A Comparative Study Of Roller And Hammer Compacted Asphalt Concrete

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Abstract

In this work, Dense and Gap graded Asphalt Concrete samples were compacted in the laboratory using two modes, the first one was the traditional Marshall method of hammer compaction; Cylindrical specimens were constructed using three different Asphalt percentages; While the second mode was the TRRL roller wheel compaction, slab samples of (30×30×7) cm were constructed using the same Asphalt percentages, core specimens were obtained from the slabs. All of the Asphalt Concrete specimens were subjected to Marshall properties determination, indirect tensile stress test, Hveem stability and cohesion tests. A comparative analysis of testing results was conducted. It was concluded that Dense graded Asphalt Concrete shows superior quality when compared to Gap graded one when roller wheel compaction was adopted. Gap graded Asphalt Concrete shows higher quality when Marshall Hammer compaction was adopted.

الخلاصة

تم في هذة الدراسة تحضير الخرسانة الاسفلتية بنوعين- عالية الكثافة ؛ وذات النواقص بالتدرج- في المختبر باستخدام طريقتين؛ الاولى كانت طريقة مارشال التقليدية بالضغط بالمطرقة؛ حيث تم تحضير نماذج اسطوانية بنسب اسفلت مختلفة؛ بينما كانت الطريقة الثانية باستخدام الضغط بالحادلة المدولبة والعائدة لمختبـر بحـوث المواصلات و الطرق البريطاني حيث تم تصنيع نماذج سقفية ذات ابعاد 30*30*7 سم وباعتماد نفس نسـب الاسفلت السابقة؛ تم استخراج عينات لباب من هذه النماذج السقفية.
تعرضت جميع نماذج الخرسانة الاسفلتية المشار اليها لفحوص الخصائص المارشالية؛ الشد غيـر المباشـر؛ ثبات وتلاصق هيفيم .
اجري تحليل مقارن للنتائج وتم الاستنتاج بان الخرسانة الاسفلتية عالية الكثافة تكون بنوعيـة متفوقـة عنـد مقارنتها بالخرسانة ذات النواقص في التدرج وباستخدام الضغط بالعجلة المدولبة؛ بينمـا تعطـي الخرسـانة الاسـفلتية ذات النـواقص فـي التـدرج نوعيـة افضـل عنـد ضغطها بالمطرقـة.
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Introduction

The variation of mode of compaction in the laboratory and in the field is vital in evaluation of Asphalt Concrete quality and life. The Marshall method of mix design usually uses hammer compaction, while in the field; Rollers do the compaction of Asphalt Concrete in a different mode using both vibration and dynamic loading.

The gradation of aggregate in a paving mixture is one of the factors that must be carefully considered in a mix design, because it affects directly or indirectly the stability, durability, skid resistance, and economy of the finished pavement. Examination of the aggregate gradation requirements in specifications used by various state highway departments in the U.S.A., Canada, Iraq, and some European countries reveals that, with few exceptions such as the British standard 594, they are approximately matching to the Fullers maximum density curves (B.S.1961;S.O.R.B.1983), or densely graded.

The demand is increasing for high quality and more durable paving mixture for modern traffic. Cost for producing maximum density or well graded aggregate is also increasing because of rapid depletion of natural deposits that meets the specifications of continuous grading, and because of increased cost of labor, transportation and processing. It is therefore desirable to examine the suitability of other types of aggregates grading as compared to well graded maximum density mix, so that more efficient use can be made of the available sources of aggregates.

On the other hand, it was believed that conventional sample preparation such as that of Marshall method which uses small compacted cylindrical specimens could be replaced by another method better adapted to the new requirements that must be met by Asphalt Concrete. It was felt that the roller wheel compactor developed by TRRL is more representative of conditions at the job site. The roller wheel compactor could give more homogeneous samples in which the element arrangement pattern come close to those obtained on the job site.

Previous Experience

Gradation of aggregate to a curve of maximum density, developed by (Fuller and Thompson-1909) and later modified and confirmed by a number of other investigators (Lees-1973) is generally accepted as the most desirable grading for the production of good and economical Portland Cement and Asphalt Concrete. These grading are also referred to as well graded or continuously grading. On the other hand, an aggregate is said to be gap graded or (skip or discontinuously graded) when certain particle sizes in the grading of aggregate are missing. The absence of such sizes can be achieved by deliberately omitting them to obtain certain desired properties of the mixture.

A large amount of literature, especially theoretical, can be found on the packing of aggregate particles and maximum density or minimum porosity grading including the classical work on concrete proportioning by (Fuller and Thomption-1909). There is also abundant published information on gap graded concrete as compared to the corresponding continuously graded concrete(Lees-1973; Sarsam-2002); However, reported data on gap graded Asphalt Concrete mixtures are few and scattered (Brien-1972; Lees-1974; Marias-1979; Sarsam-1987). The effect of gradation (Dense and Gap) on physical properties of asphalt concrete was studied by (Sarsam-1987; Sarsam-1997) using usual hammer compaction, he concluded that Gap graded mixes shows superior Hveem stability, cohesion, specific gravity, compatibility and strain resistance at various Asphalt content when compared to dense mixes. The effect of gradation on the behavior of rubber modified asphalt

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concrete was also studied by (Takallou etal-1986)

Material Properties And Testing

3.1 Coarse and fine aggregates

Crushed coarse and fine aggregates from river origin were obtained from Mosul Asphalt Plant, and were divided into different sizes by sieving, oven dried, and stored in plastic containers; Their properties were illustrated in Table 1.

3.2 Gradation

Dense gradation as per (SORB-1983) for binder course and Gap gradation as per (B.S.594-1961) were used throughout the investigation. The grain size distribution is illustrated in Table 2.

3.3 Filler

Ordinary Portland Cement obtained from Badosh Cement factory was introduced as the filler material in Asphalt Concrete mixes. Table 3 shows its properties.

3.4 Asphalt Cement

Asphalt Cement of grade (40-50) was obtained from Gayara oil refinery stock. Table 4 shows its various properties.

Testing Program

4.1 Marshall samples construction

The required amount of aggregate of different sizes to meet the dense or gap gradation were heated to 160˚C and combined, the required amount of Asphalt Cement heated to 150˚C was added and mixed with the aggregates for two minutes using a mechanical mixer, then the mix was poured into the preheated moulds and subjected to Marshall hammer compaction using 75 blows for each side as per the standard procedure. Three different Asphalt percentages (4, 5, 6) % were adopted for each gradation type and triplicate samples were constructed for each Asphalt percentage. A total of 36 Marshall Specimen was prepared.

4.2 Roller wheel slab samples construction

The required amount of aggregate of different sizes to prepare a slab specimen of (30×30×7) cm size was weighted, heated to 160˚C and combined. Asphalt Cement was also heated to 150˚C, and then the predetermined amount of Asphalt was added to the aggregate into the preheated mixing bowel. Mechanical mixing was conducted for two minutes, then the mix was poured into the preheated slab mould of the TRRL roller wheel tracking machine, leveled with a spatula, then it was subjected to 10 passes of the steel roller wheel for each of the three stages of compaction using different compaction effort for each stage by changing the applied normal load. A primary compaction by roller was applied using 10 passes of the machine shoe with a normal load of 10kg/cm width, followed by 10 passes using a normal load of 20kg/cm width. Such compaction may represent the primary and heavy compaction applied by steel and pneumatic tire rollers in the field. The final compaction was demonstrated by the application of 10 passes of the roller using 45kg/cm width normal load representing the finishing compaction by steel rollers in the field (Sarsam-2002). Samples were kept overnight in the mould for cooling, then withdrawn from the mould for further testing. A total of 12 slabs were compacted as above using both dense and gap gradations with three Asphalt percentages of (4, 5, 6) %.

Drilled core samples of 10cm diameter were obtained from the slabs. A total of six cores were obtained from each slab.

4.3 Testing of samples

All of the hammer compacted samples and the core samples were subjected to bulk density determination, and divided into three groups, then tested for Marshall stability and flow, Hveem cohesion and stability, and indirect tensile strength test as per the Asphalt institute(MS-2) and (ASTMC496-64T).

Discussion Of Test Results

5.1 Marshall properties

The first group of hammer compacted and core samples were tested for Marshall Properties at 60˚C.

As demonstrated in figure 1, the Marshall Stability increases with the increase in Asphalt content up to an optimum Asphalt percentage, then decreases for the range tested (i.e. 4, 5, and 6) % for both roller and hammer compacted samples. Dense gradation shows higher Marshall Stability for roller compacted mixes; On the other hand Gap gradation shows higher Marshall

Stability for hammer compacted mixes. Hammer compaction increases Marshall Stability by 20%.

The hammer compaction shows lower flow values when compared to roller compaction as demonstrated in figure 2. Dense mixes have lower flow values than Gap mixes for roller compaction while it shows higher values for hammer compaction, such behavior correlates well with Marshall values as explained above. Hammer compaction reduces Marshall flow values by 26%.

Figure 3 shows the changes in voids percentages at different asphalt content. Such changes is further supported by figure 4 which illustrates the changes in the voids filled with bitumen. Gap gradation shows higher voids content and lower voids filling with asphalt.

Gap gradation has higher bulk specific gravity than Dense mixes when hammer compaction was employed, while Dense mixes have the highest specific gravity when roller compaction was adopted as demonstrated in figure 5, such behavior agrees well with other research findings (Marias-1974; Takallow-1986; Sarsam-1987; Sarsam-1997; Sarsam-2000), when Gap gradation showed hardly any traffic compaction, and were at time of laying were close to laboratory density, while Dense gradation densified progressively under the traffic for a period of three years after which, it reached an asymptotic value close to the laboratory density as indicated by (Marias-1974) . Hammer compaction slightly increases the bulk specific gravity by 0.95%. Such behavior is further supported by the voids and the voids filled with bitumen relationships.

5.2Hveem cohesion

The second group of samples was subjected to Hveem stability and cohesion test at 60˚C. Figure 6 shows that for roller compacted samples, Dense gradation have better cohesion than Gap gradation at low and high Asphalt content, while both gradations have almost the same cohesion at 5% Asphalt content. This may be attributed to the good packing of aggregates of Dense gradation which is effective at both low and high Asphalt percentages, the particles interlock seems to be much better than that of Gap gradation.

When hammer compaction was employed, Gap gradation shows higher cohesion at medium Asphalt content and lower cohesion at 4 and 6% Asphalt content. This situation may indicate that Gap gradation resist the sliding of aggregate particles over each other at medium Asphalt content when compacted with impact loading such as that of hammer compaction, and the sufficient Asphalt will increase the particles contact to each other. Hammer compaction increases Hveem cohesion by 70%.

5.3 Hveem stability

Gap gradation has higher Hveem Stability than Dense gradation and the Hammer compaction shows higher stability values than roller compaction at all of the tested Asphalt percentages as illustrated in figure 7. It was felt that the impact load has a great effect on changing the particles orientation and giving high Hveem stability values which reflects the high rutting resistance of Gap gradation. This agrees well with the findings of (Marias-1972; and Sarsam-1987). Hammer compaction increases Hveem stability by 25%.

5.4 Indirect tensile strength

The third group of samples was subjected to indirect tensile strength test at 25˚C. Figure 8 illustrate that for roller compaction, Dense gradation shoes higher tensile strength than Gap gradation for the range of Asphalt Cement used, such behavior may be related to good cohesion. On the other hand, same behavior was noticed when hammer compaction was adopted.

Hammer compaction increases tensile strength values by 68%; This may be attributed to the change in particle interlock pattern when using impact loading.

Conclusions

Based on the limited testing program, the following conclusions could be drawn:

1- Dense gradation shows higher Marshall Stability, lower flow values, higher Hveem cohesion, lower Hveem Stability and higher tensile strength when compared to

Gap gradation using roller compaction and core specimens.

2- Gap gradation shows higher Marshall Stability, lower flow values, lower Hveem Stability and higher cohesion when hammer compaction was adopted.

3- The roller compaction gives higher flow values, lower tensile strength, higher Hveem Stability, and almost lower Hveem cohesion when compared to hammer compaction.

4- The hammer compaction shows better Marshall Stability than roller compaction for Gap mixes and lower Marshall Stability for Dense mixes.

5- It was felt that such effect of mode of compaction in the laboratory on Asphalt Concrete properties could be transferred to the field and may be studied thoroughly by constructing a trial section and finding the mathematical correlations of compaction variation between the laboratory and the field.

References

1- ASTM C496-64T "Splitting tensile strength of molded concrete cylinders".

2-B.S.594"Rolled Asphalt- hot process" British standard institution,1961 London.

3- Fuller W.B. &Thompson S.E. "The laws of proportioning concrete" ASCE Vol.59-1909.

4-Lees D.Y."Mechanical properties of gap graded Asphalt Concrete"TRR No.515-1974.

5- Lees D.Y. "Rational design of continuous and intermittent aggregate grading for concrete" HRR No.441-1973.

6- Marias C.P. "Tentative mix design criterion for gap graded bituminous surfaces" TRR No. 515- 1979.

7- Sarsam S.I. "A study of plastic grid reinforced Asphalt Concrete" Tikrit University Engineering scientific journal Vol.7 No.2-2000 Iraq.

8- Sarsam S.I. "Effect of various gradations on the properties of Asphalt Concrete using two design methods" Indian Highways, IRC Vol.15 No.10-1987.

9- Sarsam S.I. "Effect of mode of compaction on the properties of Asphalt Concrete" Engineering and Technology Vol.16 No. 9-1997 Iraq.

10- Sarsam S.I. "Evaluation of roller compacted concrete pavement properties" Engineering and development scientific journal of Almustansiria University, Vol.6 No.1-2002.

11- SORB "Standard specification for roads and bridges" Ministry of Housing and construction, 1983 Iraq.

12- The Asphalt Institute MS-2 "Mix design methods for Asphalt Concrete and other hot mix"March-1979.

13- Takallou H.B., Hicks R.G. &Esch D.C. "Effect of mix ingredient on the behavior of Rubber modified Asphalt mixture" TRR No. 1096-1986.

Table 1: Physical properties of aggregates

Type	Bulk specific gravity	Los- Angles abrasion%
Coarse aggregate	2.650	17
Fine aggregate	2.600	16

Table 2: Grain size distribution of the design mixes

Sieve Size (mm)	% finer by weight	
	(Dense graded)	(Gap graded)
25.4	100.0	100.0
19.2	93.0	80.0
12.5	76.0	50.0
9.5	66.0	50.0
4.75	63.0	35.0
2	35.0	35.0
1	26.0	15.0
0.6	20.0	15.0
0.25	14.0	8.0
0.125	10.0	8.0
0.075	7.0	7.0

Table 3: Gradation of cement

Sieve size	% finer by weight
No.120	100
No.200	92

Table 4: Properties of Asphalt Cement

Test	Sample	Specification SORB
Penetration at 25°C, 100 gm, 5 sec, (0.1 mm)	42	40-50
Specific gravity	1.040	
Ductility - 25 ° C, 5 cm/min	+ 100	+ 100 min.
Loss on heating 5hr, 163 ° C (%)	0.3	0.75 max.
Softening point ° C	54	51-62

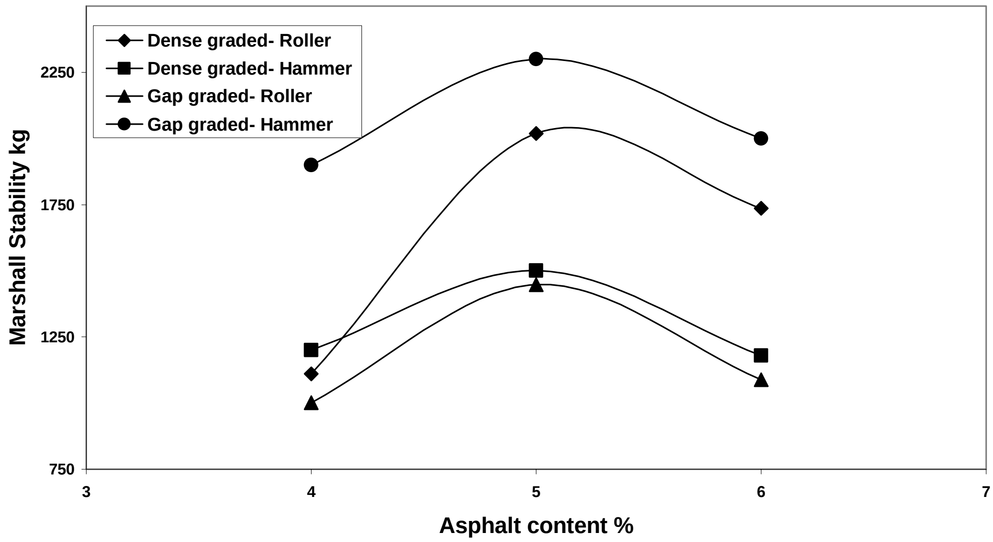

FIGURE 1 Marshall stability of Asphalt Concrete

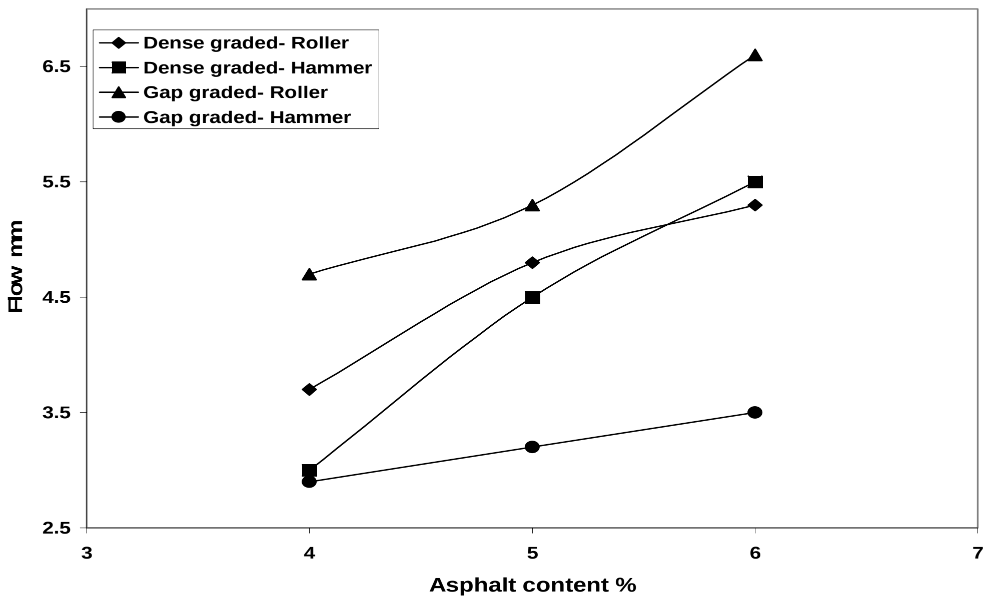

FIGURE 2 Marshall Flow of Asphalt Concrete mixes

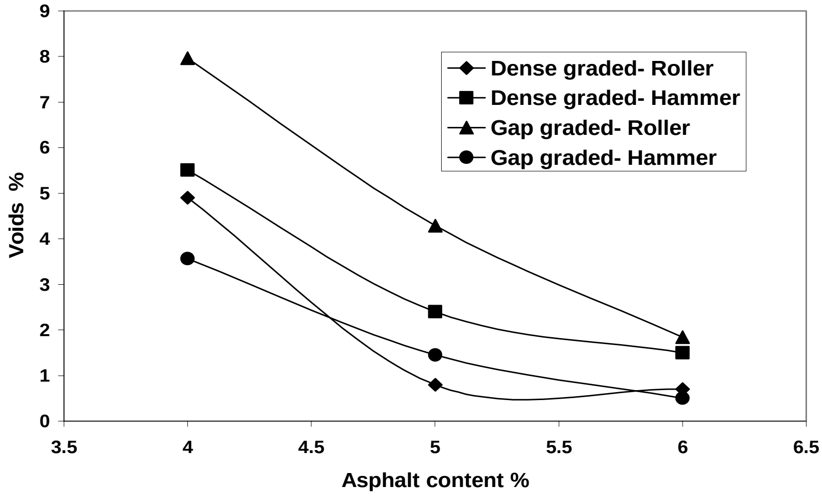

FIGURE 3 Voids % in the Asphalt concrete mixes

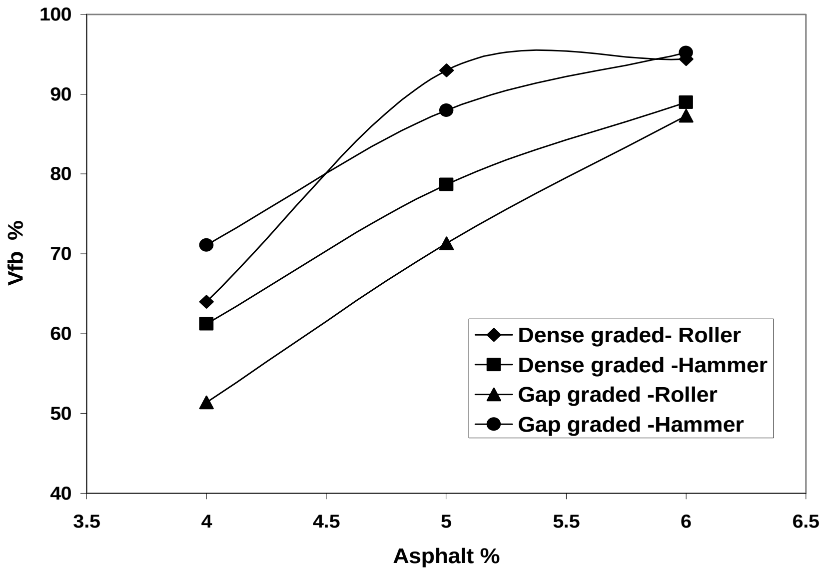

FIGURE 4 Voids filled with bitumen for Asphalt Concrete mixes

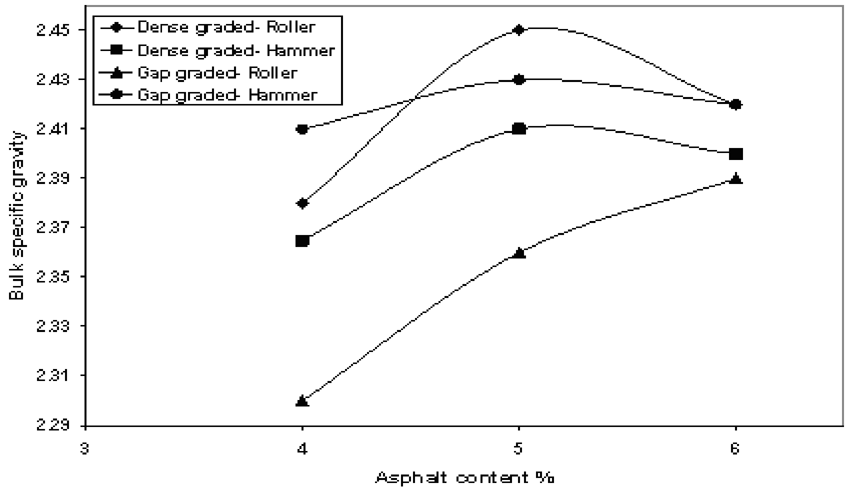

FIGURE 5 Bulk specific gravity of Asphalt Concrete mixes

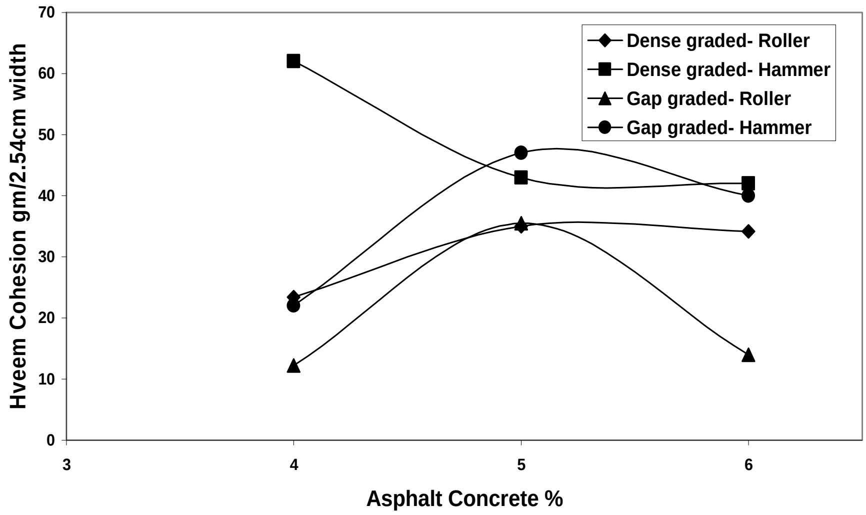

FIGURE 6 Hveem cohesion of Asphalt Concrete

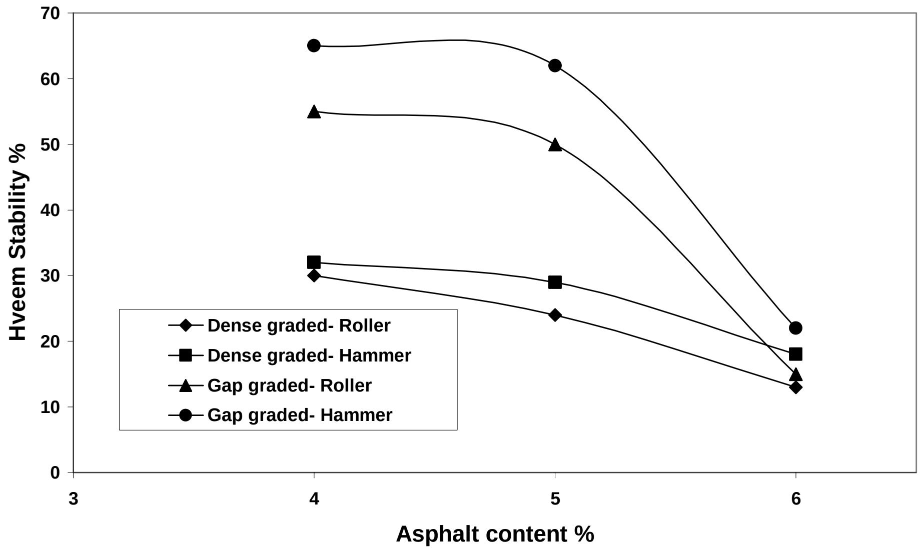

FIGURE 7 Hveem Stability of Asphalt Concrete

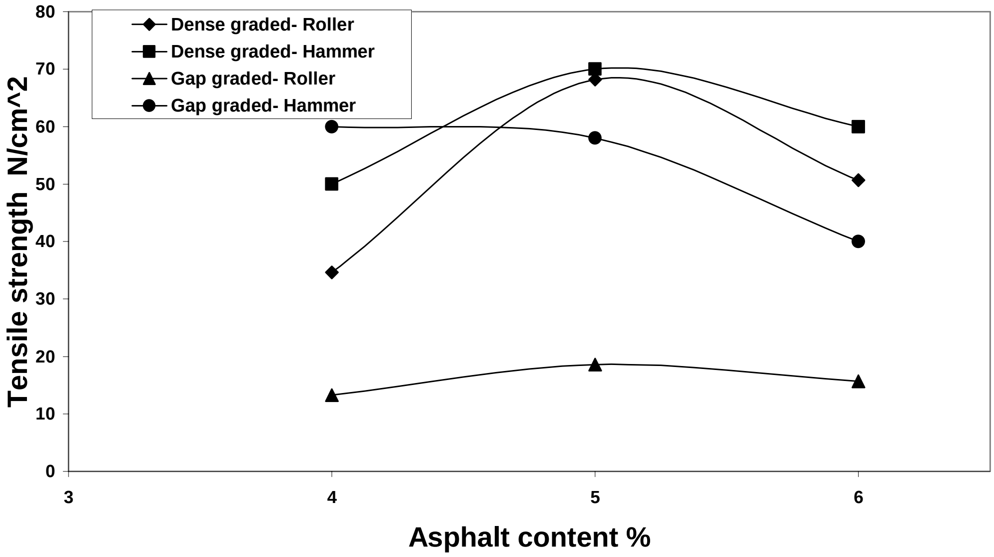

FIGURE 8 Tensile strength of Asphalt Concrete