Comparable Study of Semi-Flexible Pavement with Variable Grouts (Cement vs Hydrated Lime)

Jahanzaib Malik[1], Shamsuddin Babar Memon[1], Muhammad Bilal Memon[1], Arshyan Memon[1], Abdullah Memon[1], Rizwan Ali Memon[1]

[1]*Department of Civil Engineering, Mehran UET-Jamshoro, Sindh, Pakistan*

***Abstract*: Semi-flexible pavement is a composite pavement that unifies the advantages of flexible and rigid pavement by producing open porous asphalt skeleton and filling the voids with selected fluid grouts. Almost 95% of pavements are flexible pavements, due to less initial cost, although for heavy traffic and repeated loads, rigid pavement commonly used, because of its durability. Semi-flexible pavement exercised due to its cost effectiveness (in comparison with concrete pavement). It is composed of Open-graded asphalt and fluid grout. Open-graded Asphalt made in such a way that it contains air voids about 25-30%, while fluid grout is a mixture of cementitious material and water that penetrates in the voids of Open-grade asphalt. Our present study involves designing of pavement which is beneficial for the environment and is sustainable with respect to strength, aimed at these targets we fabricated Semi-flexible pavement with grout of lime, It is the binder that fulfills a purpose of reducing pollution by hardening (as it absorbs carbon). Furthermore, to check its feasibility for strength, we compare its compressive strength and indirect tensile strength with Semi-flexible pavement made with cement grout. The results shows us that there was slight variation in both the strength (compressive and indirect tensile). So using Semi-flexible pavement with lime grout for roads as wearing course will be feasible for the environment.**

***Keywords*: Semi-flexible Pavement, Open-graded-Asphalt, fluid Grout, Lime, Cement.**

I. INTRODUCTION:

The local road networks as well as the main highway roads in Pakistan are commonly made with HMA (hot mix Asphalt pavement) apart from this type of pavement, flexible or we can also refer as asphalt pavement, another common pavement in Pakistan is concrete pavement nowadays bricks of concrete are used, also known as paver roads , these are laid usually in streets , junctions , tool plazas , signals and all areas expected to resist breaks of heavy vehicles as well in those streets where the road is quite vulnerable due to regular flooding (flooding due to rain) due to bad sewerage systems and to avoid the regular and costly maintenance. These paver roads are more durable than the asphalt roads but the cost does not allow us to use it everywhere so we usually use it for small lengths where the road is vulnerable to breaking, heavy loads or in streets. The former type (Asphalt pavement) is cheaper than concrete pavement but it often come across problems like rutting, raveling leading to deuteriation of roads and need of regular maintenance, talking about the latter type we come across same problems in addition to its maintenance causes increase in travelling by the joints created. Well the developed countries often try to find the solution and one solution of these above mentioned problem was found and named as Semi-flexible pavement, this pavement was first used in France due to its cost effectiveness at an airport, this pavement is a type of composite pavement and is composed of Asphalt bed (hot mix asphalt with 25-30% voids) and cement binder grout to fill the pores in the Asphalt bed. As it adds the properties of both pavement its this payment is most suitable than asphalt as it gives more strength and also is cost-effective and cheaper than Concrete pavement.

II. LIETRATURE REVIEW

A. Semi-flexible Pavement:

SFP is a composite pavement, composed of Asphalt bed with 25-30% air voids and these voids are filled with cement or any other binder, with this same purpose of adding the advantages of both flexible and rigid pavement, this is used in different regions and different countries with different names such as Semi-rigid pavement, resin modified pavement densiphalt. In countries such as UK and France, this pavement has shown positive results when used at main roads.

B. Fabrication of Semi-Flexible Pavement:

i. *Fluid Grout*:

Fluid grout consisted of water with cementing binder which hardens and gains strength after curing. Water content in the fluid grout plays a vital role as its proportion is harmful in both conditions either greater or less than the optimum. If the water content in the fluid grout is greater than the optimum it will reduce its strength and if it's less then fluid grout won't penetrate inside open-graded asphalt under the action of gravity. Therefore, we require optimum water content for the fluid grout which according to the literature is the water content whose flow time is b/w 8-12 seconds in marsh flow cone test the marsh cone.

ii. *Open-graded Asphalt***:**

Open-Graded asphalt consists of optimum bitumen content and certain aggregate gradation. Open-graded asphalt with 25-30% air voids plays a very significant role in the construction of Semi-flexible pavement, if the number of voids in the mixture become less than required the mixture won't allow the grout to fully penetrate consequently we will get an unsound surface course which is favorable to be deteriorated under traffic loading. While if the number of voids are greater than the required it won't be feasible (cost will increase , strength and interlocking b/w aggregates will decrease).

iii. *Laboratory Sample preparation***:**

From the literature, we got the proper procedure to prepare the Open-graded asphalt. It requires a compaction hammer of 4 in diameter known as Marshall hand hammer, for 25-30% air voids the number of blows are 25 after compacting the Asphalt is left for 24hours at room temperature. grout is prepared at the proportions already tested and is poured on the open-graded Asphalt and is made to fill the voids under the action of gravity, the sample is observed carefully the sample is observed carefully and grout is filled until the air bubbles rise onto the surface. The sample left at room temperature for 24 hours after that it is left in the water for curing so that it can gain strength. The curing depends upon the strength required.

III. MATERIALS:

The materials used in this thesis are listed below

1) Bitumen
2) Mineral Aggregate
3) Cement
4) Lime
5) Sand
6) Superplasticizer

A. Bitumen:

To check the quality and properties of the bitumen binder to be suitable for design, following empirical tests were carried out and results are presented below in table . 1

Table. 1. Physical Properties of Bitumen

Physical tests	Results
Penetration(AASHTO T-49, ASTM D-5)	60-70
Ductility (AASHTO T-51, ASTM D-113)	140cm
Softening point(AASHTO T-53, ASTM D-36)	25
Specific Gravity(AASHTO T--288,ASTM D--70)	1.034
Flash and fire point(AASHTO T-48,ASTM D-92) 1) Flash point 2) Fire point	 1) 280°C 2) 330°C

B. Mineral Aggregate*:*

The aggregate used in this study were of 4 different sizes these are 19-16mm, 16-13mm, 9-5mm and 5-0mm are were collected from a plant Near toll plaza N-55 Indus highway. The aggregate were initially checked w.r.t their physical properties (table #2) and then blending of aggregates were performed with certain aggregate gradation (figure. 1).

Table #2 Physical properties of Mineral Aggregates

Laboratory test	Results
Abrasion test (AASHTO 96, ASTM C131)	27.3%
Impact test (AASHTO T--85, ASTM C--127)	16.45%
Shape test (AASHTO T--304 , ASTM C--1252) 1) Elongation 2) Flakiness	 1) 12.8% 2) 26%
Soundness test(AASHTO T-104, ASTM C-88)	6.22%
Static emersion test(AASHTO T-182 ASTM D-3625)	6.5%

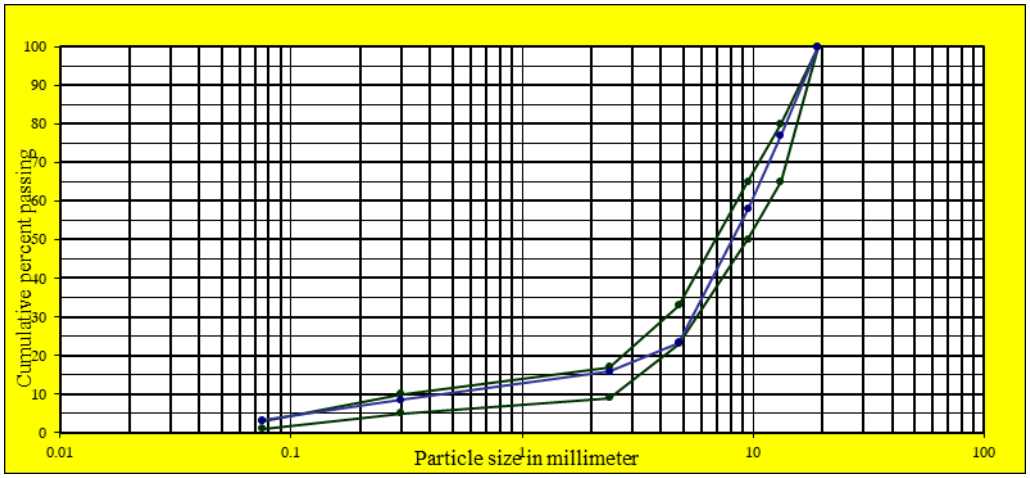


Fig. 1. Aggregate Blending graph

C. *Cement:*

The cement used in this study was ordinary Portland cement of grade 43 of Elephant's brand having the following composition in the table. 3.

Table. 3. Chemical composition of OPC

Lime (CaO)	60-67%
Silica (SiO_2)	17-25%
Alumina(Al_2O_3)	3-8%
Iron Oxide (Fe_2O_3)	0.5-6%
Magnesia(MgO)	0.1-4%
Sulphur trioxide (SO_3)	1-3%
Soda and/or Potash (Na_2O+K_2O)	0.5-1.3%

D. Lime:

The lime used in this thesis was in powdered form of Hydrated Lime having the chemical Composition shown in the table. 4

Table. 4. Chemical Composition of Hydrated Lime

Calcium Hydroxide($CaOH_2$)	>85%
Magnesium Hydroxide(MgO)	<0.8%
Iron Oxide(FeO_2)	<0.3%
Aluminum Oxide(Al_2O_3)	0.4-0.8%
Silicon Dioxide(SiO_2)	<1.3%

E. Sand:

The sand used in the fluid grout to improve shear strength. Sand used in this research was meeting the requirement of AASHTO C33 and was free from clay particles, also its grading was done and sand used was passing #40 and retaining on #200 sieve was used.

F. Superplasticizer:

MasterRheobuild® 561, naphthalene and sulphonate based water reducing (high range)/ superplasticizer admixture that helps to improves the final strengths of concrete by reducing amount of water. The range defined to use is 1-2kg if 100 kg of binder is used.

Table. 5. Superplasticizer Specification

Structure of material	Naphthalene Sulphonate Based
Color	Brown
Density	1.142-1.202kg/liter
Chloride content %	<0.1
Alkaline Content %	<10

IV. RESEARCH METHODOLOGY:

A. Conventional Mix Asphalt:

Marshal Mix design method was used to obtain the optimum bitumen content in this study and for this a total of 15 samples of hot mix asphalt were prepared at 5 different bitumen content from 3.5% to 5.5% at 0.5% interval. A mix of 1200 grams of bitumen and mineral aggregates was prepared and heated at 160ºC-170ºC and then the mixing was done at a temperature of 160ºC and it was mixed until it gained homogeneity, after getting a homogeneous hot mix it was poured in a mold of 100mm dia mold and compacted with 75 number of blows.

B. Preparation of porous Asphalt Skeleton:

The porous Asphalt skeleton was obtained at optimum Bitumen content found out using Marshal mix Design. A total of 1200 grams of bitumen and aggregate mix was heated at temperature of 160^0C-170ºC afterwards it was mixed by maintaining the temperature of 160ºC to obtain homogeneity, after it gained homogeneity it was filled in a mold of 100mm dia and compacted with 25 number of blows from one side only.

C. Preparation of Fluid Grout:

Different mix design for fluid grout were tested on trial and error basis to obtain the flow time between 8-12 seconds. The sand and Binder (Cement or Lime) were taken in proportion given in tables 6 and 7 and were mixed evenly and then water and Superplasticizer were taken on weight of binder and were mixed evenly with each other then this water containing the Superplasticizer was poured in the mechanical mixer already containing sand and binder mixture, initially only ¾ of water and plasticizer was mixed then after the mixture gained homogeneity almost in 1 minute then the remaining mix was added and it was mixed for another 2 minutes. The volume taken to mix was around 1200ml and after the fluid grout of this volume was prepared without wasting any time it was filled in the marsh cone and the time was calculated for 1000ml grout passing the marsh cone. In this way both the Cement grout and the lime grout were prepare following tables will illustrate the successful proportions of fluid grout design.

Table. 6. Design of Cement Grout

Blend#01	Proportions by weight			Plasticizer	Flow time
	Lime	Sand	W/c		(sec)
1)	1	0.5	0.4	2%	33.4
2)	1	0.5	0.5	2%	28.9
3)	1	0.5	0.6	2%	23.7
4)	1	0.5	0.65	2%	17.6
5)	1	0.5	0.70	2%	13
6)	1	0.5	0.75	2%	11

Table.7. Design of Lime Grout

Blend#	Proportions by weight			Plasticizer	Flow time
	Cement	Sand	W/c		(sec)
	1	0.5	0.4	1.5%	22
	1	0.5	0.45	1.5%	18
	1	0.5	0.5	1.5%	14.3
	1	0.5	0.55	1.5%	11.35
	1	0.5	0.57	1.5%	10.95
	1	0.5	0.6	1.5%	10.3

V. LABORATORY PREPARATION OF SAMPLES:

For the Preparation of Laboratory Samples of Semi-Flexible Pavement We firstly design Open Graded Asphalt and Fluid grout ,then the Samples of Open grouted Asphalt were Place on the vibrating table and the grout was impregnate into the Asphalt the vibrating table was switched on for 30 seconds afterwards the sample was observed for 2 minutes and was continue to impregnate until the air voids stopped coming onto the surface of the sample. Then the sample was left to dry for after 1-2 days

it was opened from molds and was left for curing under water. After the completion of curing periods the sample were taken out from water and were tested for Compressive as well as indirect Tensile strength in Universal Testing Machine.

VI. RESULTS:

A. Conventional properties of hot mix Asphalt**:**

Following table. 8 shows the result of Compacted hot Asphalt mixture, the Results are of Stability, flow, Maximum Dry Density.

Table. 8. Conventional Properties of Hot Mix Asphalt

Bitumen Content %	3	3.5	4	4.5	5
Stability(kgf)	2232	2639	2006	1490	991
Flow(mm)	6.63	6.9	7.2	7.8	8.6
Unit Weight	2.256	2.274	2.286	2.282	2.279
VMA(%)	14.6908	14.4534	14.4469	15.0405	15.5968
VFB(%)	44.5548	53.256	61.2133	66.0316	70.6583
V_v	8.14534	6.756	5.6034	5.10904	4.5764

B. Volumetric and Mechanical Properties of Marshal Mixture:

Figure 2 shows the relation of stability vs bitumen content in hot mix Asphalt by increasing the bitumen content the stability increases up to a point an then it starts decreasing that peak is known as the maximum stability of the hot Mix Asphalt. The maximum Stability is achieved at 3.5% bitumen content and that is 2639kgf.

Figure 02

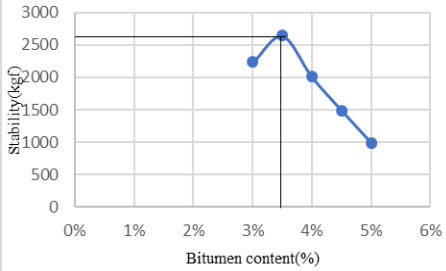
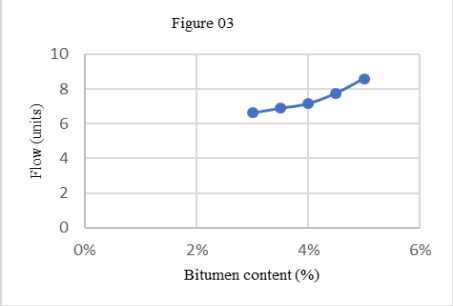


Figure 3 shows the relationship between Flow and bitumen content and from the graph it shows that the relation is directly

Figure 03



proportion as by increasing bitumen content the flow increases.

Figure 4 shows relationship between unit weight and bitumen content and the graph shows two phases, in first phase by increasing the bitumen content the unit weight increases and after it reaches its peak point it shows its second phase inverse relation by increasing bitumen content unit weight decreases, in this relation we get maximum unit weight of 2.286 at 4% bitumen content.

Figure 04

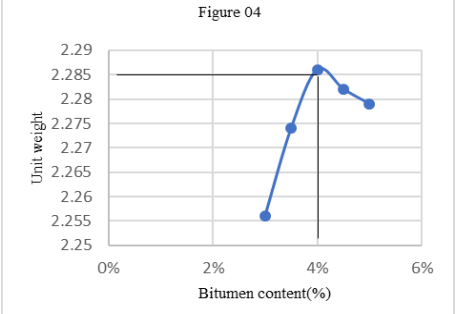


Figure 5 shows the relationship between bitumen content and air content and shows a liner decreasing or say an inverse relation by increasing bitumen content the air voids or content in the Hot mix Asphalt decreases. The minimum required air content we leave in the Hot mix Asphalt is 4% as this content needed to resist the segregation. From this graph we get 5.5% bitumen content at 4% air content.

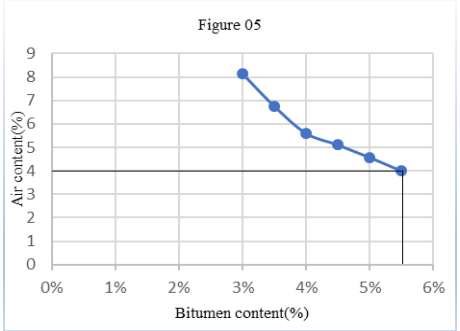


Figure 6 shows the relationship between bitumen content and VMA and this graph shows two phases, the first phase shows an inverse relation by increasing bitumen content after reaching its minimum point of 14.447 at 4% bitumen content it shows a direct relation by increasing bitumen content the voids increases in the aggregates.

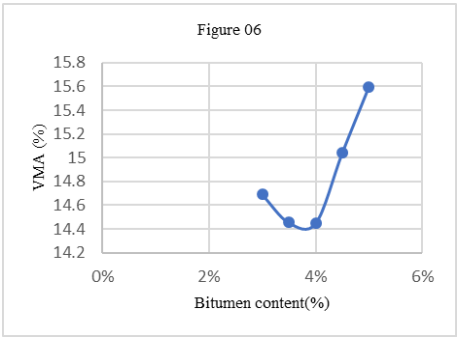
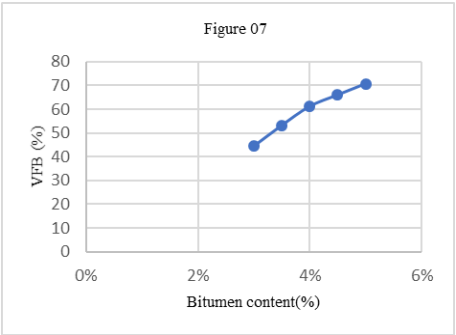


Figure. 7 shows relationship between bitumen content and VFB and we can see from that graph there is a directly proportional relation between bitumen content and VFB, by increasing bitumen content VFB increases.



A. Calculation Of Optimum Bitumen Content:

Using the above graphs in figure 2,4 and 5 we found following bitumen Contents

- Bitumen Content at Maximum Unit Weight = 4%
- Bitumen Content of Maximum Stability= 3.5%
- Bitumen Content at 4% Air Content= 5.5%

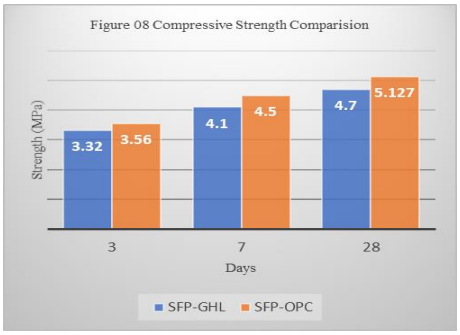
Therefore average of these 3 is 4.33%, so our Optimum Bitumen Content is 4.33%.
For open graded hot mix asphalt concrete optimum bitumen content found as 4.35%, there proportion of mix for the porous asphalt concrete skeleton given below.

Table. 9. Properties of Hot Mix Asphalt at Optimum Bitumen Content

Properties	Values at optimum Bitumen content
Stability (Kgf)	1748
Flow in 0.01%	7.45%
Unit Weight	2.284
Air Content	5.4%
VFB	63.5
VMA	14.7%

C. Compressive Strength Test:

After Curing of the Samples of Semi-flexible Pavement they were placed for under water at 60°C for 30 minutes for aging afterwards it was tested for Compressive strength in UTM machine. Below Figure 8 shows the comparison of Semi-flexible Pavement with both Cement and Lime Grouts



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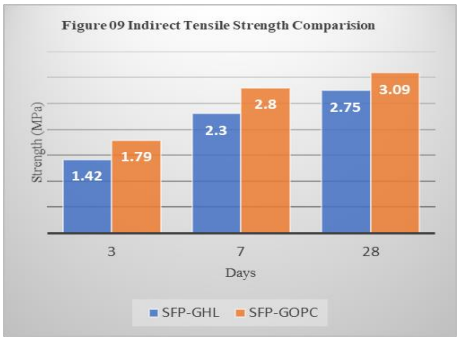
D. Indirect Tensile Strength Test*:*

After Curing of the Samples of Semi-flexible Pavement they were placed for under water at 60°C for 30 minutes for aging afterwards it was tested for Indirect Tensile strength in UTM machine. Below Figure 09 shows the comparison of Semi-flexible Pavement with both Cement and Lime Grouts.



VII. CONCLUSION:

The purpose of thesis was to fabricate the Semi-flexible pavement with two different grouts and compare both in strengths i.e. compressive and flexural (indirect tensile) strength . The results shows that the strength of Semi-flexible Pavement for 28-days of curing has a little decrement, if we use hydrated lime instead of Ordinary Portland cement say about 9-11% decrement, but this decrease is very less as compare to the environment friendly nature of hydrated lime.

VIII. RECOMMENDATIONS:

The main goal of this research was to compare strength but it also contains fabrication of Semi-flexible Pavement, here are few recommendations that we recommend with respect to our research and also with respect to the utility.

- The use of Semi-flexible Pavement impregnated with lime grout on roads as wearing surface will be feasible in this developing country where, on daily basis new machines or factories etc. are manufactured or constructed respectively , As it's nature of reducing pollution will perform a essential role in green construction.
- The mix-design SFP-GHL can be altered by replacing with various proportions of cement , to decrease the decrement in strength.
- Investigation can be made for the change in strength by different aggregate gradation in the design of SFP-GHL.
- Investigation of the variation in parameters of skid resistance, durability and abrasion resistance can be made for the design of SFP-GHL and SFP-GHL.

- An investigation for economic management can be made in design of SFP-GHL and SFP-GHL.
- A practical research in construction and evaluation of SFP-GOPC and SFP-GHL roads in Pakistan can be made.

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