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Determination of Optimum Bitumen Content of Fibre Reinforced Bituminous Concrete

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Abstract:- The proposed work presents the studies on stability, flow, and volumetric properties of fibre reinforced bituminous concrete in comparison with properties of conventional bituminous concrete .Marshall's stability tests were conducted to determine optimum binder content of ordinary mix. By varying the amount of 10mm polypropylene fibre (4%,6%,8% and 10% by weight of bitumen) optimum fibre content was obtained as 5.33% by weight of binder. By varying the binder content (3.5%,4%, 4.5%, 5% and 5.5%) and keeping the optimum fibre content as constant, optimum bitumen content was determined (4.41% by weight of mix). The results indicate that addition of PP fibre increases the stability value and decreases the flow value.

Keywords:- Fibre reinforced, PP fibres, FRBC, Marshall's test, OBC

I. INTRODUCTION

The development of transportation plays an important role in the development of a nation. Bituminous Concrete (BC) is the most widely used material for pavement construction. Bituminous concrete pavements are often subjected to various types of distresses like rutting ravelling etc., due to repeated traffic load, high traffic density and heavy load. Since bituminous concrete pavements are widely used in India, steps must be taken to increase the life of these pavements.

Usage of modified binders with additives found to be effective in improving the performance of bituminous concrete pavements. A comprehensive review of the literature shows that polypropylene, polyester, coir and glass fibres are the most commonly used fibres in Fibre Reinforced Bituminous Concrete (FRBC). However Polypropylene (PP) fibres are preferred due to their low cost and good consistency. These fibres have been found to increase Marshall stability value and decrease flow value.

II. LITERATURE REVIEW

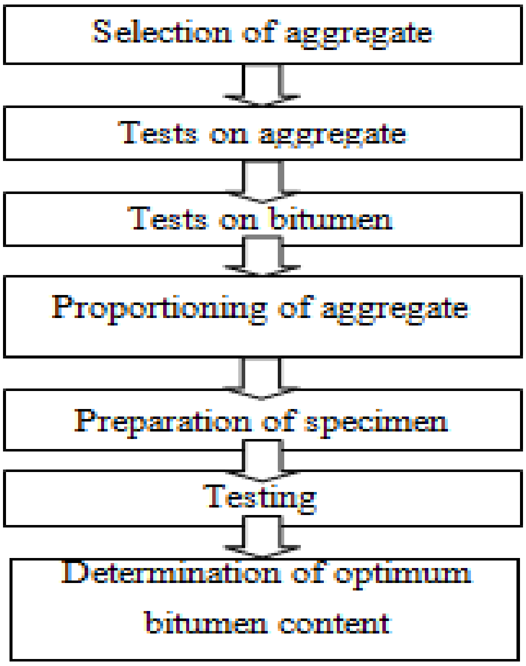
According to Remadevi M., Anjali G. Pillai, Elizabeth Baby George , Priya Narayanan addition of poly propelene fibres to bituminous mixtures increased the marshall stability value ad decreased the flow value. Addition of 5.33% of fibre and 4.83% of binder provide good stability and volumetric properties.

According to Ashok Pareek, Trilok Gupta and Ravi Sharma Polymer Modified Bitumen has high elastic recovery (79%), better age resistance, increment in marshall stability (27%) and high rutting resistance.

According to Abtahi, Ebrahimi, Kunt, Hejazi and Esfandiarpour addition of polypropelene fibre showed an increase in marshall stability (26.3%) and the percentage of air voids (67.5%) while decrease in flow property(38%).

According to Abtahi, Kunt, Hejazi and Ebrahimi**[1],** polypropylene fibre modified bituminous concrete samples exhibits superior performance compared to other fibre reinforced samples. Polypropylene fibres decreases penetration and ductility of modified bitumen while the softening point value is increased compared unmodified bitumen specimen. They also suggested that Polypropylene (PP) fibres are preferred due to their low-cost and good consistency with bituminous pavement.

III. METHODOLOGY



IV. MATERIAL PROPERTIES

The tests were conducted to ascertain various properties of selected aggregate and VG-30 bitumen. The results are shown in Table 1 and 2.

Table 1. PROPERTIES OF AGGREGATE

Sl.No	Property	Test Results
1	Aggregate crushing value	32%
2	Impact value	21%
3	Specific gravity	2.73
4	Los-Angeles Abrasion value	35%
5	Flakiness Index	11.92%
6	Elongation Index	13.82%

Table 2. PROPERTIES OF BITUMEN

No.	Properties	Test Results
1	Softening point of Bitumen	41.5°C
2	Ductility **Sl.**value	87cm
3	Specific gravity of Bitumen	0.98
3	Penetration value of Bitumen	66
5	Viscosity of Bitumen	70sec

Polypropylene fibres were selected for obtaining FRBC. The fibres were 100% virgin homo- polymer containing no reprocessed olefin material and were specifically engineered and manufactured in an ISO 9002 facility (Refer Table 3).

Table 3. CHEMICAL AND PHYSICAL PROPERTIES OF POLYPROPYLENE FIBRE

Absorption	Nil
Melting Point	324°F
Thermal Conductivity	Low
Acid and Salt Resistance	High
Specific Gravity	0.91
Ignition point	1,100°F
Electrical Conductivity	Low
Alkali Resistance	Alkali Proof

V. MIX DESIGN

The following steps were adopted for the rational design of bituminous mix:

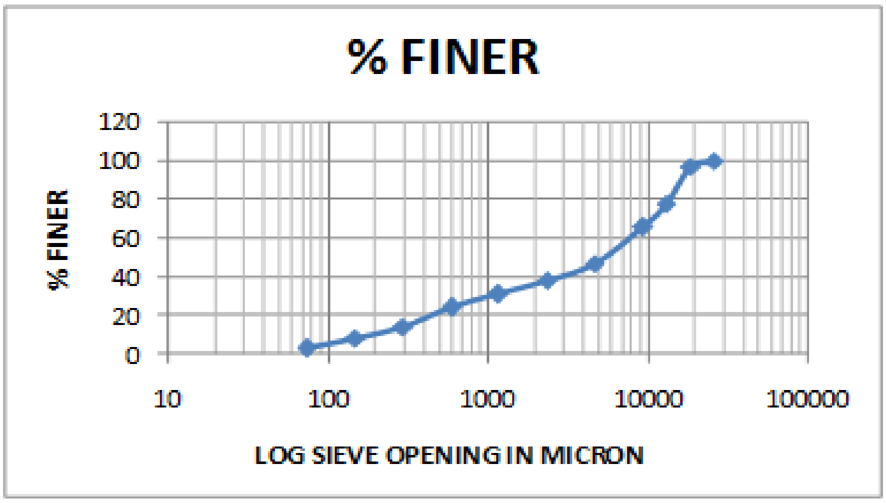
A. *Gradation of aggregate*

Aggregates which posses sufficient strength, hardness, toughness were chosen, keeping in view the availability and economic consideration. Aggregates of size 20mm (A), 12mm (B), 6mm (C) and M -sand were selected and graded.

Based on the individual grading of aggregates, a suitable gradation for the mix was arrived upon as shown in Table 4. Fig.1. shows the gradation curve of the selected proportion of aggregates

Table 4. FINAL GRADATION OF AGGREGATE

Size of sieve in mm	*% finer*	*MORTH Specification*
26.5	*100*	*100*
19	*97.5*	*79-100*
13.2	*78*	*59-79*
9.5	*65.8*	*52-72*
4.75	*47.2*	*35-55*
2.36	*38*	*28-44*
1.18	*31.02*	*20-34*
0.6	*24.2*	*15-27*
0.3	*14.4*	*20-10*
0.15	*8*	*13-5*
0.075	*3*	*2-8*
Pan	*0*	*0*



The following proportions were obtained:

Aggregate A- **15%**
Aggregate B- **25%**
Aggregate C- **15%**
Aggregate D- **45%**

B.Marshall test method- ordinary mix

To obtain the optimum bitumen content for the selected gradation of aggregates, test specimens were prepared with binder contents 4.5, 5, 5.5 and 6% by weight of mix. For each binder content, 3 specimens were prepared.

The graded aggregates were heated to a temperature of 150°c - 170°c and the required proportions of bitumen by weight of aggregates were also heated to a temperature of 150°c - 160°c. the heated bitumen and aggregates were mixed at temperature of 160°c. the test specimens were then cast and tested under specified conditions.

C. Marshall test method - Fibre reinforced mix.

To determine the optimum bitumen content, three specimens each with optimum fibre content but varying bitumen content of 3.5%, 4%, 4.5%, 5% and 5.5% by weight of aggregate were cast and the Marshall's test was conducted on them. The results are given in table 8& 9.

Applying the correction factors as per table 5, the Marshall Stability values and flow values were obtained and are tabulated in Table 6. Marshall Properties of the samples are shown in Table 7

Table 5: Correction Factors For Marshall Stability Values

Volume of specimen (cc)	*Thickness of specimen (mm)*	*Correction factor*
457 – 470	*57.1*	*1.19*
471 – 482	*58.7*	*1.14*
483 – 495	*60.3*	*1.09*
496 – 508	*61.9*	*1.04*
509 – 522	*63.5*	*1.00*
523 – 535	*65.1*	*0.96*
536 – 546	*66.7*	*0.93*
547 – 559	*68.3*	*0.89*
560 – 573	*69.9*	*0.86*

Table 6: Marshall Test Results Of Ordinary Mix

Bitumen by weight of mix (in %)	*Bitumen by weight of aggregate*	*Marshall value (in kg).*				*Flow (mm)*	
		observed	*correction*	*corrected*	*average*	*observed*	*Average*
4.5	*4.71*	*1407.8*	*0.93*	*1309.2*	*1440.53*	*4.9*	*4.42*
		1498.7	*0.93*	*1393.8*		*4.2*	
		1735.1	*0.93*	*1613.6*		*4.15*	
5.0	*5.26*	*1558.4*	*0.93*	*1449.3*	*1472.33*	*4.4*	*4.57*
		1610.38	*0.93*	*1497.65*		*4.8*	
		1580.7	*0.93*	*1470.1*		*4.52*	
5.5	*5.82*	*1062.3*	*0.96*	*1019.8*	*1122.1*	*4.9*	*4.75*
		1207.8	*0.96*	*1159.5*		*4.7*	
		1236.36	*0.96*	*1186.9*		*4.65*	
6	*6.38*	*1029.9*	*0.96*	*988.7*	*1040.2*	*4.85*	*4.86*
		1168.8	*0.96*	*1122.04*		*4.45*	
		1051.9	*0.96*	*1009.8*		*5.3*	

Table 7. Marshall Properties of Ordinary Mix

Bitumen by weight of mix (in %)	*Bitumen by weight of Aggregate*	*Weight*		*Bulk volume*	*Specific gravity*			*Volume % total*	*Voids (in %)*		
		In air	*In water*		*bulk*	*Bulk average*	*Theoretical maximum*	*bitumen*	*In aggregate (VM*	*Filled with bitumen (VFB)*	*In mix (V_V)*
4.5	*4.71*	*1192* *1207* *1195* **D.**	*690* *697* *695*	*502* *510* *500*	*2.37* *2.37* *2.39*	*2.38*	*2.56*	*10.25*	*17.81*	*57.55*	*7.56*
5	*5.26*	*1195* *1200* *1205*	*702* *727* *700*	*493* *473* *505*	*2.42* *2.54* *2.39*	*2.45*	*2.54*	*11.67*	*15.34*	*76.07*	*3.67*
5.5	*5.82*	*1205* *1210* *1185*	*707* *705* *682*	*498* *505* *503*	*2.42* *2.39* *2.36*	*2.39*	*2.52*	*12.46*	*17.90*	*69.61*	*5.44*
6	*6.38*	*1202* *1210* *1205*	*680* *686* *700*	*522* *524* *505*	*2.30* *2.31* *2.39*	*2.33*	*2.50*	*13.19*	*20.48*	*64.40*	*7.29*

Table 8 : MARSHALL PROPERTIES OF FRBC

Bitumen by weight of mix (in %)	Fibre by weight of Bitume	Weight		Bulk volume	Specific gravity			Volume % total	Voids (in %)		
		In air	In water		Bulk	Bulk average	Theoretical maximum	Bitumen	In aggregate (VMA)	Filled with bitumen (VFB)	In mix (V_V)
3.5	5.33	1188	668	520	2.28	2.3	2.54	8.39	18.79	44.65	10.4
		1203	686	517	2.33						
		1200	677	523	2.29						
4	5.33	1206	691	515	2.34	2.33	2.5	9.44	16.64	56.73	7.2
		1204	685	519	2.32						
		1200	685	515	2.33						
4.5	5.33	1206	685	515	2.33	2.35	2.48	10.7	16.2	66.04	5.5
		1203	694	509	2.36						
		1202	690	512	2.35						
5	5.33	1205	702	503	2.39	2.38	2.46	12.17	15.4	79.02	3.23
		1203	695	508	2.37						
		1205	701	504	239						
5.5	5.33	1202	698	504	2.38	2.38	2.44	13.05	15.64	83.43	2.59
		1206	700	506	2.38						
		1206	700	506	2.38						

Table 9. Marshall's Test Results of FRBC

Bitumen by weight of aggregate (in %)	*Fibre by weight of bitumen (in %)*	*Marshall value (in kg).*				*Flow (mm)*	
		observed	*correction*	*corrected*	*average*	*observed*	*average*
3.5	*5.33*	*1107.24*	*1*	*1107.24*	*1265.42*	*3.2*	*3.23*
		1344.51	*1*	*1344.51*		*2.3*	
		1594.96	*1*	*1594.96*		*4.2*	
4	*5.33*	*2095.85*	*1*	*2095.85*	*2139.79*	*3.9*	*3.27*
		1977.22	*1*	*1977.22*		*3.5*	
		2346.3	*1*	*2346.30*		*2.4*	
4.5	*5.33*	*1779.50*	*1*	*1779.50*	*1775.10*	*3.1*	*2.97*
		2003.58	*1*	*2003.58*		*3.1*	
		1542.23	*1*	*1542.23*		*2.7*	
5	*5.33*	*2029.95*	*1.04*	*2111.15*	*1769.75*	*3.2*	*3.2*
		1621.32	*1.04*	*1686.17*		*3.2*	
		1449.96	*1.04*	*1507.95*		*3.2*	
5.5	*5.33*	*1146.78*	*1*	*1146.78*	*1384.05*	*3.8*	*3.8*
		1094.06	*1*	*1094.06*		*3.8*	
		1911.31	*1*	*1911.31*		*3.8*	

Fig.2. PP Fibres mixed with bitumen

V. RESULTS

The graphs were plotted for ordinary mix and FRBC with bitumen content on X-axis andfollowing values on Y-axis

1.marshall stability
2. flow value
3. %voids in total mix
4. unit weight
5. VFB

A. Ordinary mix

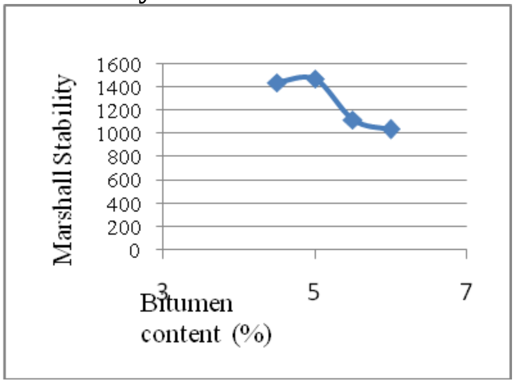


Fig. 3. Stability v/s Bitumen content

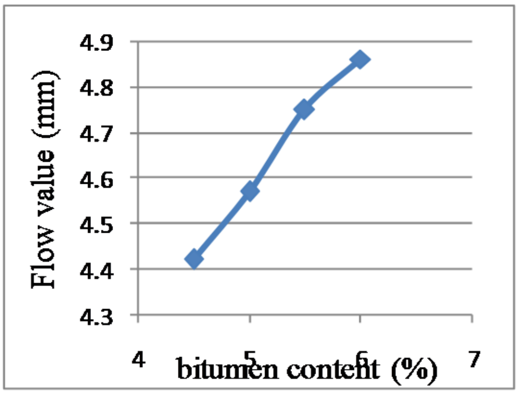


Fig. Flow value v/s Bitumen content

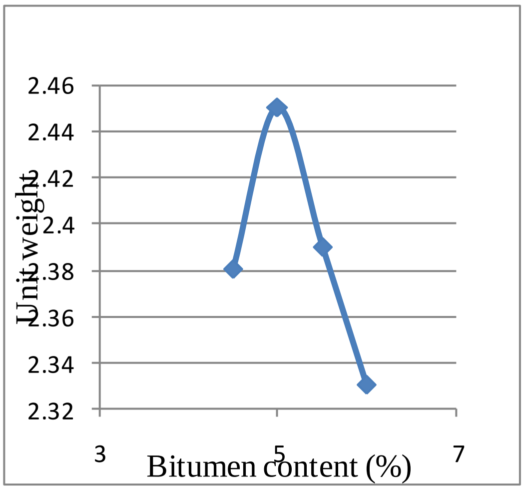


Fig. 5. Unit weight v/s Bitumen content

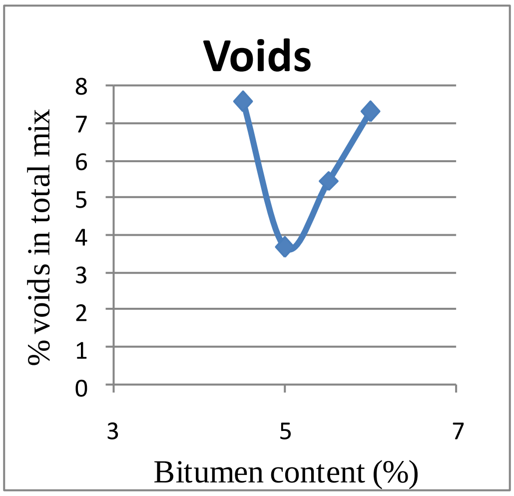


Fig. 6. %voids in mix v/s Bitumen content

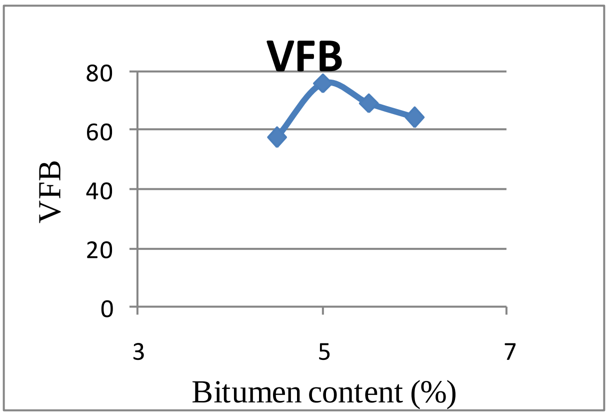


Fig. 7. VFB v/s Bitumen content

The optimum bitumen content of the mix is calculated by taking the average of bitumen content obtained from above graphs.

1. Bitumen content corresponding to maximum stability
2. Bitumen content corresponding to unit weight
3. Bitumen content corresponding to median of % of air voids in total mix.

The optimum binder content is 4.83% by weight of mix.

B. FRBC Mix.

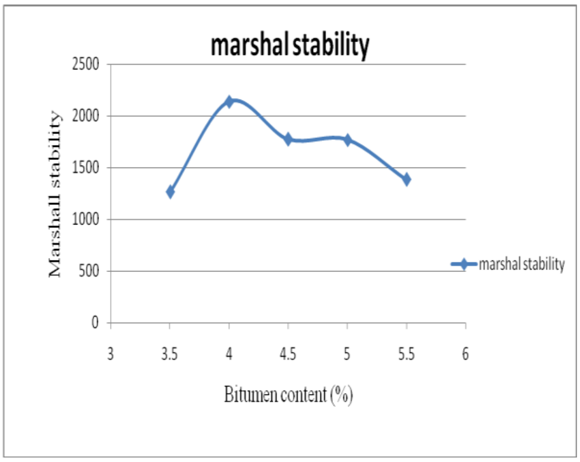


Fig.8. Stability v/s Bitumen content

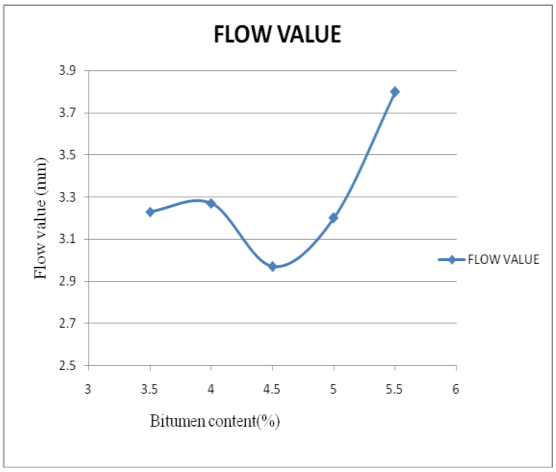


Fig .9. Flow value v/s Bitumen content

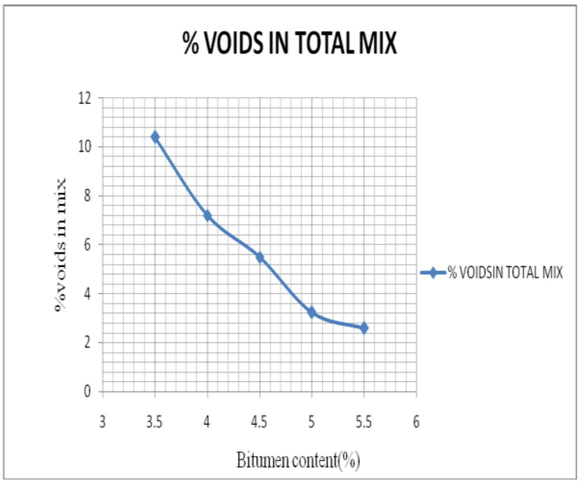


Fig. 10. % voids in mix v/s Bitumen content.

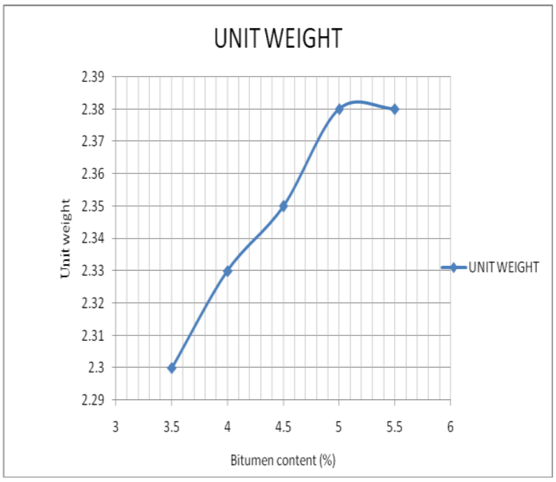


Fig .11. Unit weight v/s Bitumen content

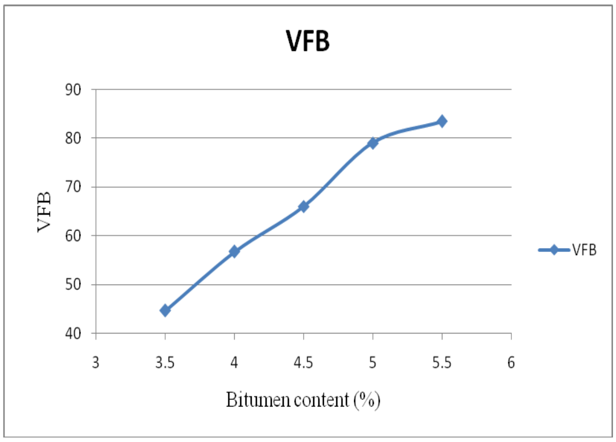


Fig .12. VFB v/s Bitumen content

The optimum bitumen content of the mix is calculated by taking the average of bitumen content obtained from above graphs.

1. Bitumen content corresponding to maximum stability
2. Bitumen content corresponding to unit weight
3. Bitumen content corresponding to median of % of air voids in total mix.

The optimum binder content is 4.41% by weight of mix

VI. CONCLUSION

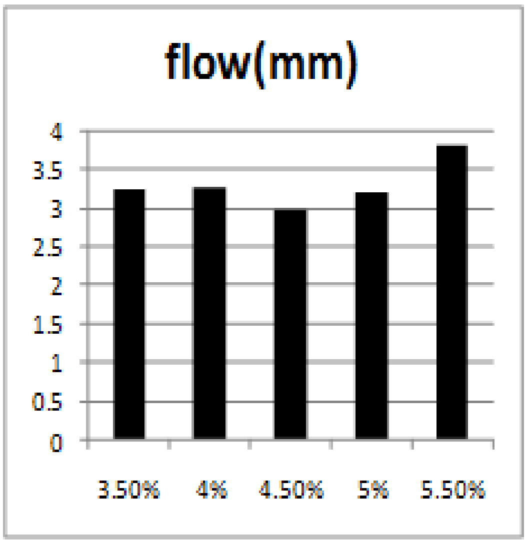


Fig. 13.Variation of flow value

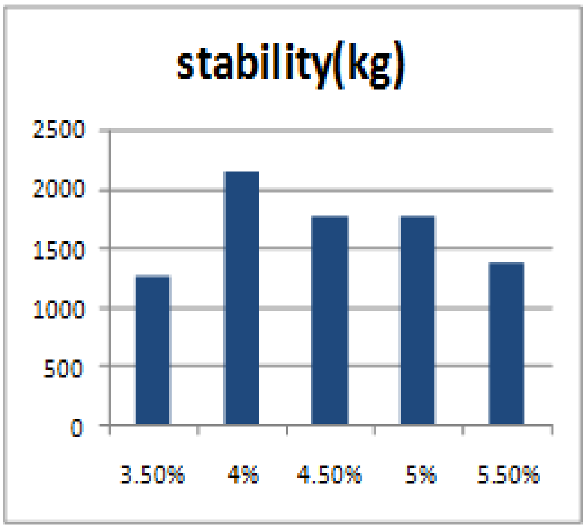


Fig.14. Variation of Marshall Stability Value

The addition of PP fibre to bituminous mixtures increased the stability value and decreased the flow value as depicted in fig 13 and 14. A fibre content of 5.33% and binder content of 4.41% provide good stability and volumetric properties. The variation in stability and flow values improves the structural resistance of bituminous concrete to distresses occurring in flexible pavements.

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