

Quality Assurance & Control of Bitumen-Viscosity Graded Approach

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Abstract: The 100 year old penetration grading system has been replaced by viscosity grading system in India for paving bitumen. The new viscosity grading system conforms to IS -73-2006 paving bitumen-specification (third revision). Viscosity grade bitumen is categorized according to viscosity. The higher the grade, stiffer the bitumen. In viscosity grade viscosity test are conducted at 60^o C and 135^o C which represents the temperature of road surface during summer and mixing temperature respectively. As per the specifications there are four grades VG-10, VG-20, VG-30, and VG-40.

The paper reviews the penetration grading system and viscosity grading system with their respective advantages and disadvantages. An effort is made to compare the specification of penetration grading with the new viscosity grading. Recommendation has been made for selection criterion of VG grades based on climate and traffic. Information about the new included tests like viscosity at 60^o C, kinematic viscosity at 135^o C, solubility in trichloroethylene and the tests on rolling thin film oven is given.

Further, 16 ongoing road construction projects in Pune, India were selected, bitumen samples from these sites were collected and tested as per the viscosity grading. The outcome as per the viscosity grade and their previous penetration grades were compared. A statistical analysis of all these test results were carried out which include descriptive statistics, one-way anova and control charts. The corresponding graphs were drawn and performance assessment of each contractor was carried out.

Keywords:- Bitumen, Penetration grade, quality control, statistics, viscosity grade.

I. INTRODUCTION

Viscosity grading system has been adopted by India recently. Bureau of Indian Standard issued IS 73: 2006 which specifies paving bitumen by viscosity at 60 °C and 135 °C rather than the old system of grading paving bitumen by penetration at 25 °C. An effort has been made in this paper to give an overview of newly adopted viscosity grading system and advantages & disadvantages of penetration grading and viscosity grading.

Nowadays there is intense road building going on in India. Most of the roads being built are with bitumen as a binder, so it is prime importance to use the appropriate bitumen. So we must use the bitumen which is best suited with Indian climatic and traffic condition, also whose physical characteristics are based on rational parameters rather than empirical. This has now been achieved by adopting the viscosity grading system for selecting paving bitumen in India.

Adoption of viscosity-graded paving bitumen specification will also reduce the number of total tests to 7, which will reduce the cost of testing bitumen. This will result from eliminating empirical tests/parameters such as – penetration ratio, paraffin wax content, and Fraass breaking point without compromising the quality of bitumen.

Since high penetration values are desirable for pavement durability, requirement for a minimum penetration value is adequate and has been retained in the viscosity-graded specification. Specifying a maximum value for penetration is undesirable and will reject some good quality bitumen's unreasonably

II. HISTORY OF BITUMEN GRADING IN INDIA

In the year 1950 the " specification for asphaltic bitumen & fluxed native asphalt for road making ": IS 73 was published. It was revised in 1961. It includes grades of materials & test method as per IS 1201 to IS 1220 : 1958 " method of testing tar & bitumen"

The IS 1201 to 1220 were revised in 1978 & as per the additional data, second revision of IS 73 made in 1992. The third revision of IS 73 was made in the year 2006, in which grading of bitumen was changed from penetration to viscosity grade.

The performance change of bitumen at high temp can be dealt by accepting this new revision. Tender mix problems can be minimized by the checking of minimum viscosity at 135°C.

2.1 Penetration grading

Grading of bitumen by penetration test at 25 °C was adopted by the American Society for Testing and Materials (ASTM) Committee D04 on Road and Paving Materials in 1903. To quantify the Penetration grading the following asphalt concrete characteristics are to be evaluated as per the standard IS: 73-1992.

- Penetration depth of a 100 g needle; 25° C
- Flash point, °C
- Softening point °C
- Penetration ratio
- Ductility at 25 °C, cm
- Paraffin wax content
- Fraass breaking point
- Solubility in trichloroethylene
- Loss on heating (TFOT)
- Retained penetration after Thin Film Oven Test (TFTO)
- Viscosity at 60 °C and 135 °C
- Water content
- Specific gravity at 27 °C

In penetration grade, the bitumen is classified as per the values of penetration test. Other tests have just to fulfill the minimum requirement as per the IS. IS 73-1992 specifies five penetration grades of bitumen as

30-40 (hardest bitumen)

40-50

60-70

80-100 (softest bitumen)

Fig shows schematic of the penetration test. In this procedure, a needle is loaded with a 100-g weight and allowed to penetrate into an asphalt sample for 5 sec. Prior to conducting the test, the asphalt cement sample is brought to the testing temperature of 25°C. Measures the depth of penetration in tenths of millimeters. The greater the penetration, the softer is the bitumen. The most widely used penetration grade in India is 60-70. The softer 80-100 penetration grade has been used for low-volume roads and spray applications (such as in surface dressing) in India

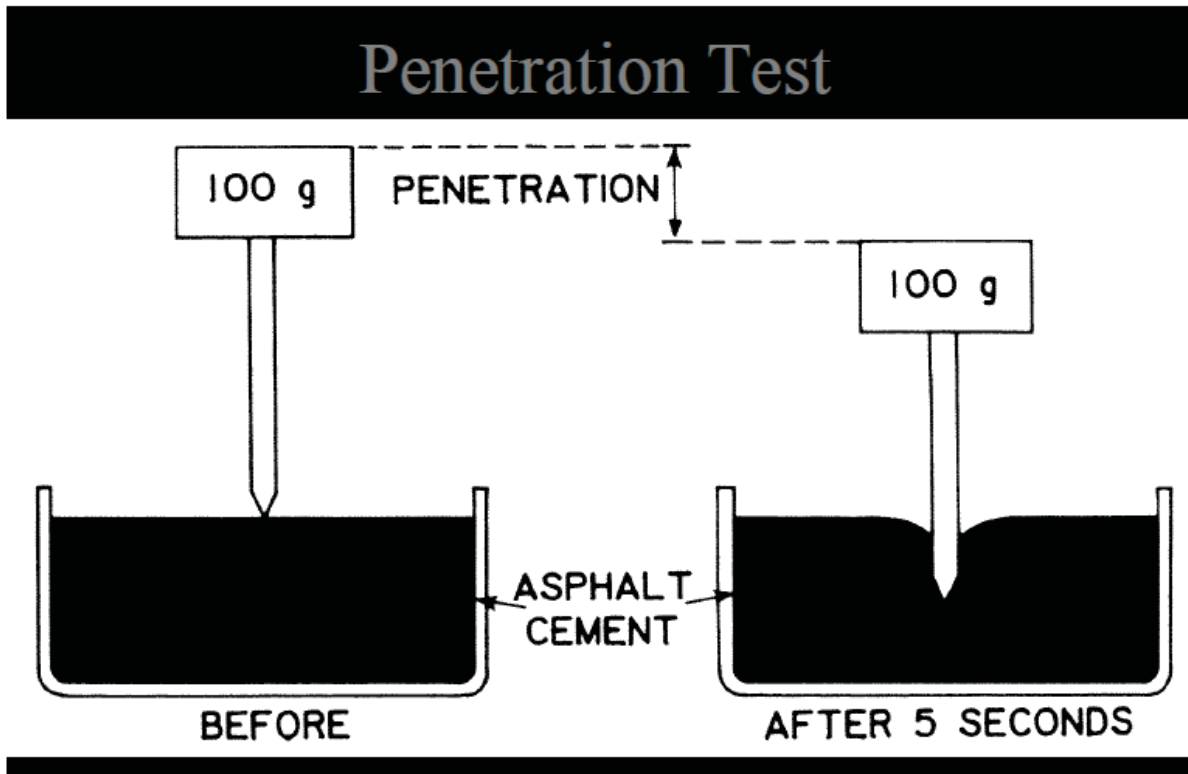


Fig 2.1 Schematics of penetration test.

The penetration grading system has the following disadvantages:

1. The base of this test is empirical not fundamental.
2. polymer modified bitumen cannot be tested by penetration grading.
3. No provision for viscosity testing at mixing and laying temp.
4. Temperature-susceptibility is controlled by penetration grading.

2.2 Viscosity grading

Bitumen obtained from refineries is used as paving bitumen which conforms to IS 73. Bureau of Indian Standards has released third revision of IS 73: 2006 recently. Earlier there were three grades of bitumen manufactured in India conforming to IS 73 1992.

In this third revision viscosity grade is accepted instead of penetration grade. As per the new specifications there are four grades of bitumen namely VG-10, VG-20, VG-30 & VG-40. Several key issues relating to performance of bitumen were dealt in this new revision. Some of the key issues are as follows

- Performance at high temperature

Earlier it was not possible to judge the performance of binder at high temp with only penetration test at 25°C. But with viscosity grades there is testing of viscosity at 60°C and at 135°C which can predict the performance of binder at high temperature.

- Issues relating to compaction

During the compaction of mix on field, tender mix is common problem, which is been addressed by having a requirement of minimum kinematic viscosity at 135°C.

- Number of total tests

There is considerable reduction in the number of tests required, as per the viscosity grade the number of tests required are 7 compared to 13 as per the penetration grade. In addition to this there is no compromising in the quality of bitumen and also no new tests are required in implementing this specification. Bitumen are classified as per the viscosity. The higher the grade, the stiffer the Bitumen.

To classify the bitumen as per the viscosity grade following bitumen characteristics tests are carried out as per the IS: 73 2006.

1. Absolute viscosity at 60 °C , poises
2. Kinematic viscosity at 135 °C, cst
3. Flash point °C
4. Solubility in trichloroethylene, %
5. Penetration test at 25 °C, 1/10th of mm
6. Softening point , °C
7. Tests on residue from Rolling Thin Film Oven.
 - i) Viscosity ratio at 60 °C
 - ii) Ductility at 25 °C, cm

• REQUIREMENT OF PAVING BITUMEN AS PER THE IS 73 : 2006.

CHARACTERISTICS	VG10	VG20	VG30	VG40
Absolute viscosity at 60 °C , poises, min	800	1600	2400	3200
Kinematic viscosity at 135 °C, cst, min	250	300	350	400
Flash point °C,min	220	220	220	220
Solubility in trichloroethylene, % min	99.0	99.0	99.0	99.0
Penetration test at 25 °C, 1/10 th of mm, min	80-100	60-80	50-70	40-60
Softening point , °C min	40	45	47	50
Tests on residue from Rolling Thin Film Oven				
Viscosity ratio at 60 °C, max	4.0	4.0	4.0	4.0
Ductility at 25 °C, cm,min	75	50	40	25

2.3 Viscosity Graded Bitumen and Equivalent Penetration Grade With Their General Application

To compare the specification of each grading system, it is necessary to find the equivalent grade of other system. As per the IS 73-2006 following table shows the equivalent penetration grades of viscosity grades with their general application.

Table 2.3- VG bitumen and equivalent penetration grade

Viscosity grade (VG)	General Applications	Equivalent Penetration grades
VG 40	The area with high stress concentration like intersections of roads, truck parking, heavy traffic. It can be used in higher temperatures	30-40
VG 30	It is the most suitable for Indian road condition.	60-70
VG 20	It is used in areas of cold climate & high altitude	-----
VG 10	Used in spraying applications, and can be used in very cold regions. Also used for the manufacture of bitumen emulsion & modified bitumen	80-100

2.4 Advantages Of Viscosity Grade :

- 1. Fundamental Engineering Properties:** Fundamental engineering properties are the base for viscosity grade
- 2. Takes care of high as well low temperature:** Both low & high temp susceptibility of bitumen is dealt with the measurement of viscosity at 60 °C and 135 °C , which is not possible with Penetration value at 25°C. Hence, road contractors can have better understanding of Bitumen performance in the field.
- 3. Rutting performance** of two same viscosity grades is identical which is not possible in penetration grade.
- 4. Easy Mix Design:** As viscosity value at two different temperatures is available, there is greater ease in handling to customers. It is possible to measure accurate mixing & compaction temperature.
- 5. Number of tests:** Viscosity grading has 7 tests as compared to 14 tests of penetration grade system. Therefore there is considerable reduction in time and cost.
- 6. Longer durability:** The pavement made with Viscosity grade bitumen is of longer durability.
- 7. Higher traffic capacity:** The pavement made with appropriate VG bitumen is of higher traffic capacity.

III. CASE STUDIES

Pune is one of the largest metropolitan city of India. Tremendous amount of infrastructural work is under construction in Pune, it include construction of bridges, rigid pavements, flexible pavements, under pass. We decide to carry out the testing of bitumen samples from the ongoing road construction sites in and around Pune as per the Viscosity Grading. Then to compare the specifications of Viscosity grading and Penetration grading.

We visited 16 ongoing flexible pavement construction sites and collected the sample. There were in total 8 contractors, the names of contractors are not disclosed here. The work of 16 sites is distributed among these contractors. The data regarding contractors, latitude and longitude of site, penetration grade claimed by the contractor, corresponding Viscosity grading after testing is shown in table below.

Sr. no	Name of contractor	Date of visit	Grade of bitumen(penetration) claimed by contractor	Viscosity Grade after testing	Penetration Grade after testing
1	Contractor 1	7/2/2014	60-70	VG 20	60-70
2	Contractor 2	10/2/2014	60-70	VG 20	60-70

3	Contractor 3	13/2/2014	60-70	VG 20	60-70
4	Contractor 4	17/2/2014	60-70	VG 30	60-70
5	Contractor 5	18/2/2014	60-70	VG 20	60-70
6	Contractor 6	22/2/2014	60-70	VG 30	60-70
7	Contractor 2	26/2/2014	60-70	VG 20	60-70
8	Contractor 3	25/2/2014	60-70	VG 20	60-70
9	Contractor 6	26/2/2014	60-70	VG 20	60-70
10	Contractor 7	6/3/2014	60-70	VG 30	60-70
11	Contractor 5	7/3/2014	60-70	VG 20	60-70
12	Contractor 8	7/3/2014	60-70	VG 30	60-70
13	Contractor 5	8/3/2014	60-70	VG 20	60-70
14	Contractor 8	14/3/2014	60-70	VG 30	60-70
15	Contractor 4	20/3/2014	60-70	VG 30	60-70
16	Contractor 8	26/3/2014	60-70	VG 20	60-70

Table 3.1

Above analysis shows the classification of bitumen as per VG system. It is clear that out 16 samples 10 samples belong to VG 20 & 6 samples belong to VG 30, though all the samples have same penetration grading of 60-70. The equivalent 60-70 penetration grading is VG 30. There are only 6 sites which fulfill the requirement. So any two samples of same viscosity grade would give similar performance but the possibility of the same in penetration grade is less. In another words two samples having same penetration grade may show different behavior at high & low temperatures.

IV. STATISTICAL ANALYSIS OF DATA

Statistics is the science of gathering, analyzing, interpreting and presenting data. It is branch of Mathematics. In another words Statistics are numerical statements of facts in any department of enquiry, placed in relation to each other. Statistics teaches us how to summarize, analyze and draw meaningful inferences from data that then lead to improve the functioning of a particular department, entire company etc. In this work SPSS software is used to analyze the data. Following are the analysis made in this paper.

- i) Descriptive statistics.
- ii) Analysis of variance.
- iii) Control Charts.

4.1 Descriptive statistics

Descriptive statistics are the tabular, graphical, and numerical methods used to summarize and present data. Descriptive statistics involve the following steps

- Collect data
- Organize data
- Summarize data
- Display data
- Analyze data

Hence descriptive statistics is about using data gathered on a group to describe or reach conclusion about the same. As said earlier computer software SPSS is used for the descriptive statistics analysis. The graphical representation of the analysis is shown in the following table.

Descriptive Statistics of Each test

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Absolute viscosity at 60 ° c poise	16	1615.3500	2813.4500	2143.108438	407.2114641	165821.176
kinematic viscosity at 135° C cst	16	310.8000	388.5400	342.217500	24.5971295	605.019
viscosity by tar viscometer secs	16	51	76	63.62	7.164	51.317
Flash point ° C	16	270	305	286.81	10.710	114.696
fire point ° C	16	285	315	301.81	11.131	123.896
Ductility at 27° C in cm	16	69.00	87.66	80.6156	4.91971	24.204
solubility in trichloroethylene %	16	98.86	99.60	99.2750	.21516	.046
Penetration at 25 ° C in 1/10 th of mm	16	55.00	76.00	63.2819	5.05630	25.566
softening point ° C	16	46.0000	53.0000	49.014063	1.9901417	3.961
Valid N (listwise)	16					

Table 4.1

4.2 Analysis of variance(one way anova)

In an experimental study, one or more factors are controlled so that data can be obtained about how the factors influence the variables of interest. Analysis of variance (ANOVA) can be used to analyze the data obtained from experimental studies. A completely randomized design is an experimental design in which the treatments are randomly assigned to the experimental units. ANOVA can be used to test for the equality of three or more population means. Data obtained from experimental studies can be used for the analysis.

We want to use the sample results to test the following hypothesis:

If H_0 is rejected, we cannot conclude that all population means are different.

Rejecting H_0 means that at least two population means have different values.

For the purpose of ANNOVA the software SPSS was used. The following table shows the outcome of analysis as per the ONE WAY ANNOVA from SPSS software.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Absolute viscosity at 60 ° C poise	Between Groups	1440579.587	6	240096.598	2.286	.138
	Within Groups	840239.313	8	105029.914		
	Total	2280818.900	14			
kinematic viscosity at 135 ° C cst	Between Groups	4061.667	6	676.945	1.559	.274
	Within Groups	3474.766	8	434.346		

	Total	7536.433	14			
viscosity by tar viscometer secs	Between Groups	272.067	6	45.344	.798	.597
	Within Groups	454.333	8	56.792		
	Total	726.400	14			
Flash point ° C	Between Groups	1230.767	6	205.128	4.815	.023
	Within Groups	340.833	8	42.604		
	Total	1571.600	14			
fire point ° C	Between Groups	1095.600	6	182.600	3.166	.068
	Within Groups	461.333	8	57.667		
	Total	1556.933	14			
Ductility at 27 ° C in cm	Between Groups	187.137	6	31.189	1.540	.279
	Within Groups	162.059	8	20.257		
	Total	349.196	14			
solubility in trichloroethylene %	Between Groups	.391	6	.065	2.089	.165
	Within Groups	.249	8	.031		
	Total	.640	14			
Penetration at 25 ° C in 1/10 th of mm	Between Groups	61.324	6	10.221	.263	.940
	Within Groups	311.369	8	38.921		
	Total	372.693	14			
softening point ° C	Between Groups	23.018	6	3.836	.870	.555
	Within Groups	35.295	8	4.412		
	Total	58.313	14			

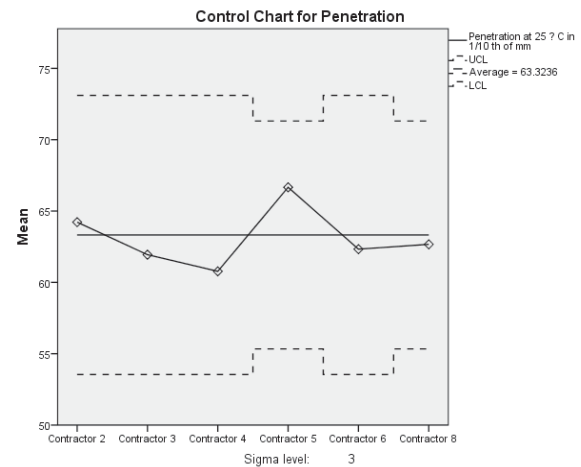
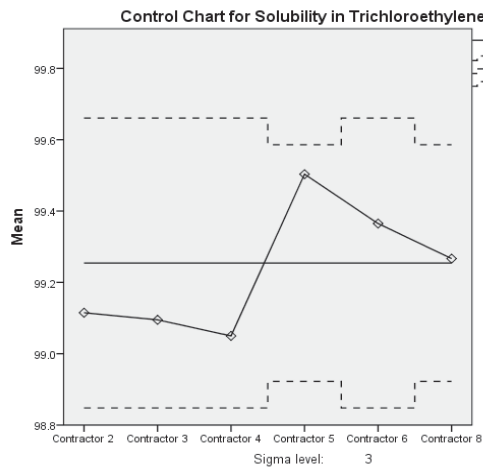
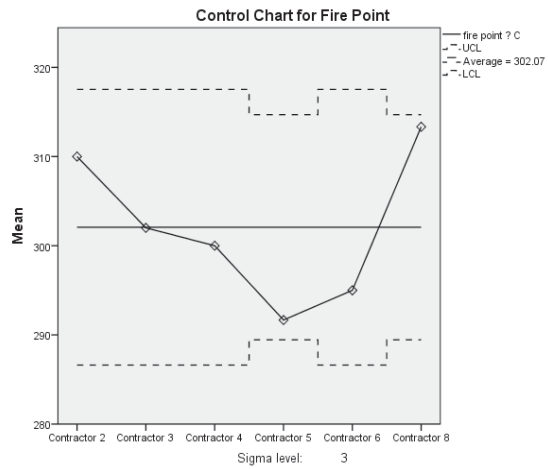
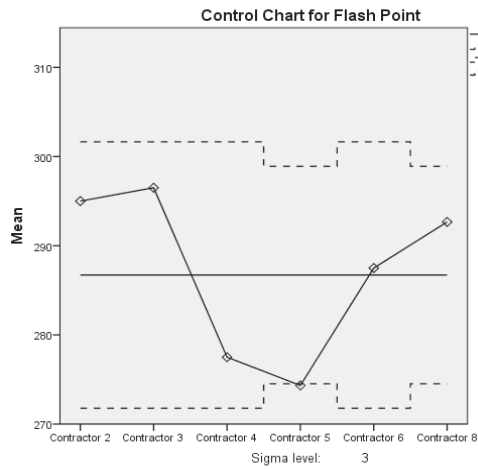
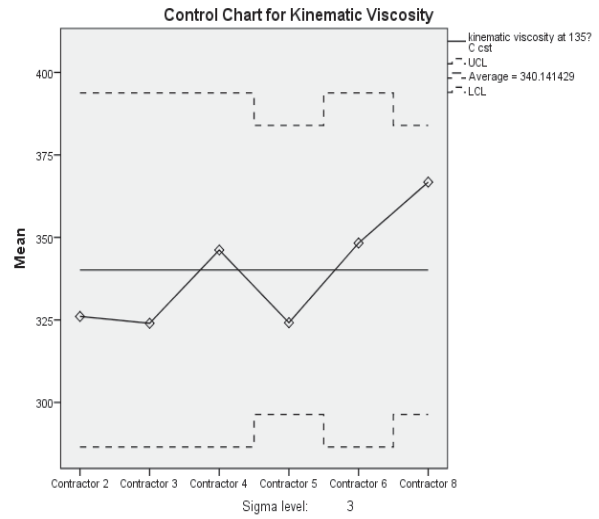
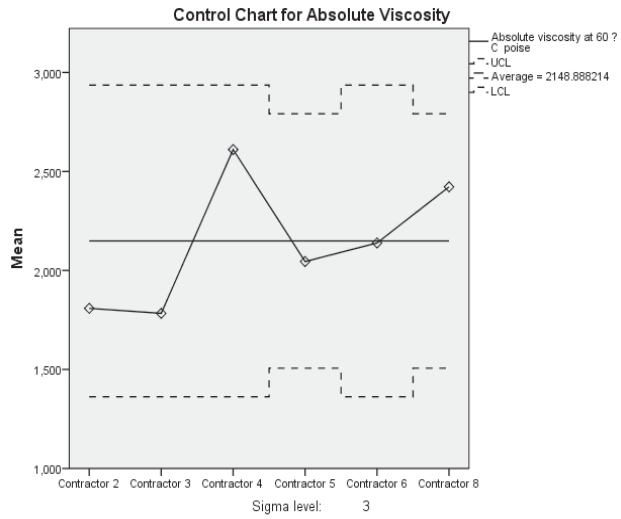
Table 4.2

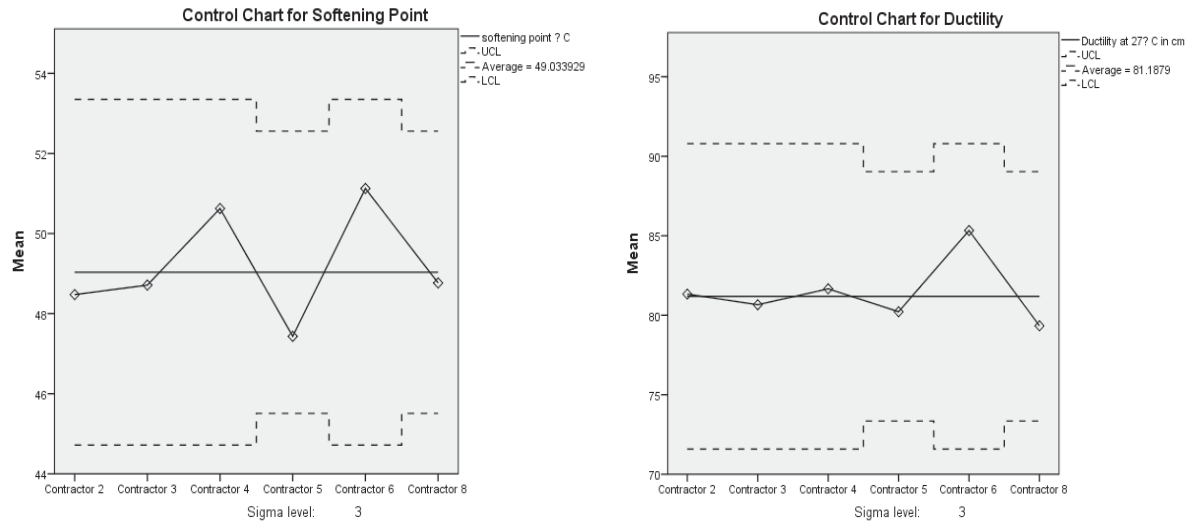
Flash point ° C is significantly different between the contractors at 5 % level of significance. All other parameters are nearly same for all the contractors.

4.3 Control charts:-

All the processes exhibit variation. Control charts help to minimize process variation. Control limits identify the normal operating zone of a process. A control chart contains a set of limits around the hypothesized normal distribution of common cause. Any observation falling outside these limits indicates the presence of a special cause.

The control charts used in statistical quality control represents a picture of a process. When used and continuously updated, control charts represent a moving picture of the process. Control limits represents three standard deviation either side of the mean, so 99.7% of points are within these limits. Process is not under control, if one or more points are found outside the control limits. Following charts are the outcome from SPSS software, control chart is drawn for each test.





From the above analysis ,it is clear that all the tests are under control as no points are found outside the control limits.

V. CONCLUSION

- Out of 16 samples, 10 samples belong to VG 20 & 6 samples belong to VG 30, though their penetration grade lies between 60-70. So any two samples of same viscosity grade would give similar performance but the possibility of the same in penetration grade is less. In another words two samples having same penetration grade may show different behavior at high & low temperatures.
- Viscosity is measured at 60⁰ C & 135⁰ C , which takes care of both low and high temperature susceptibility of binder, which is not possible with only penetration value @ 25⁰ C.
- Greater ease in handling for users as viscosity value at two different temperatures (@60⁰ C & 135⁰ C) is available which would enable users to measure accurate mixing & compaction temperatures.
- Penetration test was developed in times of significantly lower pavement loading. Today there is almost 10 % increase in pavement loading which contributes to 40 % increase in stresses applied to pavements & further heavy traffic and change in weather conditions. Therefore to cope up with the change, there is need to shift from penetration to viscosity grade.

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