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An Investigation on OGFC Mix Made with VG-40 and CRMB-55 Binders

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***Abstract* -** The present study exhibits the effect of different bitumen binders on the open-graded friction course (OGFC) mix prepared using Indian Road Congress (IRC) OGFC aggregate gradation. The two different bitumen binders, VG-40 bitumen and CRMB-55 binder were used to prepare the mixes which were compacted at 80 gyrations in a Superpave Gyratory Compactor (SGC). Different tests were utilized to evaluate the optimum binder content (OBC) and performance characteristics of the mix. The tests conducted to estimate the OBC are the Marshall test, Cantabro abrasion loss test, drain down test, and moisture susceptibility test, while the performance evaluation of the OGFC mix was examined using the wheel tracking rut depth test and the falling head permeability test. The OBC for a mix prepared with binder VG-40 and CRMB-55 was found to be 3.5% and 4.0%, respectively. Compared to VG-40, the mix prepared with CRMB-55 exhibited to perform better with more resistance to rut depth and less permeability at OBC.

***Keywords*:** OGFC; VG-40; CRMB-55; Superpave Gyratory Compactor; OBC

1. Introduction

Open-graded friction course (OGFC), which is also termed as porous asphalt, is a special kind of mixture that is increasingly being used in bituminous road paving worldwide. OGFC mix consists of a high percentage of air void, which is achieved by employing a higher percentage of coarse aggregate (often less than 20% of the material passing through a 2.36 mm sieve size) [1,2,3]. Open-graded mixes are designed to be permeable to water, which differentiates them from other types of mixes that are relatively impermeable. OGFC mixes consist of relatively uniform graded aggregate having a high amount of coarse aggregate, and smaller amount of fines, using a high viscosity modified binder. To achieve this property, OGFC mixes are designed to have a high percentage of interconnected voids about 18-20% of the total volume, which makes the mix permeable [ASTM D 7064, 2004]. OGFC mix helps in the removal of water from the surface of pavement, which ultimately reduces aquaplaning and improves visibility of pavement, skid resistance, wet pavement friction, and surface reflectivity [4,5,6,7].

OGFC mix may be affected by different kinds of distresses like raveling, moisture damage, and binder aging due to its high porosity. These distresses can be reduced by using rubber or polymer-modified binders [8]. The use of a modified binder in the OGFC mix provides higher permeability as well as higher air-void content with less compaction efforts [9]. The use of modified binders in OGFC mixes gives an appreciable increment in strength and improves the resistance towards abrasion and raveling [2].

Past researchers compare different modified binders using polymer and fibres in OGFC mix using NCAT gradation [1,3,9,10,11]. As gradation is imperative to the performance of any kind of mix, the authors have been motivated to take up a study on evaluation of OGFC mix made with unmodified and modified binders commonly used in India as per Indian gradation (IRC-129, 2019) [12].

2. Objective

This study aims to analyse the effects of bituminous binder on the design and performance of OGFC mix using Indian gradation. This was accomplished by preparing two different mixtures using two different kinds of binder: high viscous unmodified bitumen VG-40 and modified binder CRMB-55. The evaluation of the mix was analysed by conducting volumetric and performance-based tests such as Marshall stability, permeability, rutting, etc. on each mix type and comparing the results.

3. Material Required

3.1 Aggregate

For the study, one aggregate type was utilized, and aggregate gradation was chosen as per the IRC-129:2019 to prepare the OGFC mix. Table 1 represents the aggregate gradation used for OGFC mix design while Table 2 represents the physical properties of aggregate.

Table 1. OGFC aggregate gradation (IRC:129-2019).

Sieve size (mm)	Percentage Passing	
	Specified	Adopted
13.2	100	100
9.5	85-100	92.5
4.75	20-40	30
2.36	5-10	7.5
0.075	7.5	3

Table *2*. Physical properties of coarse aggregate.

Property	Test method	Test Results	Standard Requirement
Los Angeles abrasion value (%)	IS:2386 (P IV)	18	30
Aggregate impact value (%)	IS:2386 (P IV)	8	15
Aggregate crushing value (%)	IS:2386 (P IV)	13	30
Flakiness index (%)	IS:2386 (P I)	8.83	20
Elongation index (%)	IS:2386 (P I)	11.5	20
Specific gravity	IS:2386 (P III)	2.7	-
Water absorption (%)	IS:2386 (P III)	0.13	< 2

3.2 Binder

The present study utilizes two different types of binder: conventional unmodified VG-40 grade bitumen and crumb rubber modified binder CRMB-55 grade. Table 3 presents the physical properties of VG-40 and CRMB-55 bitumen binders.

Table *3*: Physical properties of bitumen binders.

Properties	Test Result			Relevant Specification
	VG-40	CRMB-55	Recommended Value	
Penetration at 25ºC (0.1 mm)	56	54.8	40-60	IS:1203
Specific gravity	1.01	1.02	Min 99	IS:1203
Softening point(ºC)	50	55	50	IS:1205
Viscosity at 150 ºC, cP	-	5	2-6	IS:1206 (Part 1)
Absolute viscosity at 60°C (Poise)	3308	-	Min 3200	IS: 2006
Kinematic viscosity at 135°C (cSt)	506	-	Min 400	IS:2006

4. Experiment Performed

For the present study, the OGFC mixes were prepared using one type of coarse aggregate (granite), fine aggregate, aggregate, ordinary Portland cement (OPC-53) as a filler with two different types of binder: VG-40 and CRMB-55. The 55. The obtained OGFC mix was analysed to determine the different properties of the mix and compare the variation in in properties using different binder types.

4.1 Marshall Stability Test

The bituminous samples were prepared as per ASTM D6925-2015 and ASTM D1559-89 was utilized to determine the Marshall properties of OGFC mix. It applies to a bituminous mixture to calculate mixture resistance against plastic deformations. In India, Marshall tests are conventionally used for design of bituminous mixes. Though ASTM D7064 does not deal with stability, this has been used to select a suitable mix with appropriate gradation considering that Marshall test is simple, too less costly, and widely used in India and in many countries.

4.2 Cantabro Abrasion Loss Test

The Cantabro abrasion loss test proposed by ASTM D 7064 was utilized to evaluate the abrasion loss of compacted OGFC specimens. The Cantabro loss (CL) can be obtained by using Eq. (1).

$$\mathrm{CL} = \left(\frac{\mathrm{A-B}}{\mathrm{A}}\right) \times 100 \tag{1}$$

Where,
A is the initial weight of the sample.
B is the final weight of the sample.
CL is the percentage weight loss of the sample.

The test was conducted on aged compacted OGFC to assess the effects of accelerated laboratory aging on its resistance to abrasion. The specimen was placed in a forced draught oven at a temperature of 60°C for 7 days. Subsequently, it was cooled down to a temperature of 25°C in about 4 hours. Following this thermal treatment, the test was conducted.

4.3 Drain Down Test

The drain-down test was conducted as per ASTM D 6390-2011. This test was utilized to evaluate the degree of drainage that may occur in the field from an OGFC mix. The equation presented in Eq. (2) was employed to ascertain the extent of the binder drain-down.

$$\mathrm{d} = \left(\frac{\mathrm{D-C}}{\mathrm{B-A}}\right) \times 100 \tag{2}$$

Where,
A is the empty mass of the wire basket.
B is the mass of the wire basket and sample.
C is the empty mass of the catch plate.
D is the mass of the catch plate and drained material.

4.4 Moisture Sensitivity Test

The investigation of the OGFC mix on moisture sensitivity was conducted using the tensile strength ratio (TSR) test recommended as per AASHTO T 283 (2014). TSR is the ratio of indirect tensile strength of a conditioned specimen to that of an unconditioned specimen which is generally represented in percentage and should not be less than 80 percent. The indirect tensile strength (ITS) of both conditioned and unconditioned test specimens was determined using Eq. (3).

$$S_t = \left(\frac{2000 \times P}{\pi \times t \times D}\right) \quad (3)$$

Where,
S_t is the indirect tensile strength of the sample (kPa).
P is the maximum load (N).
D is the diameter of the specimen (mm).
t is the height of the specimen (mm).

4.5 Hamburg Wheel Tracking Test

Hamburg wheel tracking test on OGFC mixes was conducted as per the European standard [EN12697-22 (CEN 2013)] which helps to assess the rutting resistance of mixes. The sample was conditioned at 60°C for four hours to conduct the test, after which the wheel tracking test was carried out. For failure criteria of OGFC mixes, a maximum rut depth of 20 mm or the quantity of wheel tracking test loaded passes up to 10,000 cycles, whichever occurs first, were used. Here, a frequency configuration of 25 cycles per minute was used.

4.6 Permeability Test

The water permeability of samples of water-saturated asphalt was assessed using a falling-head permeability apparatus. As per Florida DOT (2004), a permeameter was set up for the present study. Permeability value was obtained using Eq. (4).

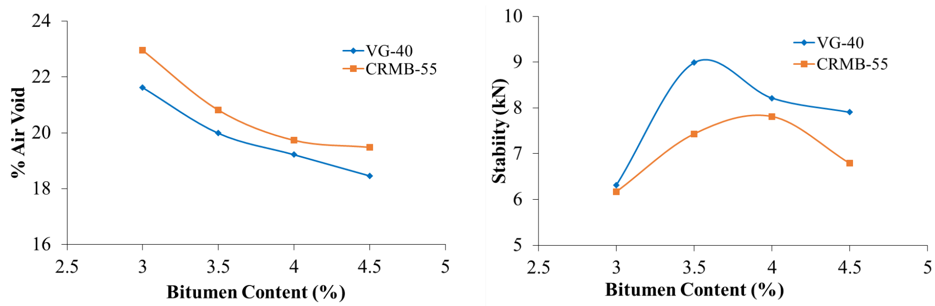
$$\mathrm{k} = \frac{aL}{AT} \times \ln \frac{h_1}{h_2} \quad (4)$$

Where,
a is the cross-section of the test tube.
L is the specimen thickness.
A is the cross-section of the specimen.
h_1 is the initial head and h_2 is the final head.
T is the time interval between h_1 and h_2.

5. Results and Discussion

5.1 Marshall Stability

In this study, all samples were prepared by choosing the Indian aggregate gradation of OGFC (IRC:129-2019). Each sample was compacted at 80 gyrations in a Superpave Gyratory Compactor. Several specimens were prepared using VG-40 and CRMB-55 at various asphalt content, such as at 3.0%, 3.5%, 4.0%, and 4.5%. Fig. 1a shows the variation of bitumen content and the (%) of air voids of OGFC mix with VG-40 and CRMB-55. The air void content on the sample with CRMB-55 is relatively higher than the VG-40 at an equal amount of bitumen content.



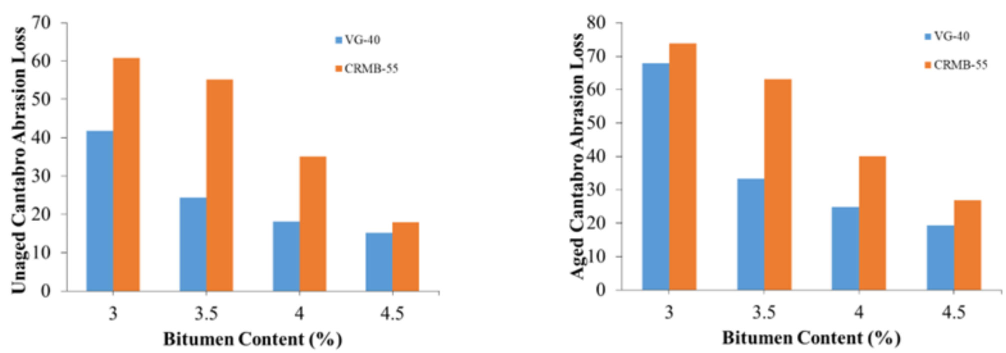
(a) (b)

Fig. 1: Variation of (a) % air voids and (b) Marshall stability with bitumen content.

The results indicate that, for a given bitumen amount, the Marshall stability of the VG-40 mix was higher than that of the CRMB-55 as shown in Fig. 1b. For VG-40 and CRMB-55 OGFC mix, the highest Marshall stability (8.98 and 7.80 kN) was observed at 3.5% and 4.0% bitumen content respectively.

5.2 Results of Unaged and Aged Cantabro Loss

The test was performed to determine the durability and the ravelling resistance of the OGFC mix. Fig. 2a and Fig. 2b represent the variation of unaged and aged abrasion loss with bitumen content, respectively. For both aged and unaged samples at OBC, the Cantabro abrasion loss in CRMB-55 was found to be 20.49% and 44.39% higher than that of VG-40, respectively. The results revealed that the performance of VG-40 in durability and resistance to raveling is better than the CRMB-55.



(a) (b)

Fig. 2: Variation of (a) Unaged and (b) Aged abrasion loss with bitumen content.

5.3 Results of Drain Down Test

The test was carried out to investigate the possibility of bituminous binder separation from the coarse aggregate in the mix. Fig. 3 represents the variation of drain down with different binder content for VG-40 and CRMB-55 binder. The drain down values for CRMB-55 was found to be lower than that of the VG-40. The possible reason for the lower drain down value of CRMB-55 is due to its higher viscous nature compared to the VG-40.

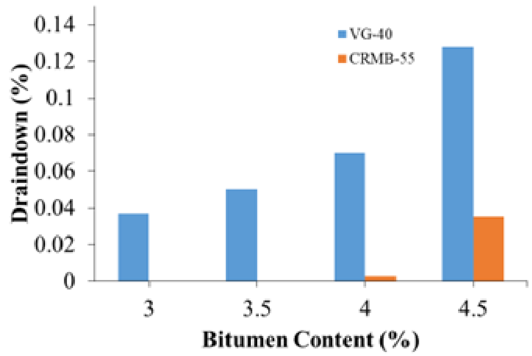
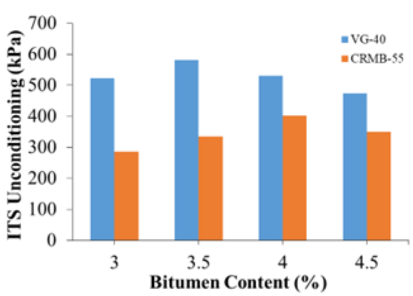


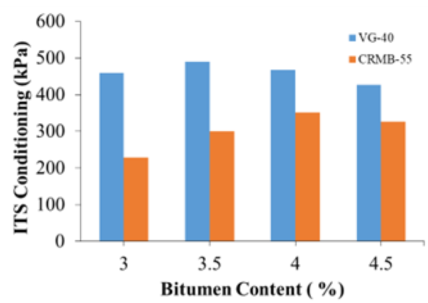
Fig. 3: Results of drain down test.

5.4 Results of Moisture Susceptibility Test

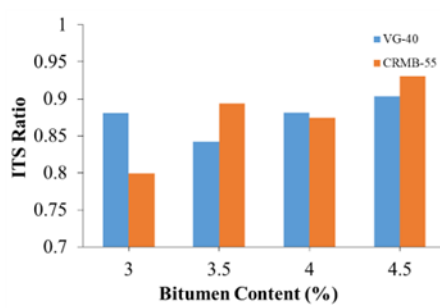
Moisture susceptibility is a critical attribute that plays a crucial role in the long-term durability of the OGFC bitumen mixture. Binder-aggregate striping is sophisticated and depends on several factors such as bitumen mix type, source and type of bitumen, source, and type of aggregate [13]. So, it is important to examine the effect of binder type on the moisture damage of the OGFC mix. Moisture susceptibility results show that OGFC mix with VG-40 have better resistance in un-conditioning as shown in Fig. 4a and conditioning as shown in Fig. 4b than CRMB-55. The indirect tensile strength ratio of both types of mix as shown in Fig. 4c was found to be greater than 80%, which also met the minimal requirement for resistance to moisture damage.



(a)



(b)



(c)

Fig. 4: Illustration of ITS (a) Unconditioned ITS, (b) Conditioned ITS and (c) ITS ratio.

5.5 Optimum Bitumen Content (OBC)

The optimum binder content of the OGFC mix was determined based on the recommended values mentioned in Table 4. The test results of various experiments conducted on OGFC samples, such as air void content, Marshall stability, abrasion loss, drain down, and aging potential, were used to determine the OBC. All the tests satisfied the recommended values at OBC except Abrasion values.

Table 4: Characteristics of samples at OBC.

Properties	Mix Type		Recommended Value
	Sample with VG-40 binder	Sample with CRMB-55	
OBC (%)	3.50	4.0	-
Air voids (%)	19.98	19.73	18-20
Stability (kN)	8.98	7.80	-
Unaged abrasion loss (%)	24.35	35.16	20
Aged abrasion loss (%)	33.23	40.04	30
Drain down (%)	0.05	0.003	0.3
T.S.R (%)	84.18	89.74	80

5.6 Results of Wheel Tracking Rut Test

Rutting susceptibility was measured by preparing the samples of both types of bitumen binder with their OBC. Fig. 5 shows that the mix prepared using CRMB-55 is more resistant to rut depth compared to VG-40 and the value of rut depth is also below the maximum recommended limit. Both CRMB-55 and VG-40 rut depth at 10000 cycles were found 3.22 mm and 3.75 mm respectively which is below the maximum allowable value 20 mm, discussed in section 4.5.

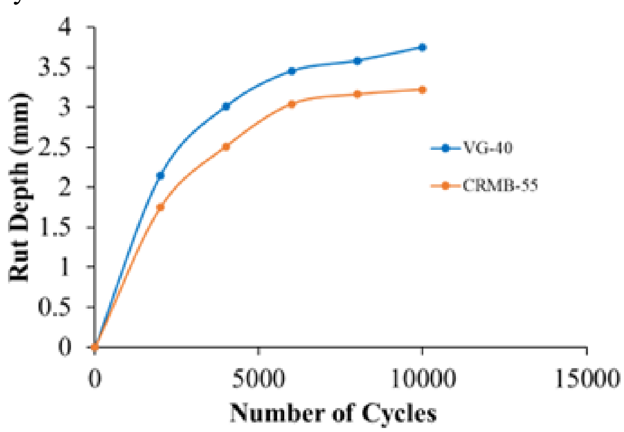


Fig. 5: Variation of rut depth with bitumen content.

5.6 Results of Permeability Test

A falling head permeability test was conducted on both VG-40 and CRMB-55 OGFC mix samples. The test was conducted only on samples prepared at OBC, mentioned in Table 4. The coefficient of permeability was found 136.12 m/day and 129.32 m/day respectively in VG-40 and CCRMB-55 samples. The results satisfied the recommended value of permeability 100 m/day as per Florida DOT, 2004.

6. Summary of Investigations

The present research was aimed to examine the effect of a bituminous binder on the performance OGFC mix prepared using IRC aggregate gradation. The mix was prepared using two different viscous binders, VG-40, and CRMB-55. The OBC of the mix VG-40 and CRMB-55 was obtained at 3.5 % and 4.0 %, respectively. From the test results found, the mix prepared with VG-40 showed higher moisture susceptibility and stability than CRMB-55. Because of the higher air void at OBC, the permeability of the VG-40 mix was higher than that of the CRMB-55 mix. The wheel tracking rut test results showed that the mix prepared with CRMB-55 has higher rutting resistance than VG-40.

References

[1] H. F. Hassan, S. Al-Oraimi, and R. Taha, "Evaluation of open-graded friction course mixtures containing cellulose fibers and styrene butadiene rubber polymer" in *Journal of materials in civil engineering*, *17*(4), 416-422. 2005.

[2] K. R. Lyons and B. J. Putman, "Laboratory evaluation of stabilizing methods for porous asphalt mixtures" in *Construction and Building Materials*, *49*, 772-780, 2013.

[3] K. D. Jeong, S. D. Hwang, S. J. Lee, and K. W. Kim, "Investigation of rutting potential of open-graded friction course (OGFC) mixes using asphalt pavement analyzer" in *KSCE Journal of Civil Engineering*, *15*, 1259-1262, 2011.

[4] W. Kabir, S. B. Cooper, and C. Abadie, "Evaluation of open graded friction course (OGFC) mixtures" in *(No. FHWA/LA. 13/513), Louisiana. Dept. of Transportation and Development,* 2013.

[5] G. Huber, and G. A. Huber, "Performance survey on open-graded friction course mixes" in *Transportation Research Board (284).* 2000.

[6] L. Chu, and T. F. Fwa, "Functional sustainability of single-and double-layer porous asphalt pavements" in *Construction and Building Materials*, *197*, 436-443, 2019.

[7] M. L. Pattanaik, R. Choudhary, and B. Kumar, "Clogging evaluation of open graded friction course mixes with EAF steel slag and modified binders" in *Construction and Building Materials*, *159*, 220-233, 2018.

[8] H. Wu, J. Yu, W. Song, J. Zou, Q. Song, and L. Zhou, "A critical state-of-the-art review of durability and functionality of open-graded friction course mixtures" in *Construction and Building Materials*, *237*, 117759, 2020.

[9] S. N. Suresha, G. Varghese, and A. R. Shankar, "A comparative study on properties of porous friction course mixes with neat bitumen and modified binders" in *Construction and Building Materials*, *23*(3), 1211-1217, 2009.

[10] V. S. Punith, S. N. Suresha, S. Raju, S. Bose, and A. Veeraragavan, "Laboratory investigation of open-graded friction-course mixtures containing polymers and cellulose fibers" in *Journal of Transportation Engineering*, *138*(1), 67-74. 2012.

[11] V. S. Punith, and A. Veeraragavan, "Characterization of OGFC mixtures containing reclaimed polyethylene fibers" in *Journal of Materials in Civil Engineering*, *23*(3), 335-341, 2011.

[12] Specifications for Open-Graded friction course. *Indian Road Congress-129*, 2019.

[13] M. L. Pattanaik, R. Choudhary, and B. Kumar, "Moisture susceptibility of open-graded friction course mixes with EAF steel slag and modified binders" in *Advances in Civil Engineering Materials*, *8*(1), 248-266,2019.