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Viscosity Graded Approach for Quality Control of Bitumen

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Abstract: There is a need of maintenance of road during the construction as well as after the construction. To improve the quality of road construction one has to observe strict quality assurance and its control. This paper is related to quality control of roads through viscosity graded approach. In viscosity grade, viscosity tests are conducted at 60oC and 135oC which represents the temperature of road surface during summer and mixing temperature respectively. Various laboratory tests and analysis are carried out from the test results. From that we can ascertain the quality of bitumen and compare it with the given standards and quality of bitumen was observed after passing through Rolling Thin Film Oven (RTFO). As the time passes, there is change in bitumen content, density and gradation of material. We can see that there is a reduction in these properties after the years of construction. And by this we can predict the quality of road layers. Further, 16 ongoing as well as previously constructed road projects in Pune, India were selected, bitumen samples as well as cores from these sites were collected and tested as per the viscosity grading and compared with the standards. A statistical analysis of all these test results was carried out.

Keywords: *Bitumen, Quality control, Viscosity, RTFO, Gradation*

1. Introduction

Bitumen is used as a binding material in highways in India and also in the rest part of the world. As the time passes, the system of characterization of bitumen was felt to be changed. Till 2006 there was a huge gap in India between proper characterizations of bitumen.

In India most of the roads are constructed as flexible pavement with bitumen surfacing. It is because of its lower initial cost, possibility of stage construction, easy construction, requires less time, repairing of underground utility services and maintenance techniques. These roads are mainly affected by increasing traffic volumes, increasing axle loads due to increase in commercial vehicle and significant variations in daily and seasonal climate such as rainfall, temperature changes, etc. Due to this roads get damaged. It gives major distress like rutting, raveling, fatigue, cracking, bleeding, shoving, undulations, ageing and potholes in bituminous surface. This ageing is start from the very first exposure of the bituminous binder to the plant burner and hot aggregates and continues to hauling, laying till the final compaction. It is simulated by Rolling Thin Film Oven Test (RTFOT). In this study, an attempt has been made to find out the changes of characterization, properties of bitumen mainly in Indian context with the technical justification behind them along with discussion about viscosity grading.

Total 16 ongoing as well as previously constructed road projects in Pune city of Maharashtra state were selected, bitumen samples and cores from different sites were collected and tested as per the viscosity grading for its quality. Purposely the names of the corresponding contractors are not disclosed off. The outcomes as per our analysis were compared. The corresponding graphs were drawn and performance assessment of each road was carried out. The ageing of bitumen binder has an influence on how long is in service a road coating. Thus, it is important to have reliable methods to predict pavement behavior with time. During its service period, bituminous material suffers a gradual loss of its desirable properties due to continuous exposure to environment and traffic. To determine the changes of bituminous material characteristics with respect to time, this study is important.

2. Scope of work

There is a need of maintenance of road during the construction as well as after the construction. We have to develop quality assurance and quality control methodology to improve the road quality. By this study we can predict the quality of bitumen as well as road layers. We can improve the quality of material as well as construction process of the road.

3. Objective of the work

The objective of the work is as follows

1) To observe the effect on ageing of construction and compare it with ongoing construction.
2) To ascertain quality of the onsite bitumen through conventional, RTFO and relative viscosity method.
3) To arrive at the conclusion regarding quality of bitumen and bituminous mixes.

4. Literature review

Jim Erickson [1] worked on quality management of highway construction and suggested elements of

quality assurance and quality control. The study was from management perspective. The concept of quality management programs was discussed for highway construction. E. Ray Brown et al. [2] mentioned the significance of tests like penetration test, softening point, viscosity test, etc. and mentioned the standard procedures and related causes. Rajib Chattaraj [3] found out the need of grading and its basis and worked on penetration grading and viscosity grading suggested that viscosity grading is more accurate and discussed advantages over penetration grading. Prof. Prithvi Singh Kandhal [4] discussed Viscosity graded system which has recently been adopted in India for paving bitumen based on IS 73:2006. Recommendations have also been made to implement the VG grades as soon as possible to improve the consistency, quality, and durability of bituminous pavements. Information about the viscosity test such as testing equipment, testing procedure has been given. M.S. Ranadive et al. [5] reviewed the penetration grading system and viscosity grading system with their respective advantages and disadvantages along with ongoing road construction case studies and compared the results of both grading systems. Ahmed Shalaby [6] studied ageing of bitumen and replaced the TFOT with the RTFOT for short term ageing procedure. The models were developed that can determine the extent of ageing and impact on mix performance. Praveen kumar et al. [7] reported the proper data about ageing of bitumen binder. The conventional properties of bitumen before and after ageing through RTFO test were checked and concluded significant results that the physical properties of bitumen were improved after short term ageing. Samia Saoula et al. [8] did the same thing. The aging of bitumen was determined from changes in physical and rheological properties of bitumen, as measured before and after the oven treatment along with performed risk of deformation of bitumen pavement. F. G. Pratico et al. [9] indicated that the expected life of the pavement depends on the bitumen viscosity. Viscosities higher than the critical value result in a small increase in the expected life +4% and viscosities lower than the critical value result in an appreciable decrease in the expected life −3 to 65%.

From the above literature review it is observed that the quality control of bitumen have to be improve through research works. Also, study of effect of distresses on roads after the years of construction has to be studied in greater depth; hence herein attempt is made for the same.

5. Research Methodology

The present work is divided into two parts. In first part, eight ongoing road construction sites from Pune city were selected. Samples of bitumen used for tests were collected from ongoing construction. The bitumen samples were tested for conventional, RTFO and relative viscosity test and some other laboratory tests and report of same is prepared.

In second part, additional eight road sites were selected which were constructed about two years ago. Cores of roads were taken and tested for various tests like bitumen content, gradation and density. Comparison was done for the results obtained during construction, at present and in term these results were compared with Ministry of Road Transport and Highways (MORTH) guidelines. The overall methodology of experimental program is described as follows.

1) Site selection
2) Site work
3) Testing program
4) Analysis

5.1. Site Selection

College of Engineering, Pune is providing consultancy services to many projects in Pune, which also includes consultancy services to flexible road construction in Pune. The client to such work is Pune Municipal Corporation. With the permission of concerned authority, visit was arranged to 16 ongoing as well as previously constructed flexible road construction sites in and around Pune. The names of the case studies are as follows:

***Table 1**: Case studies*

Sites	Ongoing road construction	Sites	Road constructed 2 years before
R1	Madhukosh society, Sinhagad road	**R9**	Bavdhan DSK main road
R2	Central mall, shivajinagar	**R10**	Bavdhan ram river
R3	Katraj bypass	**R11**	Spicer college, Aundh
R4	KEM hospital, vishrambaug	**R12**	Dnyanprabhodhini, Sadashiv peth
R5	Sahyadri society, Kondhawa	**R13**	Lokmanyanagar
R6	Ruby clinic, wanowarie	**R14**	Rajendranagar
R7	Trimurti chowk, Dhanakwadi	**R15**	Sopanbaug canal to rly ROB
R8	Boradenagar	**R16**	sadhu waswani chowk, Pune

5.2. Site Work

All onsite observations regarding quality and maintenance of roads were recorded. After that collection of bitumen samples of eight road sites for part 1 was done. Similarly for the part 2, physical observation of roads was recorded regarding quality and maintenance. After observation, two cores from each road were taken using core cutter machine.

5.3. Testing Program

The following tests as mentioned in the next section were conducted in laboratory to draw important conclusions based on tests.

5.4. Analysis

All the results were presented here along with required analysis along with corresponding graphical presentation.

6. Experimental Set up and Work

Various tests on the samples have been explained in this section. The tests are as follows
For part 1-

a) Penetration test at 25°C
b) Ductility test at 27°C
c) Softening point, °C
d) Flash and fire point, °C
e) Specific gravity at 27°C
f) Viscosity at 60°C and 135°C
g) Rolling Thin Film Oven Test (RTFOT)

For part 2-

a) Bitumen content test
b) Gradation test
c) Density test

6.1. Penetration Test

The test was conducted as per IS:1203-1978. Penetration test measure the depth of penetration of needle in bitumen sample in 1/10th of mm. indirectly it shows the consistency of bitumen sample. The needle was loaded with 100g weight and allowed to penetrate for 5 sec. at 25°C.

6.2. Ductility Test

The test was conducted as per IS: 1208-1978. The ductility test measures the cohesive strength of bitumen. The sample was pulled at a constant rate at 27°C. The length at which the sample breaks is called the ductility of the sample.

6.3. Softening Point Test

The test was conducted as per IS: 1205-1978 In this test a standard Ring and Ball apparatus was used. The sample was taken in a standard mould and system was heated in a water bath at a standard temperature rate. The temperature at which bitumen coated ball touches the bottom is called softening point of bitumen. Samples with higher softening point melt at higher temperatures and have better rutting resistance.

6.4. Flash and Fire Point

The test was conducted as per IS: 1209-1978. Flash-point measures the tendency of the sample to form a flammable mixture with air under controlled laboratory conditions. Fire point measures the characteristics of the sample to support combustion. The test cup was filled to a specified level with the sample. The temperature of the sample was increased at a constant rate as the flash point is approached. At specified intervals a small test flame was passed across the cup. The lowest temperature at which application of test flame causes the vapors above the surface of the liquid to ignite was taken as the flash point. To determine the fire point, the test was continued until application of the test flame causes the sample to ignite and burn for at last 5 sec.

6.5. Specific Gravity

The test was conducted as per IS: 1202-1978. The test involves placing sample of bitumen into a pycnometer and measuring the weight of the sample compared to that for an equal volume of water. The specific gravity is the ratio of weight of a sample compared to the weight of an equal volume of water. This is typically conducted at 25°C.

6.6. Viscosity test at 60°C and 135°C

The test was conducted as per IS:1206 (Part II and III)-1978. Viscosity at 135°C is a fair indicator of the ability of bitumen to coat the aggregates properly. In order to get best coating, the viscosity has to be optimum. Too viscous bitumen would result in inadequate and non-uniform coating of the aggregates. Very low viscosity would again result in inadequate coating as the bitumen will tend to bleed. Therefore viscosity at 135°C is a true reflection of the quality of bond that is likely to be formed with the aggregates. Viscosity at 60°C is a very good indicator of the resistance of bitumen to melting/flowing on the road. It is considered to be replacement test for Softening point. In this test U tube with sample was maintained at above temperatures in the silicon oil bath for 30mins. At a constant pressure of 40KPa. Bitumen flow was recorded after 30mins. And viscosity was calculated.

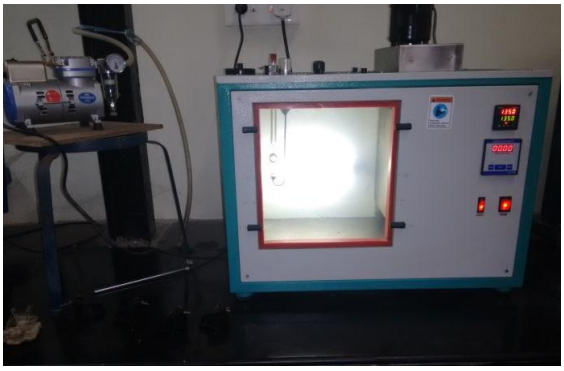

Image 5 *Test Set-Up for viscosity*

6.7. Rolling Thin Film Oven Test (RTFOT)

The test was conducted as per ASTM D2872. This test method indicates approximate change in properties of bitumen. It yields a residue which approximates the bitumen condition as incorporated in the pavement. This test method also can be used to determine mass change, which is a measure of bitumen volatility.

A moving film of bitumen is heated in an oven for 85 min at 325°F (163°C). The effects of heat and air are determined from changes in physical test values as measured before and after oven treatment. By the

RTFOT apparatus it is possible to perform the loss on weight test and to provide the pure sample "aged", ready for other tests like Softening point, Penetration, viscosity at 60°C & 135°C, Ductility and other tests in order to verify that the hardening data of bitumen fall within the limits fixed by the specifications for binders.

Image 6 *RTFO test*

6.8. Bitumen Content Test

The test was conducted as per IRC: SP11-1988. The bitumen content of mixtures as determined by the described test method is used for product acceptance, quality assurance, and process quality control and research activities.

First core cutting was done and layer of BM and AC was separated. These layers were broken into small pieces. About 500-1000gm of bituminous mixture was taken in preweighed bowl of bitumen extractor. Close the lid of extraction bowl and allow the contents to remain submerged condition in solvent for about 1 h. The process repeated till the aggregate was free from bitumen. Dry the aggregate in an oven at 120°C for about 2 h. Take the weight of bowl+ aggregate for determination of bitumen content (W2). The difference in W1 and (W2 + weight of filler) indicates weight of residual bitumen in mixture.

Image 8 *Test Set-Up for Bitumen content*

6.9. Gradation Test

The test was conducted as per IRC:29-1988. After conducting the bitumen extraction test as above, the aggregates were carefully collected, dried and subjected to sieve analysis, through the specified set of sieves as given in the mix design. The results of sieve analysis were tabulated and grain size distribution was compared with grain size distribution specified at the time of construction of that road as well as with the MORTH guidelines to find whether this is within the acceptable limits.

6.10. Core Density Test

The density test was carried out on those samples. The weight and volume of each specimen was determined and density value was calculated. The volume of each core sample was determined from the measured values of the mean diameter and mean thickness.

7. Results

Results obtained are tabulated and shown in a graphical representation as follows-

7.1. Penetration Test

It was observed that penetration value of samples was decreased after passing through RTFO. Hence the consistency of bitumen is increased and it became stiffer than the original sample. This may due to syneresis effect, removing low viscous molecules from high viscous molecule. Fig. 1 shows the percent change in penetration value after RTFO.

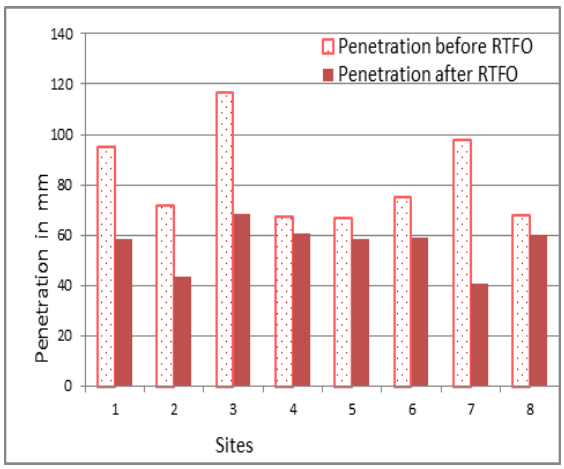

Figure 1 *Effect on penetration*

7.2. Softening Point Test

It was observed that softening point value of samples was increased after passing through RTFO. Hence the bitumen became harder than the original sample and it requires more temperature to melt and thus it is good for the roads in hot weather conditions. Sometimes there may be mixing of various by-products for low cost purpose. So that it melts at low temperature. After passing through RTFO we can see here in fig. 2 that softening point temperature is increased.

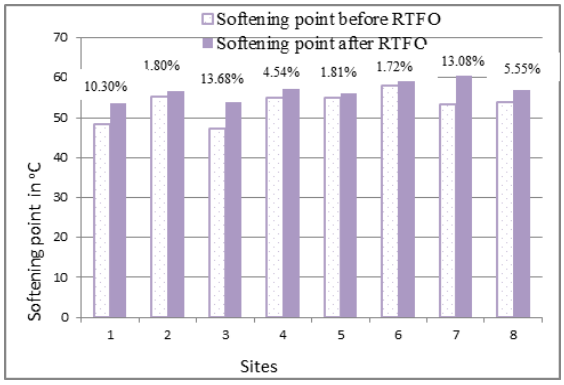

Figure 2 *Effect on softening point*

7.3. Flash Point Test

It was observed that Flash point temperature of samples was increased after passing through RTFO. Hence the heating property of bitumen was improved as well as level of fire hazards was reduced. This is due to mixing of impurities like kerosene which having low flash point than bitumen. So we can see here in fig.3 the variation in test results.

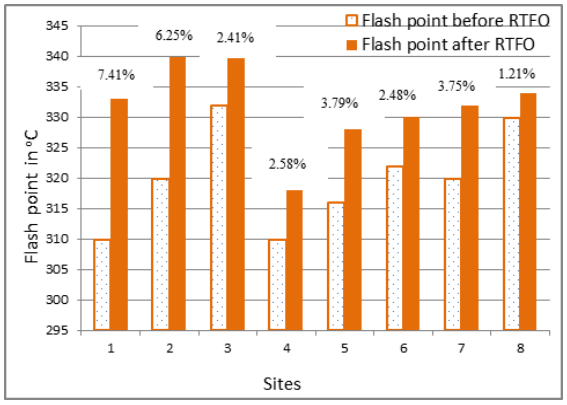

Figure 3 *Effect on flash point*

7.4. Fire Point Test

It was observed that Fire point temperature of samples was increased after passing through RTFO. Hence the heating property of bitumen was improved as well as level of fire hazards was reduced. That was due to maybe there was a mixing of impurities like kerosene, naptha, etc. as discussed earlier.

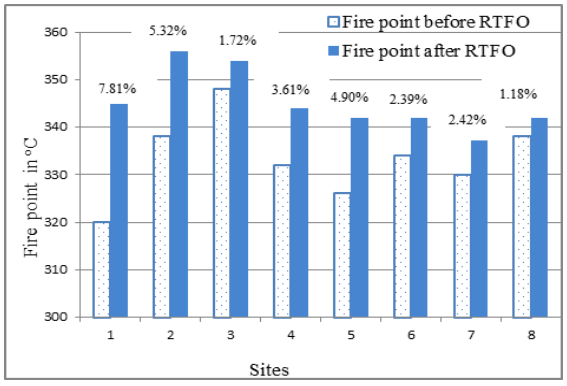

Figure 4 *Effect on fire point*

7.5. Specific Gravity Test

There is a variation in specific gravity. This may due to excessive chemical compounds as well as impurities present in the original sample. After RTFO these are get reduced and purity increases.

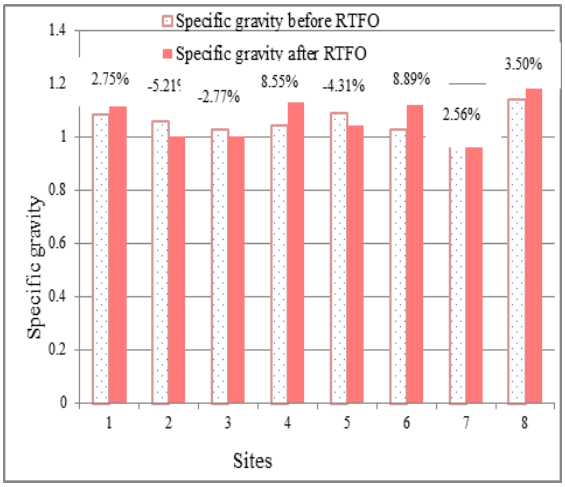

Figure 5 *Effect on specific gravity*

7.6. Absolute Viscosity Test

It was observed that absolute viscosity increased after RTFO hence material showing more viscosity. In fig. 6, for site 1 and 8, there was also change in viscosity grade after passing through RTFO. From this we can get accurate grades of the bitumen sample. We get improved and pure material after passing through RTFO as per IS code standards.

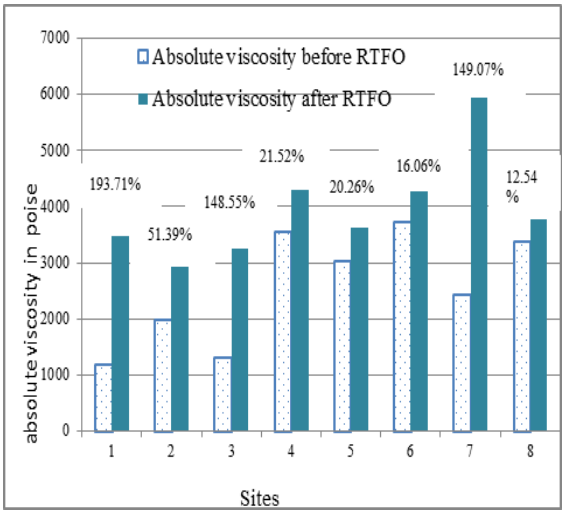

Figure 6 *Effect on absolute viscosity*

7.7. Kinematic Viscosity Test

As discussed earlier it was observed that kinematic viscosity increases after RTFO hence material showing more viscosity. There was also change in viscosity grade after passing through RTFO. We get improved and pure material after passing through RTFO as per IS code standards. These viscosities are nothing but the measure of grading system.

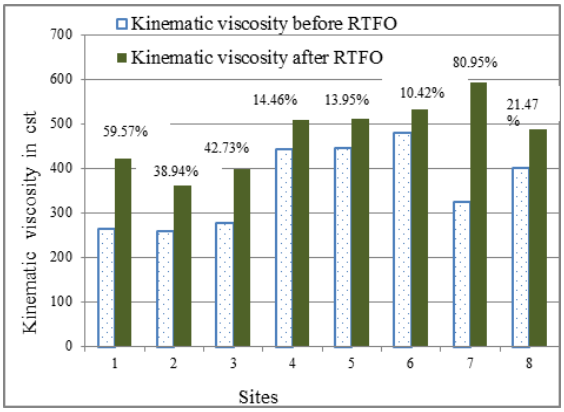

Figure 7 *Effect on kinematic viscosity*

7.8. Bitumen Content Test

Here we checked the bitumen content of those cores. The permissible limit of bitumen content by concerned authority for AC and BM are 6.2 and 4.2 respectively. We found that there was a change in bitumen content after the years of construction. It get reduced as compared to concerned authority's criteria. This is due to traffic volume, weathering actions, improper mixing. This results in cracking, raveling, etc. As we see from the results, there was much reduction in bitumen content during the construction and after the years of construction. It reduces the bonding strength between materials.

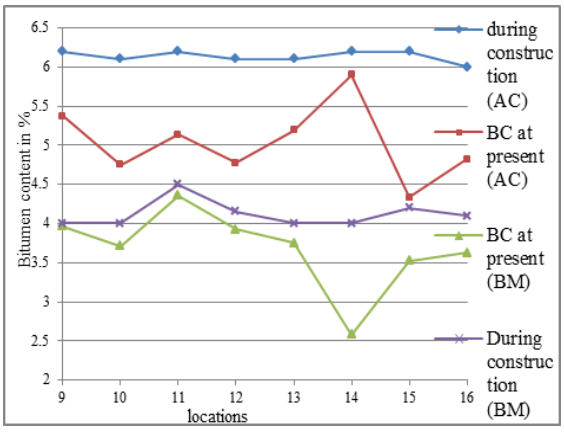

Figure 8 *Effect on bitumen content*

7.9. Gradation Test

On those cores, gradation test was taken. Each sieve from eight case studies was averaged out and change in percentage was calculated compared to MORTH specification. There was a reduction in percentage finer of those aggregate. The change in the gradation after years of construction may be due to weathering actions, drainage conditions, and traffic volume.

Fig. 9 shows gradation of AC in a particular way. On X-axis numbers 1 to 10 represents various sieve sizes ranging from 19mm to 0.075mm as per MORTH (table500-18) guidelines respectively. Y-axis represents the range in percentage fines for grade-II as described in MORTH guidelines.

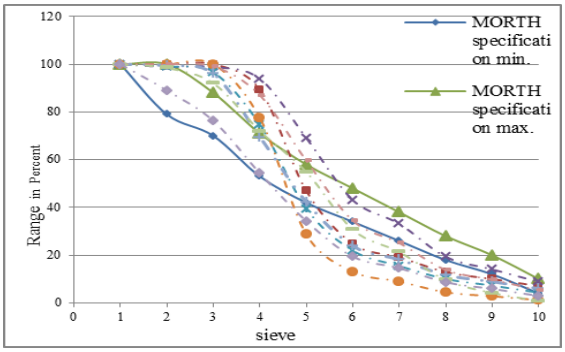

Figure 9 *Gradation of asphalt concrete*

Fig. 10 shows gradation of BM in a particular way. On X-axis numbers 1 to 10 represents various sieve sizes ranging from 45mm to 0.075mm as per MORTH (table500-4) guidelines respectively. Y-axis represents the range in percentage fines for grade-II for BM as described in MORTH guidelines.

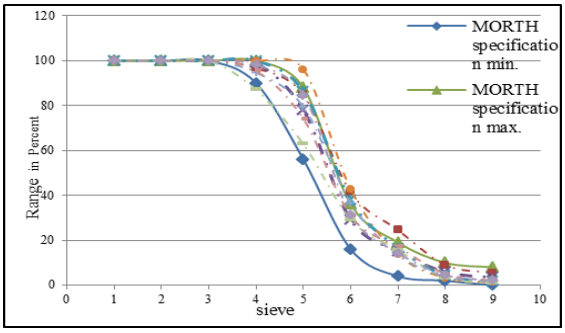

Figure 10. *Gradation of bituminous macadam*

7.10. Core Density Test

There was not much change in densities of materials of those layers after the years of construction. Maximum change was of about 10% so the material or aggregates used for those roads construction was of good quality. In general the reduction in density is sometimes due to erosion of aggregates due to weathering actions. Normal range of AC density suggested by MORTH is 2.48-2.52g/cc and for BM it is 2.39-2.42g/cc. however it is observed from fig. 11 that the variation in AC densities is less as compared with BM densities. The BM density is deteriorating from site to site. It may due to weathering actions, traffic loads, contact with water, etc.

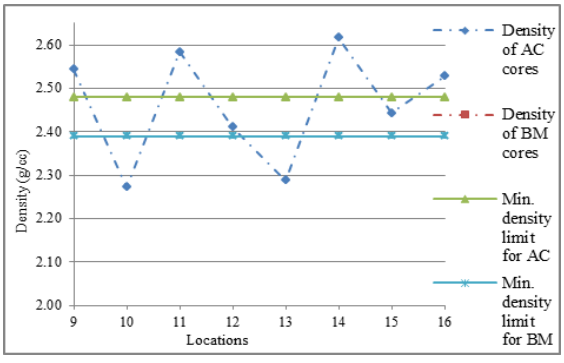

Figure 11. *Effect on density*

8. Conclusion

Following conclusions were noted:

- Samples collected from 8 ongoing road constructions are belonging to VG30. Sample having a penetration grade may show different behavior at high and low temperature and show different grade when studied through viscosity graded approach.
- Percentage deviation for each test was noted after RTFO test. This deviation is in positive manner, so bituminous properties improved after the application of heat at $163^{O}C$ and air by RTFO test.
- There may be mixing of impurities or other products like kerosene, naptha, grease, etc. in bitumen for low cost purpose, due to this quality of bitumen get reduced.
- Change in grade type from one grade to another for the same sample after passing through Rolling Thin Film Oven is observed due to impurities present in bitumen. Here sample number R1, R3, R7 were not acceptable as they were not in the given range.
- Reduction in bitumen content varies from site to site depending on traffic volume, rainfall and other weathering condition, continuous contact with water. Road sites R14, R15, R16 are affected more because of high traffic volume as compared to other sites.
- Negative deviation in gradation of aggregates as well as material density due to weathering actions, heavy traffic loads, voids and drainage. This reduction is more in asphalt concrete layer and for road sites R14, R15, R16.

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