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INFLUENCE OF ACID MODIFICATION IN ASPHALT LAYER WHEN REINFORCED WITH GLASS FIBRE

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ABSTRACT

The progressive traffic load intensity with its volume and tyre pressure showed a huge changes in structural stability of pavements and had resulted in pavement failure. Failure in structure is observed in the form of rutting or fatigue, to overcome from these failure number of effort were made in the past to improve the structural properties of hot mix asphalt layer using additives, chemicals etc. In this study an attempt is made to evaluate the behaviour of acid modification with the inclusion of glass fibre. The modified binder has shown better performance in G*/sinδ and G*sinδ value when compared with conventional mix. The inclusion of glass fibre in modified mix showed a beneficial improvement on performance characteristics at an optimum of 2.7%.

Keywords—*PPA (Polyphosporic acid), Fibre, Rutting, Fatigue*.

I. INTRODUCTION

Highway pavement is a structure consists of different layers with processed materials whose main function is to distribute vehicle load to subgrade. It essentially comprises of black-top sheet and mineral totals. HMA is the composite material comprising of total fragment with various sizes, a black-top fastener and air voids. At the point when mineral totals are bound with black-top cover, it goes about as stone system that gives quality and durability to the mix .Asphalt pavements crack due to heavy traffic loads, and the pavement surface experiences wear and tear due to various climatic conditions in addition to heavy traffic loads. The load carrying capacity is mainly based on the base, structural and friction courses of the pavement. Therefore, the aggregates should be hard enough to resist abrasion. Pavement failure occurs when an asphalt surface no longer holds its original shape and develops material stress which causes issues**.** Pavement major failure are rutting and fatigue ,so it is essential to reduce ruts and cracks in flexible pavement layers. So each pavement material which is being used in a construction should generally have balanced design between the rutting and fatigue modes of distress. The increased rutting or decreased fatigue life of the flexible pavements may be directly affecting the service life of pavement.Depressions which along wheel path due to heavy wheel loads results in rutting failure. Fatigue is caused by failure of the surface layer or base due to excessive application of repeated wheel load. To improve the characteristics properties of pavment layer and protect the HMA layer from failures modification of binders and mixes is carried out. One among the measures of binder modification with the addition of PPA and reinforcement with fibre. Abdul (2015) studied on acid modified bituminous mixes and explained that PPA addition improves rutting resistance. Sowjanya (2017) examined on performance of bituminous mixes using the bitumen, modified with polyphosphoric acid. Jack Federal Highway Administration demonstrates the impact of expanding dimensions of acid modification on dampness affectability.In thefibre-bitumen composites, bitumen can be called the matrix material, the characteristics of which are changed by using fibres in this matrix as stabilizing additives. Characteristics.Fan ,(2012), outcomes demonstrated that the enhancement impacts for Marshall record are exceptional by expansion of fiber, and contrasted with polyester fiber andxylogenfiber, the enhancement impacts of basalt fiber is better. Suresh (2013) carried out studies onmodifying strength pavement of bitumen using fibres. Nihat (2013) investigated on usability of basalt fibre in hot mix asphalt concrete. Olumide (2014) explained Performance of Glass Fibre with bitumen emulsion to delay the cracking on surface of the pavement .Yuanxun (2014) identified Fatigue Property of Basalt Fibre in modified asphalt mixture under Complicated Environment. Midhila (2015) carried a comparative study of bitumen modification using synthetic and natural fibre. Sateesh (2017) evaluated Performance Of Basalt Fibre Modified Bitumen In Dense Bitumen Macadam. Harsha(2017) carried partial replacement of bitumen with glass fibre in flexible pavement .the result indicate that by addition of glass fibre the penetration value increased as compared to the nominal mix.

Yongchun ,(2017) carried research facility Study on Properties of Diatomite and Basalt Fiber Compound Modified Asphalt Mastic .The present study is focused on improving the characteristics with binder modification through inclusion of PPA and reinforcement of modified mixture using fibre.

Acid Modification by usingPolyphosporic acid (PPA)

Source- Ylidizel (2017).

PPA, a medium solid corrosive (Hammet causticity work = 6, sulfuric corrosive H_2SO_4 = 12), is an inorganic polymer, all the more explicitly an oligomer, gotten by buildup of monophosphoric corrosive or by hydration of phosphorous pentoxide (P_2O_5) from TRC (2012)

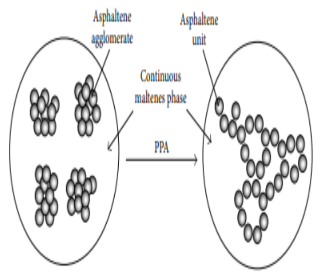

Figure. 1 Influence of PPA on the colloidal structure of bitumen

Source- Catarina(2016)

The reactivity of PPA increments with the extremity of the asphaltene portion since it upgrades PPA separation (into PPA− and H+) [3] upsetting the hydrogen security arrange framed inside the agglomerates of asphaltene micelles. Therefore, the atomic weight of the asphaltene portion is brought down and the appropriation of asphaltenes in the rest of the parts is enhanced, moving the bitumen towards a more flexible gel-type structure, as shown in Figure 1.

Fibre

Fibre is used as reinforcement in modified mix. In this study glass fibre is used and the properties are tabulated in table I.

TABLE I Glass fibre properties

Description	**Value**
Ultimate strength, bending (MPa)	20-28
Elastic limit, bending (MPa)	7-11
Ultimate strength, tensile (MPa)	8-11
Elastic limit, tensile (MPa)	5-7
Compressive Strength (Mpa)	50-80
Elastic Modulus (GPa)	10-20

II. METHODOLOGY

The sequence of stages was followed in achieving the objectives of study
Stage 1: Literature review study
Stage 2: Aggregate gradation selection
Stage 3: Marshall Mix design for Conventional mix, modified and fibre reinforced mixes
Stage 4: Evaluating the Tensile strength, Resilient Modulus and Rutting for above mix combination

III. EXPERIMENTAL PROGRAMME

In order to meet the objective of study following experimental process is adopted as per ASTM MORTH guidelines.

a) Aggregate Gradation

Bituminous concrete (BC) mix of grade – I with nominal maximum aggregate size of 19mm is used in the study as per MORTH specifications. The selection of percentages of different ingredients for preparation of BC mix of Grade –I study is shown in Figure 2.

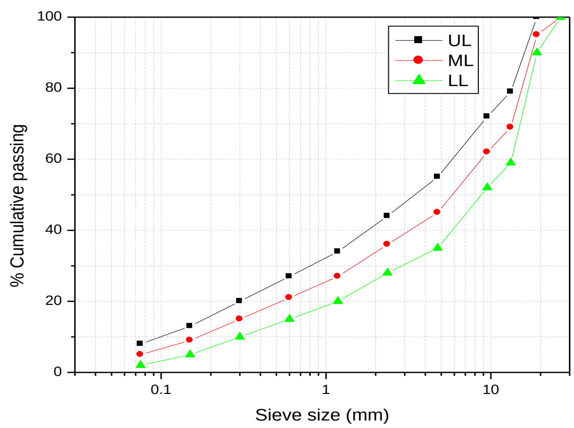

Figure. 2 Gradation of Aggregate

b) Materials

The materials used for this study are aggregates, bitumen(VG-30), polyphosporic acid(PPA), glass fibre(12mm length) chopped. Crushed aggregates were collected from local quarry of Hyderabad city, Telangana State, VG 30 grade bitumen was collected from the Vishakhapatnam provided by (IOCL).PPA Polyphosporic acid of reagent grade, 115% H_3PO_4 basis and glass fibres were collected from dwarikamai agency near koti Hyderabad. Initially physical properties of aggregates (as per IS 2386) were determined. Crushing, impact, hardness, specific gravity, water absorption and elongation and flakiness indices (combined) are performed. Physical properties of bitumen carried out.

c) Modified Binder

Binder modification has carried by introducing PPA to the virgin binder at an increment of 1% . The rheological properties of modified binder was studied using Dynamic Shear Rheometre DSR and is depicted in fig. 3.The dynamic shear rheometer test is a measure of consistency and flexible properties of black-top mastic at medium and high temperature. (ASTM D7175) , the tests were performed by a parallel plate that had a hole of 1.0mm and distance across of 25mm. The modified bitumen was placed between two parallel plates; the base plate was settled. The upper plate was swayed at a stacking recurrence of 10rad/s (1.59Hz). Rutting and fatigue parameter is arrived for the adjusted cover. In this study five sample were taken to know the rheological properties of binder with PPA.

Figure.3 Dynamic shear rheometer

d) Preparation of specimen(Marshall specimen)

Around Around 1200gm of totals blend is required for readiness of BC blend sample. The dry blend of totals and filler material is preheated to test temperature of 135̊C and bitumen is included proportionately. Mix arrangement was finished by incorporation of PPA using stirrer shown in fig 4. The response time is normally short. The run of the mill lab test is set up by including the coveted measure of PPA to a bitumen sample at 149˚C, and mixing improved the situation no less than 30 minute. When an objective plan has been created, lab mixes ought to be assessed for all particulars and whole blend is set up at temperature of 135̊ C. The mix is placed in 100 diameter mould and compacted by rammer of weight 4.54kg for 75 blows on each side. The height of fall of rammer is 45.7 cm and compaction is carried through automatic compactor. The compacted specimen should have a thickness of 63.5 mm. This test is conducted in accordance with ASTM D6927 - 15. The Marshall test is used to determine the optimum binder content for the mix. A progression of test samples was set up for a scope of various cover content (4-6) as determined in MORTH for BC blend. The elements of the test examples were 100 mm in breadth and 63.5mm in tallness with an objective void substance of 4%. Three test examples were compacted for every level of cover content; altogether 69 specimens were used to arrive the Marshall parameters. The Marshall Stability and flow test gives the forecast measure to the Marshall blend structure technique. The stability parts estimates the greatest load upheld by the test sample at a loading rate of 50.8 mm/minute. Load is connected to the sample till it comes up short, and the most extreme load is considered as dependability. At the loading time, an appended dial check estimates the specimen plastic stream (deformation) because of the loading. The flow esteem is recorded in 0.25 mm (0.01 inch) augments in the meantime when the greatest load is recorded. Following setup shown in Fig.5

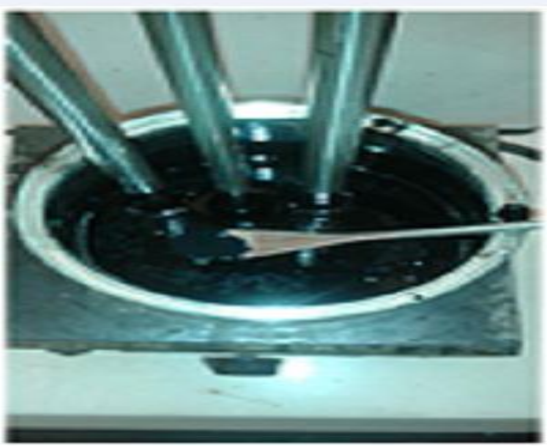

Figure. 4 Magnetic Stirrer

Fig. 5 Marshall Stability apparatus

e) Indirect tensile strength test

The tensile features of bituminous mixtures are gauged by loading the Marshall specimen along a diametric plan with a compressive load at a constant rate acting parallel to and along the vertical diametrical plane of the specimen provided through two opposite loading strips shown in Fig6. This loading arrangement develops a relatively uniform tensile stress perpendicular to the direction of the applied load and along the vertical diametrical plane, finally causing the specimen tested to fail by splitting along the perpendicular diameter. The IDT strength test was conductedto measure the resistance of each mixture to cracking according to ASTM D4 4123-82 IDT=2P/π.d.t ……………………equation (1),

Where, IDT = indirect tensile strength test; P = failure load; t = thickness of specimen d = diameter of specimen. Three test specimens were prepared from the obtained optimum result first specimen is of conventional mix, remaining specimen is of modified mixes with glass fibre using additive as PPA in binder.

Figure. 6 IDT set-up with sample & on Line D

construction materials under a variety of conditions. However, if the strength of the material is large as compare with load and is applied repetitively, the deformation under each loads application completely recoverable and proportional to the load which gives the elastic behaviour of material. ASTM D7369-11 standard code to determine the resilient modulus of bituminous mixes by indirect tension test. In this test a linear force along the diameter axis of the specimen is applied as shown in Fig.5.. Each loading cycle was 0.1s long. Thus, given the total duration of loading and unloading of 1 s, the rest time period of each cycle is 0.9s.The scale of load applied was 10% of tensile strength obtained from IDT at 350̊C The rigidity modulus for cylindrical specimens is determined as

MR=P(0.27+ μ) / t. Δh ………….. Equation (2)

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Where, MR= Resilient modulus (MPa); P = Repeated load (N); μ = Poisson's ratio, t= Thickness of HMA sample (mm); Δh = Horizontal deformation (mm). One samples for each mix with a total of 3(virgin mix, glass, fibre and basalt fibre) were tested along the diametrical plane to calculate strain and modulus parameters.

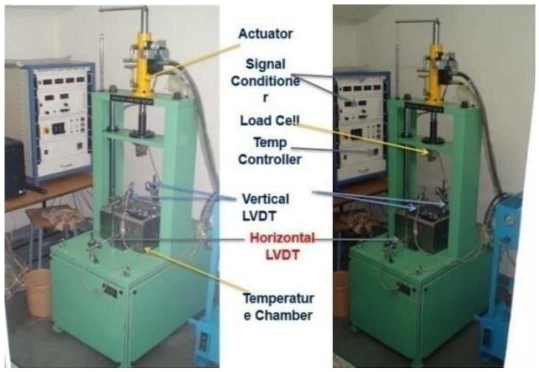

Fig.7 Repeated load instrument

f) Specimens for Rutting

The specimen is composed in a slab compactor also known as roller compacting device shown in Fig 3.4(a) its volume is of around 6000 cc. The specimens were set up with densities gratified base from Marshall Stability test. The specimens were compacted using hydraulic pressure in oscillatory motion. When the desired densities of blend are accomplished as clarified in (BS EN 12697 33) at that point the compaction has been stopped. In this research three slab with different mix were prepared (conventional mix, Modified mix of glass and basalt fibre with PPA) with total weight of mix 13.5 kgs in which filler amount consist of 732.9 gms and 717 gms of bitumen.

g) Immersion type of wheel tracking device

In the present research, an augmented test replicated in the laboratory for estimation of rutting resistance was used and is presented through Fig.3.The wheel utilised in the analysis is steel wheel of 47 mm wide and the total weight of the wheel with surcharge is 710N.To measure rut depth LVDT is used. Specimens were tested in soaked condition at a temperature of 50oC. Immersion test is carried for understanding the strip off obstacle of mixes. The moment of the wheel path is 230 mm and the speed of the wheel for one pass is nearly1.46 kmph (72 wheel passes per min). B.C grade I as per MORTH is adopted for the present investigation in preparation of specimens. 24102 passes will simulate traffic of 30 msa in the field (Nahi, 2011).

Figure.8 Immersion type of wheel tracking device

IV. RESULTS

a) Physical properties of aggregates and bitumen

Aggregates and bitumen test were conducted for the preparation of adopted mixes. Aggregates test as per MORTH specification to find the strength ,hardness, shape etc , where as bitumen test is to find the grade of bitumen as per IS:73:2016 shown below ,Table II and Table III.

TABLE II Physical properties of aggregates

TEST CONDUCTED	LABORATORY RESULTS (%)	MORTH SPECIFICATION	TEST STANDARDS
Aggregate crushing value	23	Max 30	IS:2386 (IV)
Aggregate Impact Value	20	Max 30	IS:2386 (IV)
Elongation index	12.45	<15	IS:2386 (I)
Flakiness index	12.32	<15	IS:2386 (I)
Water absorption	0.4	0.1-2	IS:2386 (III)
Specific Gravity	2.6	2-3	IS:2386 (III)
Los Angeles abrasion value	23	Max 30	IS:2386 (IV)

TABLE III Physical properties of Bitumen

CONSISTENCY CHARACTERISTICS	VG-30	SPECIFICATIONS OF VG-30	TEST STANDARDS
Penetration at 25^0C	55	50-70	IS:1203
Softening point(^{0}C)	47.5	Min 47	IS:1205
Ductility(cm)	50.33	Min 50	IS:1208
Absolute Viscosity (Poise)	2567	Min 2400	IS:1206(II)
Kinematic Viscosity ((cSt)	358.67	Min 350	IS:1206(II)

From the table results of aggregate and binder obtained as per MoRT&H guide lines for BC-1 mix and IS 73:2016 for binder properties.

b) Modified Binder

The rheological parameters dynamic shear rheometer test was conducted on the modified binder samples, test results are as presented in Table IV. The test was conducted under stress controlled mode at a frequency of 10 rad/s. and at a constant temperature of 135℃

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TABLE IV Results Of Dynamic Shear Rheometre

MEAN INTERVALS	PHASE ANGLE δ	COMPLEX MODULUS G* (Pa)	STRAIN (%)	G*/SIN δ(RUTTING PARAMETER) KPa	G* SIN δ (FATIGUE) KPa
P1	83.9	1.29E+04	12.1	14.142	13.828
P2	83.6	1.48E+04	13.3	10.9	12.314
P3	84.5	1.15E+04	14.1	9.24	9.56
P4	84.7	1.12E+04	15.1	10.68	10.585
P5	85.2	9.38E+03	15.1	9.86	9.781

From the test results is observed that 3% PPA has improved G*sinδ and G*/sinδ value.

c) Marshall Stability properties

TABLE V Sample Codes For Different Mixes

Suitable mix code was used for understanding the propertiesand is tabulated in table V

Mix No.	Description	Code
1	Conventional mix with virgin bitumen	Conv.
2	Conventional mix with glass fibre as an additive	CG
3	Conventional mix optimum with PPA as binder modifier	PPA
4	Modified bituminous mix with optimum of PPA along with glass fibre	CPPAG

Marshall Results of conventional mix is tabulated in table VI

TABLE VI Marshall Results For Conventional Mix

Binder content (%)	Stability (kN)	Air voids (%)	Bulk density (g/cc)
4	4.655	6.545	2.353
4.5	7.242	3.645	2.374
5	9.398	3.251	2.379
5.5	11.005	3.218	2.348
6	4.782	3.106	2.333

The optimum binder content for the conventional mix is obtained at 5%. with stability is 11.005 kN as shown in Table VI. PPA was added at regular interval to OBC of virgin mix and the result is tabulated in table VII

TABLE VII Marshall Results of modified bituminous mix with PPA

PPA (%)	Stabality (kN)	Air voids (%)	Demsity(g/cc)
1	9.56	7.36	2.38
2	10.25	6.10	2.40

3	11.68	4.15	2.452
4	8.56	2.46	2.432
5	7.52	2.38	2.36

From table VII it is observed that PPA at 3% provides better Marshall Properties, this is because of improved gel - type structure in mix combination.Based on the optimum PPA content in bitumen mix, glass fibre was added at 1,2,3,4, and 5% with weight of bitumen mix. The Marshall Results are depicted in fig 8.

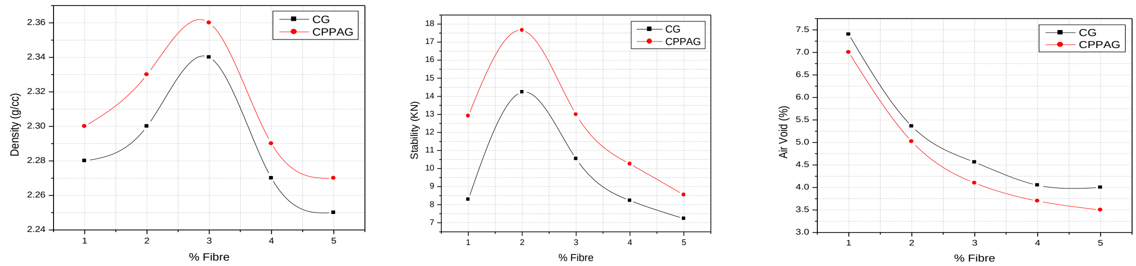

Fig.9 Stability, Air voids and Density for different CG and CPPAG mixes

The stability of fibre added to PPA mix is higher compared with only fibre mix. From above graph, the air void is also improved for acid fibre mix which is having good structure and interlocking properties.The optimum result is tabulated in table VII.

TABLE VIII Optimum Marshall Results For Mix Combinations

Mix Type	Binder Content (%)			
	Max Stability (kN) at	4% Volume of Voids (%) at	Max Bulk Density (gm/cc) at	Average Binder Content (%)
Conv	5.5%	4.3	5%	5
CG	2%	4.3	3%	3.1
PPA	3%	3	3%	3
CPPAG	2%	3.1	3%	2.7

d) Tensile Strength Ratio (TSR)

HMA mix has reduction in adhesion property between the surface of aggregate and binder its susceptible to moisture damage. The ITS is conducted to evaluate the damages due to moisture takes place in bituminous mix. TSR ratio is a measure of water sensitivity. It is the ratio of the tensile strength of soaked specimen, (ITS wet, 60˚C, and 24 h) to the tensile strength of un soaked specimen (ITS dry) which is expressed as a percentage.

TSR= S1/S2

S1 = Tensile Strength of soaked sample (MPa)

S2= Tensile Strength of un soaked sample (MPa)

The complete mix is said to perfect and having well resistance toward moisture damage only when the TSR value is high. The minimum of 0.70 to 0.80 .TSR is often used as a standard mentioned in ASTM D 4867.

TABLE IX Tensile strength ratio for different mix combination

Mixture Combination	Soaked (S1) MPa	Unsoaked (S2) MPa	TSR (S1/S2)
CONV	0.756	0.968	0.780
CG	0.862	1.045	**0**.824
CPPAG	0.959	1.064	0.901

The above result exhibit that CPPAG mix has better moisture susceptibility then other mix combination.

e) Resilient Properties

Repeated load test is performed to determine the resilient modulus for each combination. The results are shown in Table X.

TABLE X Repeated load test results

MIX	BINDER CONTENT %	LOAD (N)	HORIZONTAL DEFORMATION(MM)	TENSILE STRESS (MPA)	RESILIENT MODULUS (MPA)	INITIAL TENSILE STRAIN (MM)
CONV	5	950	0.006282	0.95	2416	0.000806
CG	3.1	1045	0.004389	1.045	2587	0.000828
CPPAG	2.7	1064	0.003585	1.064	2890	0.000754

f) Rutting behaviour

The rutting test is performed based on the standard of AASTHO- T 324 and used to the deformation behaviour of mix combination. In this paper three slabs were prepared at optimum binder cotent (OBC), optimum fibre content (OFC), optimum PPA content (OPPAC) and densities obtained from Marshall results. Bituminous mix prepared with glass fibre using PPA as an additive shows best result when compared with other mixes presented in Fig.9.

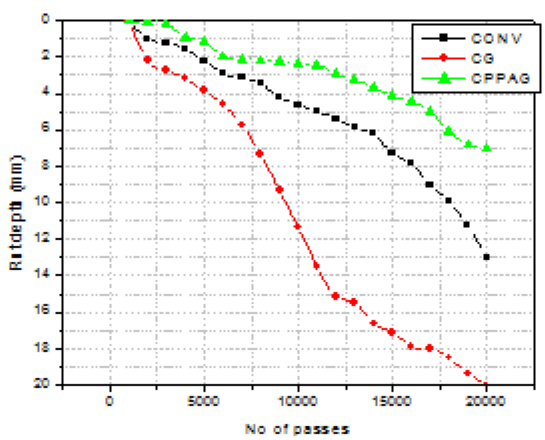

Fig.10 Rutting characteristics for different mix combinations

CPPAG mix provides better resistance towards rutting than other mix combination. This because of gel-type structure and improved void ratio results in rutting resistance for same number of wheel passes.

V. CONCLUSIONS

The following summary and conclusion are drawn from study

- Complex modulus and fatigue properties enhanced with addition of PPA when compared to conventional binder.
- Marshall properties were improved in CPPAG mix because of gel-type structure in PPA.,
- There is an improvement in moisture susceptibility, resilient property and resistance toward rutting for CPPAG mix combination.
- Hence acid modification with fibre provides better performance characteristics than conventional mix.

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