

OPTIMIZATION OF PERMEABLE PAVEMENT SUITABLE FOR ALL TRAFFIC CONDITIONS

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering Degree in civil engineering

By

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SATHYABAMA

**INSTITUTE OF SCIENCE AND
TECHNOLOGY (DEEMED TO BE
UNIVERSITY)**

Accredited with Grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **AMRUTHA SHESHADRI (37200004)** and **KAVIMOZHI R (37200032)** who carried out the project entitled **“OPTIMIZATION OF PERMEABLE PAVEMENT SUITABLE FOR ALL TRAFFIC CONDITIONS”** from JANUARY 2021 TO MARCH 2021.

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DECLARATION

We **AMRUTHA SHESHADRI (37200004)** and **KAVIMOZHI R (37200032)** hereby declare that the Project Report entitled **“OPTIMIZATION OF PERMEABLE PAVEMENT SUITABLE FOR ALL TRAFFIC CONDITIONS”** done by us under the guidance of Mrs. **M.PRABA** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering Degree in Civil Engineering

DATE:

PLACE:

SIGNATURE OF THE CANDIDATE

1.

2.

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ABSTRACT

Porous asphalt pavements are an alternative technology that differs from traditional asphalt pavement designs in which the structure permits fluids to pass freely through it, reducing or controlling the amount of run-off from the surrounding area.. Even though this technology is efficient for storm water management, it is not yet used as a traditional pavement or replacement. It is because of the greatest limitation of porous asphalt pavement. Porous asphalt pavement cannot withstand heavy traffic and heavy vehicular loads. The goal is to optimize or identify a proper methodology to make porous asphalt pavement susceptible to all traffic conditions and vehicular loads and also to induce a material or add an admixture to mitigate this limitation of heavy loading condition. Based on multiple references Glass fibre and Polyester resin were used as additive. Glass fibre was used to improve the stability and strength mainly to increase the load withstanding capacity and Polyester resin was used to improve the bonding behaviour as well as adhesion property of porous asphalt pavement. Marshal method of bituminous mix design was carried out for different percentages of VG-30 grade bitumen to determine the different characteristics of mix design on adding the additives. These additives were added with various bitumen contents among them specimen with 5% bitumen content with both additives polyester resin and glass fibre showed appreciable stability, flow character and bonding was also good.

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LIST OF SYMBOLS AND ABBREVIATIONS

°C	Degree Celsius
%	Percentage
CBR	California Bearing Ratio
IRC	Indian Road Congress
IS	Indian Standard
PAP	Porous Asphalt Pavement
OGFC	Open Graded Friction Course
VG	Viscosity Grade
PVC	Poly Vinyl Chloride
°c	Degree Celsius
Kg	Kilogram
Sec	Second
mm	Millimeter
Gms	Grams
VMA	Voids in Mineral Aggregate
VFB	Voids Filled with Bitumen
ml	Milliliter

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Pavement is a surface which hard generally of asphalt or concrete that is a road or driveway. They are generally classified into two Flexible and Rigid. Different types of pavement are generally hot mix asphalt, porous asphalt, fine or coarse grade asphalt, stone mastic asphalt, concrete and composite.

Flexible pavements are which reflect the deformation of sub- grade and the subsequent layers to the surface for which asphalt is generally laid over the surface without giving any reinforcement. Flexible pavement is so named as the pavement surface reflects the total deflection of all subsequent layers due to traffic load acting upon it. The main advantage of flexible pavement is that it can be opened for traffic within 24 hours after completion.

Porous asphalt pavements are also known as permeable pavement, these pavements vary a lot from traditional asphalt pavements with a unique characteristic of allowing water to drain and uses open graded frictional course (OGFC). Permeable pavement allows storm water management but cannot withstand heavy vehicular load and heavy traffic. They are mainly used for roads, parking lots, and pedestrian walkways.

1.2 INFERENCE FROM LITERATURE REVIEW

1. Porous asphalt pavement is rough textured, and has a honeycombed surface, with moderate amount of surface ravelling which occurs on heavily travelled roadways.
2. The void space in porous asphalt should be 10 to 15 percent This empty space allows water to infiltrate the underlying soil instead of either pooling on the surface or being discharged as runoff.
3. High bitumen content is used in this porous asphalt mix so that thicker film of bitumen is obtained to avoid premature oxidation of bitumen.

4. PAP does not exhibit cracking and pothole formation problems. It works best on flat or gently sloping areas.
5. PAP limited its use for heavy loading areas where sharp turns are probable.
6. In order that the stone-on-stone contact condition is achieved in Porous Asphalt pavements, it demands the use of modified binders such as Polymer modified Bitumen or Crumb Rubber modified Bitumen.
7. PAP removes water from the surface of a roadway much faster than traditional dense-graded pavement and it can be used for parking lots, recreational areas, low-volume roads and streets.
8. Mineral filler with hydrated filler improves asphalt resistance with water and also increases permanent deformation
9. The effect of nano- Silica material and alkali resistant glass fiber on the OGFC asphalt mixture reduces porosity and improved rutting resistance by 50%.
10. Effect of modified asphalt with SBS polymer on mechanical properties of recycled pavement mixture that is, % of SBS modified mixture gave the best results due to its improvement of mechanical properties.
11. Modified OGFC mixes with different polymers and fibers have comparable performance. Mainly fibers decrease rutting by 19% and polymers decrease rutting by 7%, fibers found to be more effective than polymers, glass fibers showed 24% reduction in permanent deformation than other additives.
12. Adding graphene oxide to PAP helps to obtain thick and strong binder films and reduces permanent deformation but it is not economical.
13. The use of ferrous, non ferrous and non metallurgical slag aggregate products boosts the durability and strength of pavement.
14. Dynamic and rutting performance of recycled asphalt mixtures on addition of anti-stripping agents were satisfactory in the case of improving rutting resistance and greater engineering performance and had higher dynamic modulus.

CHAPTER 2

2.1 AIM

To optimize and to identify a proper methodology to make permeable pavement susceptible to all kinds of vehicular loads and heavy traffic and to design the estimation of road per 1km.

2.2 OBJECTIVE

- To control surface run-off and flood control management.
- To induce a material or add an admixture to mitigate this limitation of heavy loading condition.
- To identify a proper methodology to make PAP susceptible to all kinds of vehicular loads and heavy traffic.
- To design estimation of road per 1KM.

CHAPTER 3

3.1 METHODOLOGY

- Problem Identification
- Collection of Related Case studies
- Selection of Materials
- Collection of Materials
- Tests on Samples (Aggregate & bitumen)
- Marshall Mix design
- Preparation of mould
- Test on bituminous mix
- Test Result Analysis
- Conclusion
- Estimation of road per 1KM
- References

3.2 MATERIALS SPECIFICATION

3.2.1 ASPHALT

Asphalt, also known as bitumen is a sticky, black, and highly viscous liquid or semi-solid form of petroleum which is obtained by the method of fractional distillation. VG -30-graded bitumen was used.



Fig 3.2.1 Asphalt

3.2.2 COARSE AGGREGATE

Locally available crushed granite stones are used based on sieve numbers as per IS - 37 (2001). The nominal size of aggregates used are 12.5 mm, 10 mm.



Fig 3.2.2 Coarse aggregate

3.2.3 ADDITIVES (GLASS FIBER AND POLYESTER RESIN)

Glass fiber is a material consisting of numerous extremely fine fibers of glass. Glass fibers are used as reinforcement of polymers in various fields. One of the principal advantages of using glass fiber for reinforcement of polymers is their high performance per cost ratio and it is economical, easily available.

Polyester resins are synthetic resins formed by the reaction of dibasic organic acids and polyhydric alcohols. Resin is used to improve the adhesion property of bituminous mix and for proper binding.



Fig 3.2.3 additive (glass fiber and polyester resin)

EXPERIMENTAL WORKS

3.3TEST FOR ASPHALT

3.3.1 DUCTILITY TEST

This test helps to measure the adhesion property of bitumen which can identify how the bonding of bitumen varies with several materials. Ductility generally measures the stretching ability of bitumen with the code provision IS: 1208.

Table No.3.3.1Ductility test (IS 1208-1978)

GRADE OF BITUMEN	VG-30
TEST TEMPERATURE	18°C
DUCTILITY VALUE	114



Fig 3.3.1.1 Briquette Apparatus



Fig 3.3.1.2 ductility test

3.3.2 FLASH AND FIRE POINT TEST

Application temperature and mixing temperature of bitumen varies accordingly for different grades. It is very much important to know the temperature at which bitumen can get ignited so that it doesn't turn out to be harmful. Temperature at which bitumen takes up fire in the form of a flash or a spark is called as flash point. After ignition there is temperature at which the material continues to burn this point is called as flash point.

Table No.3.3.2 Flash and fire point test (IS 1209-1978)

FLASH POINT	233°C
FIRE POINT	298°C



Fig 3.3.2.1 Flash and fire point test



Fig 3.3.2.1 flash and fire point test

3.3.3 SOFTENING POINT TEST

Softening point is the temperature at which bitumen achieves the particular degree of softening. Temperature up to which bitumen could be heated is determined from conducting softening point test

Table No.3.3.3 Softening point test (IS 1205-1978)

SL.NO:	SOFTENING POINT (°C)	MEAN (°C)
BALL 1	46.4	46.5
BALL 2	46.7	



Fig 3.3.3.1 Ring and ball apparatus



Fig 3.3.3.2 softening point test

3.3.4 VISCOSITY TEST

Test is carried out to resist the flow and bitumen is classified based on various viscosity grades.

Table No.3.3.4 Viscosity test (IS 1206-1978)

Viscosity value (for VG-30 grade bitumen)	2400 poise
--	------------



Fig 3.3.4.1 viscosity apparatus



Fig 3.3.4.2 viscosity test

3.3.5 PENETRATION TEST

It is very essential to know the hardness as well as softness of bitumen. Penetration test also helps to understand the consistency of bitumen.

Table No. 3.3.6 Penetration test (IS 1203-1978)

SAMPLE	PENETRATION (mm)	
	READINGS	MEAN
SAMPLE 1	79	76.33
	76	
	74	
SAMPLE 2	79	76
	75	
	74	
SAMPLE 3	80	76
	75	
	73	



Fig 3.3.5.1 penetration test



Fig 3.3.5.2 penetration test

3.4 TEST ON AGGREGATES

3.4.1 LOS ANGELES ABRASION TEST

Test is used to determine the abrasion and toughness characteristics of aggregates taken.

Table No. 3.4.2 Los Angeles Abrasion test (IS 2386-1963 IV)

SAMPLE	WEIGHT OF AGGREGATE TAKEN (W1) Kg	WEIGHT OF AGGREGATE PASSING (W2) Kg	ABRASION VALUE (%)
Sample 1	5	1.424	28.48
Sample 2	5	1.295	27.91
Sample 3	5	1.365	27.35
		Average	27.91



Fig 3.4.1 Los Angeles Abrasion Test

3.4.2 SHAPE TEST

Test to identify and determine the relative shape of aggregate so that it will be helpful to segregate the aggregates for different purposes.

Table No. 3.4.3 Shape test (IS: 2386-I)

3.4.2.1 FLAKINESS INDEX

SAMPLE	WEIGHT OF AGGREGATE TAKEN (W1) kg	WEIGHT OF AGGREGATE PASSING (W2) Kg	FLAKINESS INDEX (%)
SAMPLE 1	2.604	0.094	3.6
SAMPLE 2	2.809	0.102	3.63
SAMPLE 3	2.724	0.075	2.7
		AVERAGE	3.3

3.4.2.2 ELONGATION INDEX

SAMPLE	WEIGHT OF AGGREGATE TAKEN (W1) Kg	WEIGHT OF AGGREGATE RETAINED (W2) Kg	ELONGATION INDEX (%)
SAMPLE 1	2.604	1.065	40.89
SAMPLE 2	2.809	1.154	41.08
SAMPLE 3	2.724	1.109	40.70
		AVERAGE	40.9



Fig 3.4.2.1 flakiness test



Fig 3.4.2.2 elongation index

3.5 SPECIFICATION USED FOR THE MIX DESIGN

Open graded for porous asphalt pavement is as per NAPA specification (National Asphalt Pavement Association).

3.5.1 GRADATION AS PER NAPA SPECIFICATION

Table 3.5.1 gradation as per NAPA specification

SIEVE SIZE IN MM	% PASSING
20	100
12.5	85-100
10	55-75
4.75	10-25
2.36	5-10
1.18	-
0.6	-
0.075	2-4

3.5.2 SIEVING AND GRADATION FOR OUR MIX

Table 3.5.2 Sieving and gradation for our mix

IS SIEVE (mm)	%PASSING	%RETAINED	QUANTITY OF AGGREGATES FOR VARIOUS BITUMEN CONTENT (gm)		
			5%	5.5%	6%
20	100	0	0	0	0
12.5	93	7	80	80	80
10	65	28	332	332	332
4.75	17	48	568	568	568
2.36	5	12	140	140	140
1.18	-	-	-	-	-
0.6	-	-	-	-	-
0.075	3	2	20	14	8

3.6 MIX DESIGN & QUANTITY OF MATERIALS REQUIRED

Table 3.6.1 MIX DESIGN CALCULATION AND QUANTITY FOR CONVENTIONAL MOULD

QUANTITY OF MATERIALS CORRESPONDING TO VARIOUS PERCENTAGE OF BITUMEN			
MATERIALS	5%	5.5%	6%
AGGREGATES REQUIRED (gm)	1140	1134	1128
BITUMEN CONTENT (gm)	60	66	72

Table 3.6.2 MIX DESIGN CALCULATION AND QUANTITY FOR MOULD (GLASS FIBER + RESIN)

Various % of bitumen (%)	Quantity of aggregate (gm)	Quantity of bitumen (gm)	Quantity of glass fiber (gm)	Quantity of polyster resin (gm)
5%	1140	52.8	4.8	2.4
5.5%	1134	58.8	4.8	2.4
6%	1128	64.8	4.8	2.4

TABLE 3.6.3 MIX DESIGN FOR ONLY GLASS FIBER AS ADMIXTURE

Various % of bitumen (%)	Quantity of aggregate (gm)	Quantity of bitumen (gm)	Quantity of glass fiber (gm)
5%	1140	50.2	4.8
5.5%	1134	61.2	4.8
6%	1128	67.2	4.8

TABLE 3.6.4 MIX DESIGN FOR (ONLY POLYSTER RESIN AS ADMIXTURE)

Various % of bitumen (%)	Quantity of aggregate (gm)	Quantity of bitumen (gm)	Quantity of resin (gm)
5%	1140	57.6	4.8
5.5%	1134	63.6	4.8
6%	1128	69.6	4.8

3.7 MARSHALL STABILITY TEST



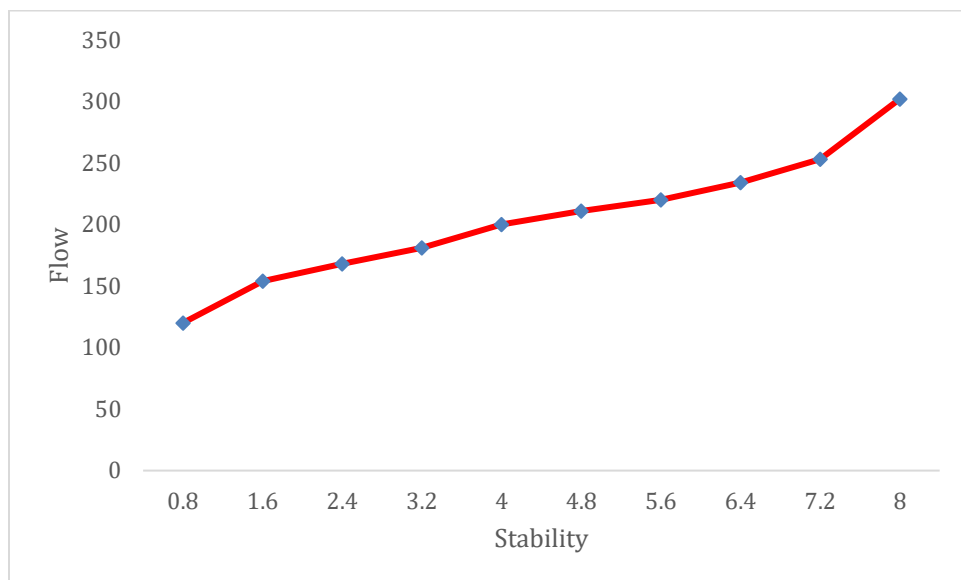
Fig 3.7.1 MARSHALL STABILITY TEST APPARATUS



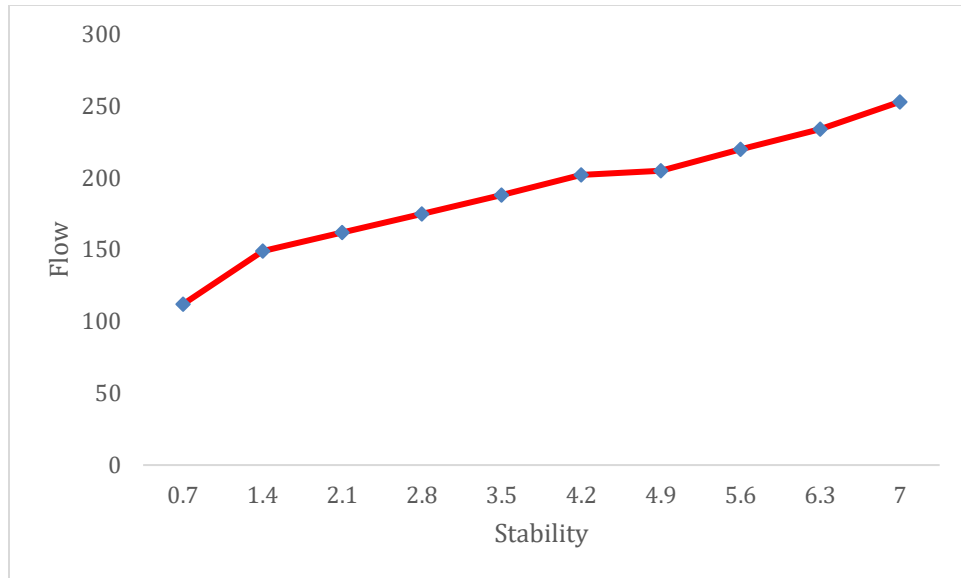
Fig 3.7.2 DIAL GAUGE READINGS

3.8 GRAPH FROM MARSHALL STABILITY TEST

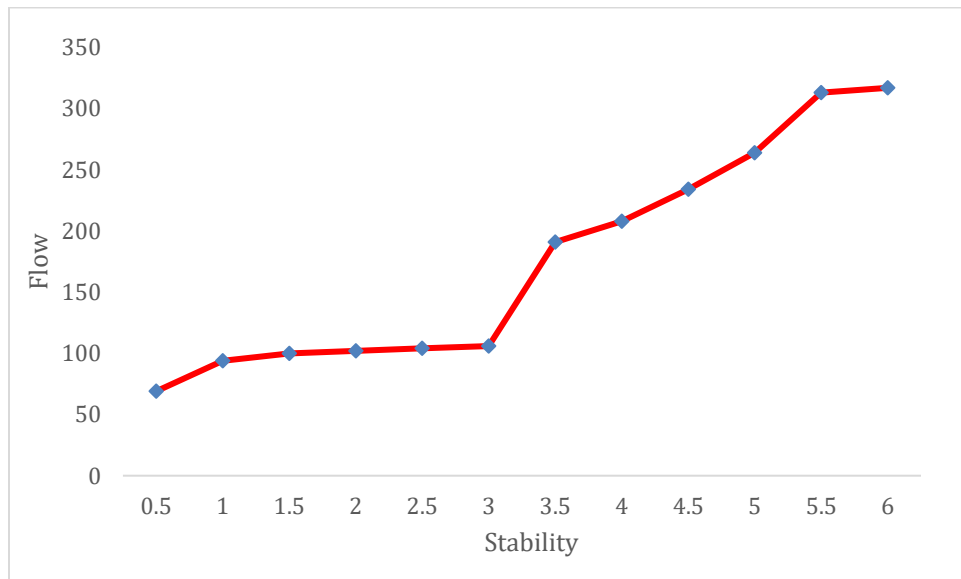
STABILITY Vs FLOW GRAPH FOR 5% BITUMEN CONTENT



5% BITUMEN CONTENT WITH GLASS FIBRE AS ADMIXTURE

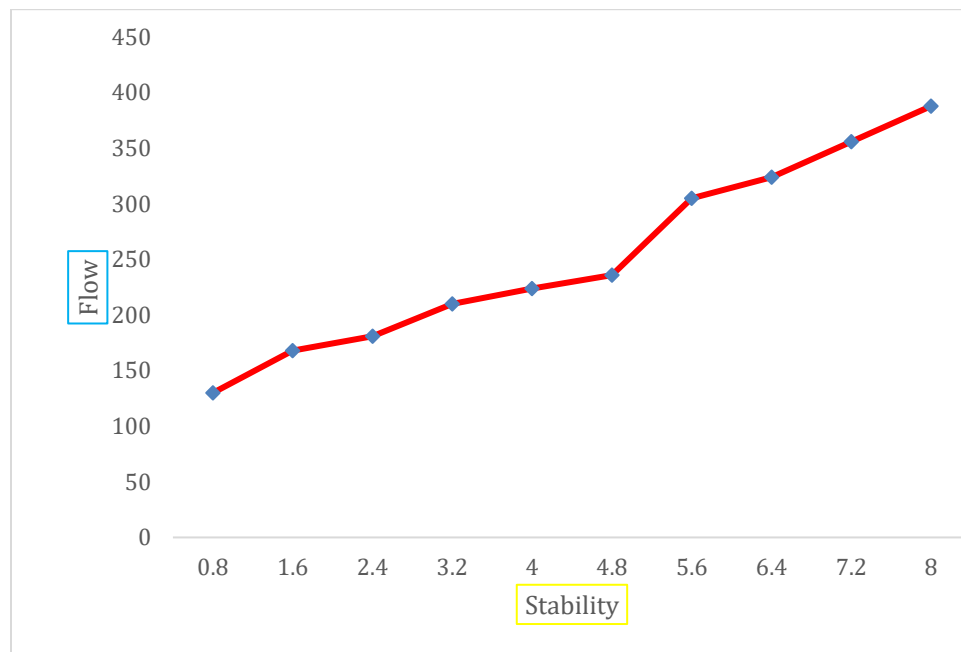


5% BITUMEN CONTENT WITH ONLY POLYESTER RESIN AS ADDITIVE

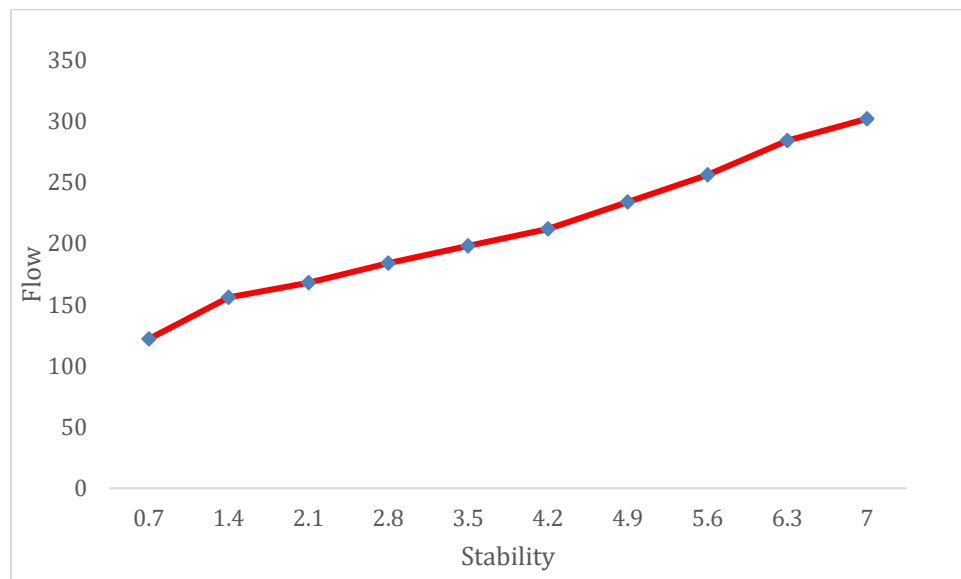


5%BITUMEN CONTENT WITH BOTH GLASS FIBRE AND POLYESTER RESIN

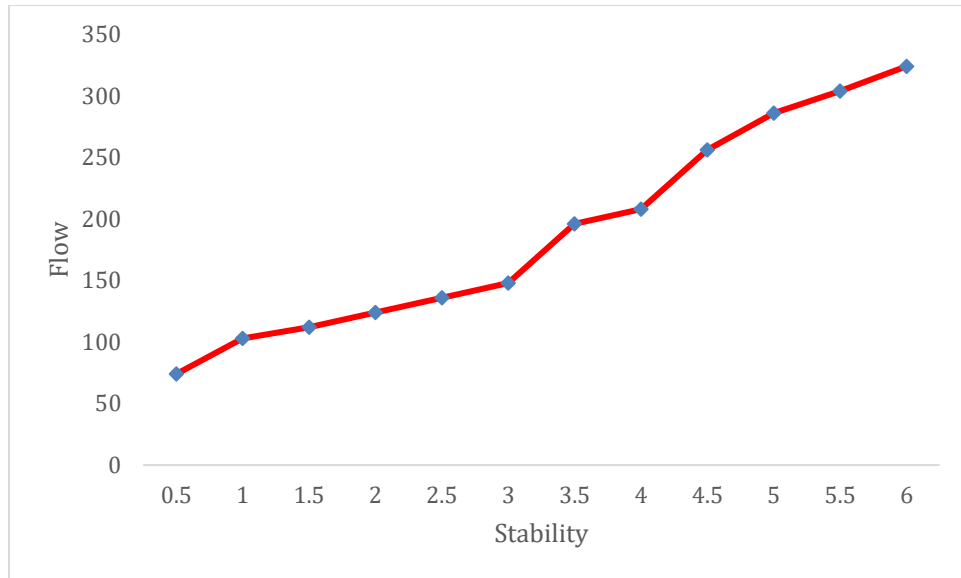
STABILITY Vs FLOW GRAPH FOR 5.5% BITUMEN CONTENT



With only glass fibre (5.5% bitumen content)

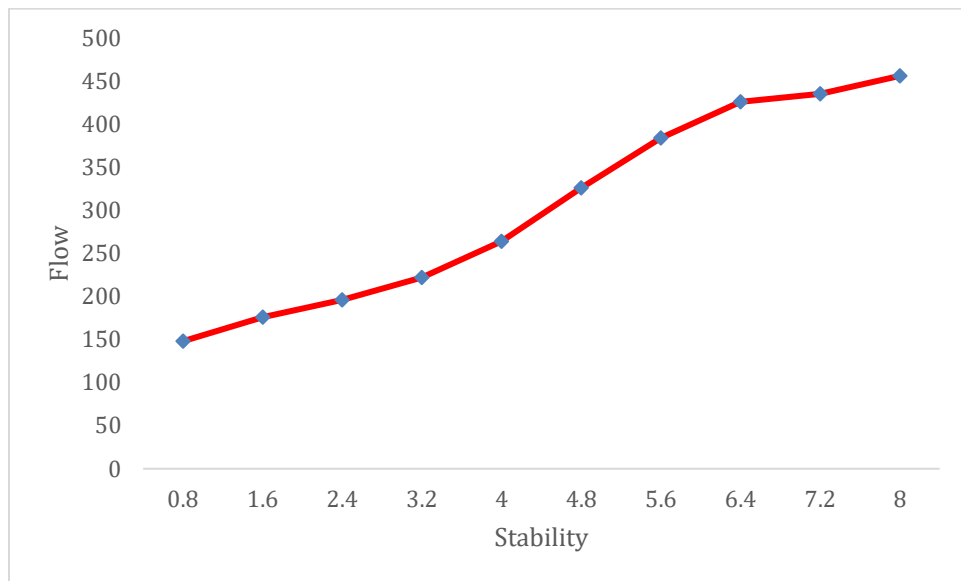


With only Polyester resin as an additive (5.5% bitumen content)

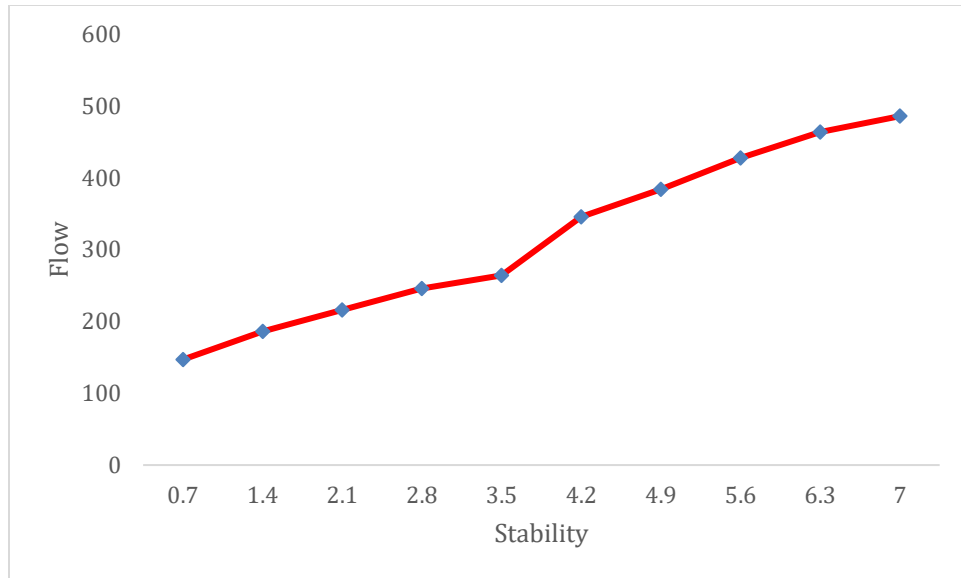


Glass fibre + Polyester Resin (5.5% bitumen content)

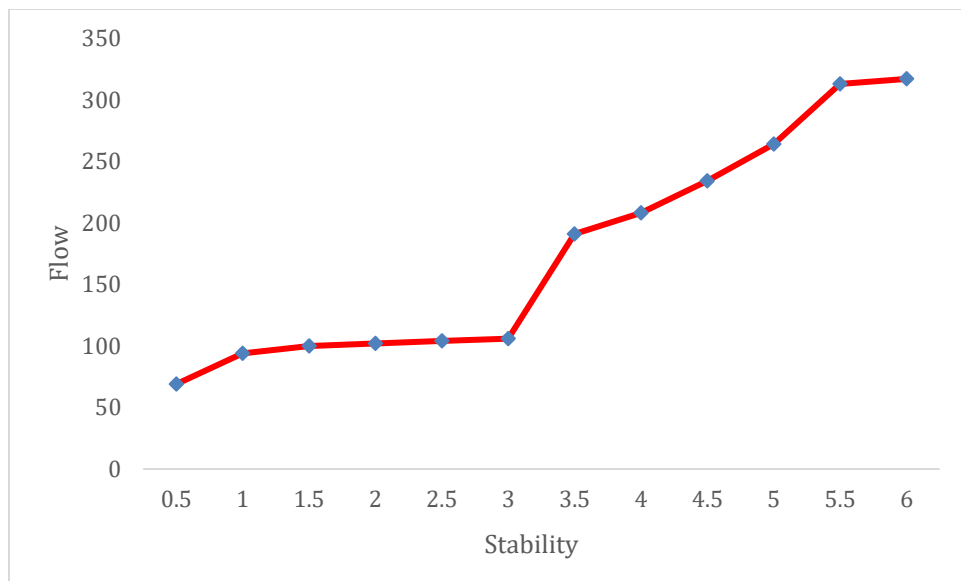
STABILITY Vs FLOW GRAPH FOR 6% BITUMEN CONTENT



Only glass fibre as additive (6% bitumen content)



Only polyester resin as an additive (6% bitumen content)



Glass fibre + Polyester Resin (6% bitumen content)

3.9 ESTIMATION OF ROAD PER 1KM

QUANTITY OF ASPHALT

$$\begin{aligned}\text{Volume of asphalt} &= L*B*H \text{ cu.m} \\ &= 1000*7*0.075 \\ &= 525 \text{ cu.m}\end{aligned}$$

$$\text{Density of asphalt} = 2330 \text{ kg/cu.m}$$

$$\begin{aligned}\text{Asphalt in tons} &= \text{Volume}*\text{Density} \\ &= (525*2330)/1000 \\ &= 1223.25 \text{ tons}\end{aligned}$$

QUANTITY OF GLASS FIBRE

$$\begin{aligned}\text{Volume of glass fibre} &= L*B*H \text{ cu.m} \\ &= 1000*7*0.075 \\ &= 525 \text{ cu.m}\end{aligned}$$

$$\text{Density of glass fibre} = 2.44 \text{ g/cu.cm}$$

$$\begin{aligned}\text{Glass fibre in KG} &= \text{Volume}*\text{Density} \\ &= (525*2.44) \\ &= 1.281 \text{ Kg}\end{aligned}$$

QUANTITY OF POLYESTER RESIN

$$\begin{aligned}\text{Volume of polyester resin} &= L*B*H \text{ cu.m} \\ &= 1000*7*0.075 \\ &= 525 \text{ cu.m}\end{aligned}$$

Density of polyester resin = 1.5 g/cu.cm

Polyester resin in KG = Volume * Density

$$= (525 * 1.5)$$

$$= 0.7875 \text{ Kg}$$

QUANTITY OF FINE AGGREGATE

Volume of fine aggregate = L * B * H cu.m

$$= 1000 * 8 * 0.1$$

$$= 800 \text{ cu.m}$$

Density of fine aggregate = 1600 kg/cu.m

Fine aggregate in tons = Volume * Density

$$= (800 * 1600) / 1000$$

$$= 1280 \text{ tons}$$

QUANTITY OF COURSE AGGREGATE

Volume of course aggregate = L * B * H cu.m

$$= 1000 * 8 * 0.25$$

$$= 2000 \text{ cu.m}$$

Density of course aggregate = 1500 kg/cu.m

Course aggregate in tons = Volume * Density

$$= (2000 * 1500) / 1000$$

$$= 3000 \text{ tons}$$

QUANTITY OF SOIL

GRAVEL

$$\begin{aligned}\text{Volume of gravel} &= L \times B \times H \text{ cu.m} \\ &= 1000 \times 8 \times 0.15 \\ &= 1200 \text{ cu.m}\end{aligned}$$

$$\text{Density of gravel} = 1800 \text{ kg/cu.m}$$

$$\begin{aligned}\text{Gravel in tons} &= \text{Volume} \times \text{Density} \\ &= (1200 \times 1800) / 1000 \\ &= 2180 \text{ tons}\end{aligned}$$

COMPACTED SOIL

$$\begin{aligned}\text{Volume of compacted soil} &= L \times B \times H \text{ cu.m} \\ &= 1000 \times 8 \times 0.2 \\ &= 1600 \text{ cu.m}\end{aligned}$$

$$\text{Density of compacted soil} = 2200 \text{ kg/cu.m}$$

$$\begin{aligned}\text{Compacted soil in tons} &= \text{Volume} \times \text{Density} \\ &= (1600 \times 2200) / 1000 \\ &= 3520 \text{ ton}\end{aligned}$$

Bitumen content	Nominal Stability value (KN)	Conventional (KN)	Glass fibre (KN)	Resin (KN)	Combined (KN)
5%	10.6	9.6	9.0	8.9	10.8
5.5%	8.9	8.1	7.6	8.0	9.0
6%	8.5	7.9	7.2	7.8	8.75

Table 3.8 Result comparison of stability values

CONCLUSION

- Among 5%, 5.5% and 6% bitumen content that we have selected, 5% bitumen content was ideal comparatively based on the performance that 5.5% and 6%.
- For the specimen that was added with combination of glass fiber and resin (5% bitumen content) showed much improved characteristics than the specimen with only glass fiber, resin and also than the conventional specimen.
- Specimen with only glass fiber showed less strength and weak binding among the bituminous mix.
- Specimen with only resin showed great bonding and improved adhesion property with the bituminous mix but stability was not that appreciable.
- From 5%, 5.5%, 6% *without any admixture* that is the conventional specimen showed that specimen with mix of 5% bitumen content was appreciable.
- It is also noted that specimen with increased bitumen content can also be a reason for the failure.
- *For specimens with only glass fiber as admixture:*
 - 5% - glass fiber did not mix well with the entire bituminous mix and strength and stability were partial.
 - 5.5% - bonding was weak and strength and ability was not appreciable.
 - 6% - poor bonding and stability. Specimen collapsed after extruding from the mould
- *For specimens with only polyester resin as additive:*
 - 5% - It exhibited increased adhesion property which also improved the stability and flow value.
 - 5.5% - bonding was appreciable but it decreased the stability character as well as the deflection corresponding to the stability.
 - 6% - Specimen collapsed which affected bonding due to increased bitumen content.
- *For specimen with glass fiber and polyester resin:*

- 5% - appreciable bonding due to improved adhesion property and good stability and flow character. It can be used for heavy loads.
- 5.5% - stability was comparatively less than 5 %. Bonding was appreciable.
- 6% - poor characteristics in terms of stability and flow. Adhesive character was appreciable. Due to increased bitumen content fractures occurred on the surface of specimen at the time of extruding.

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