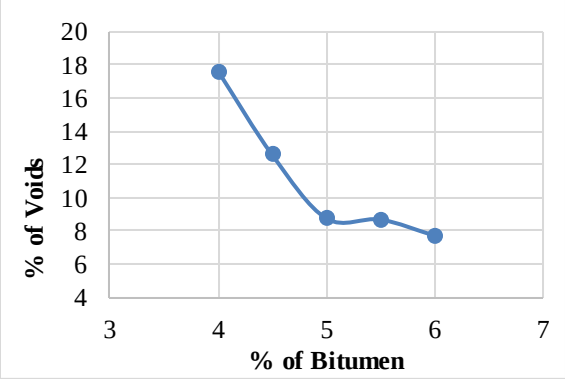

Graph 1: Percentage of bitumen Vs Marshal stability value



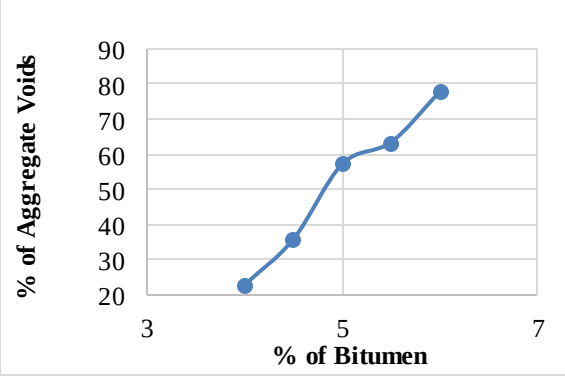

Graph 2. Percentage of bitumen Vs Flow value




Graph 3. Percentage of bitumen Vs Unit weight



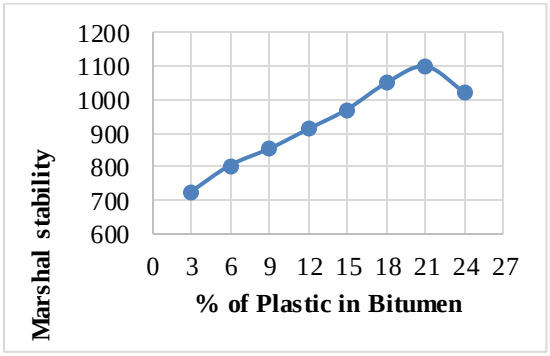

Graph 4. Percentage of bitumen Vs Percentage of Air voids



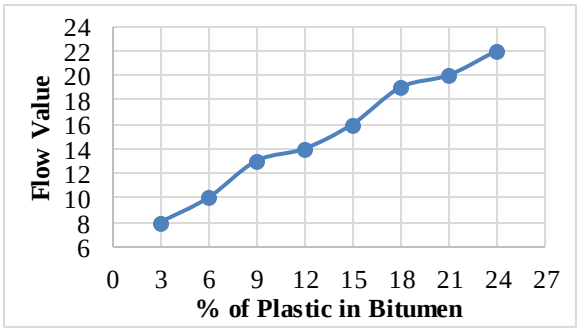

Graph 5. Percentage of bitumen Vs Percentage of aggregate voids filled with bitumen

*B. BEHAVIOUR OF SPECIMEN -ADDITION OF PLASTIC TO BITUMEN:*

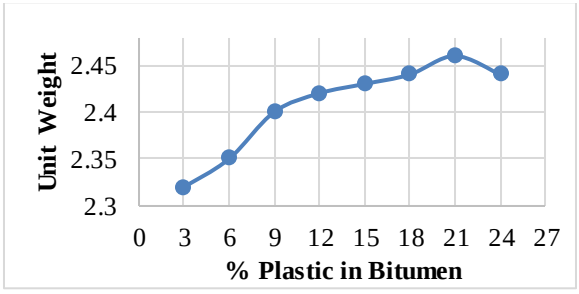
After completion of the nominal mix of bitumen and then test the bitumen by replacing it with plastic partially. In which the percentage of bitumen satisfies the required specifications is taken as design mix percentage, for that optimum percentage, waste plastic is add by weight of bitumen content. The percentage of plastic should be taken as 3%, 6%, 9%, 12%, 15%, 18%, 21%, 24% and the behavior of specimen for different percentage of plastic is expressed in the following graphs (6) to (10).



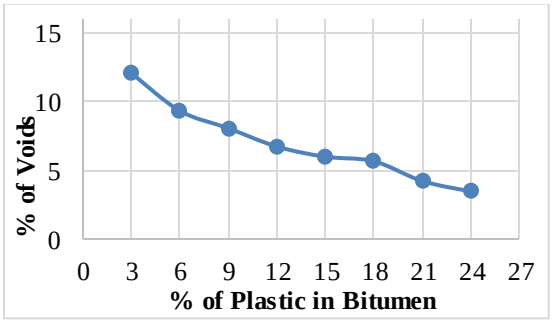

Graph 6. Percentage of Plastic in bitumen Vs Marshal stability value



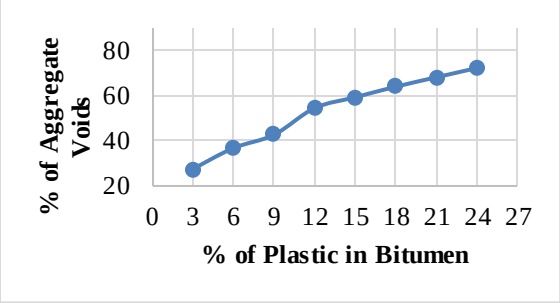

Graph 7. Percentage of Plastic in bitumen Vs Flow value




Graph 8. Percentage of Plastic in bitumen Vs Unit weight



Graph 9. Percentage of Plastic in bitumen Vs Percentage of Air voids

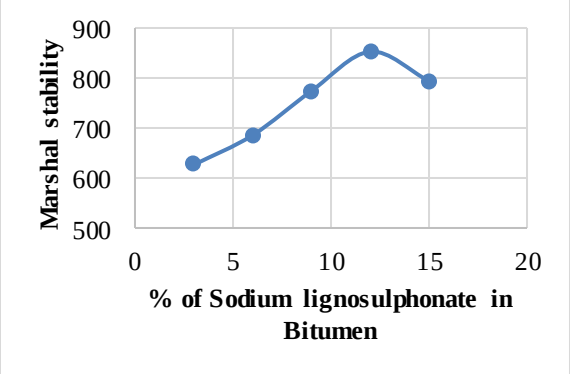



Graph 10. Percentage of Plastic in bitumen Vs Percentage of aggregate voids filled with bitumen

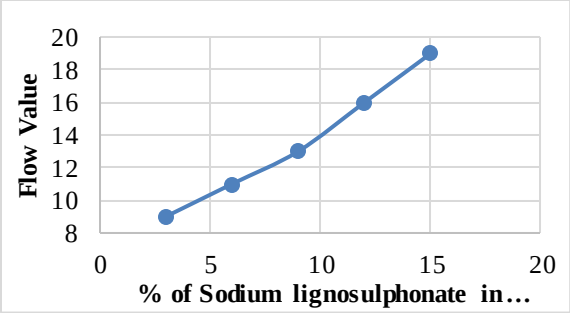
By observing, the behaviour of plastic in different percentages and its results 21% of plastic expose the best properties and good strength. It concludes that 21% of plastic by weight of bitumen is better to use as binder material.

*C. BEHAVIOUR OF SPECIMEN -ADDITION OF SODIUM LIGNOSULPHONATE TO BITUMEN:*

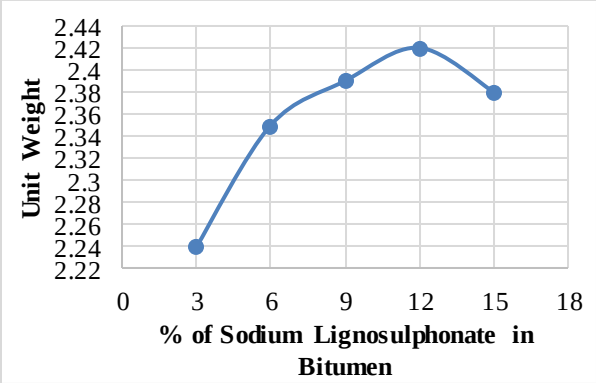
After completion of the design mix of bitumen and plastic and then test the bitumen by replacing it with Sodium lignosulphonate partially. In which the percentage of bitumen satisfies the required specifications is taken as design mix percentage, for that optimum percentage, Sodium lignosulphonate is add by weight of bitumen content. The percentage should be taken as 3%, 6%, 9%, 12%, 15%. and the behavior of specimen for different percentage of Sodium lignosulphonate is expressed in the following graphs (11) to (15).



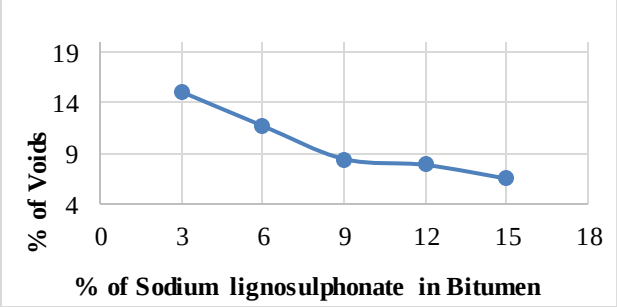

Graph 11. Percentage of Sodium lignosulphonate in bitumen Vs Marshal stability value



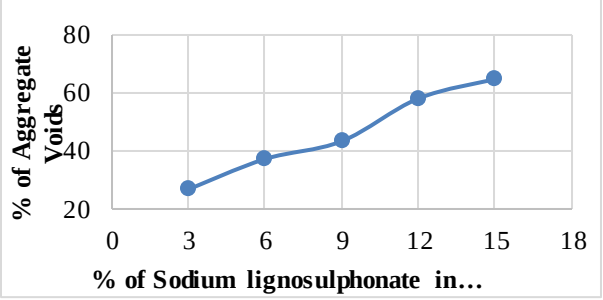

Graph 12. Percentage of Sodium lignosulphonate in bitumen Vs Flow value




Graph 13. Percentage of Sodium lignosulphonate in bitumen Vs Unit weight




Graph 14. Percentage of Sodium lignosulphonate in bitumen Vs Percentage of Air voids




Graph 15. Percentage of Sodium lignosulphonate in bitumen Vs Percentage of aggregate voids filled with bitumen

By observing, the behaviour of Sodium lignosulphonate in different percentages and its

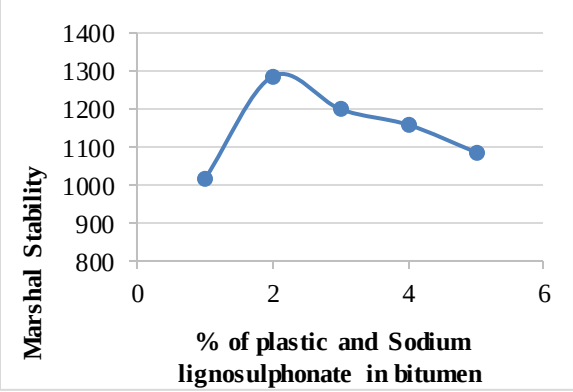
results 12% of Sodium lignosulphonate expose the best properties and good strength. It concludes that 12% of Sodium lignosulphonate by weight of bitumen is battering to use as binder material.

*D.: BEHAVIOUR OF SPECIMEN -ADDITION OF PLASTIC AND SODIUM LIGNOSULPHONATE TO BITUMEN:*

After completion of the design mix of bitumen, plastic and bitumen, Sodium lignosulphonate, we got the optimum values at 21% and 12% respectively. To get the percentage of bitumen satisfies the required specifications of plastic and Sodium lignosulphonate is taken as design mix percentage. For that, tests are conducted at different percentages of partial replacement of plastic and Sodium lignosulphonate. Partially replaced bitumen with plastic and Sodium lignosulphonate in the percentages of 18% & 9%, 19% & 10%, 20% & 11%, 21% & 12%, 22% & 13% respectively. The results obtained for different percentages are expressed in following table (1) to (6) and the behavior of specimen for different percentage of Plastic & Sodium lignosulphonate in bitumen are shown in graphs (16) to (20)

Table 2: Percentage of plastic, Sodium lignosulphonate in bitumen and Marshal Stability value

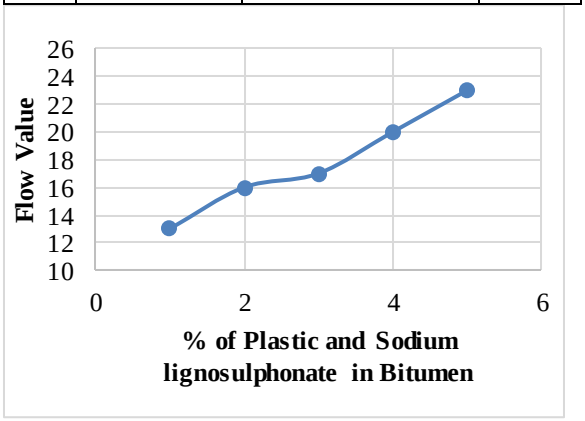
| S.no | Percentage of Bitumen (%) | Percentage of Plastic & sodium Lignosulphonate by Weight of Bitumen | Marshall Stability (Kg) |
|---|---|---|---|
| 1 | 5.5 | 18 & 9 | 1018.03 |
| 2 | 5.5 | 19 & 10 | 1285.26 |
| 3 | 5.5 | 20 & 11 | 1198.09 |
| 4 | 5.5 | 21 & 12 | 1157.36 |
| 5 | 5.5 | 22 &13 | 1085.43 |




Graph 16. Percentage of plastic and Sodium lignosulphonate in bitumen Vs Marshal stability value

Table 3: Percentage of plastic, Sodium lignosulphonate in bitumen and Flow value

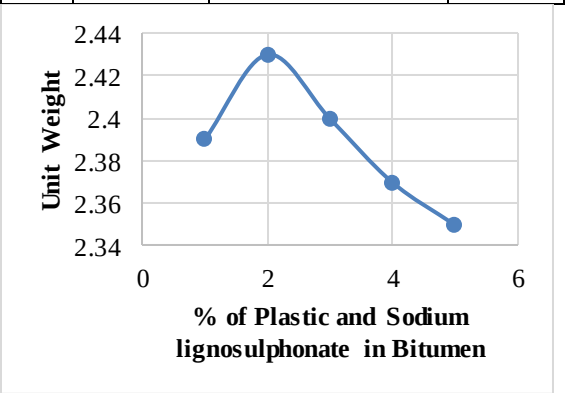
| S.no | Percentage of Bitumen (%) | Percentage of Plastic & sodium Lignosulphonate by Weight of Bitumen | Flow Value (mm) |
|---|---|---|---|
| 1 | 5.5 | 18 & 9 | 13 |
| 2 | 5.5 | 19 & 10 | 16 |
| 3 | 5.5 | 20 & 11 | 17 |
| 4 | 5.5 | 21 & 12 | 20 |
| 5 | 5.5 | 22 &13 | 23 |




Graph 17. Percentage of plastic and Sodium lignosulphonate in bitumen Vs Flow value

Table 4: Percentage of plastic, Sodium lignosulphonate in bitumen and Unit weight

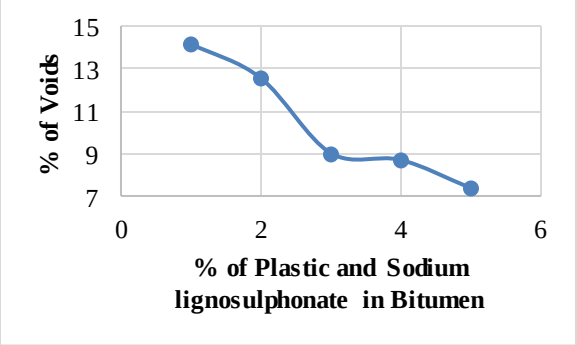
| S.no | Percentage of Bitumen (%) | Percentage of Plastic & sodium Lignosulphonate by Weight of Bitumen | Unit Weight (g/cm3) |
|---|---|---|---|
| 1 | 5.5 | 18 & 9 | 2.39 |
| 2 | 5.5 | 19 & 10 | 2.43 |
| 3 | 5.5 | 20 & 11 | 2.4 |
| 4 | 5.5 | 21 & 12 | 2.37 |
| 5 | 5.5 | 22 &13 | 2.35 |




Graph 18. Percentage of plastic and Sodium lignosulphonate in bitumen Vs Unit weight

Table 5: Percentage of plastic, Sodium lignosulphonate in bitumen and Percentage of Air voids

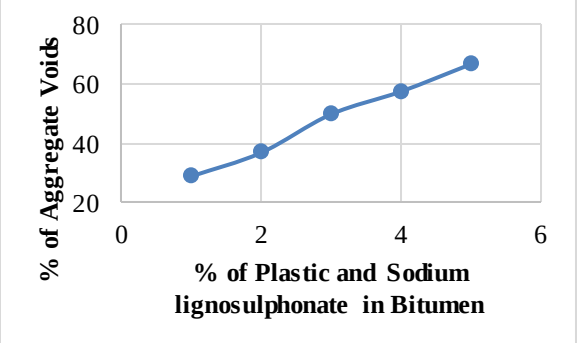
| S.no | Percentage of Bitumen (%) | Percentage of Plastic & sodium Lignosulphonate by Weight of Bitumen | Percentage of Voids (%) |
|---|---|---|---|
| 1 | 5.5 | 18 & 9 | 14.17 |
| 2 | 5.5 | 19 & 10 | 12.57 |
| 3 | 5.5 | 20 & 11 | 9.06 |
| 4 | 5.5 | 21 & 12 | 8.74 |
| 5 | 5.5 | 22 &13 | 7.43 |




Graph 19. Percentage of plastic and Sodium lignosulphonate in bitumen Vs Percentage of Air voids

Table 6: Percentage of plastic, Sodium lignosulphonate in bitumen and Percentage of aggregate voids filled with bitumen

| S.no | Percentage of Bitumen (%) | Percentage of Plastic & sodium Lignosulphonate by Weight of Bitumen | Percentage of Aggregate Voids (%) |
|---|---|---|---|
| 1 | 5.5 | 18 & 9 | 28.8 |
| 2 | 5.5 | 19 & 10 | 36.74 |
| 3 | 5.5 | 20 & 11 | 49.65 |
| 4 | 5.5 | 21 & 12 | 57.31 |
| 5 | 5.5 | 22 &13 | 66.48 |

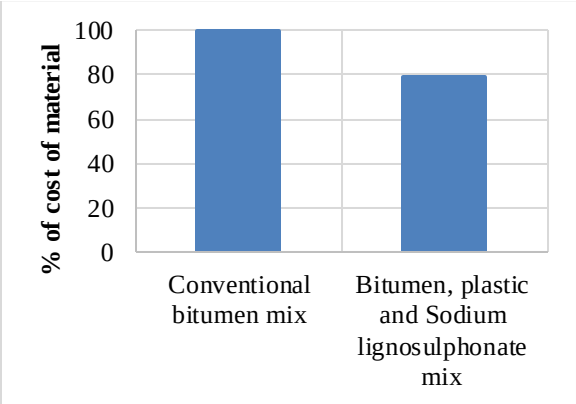



Graph 20. Percentage of plastic and Sodium lignosulphonate in bitumen Vs Percentage of aggregate voids filled with bitumen

By observing, the behaviour of plastic and Sodium lignosulphonate in different percentages and its results 19% & 10% of plastic and Sodium lignosulphonate expose the best properties and good strength. It concludes that 19% & 10% of plastic and Sodium lignosulphonate by weight of bitumen is better to use as binder material.

## VIII. COST ANALYSIS

The following bar chart [(1)] shown cost variation between bituminous mix and Bitumen, plastic and Sodium lignosulphonate mix. It shows that the cost of Bitumen, plastic and Sodium lignosulphonate mix is 21.4% is less than conventional bitumen mix. Bitumen, plastic and Sodium lignosulphonate mix is economical and eco-friendly than conventional bitumen mix




Bar chart 1: Percentage of cost variation

## VIII. CONCLUSION

From this experimental study, it is evident that the ductility property of bitumen has been increased up to 21% when compared with conventional bitumen mix. The increase in ductility property enhances the binding property of the bitumen.

- Bitumen is a non-renewable source which should be efficiently used where these replacements (sodium lignosulphonate and waste plastic) plays a main role.
- By consuming these waste materials quantities of waste produced becomes less. Therefore, we conclude that by using Sodium lignosulphonate and plastic as a partial replacement of bitumen in

pavements, the results are very effective when compared to the usual usage of bitumen in the construction of pavements.

- The properties of bitumen such as ductility, viscosity, softening point, penetration was improved in all the aspects which helps in increasing the life span of the pavements. A gradual increase has been observed in all these properties of bitumen by partially replacing it with plastic and Sodium lignosulphonate up to 19% and 10% respectively.
- The marshal stability of bitumen when it is replaced with 21% of plastic is 31.764% more than conventional bitumen mix.
- The marshal stability of bitumen when it is replaced with 12% of sodium lignosulphonate is 2.35% more than conventional bitumen mix.
- The marshal stability of bitumen when it is replaced with 19% of plastic and 10% of sodium lignosulphonate is 54.13% more than conventional bitumen mix.
- The flow value of bitumen when it is replaced with 19% of plastic and 10% of sodium lignosulphonate is 6.7% increased when compared to conventional bitumen mix
- The cost of Bitumen, plastic and Sodium lignosulphonate mix is 21.4% less than conventional bitumen mix
- It concludes that Bitumen, plastic and Sodium lignosulphonate mix is economical and eco-friendly.

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