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Cost Effective Improvement of Bitumenous Pavement using Polymers, Poly-Phosphoric Acid and Industrial Waste

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***Abstract*— India is developing at fast rate. Industrial and infrastructure development at its peak. Geographically the area of the country is very large. This development requires a well-planned and developed road network. Bitumen is the important material required for this road development. For cost effective and sustainable roads bitumen is modified with the poly phosphoric acid and industrial waste. This paper gives the effective content of mixing of the poly phosphoric acid and industrial waste with the bitumen.**

***Keywords*— Bitumen; Poly phospheric acid; Industrial waste.**

I. INTRODUCTION

These days a disposal of various waste produced from industries is a giant problem. Waste material pose problem of environmental pollution in surrounding area as many of these industrial waste products are non-biodegradable. Globally the issue of waste tires and plastic needs a sustainable solution. Every year 1.6 billion new tyres are produced and around 1 billion of waste tyres are generated. However, the recycling industry processed only 100 million tires every year. Application of recycled tyres and plastic will not only solve the environmental disposal problems, but it will be act as good modifier for bituminous pavement.

The modified bitumen and granular or crumb rubber can be used as a replacement of the fine stone aggregate. Bitumen is used in over two hundred applications, most of which relate to civil engineering, there is now much interest in the use of poly-phosphoric acid (PPA) to modify bitumen. By itself or in combination with a polymer, PPA provides a means of bitumen modification usually produced more expensively with a polymer alone. Plastic is user friendly but not eco-friendly as they are non-biodegradable. Today in India nearly more than 12 million tons of plastics are used. There visibility has been perceived as a serious problem and made plastic a target in the management of solid waste. They also have a very long lifetime and burning of plastics waste under uncontrolled conditions could also lead to generation of many hazardous air pollutants depending upon the type of polymers and additives used. Polymer modified bitumen is emerging as one of the important constructions of flexible pavement. The polymer modified bitumen show better properties for road construction and plastic waste can find its use in this process and this can help solving problem of pollution. The better binding property of plastic in its molten state has helped in finding out a method of safe disposal of waste plastic. Slag forms when iron ore is melted and reduced into molten pig iron in blast furnaces. In India almost 100 million tons of steel is produced every year. An Average one ton of steel production 400 kg of Blast furnace produced as by product. So, combine use of these materials should give economical advantage and should help for easy availability of materials & improving properties of bituminous pavement.

II. METHODOLOGY

1. Studies of various materials for bituminous pavement – Various tests are performed on constituent material.
2. Finding the optimum binder content for mix-Three samples casted for bitumen content as 6%, 6.5% and 7% to know the optimum binder content for the mix.
3. Finding the optimum content of materials to be used- Tests are performed on each and every modified material to be added to mix , to find out the optimum content of materials to be added in mix separately
4. Casting and Testing of final bituminous mix – Preparation of Bituminous mix for modified materials and casting has been done to find out optimum mix proportion.
5. Cost Comparison for bituminous mix – Cost comparison of finalized mix with conventional mix.

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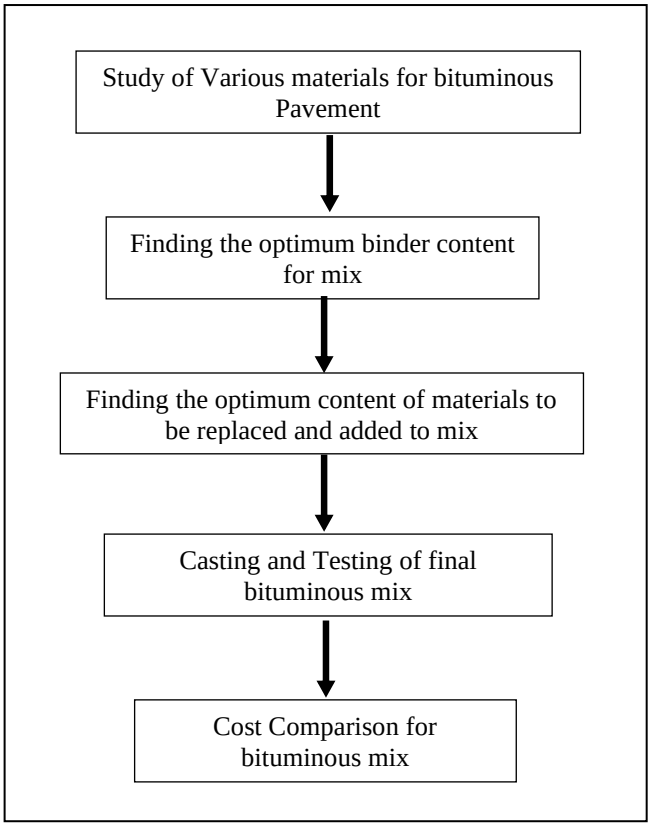

Fig.1 Methodology flow chart

III. EXPERIMENTAL PROGRAM

A. Material characterization

a. Coarse Aggregate: The coarse aggregate for the mix consists of crushed rock passing through 12mm IS sieve & retained on 10mm IS sieve. Aggregate should be clean, hard, durable, and free from dust and organic matters.
Properties of sample used:
Impact Value: 6.67%
Crushing Value: 15%
Abrasion Value: 16%
b. Fine Aggregate: Fine Aggregate for the mix consists of crushed rock, passing through 4.56 mm IS sieve & retain on 2.36 mm IS sieve. Aggregate should be clean, hard and free from organic matter.
Properties of Fine Aggregates: Specific Gravity: 4.17
Fineness Modulus: 2.99
Water Absorption: 2.74%
c. Bitumen:
Penetration Grade of Bitumen: 60-70
Softening point of Bitumen: 50.6
Viscosity of Sample: 2min 58sec.
Ductility of Sample: 71.5cm.
d. Blast Furnace Slag:
Water Absorption: 0.5%
Specific Gravity: 2.70
e. Stone Dust:
Stone Dust passing through 300 micron & retain on 90 micron

B. Experimental program

The experimental program started with material characterization.
We performed standard tests on material and results are given as above. For finding the optimum bitumen content we have performed tests for as 6%, 6.5% and 7%. Samples were casted and results were checked for Stability value and flow value. From the test results optimum binder content selected as 6.5%.
In next step we performed tests for each individual material to be added or replaced with 6.5 % of bitumen. Replacement of bitumen with Crumb Rubber in 5%, 10% and 15% proportions, we found 10% mixture is suitable for replacement shown in Table II. PPA added to mix 0.5%,1%,1.5% to the weight of bitumen.1% of addition given the best results shown in Table III. Blast furnace slag is replaced with weight of fine aggregate. 10 % ,20% ,30%. We found that 30 % replacement has given good results shown in Table IV. Polymer are also replaced to weight of bitumen in 5%, 10% and 15%. Out of this 15 % samples given good results shown in table V.
In the next step we have casted the bituminous mix with modified material to be added or replaced in optimum content as found in earlier step. This samples were casted with following materials.

1. Coarse aggregates
2. Fine aggregates
3. Bitumen
4. Crushed stone dust (filler material)
5. Polyphosphoric acid (PPA)
6. Crumb rubber
7. Polymers (plastic bottles)

For this final modified bituminous mix, we have performed the Marshall stability test and flow test and results are tabulated in Table no VI.
Cost comparison of modified mix with conventional mix has been done. The cost of Modified mix is less of Rs.307.12 than that of conventional mix. Modified mix is economical than conventional mix.

TABLE I RESULT OF CONVENTIONAL BITUMENOUS MIX

Bitumen %	6.5		
Sample No.	1	2	3
Wt in Air GM	1190	1192	1194
Wt in Water GM	690	688	698
Flow value (mm)	5	5	4
Stability Value (KG)	370	372	375
Gt	2.7	2.7	2.71
Unit wt (g/cc)	2.47	2.47	2.48
% air voids Vv	5.1	5	5.05
VMA %	20.49	20.37	20.44
Vb %	15.39	15.37	15.39
VFB %	75.29	75	75.1

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TABLE II RESULT OF REPLACEMENT OF BITUMEN WITH CRUMB RUBBER

Bitumen 6.5 %	Crumb Rubber 10%		
Sample No.	1	2	3
Wt in Air GM	1198	1200	1200
Wt in Water GM	685	690	695
Flow value (mm)	5	5	4
Stability Value (KG)	382	380	380
Gt	2.26	2.26	2.26
Unit wt (g/cc)	2.48	2.49	2.49
% air voids Vv	5	5.1	5
VMA %	20.39	20.47	20.39
Vb %	15.39	15.37	15.39
VFB %	75.35	75.12	75

TABLE III RESULT OF REPLACEMENT OF BITUMEN WITH PPA

Bitumen 6.5 %	PPA 1%		
Sample No.	1	2	3
Wt in Air GM	1198	1200	1200
Wt in Water GM	700	680	685
Flow value (mm)	5	5	4
Stability Value (KG)	378	380	376
Gt	2.25	2.25	2.25
Unit wt (g/cc)	2.48	2.49	2.49
% air voids Vv	5.05	5	5
VMA %	20.42	20.32	20.33
Vb %	15.37	15.32	15.33
VFB %	75.4	75	75.35

TABLE IV RESULT OF REPLACEMENT OF BITUMEN WITH BFS

Bitumen 6.5 %	BFS 30%		
Sample No.	1	2	3
Wt in Air GM	1200	1197	1200
Wt in Water GM	695	690	680
Flow value (mm)	4	5	5
Stability Value (KG)	376	374	372
Gt	2.32	2.32	2.32
Unit wt (g/cc)	2.49	2.48	2.49
% air voids Vv	5.15	5	5
VMA %	20.52	20.34	20.32
Vb %	15.37	15.34	15.32
VFB %	75.55	75.65	76.1

TABLE V RESULT OF REPLACEMENT OF BITUMEN WITH POLYMER

Bitumen 6.5 %	Polymer 15%		
Sample No.	1	2	3
Wt in Air GM	1200	1195	1197
Wt in Water GM	695	680	685
Flow value (mm)	5	5	4
Stability Value (KG)	376	370	374
Gt	2.29	2.29	2.29
Unit wt (g/cc)	2.49	2.47	2.48
% air voids Vv	5	5.05	5.15
VMA %	20.37	20.38	20.46
Vb %	15.37	15.33	15.31
VFB %	75.25	75.8	75

TABLE VI RESULT OF MODIFED MIX

Bitumen %	6.50%		
Sample No.	1	2	3
Wt in Air GM	1198	1200	1200
Wt in Water GM	700	690	700
Flow value (mm)	4	4.3	4
Stability Value (KG)	378	380	382
Gt	2.28	2.28	2.28
Unit wt (g/cc)	2.47	2.49	2.49
% air voids Vv	5.35	5.25	5.1
VMA %	20.67	20.61	20.44
Vb %	15.32	15.36	15.34
VFB %	73	74	75.8

IV. CONCLUSION

This study illustrates the use of industrial waste materials for the cost-effective modification of bituminous pavement. The selected materials such as crumb rubber, PPA, Polymer and blast furnace slag. The experimental study has been performed for finding the optimum content of modifying the bituminous mix with selected materials. The individual tests have been taken place for finding out the optimum content of modifying material. Modified bituminous mix has been prepared and tests were performed and compared with conventional bituminous mix results. The results we found that stability has increases with 2 %. The flow value lowered by 12 %. Cost of both the mix compared and it is 20 % more cost effective as compared to the conventional mix. The results are motivating for utilization of waste material for modification of bituminous mix and achieve the goal of sustainable development.

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