

## **The Most Preferable Grade of Bitumen for the Road and Weather Conditions of Bangladesh**

Mahnaz Dil Afroz and Sumaiya Jabin

Bangladesh has vast road networks under the road transport and bridges ministry. There is no statistical report available about the suitability of different grades of bitumen. This study principally shows the results of the analysis of different bitumen characteristics in order to identify the most suitable grade for construction works. After an in depth statistical analysis considering the major characteristic parameters, the grade range 60/70 have been proven and justified as the best suited bitumen grade for the road and weather condition of Bangladesh.

**FIELD OF RESEARCH: Highways engineering**

### **INTRODUCTION:**

This paper deals with the statistical comparison and analysis of various bituminous properties of bitumen with different penetration grades. Test records of different samples of bitumen for a period spanning over a year were collected. Statistical analysis was performed on test data consisting of physical properties of different grades of bitumen, softening point, flash and fire point, solubility and specific gravity. Different statistical parameters like normal distribution, standard deviation, variance, skewness, kurtosis and correlation coefficient were used to make relations between different characteristics of bitumen.

---

Mahnaz Dil Afroz, Dept of Civil Engineering, Bangladesh University of Engineering and Technology, Email: [mahnazafroz12@gmail.com](mailto:mahnazafroz12@gmail.com), Mobile: +8801957957665

Sumaiya Jabin, Dept of Civil Engineering, Bangladesh University of Engineering and Technology, Email: [jabin.sumaiya145@gmail.com](mailto:jabin.sumaiya145@gmail.com), Mobile: +8801764196696

The study has shown some compelling results. In case of softening, fire point and specific gravity of different grades of bitumen, <60 and (60-70) grade has the highest average value. In case of solubility and flash point of different grades of bitumen, the grade range (70-80) and (80-100) has the highest average solubility.

Normal distribution of softening point, flash and fire point, solubility and specific gravity of different grades of bitumen has provided an idea about the probability percentage of different grades of bitumen satisfying the minimum standard requirements. Ranking method has been used to identify the most suitable grade range. Ample explanations behind the results have been given and also some methods for improvements have been suggested. Overall the provided data have been analyzed in all possible ways for figuring out a satisfactory result. The context of the roadway and climate condition of our country has been kept under consideration throughout the process.

### **LITERATURE REVIEW:**

This segment contains a brief idea about the composition and characteristics of bitumen materials as well as the statistical parameters used.

To ensure the quality of bitumen several tests were performed. Only six major tests were highlighted which are as follows.

- Penetration Test
- Fire Point Test
- Flash Point Test
- Softening Point Test
- Specific Gravity Test
- Solubility Test

**PENETRATION TEST:**

The penetration value of bitumen is measured by distance in tenths of mm that a standard needle would penetrate vertically into bitumen sample under standard conditions of test. By this test we can determine the hardness or softness value of bitumen.

**FLASH POINT TEST:**

Flash point of bitumen is defined as the point of lowest temperature at which bitumen catches vapors of test flame and fires in the form of flash.

**FIRE POINT TEST:**

Fire point of bitumen is defined as the point of lowest temperature at which the bitumen ignites and burns at least for 5 second under specific conditions of test

**SOFTENING POINT TEST:**

Softening point of bitumen indicates the point at which bitumen attains a particular degree of softening under specified conditions of the test.

**SPECIFIC GRAVITY TEST:**

Specific gravity of bitumen is the ration of mass of given volume of bitumen to the mass of equal volume of water at specified temperature. Specific gravity is the good indicator of quality of binder.

**SOLUBILITY TEST:**

Solubility test is used to determine the degree of solubility of bitumen in trichloroethylene of asphalt materials having little or no mineral matter. It indicates the chances of pollutants being mixed with bitumen.

The collected data were analyzed with the help of a few statistical tools which are,

- Mean, Median and Mode
- Variance
- Standard Deviation
- Skewness

- Kurtosis
- Co-relation Coefficient
- Normal Distribution

**MEAN:**

The mean is the average of all numbers and is sometimes called the arithmetic mean.

**MEDIAN:**

In the data center, means and medians are often tracked over time to spot trends, which inform capacity planning or power cost predictions. The statistical median is the middle number in a sequence of numbers.

**MODE:**

The mode is the number that occurs most often within a set of numbers. Mode helps identify the most common or frequent occurrence of a characteristic.

A large standard deviation indicates that the data points can spread far from the mean and a small standard deviation indicates that they are clustered closely around the mean.

**VARIANCE:**

In probability theory and statistics, variance is the expectation of the squared deviation of a random variable from its mean, and it informally measures how far a set of (random) numbers are spread out from their mean.

**STANDARD DEVIATION:**

In statistics, the standard deviation is a measure that is used to quantify the amount of variation or dispersion of a set of data values. A low standard deviation indicates that the data points tend to be close to the mean (also called the expected value) of the set, while a high standard deviation indicates that the data points are spread out over a wider range of values.

**SKEWNESS:**

In probability theory and statistics, skewness is a measure of the asymmetry of the probability distribution of a real-valued random variable about its mean. The skewness value can be positive or negative, or even undefined.

**KURTOSIS:**

In probability theory and statistics, kurtosis is a measure of the "tailedness" of the probability distribution of a real-valued random variable.

**CO RELATION COEFFICIENT:**

A correlation coefficient is a number that quantifies a type of correlation and dependence, meaning statistical relationships between two or more values in fundamental statistics.

**NORMAL DISTRIBUTION:**

Normal distributions are important in statistics and are often used in the natural and social sciences to represent real-valued random variables whose distributions are not known.

**METHODOLOGY:**

Bitumen under this project is grouped according to their penetration value and the groups are:

- Grade range <50
- Grade range <60 and (60-70)
- Grade range (70-80) and (80-100)
- Grade range >100

Normally two grade ranges are considered for the roadway construction in Bangladesh. These are (60-70) and (80-100). But more grade ranges apart from these such as, <50, (70-80) and >100 have been considered for our thesis work.

The grade wise sorted data were later on sorted on the basis of 5 tests, namely;

- Softening point test.
- Flash point test.
- Fire point test.
- Solubility test.
- Specific gravity test.

The significance of statistical data are given in full description below,

- Average gives the general idea about a grade of bitumen, what will be the value of a particular characteristic.
- Standard deviation gives the idea about how much the value can be deviated from the average value. Less the deviation means the average value is more representative.
- The right and the left side may not be mirror images. Skewness measures this extent of asymmetry. If the data is positively skewed then it will have a much longer right tail than the left tail. In this case, mean and median will be greater than mode. In most of the cases, mean will be greater than median.
- Similarly, if the data is skewed to the left then it will have a much longer left tail and the data is called negatively skewed, left-skewed, left-tailed or simply tailed to the left.
- A high kurtosis value indicates a distinct peak near the mean and fatter tails while a lower or negative kurtosis value indicates wider peak around mean and thinner tails.

Mainly four types of analysis criteria are discussed here.

- Statistical Analysis, that is the test wise analysis of different statistical parameters of each grade of bitumen.
- Co-relation Coefficient Analysis, that is the test wise analysis of the co-relation between the penetration and other test values for each grade of bitumen.
- Normal Distribution Analysis, that shows how the various test result data vary around their mean.
- Quantity Of Test Analysis, that is the grade wise analysis of number of tests.

## **RESULTS & DISCUSSION:**

The results obtained from the analysis can be expressed in the tabular forms. It will assist in getting the whole idea of this thesis work at a glance. The results of have also been presented in the sequence of analysis criterion. Comments are provided in order to hold the summarization together.

The tabular summarization is given below,

- **RESULTS FROM STATISTICAL ANALYSIS :**

<b>NAME OF THE TEST</b>	<b>STATISTICAL PARAMETERS</b>	<b>CHANGING PATTERN WITH GRADE INCREMENT</b>	<b>COMMENTS</b>
<b>SOFTENING POINT</b>	Mean	Decreasing	The lower grades with lower Softening point indicates low temperature susceptibility and better quality
	Median	Decreasing	
	Mode	Decreasing	
	Standard Deviation	Increasing	In this study lower grades with low SD and Variance is less deviated from the mean
	Variance	Increasing	
	Skewness	Increasing (+/-)	Less asymmetry in (>60 and 60-70) range with less value

	Kurtosis	Decreasing	Peak distribution for less grade with positive value
<b>FLASH POINT</b>	Mean	Decreasing	The lower grades have greater Flash point and indicates better quality
	Median	Decreasing	
	Mode	Same	
	Standard Deviation	Close value	All these grades have large deviations and are largely spread out from the mean with irregular changing pattern
	Variance	Irregular	<60 and (60-70)range has asymmetric distribution and peakdistribution
	Skewness	Irregular	
	Kurtosis	Irregular	
<b>FIRE POINT</b>	Mean	Decreasing	The lower grades have greater Fire Point and indicates better quality and safety
	Median	Decreasing	
	Mode	Same	
	Standard Deviation	Increasing	All these grades have large deviations and largely spread out from the mean with irregular changing pattern but the grade >60 and (60-70) is less deviated from the mean
	Variance	Increasing	<60 and (60-70)range has asymmetric distribution and peakdistribution
	Skewness	Irregular	
	Kurtosis	Decreasing	
<b>SOLUBILITY</b>	Mean	Increasing	Lower grades have lower solubility with lower contamination and better quality
	Median	Increasing	
	Mode	Increasing	
	Standard Deviation	Irregular	All the grades have low SD and variance and the values are close to the mean with less deviation
	Variance	Irregular	Both groups asymmetric distribution and flat distribution with negative values
	Skewness	Increasing (+/-)	
	Kurtosis	Irregular	
<b>SPECIFIC GRAVITY</b>	Mean	Decreasing	Values are close and in between ASTM provided range of 1.01-1.06
	Median	Decreasing	
	Mode	Irregular	
	Standard Deviation	Irregular	All the grades have low SD and variance and the values are close to the mean with less deviation
	Variance	Zero	Asymmetric distribution and peak distribution
	Skewness	Decreasing	
	Kurtosis	Decreasing	

From the results analysis above we can see that the grade range **<60 and (60-70)** is the most suitable and widely used penetration grade range of Bitumen for the roadway conditions of Bangladesh.

TESTS	STANDARD	<60 AND (60-70)	COMMENTS
<b>SOFTENING POINT (°C)</b>	46~58	49.28	OK
<b>FLASH POINT (°C)</b>	250 (min)	283.7	OK
<b>FIRE POINT (°C)</b>	400 (max)	339.98	OK
<b>SOLUBILITY (%)</b>	99.5 (max)	99.43	OK
<b>SPECIFIC GRAVITY</b>	1.01~1.06	1.03	OK

- **RESULTS FROM CO-RELATION ANALYSIS:**

NAME OF THE TEST	TYPE OF CORRELATION	COMMENTS
<b>SOFTENING POINT</b>	negative	Softening point decreases with increasing penetration grade
<b>FLASH POINT</b>	negative	Flash point decreases with increasing penetration grade
<b>FIRE POINT</b>	negative	Fire point decreases with increasing penetration grade
<b>SOLUBILITY</b>	positive	Solubility increases with increasing penetration grade
<b>SPECIFIC GRAVITY</b>	negative	Specific Gravity decreases with increasing penetration grade

This table provides a clear view of changing pattern and co-relation of other properties with penetration grade and we can clearly see lower penetration grades provide better results.

• **RESULTS FROM NORMAL DISTRIBUTION ANALYSIS:**

NAME OF THE TEST	NAME OF PARAMETER	GRADES			COMMENTS ON PROBABILITY
		<60 and (60-70)	(70-80) and (80-100)	>100	
SOFTENING POINT	Standards	46/58 °C	43/51°C	39/47°C	High
	Probability of meeting the range(%)	90.29	88.86	61.09	
FLASH POINT	Standards	250 °C min	250 °C min	230 °C min	High
	Probability of meeting the range(%)	99.86	99.98	90.66	
FIRE POINT	Standards	400°C max	400°C max	400°C max	Perfect
	Probability of meeting the range(%)	100	100	100	
SOLUBILITY	Standards	99.5 % max	99.5 % max	99.5 % max	Moderate
	Probability of meeting the range(%)	57.53	47.61		
SPECIFIC GRAVITY	Standards	1.01/1.06 kg/cm <sup>3</sup>	1.01/1.06 kg/cm <sup>3</sup>	1.01/1.06 kg/cm <sup>3</sup>	Moderate
	Probability of meeting the range(%)	77.45	66.87		

We can see the grade <60 and (60-70) has higher probabilities of meeting the standards.

• **RESULTS FROM QUANTATIVE ANALYSIS OF TESTS:**

<b>NAME OF THE TEST</b>	<b>NO. OF DATA ANALYZED</b>	<b>RANK BASED ON NO. OF TEST DONE</b>	<b>SCOPE OF THE TEST</b>
<b>PENETRATION</b>	314	1	Hardness , consistency, suitability in different climate
<b>DUCTILITY</b>	284	3	Measure of tensile strength, the amount bitumen will stretch at temperature below its softening point.
<b>SOFTENING POINT</b>	312	2	Temperature susceptibility
<b>FLASH POINT</b>	109	4	Temperature at which a fluid generates enough vapor to be ignited
<b>FIRE POINT</b>	109	5	Temperature of continuous vaporization and ignition
<b>SPECIFIC GRAVITY</b>	97	6	Amount of impurities
<b>SOLUBILITY</b>	66	7	Detect contamination
<b>LOSS ON HEATING</b>	16	8	Amount of loss of volatile components
<b>KINEMATIC VISCOSITY</b>	1	9	Fluid property , resistance to flow, stability, strength of the resulting paving mixes
<b>ABSOLUTE VISCOSITY</b>	1	10	

From the above charts we can conclude that,

- The top 3 most demanded tests in the BUET laboratory as well as Bangladesh is penetration, softening point and Ductility tests of Bitumen. These tests focus on the areas of hardness, consistency, suitability with climate, temperature susceptibility, tensile strength etc.
- Other tests like flash-fire points, specific gravity and solubility are given moderate importance as number of tests performed in our data set is moderate. These tests focus on the areas of ignition temperature, presence of impurities etc.

- The low focusing tests in these data sets are loss on heating and viscosity; these parameters are less considered or almost ignored. These tests focus on the areas loss of volatile components, fluid property and stability.

As the climate of Bangladesh is hot during summer , to resist rutting under heavy truck loads we need harder and less temperature susceptible Bitumen which we get from low penetration grades and high viscosity grade. Different grades of Bitumen suitable in different atmospheric temperature is shown in the table below:

<b>PENETRATION GRADE (PG)</b>	<b>VISCOSITY GRADE (VG)</b>	<b>ATMOSPHERIC TEMPERATURE(°C )</b>
<b>30/40</b>	VG-40	15 to 55
<b>50/60</b>	VG-30	10 to 50
<b>60/70</b>	VG-20	0 to 40
<b>80/100</b>	VG-10	-10 to 30

[Source: Nagabhushana, 2008]

As the temperature range is in between 0-40 °C in Bangladesh, the 60/70 to lower PG or VG-20 to higher VG is suitable in the weather condition of Bangladesh.

## **CONCLUSION:**

Bitumen gains certain unique properties that are inbuilt in it during its manufacture. The bitumen as a raw material in flexible road construction and bitumen as a mix (composing other materials i.e. aggregates/pozzolans) serves certain advantages, that prompt to use bitumen widely in road construction. So far following steps have been taken in finding out the best suited bitumen grades and measures to improve the quality,

- The raw data were sorted in two steps, at first grade wise and then test wise.
- The data were then analyzed using several statistical parameters such as, mean, median, mode, standard deviation, variance, skewness, kurtosis, co relation coefficient and normal distribution.

- Taking under consideration the analyzed values, the comparatively better grades were chosen with the help of ranking method.
- The best grade range was found to be the range **<60 and (60-70)**.
- This grade range has an average softening point of **49.28°C**. Which is satisfactory since it is slightly above the allowable range for this grade which is 43°C~49°C.
- The range has the average flash point of **283.70°C**. Which is satisfactory since it is greater than the allowable minimum of 250°C.
- The range has the average fire point of **339.98°C**. Which is satisfactory since it is greater than the allowable minimum of 250°C.
- The average value for solubility is **99.43%**. The maximum allowable solubility for grade <60 and (60-70) is 99.49%. So the obtained value can be considered acceptable.
- The average value for specific gravity is **1.03** The maximum allowable specific gravity for grade <60 and (60-70) is 1.02. So the obtained value can be considered acceptable.
- Besides these the analysis by normal distribution graph have also been conducted which gave us a clear idea about the probability of meeting the standards fixed for various tests of different grade ranges. Grade >60 and 60-70 also shows better meeting probability here.
- Qualitative and quantitative analysis have paved the way of understanding the main idea within a single pie chart and a histogram.
- The weather condition of our country has been analyzed and suitable grades warranted in these weather has also been shown and that is also 60/70 and lower penetration grades.
- Some scopes of improvements by modification of bitumen with addition of polymers from various waste sources have paved the way of both quality improvements and waste recycling. These scopes have been derived from previous researches on this context which has been conducted in Bangladesh and India mainly.

These analysis works showed us why accurate gradation and analyzing studies of bitumen are important, specially for the roadway condition of our country. The roadway condition of Bangladesh is critical because of the hot weather condition. It is highly appreciable about the fact that bitumen has a favorable melting point that helps in both surface dressing and wearing resistance with ease.

Also the super adhesive nature and lower melting point has gained bitumen the importance that it holds for the roadways in our climate condition. Excessive studies in this field will hopefully lead to a better realm and open the door of unlimited potential.

### **REFERENCES:**

1. Islam, M. Nurul. "An introduction to statistics and probability." *Mullick & Brothers, Dhaka New Market, Dhaka* (2004).
2. Gupta, S. P., and M. P. Gupta. "Business statistics." *New Delhi, Sultan Chand*(1997).
3. Dixon, Wilerid J., and J. Massey Frank. *Introduction To Statistical Analysis*. McGraw-Hill Book Company, Inc; New York, 1950.
4. Cooper, Brian Edward. *Statistics for experimentalists*. Elsevier, 2014.
5. Vamshi, Avula. "Use of Waste Plastic in Construction of Bituminous Road." *Journal of Engineering (JOE) ISSN: 2325-0224*.
6. Arun, Miss Mane Priyanka, and Mr Petkar Deepak Ganesh. "Laboratory Evaluation of Usage of Waste Tyre Rubber in Bituminous Concrete." (2013).
7. Shah, Syed Shahan Ali, and Rawid Khan. "Re-Use of Hospital Plastic Waste in Asphalt Mixes as Partial Replacement of Coarse Aggregate." *Open Journal of Civil Engineering* 6.03 (2016): 381.
8. Soon. "Rheology of waste paint blended binders". *Australian Journal of Basic and Applied Sciences*, (2016).
9. Abul Kashem, Mohammad. "Use of waste plastic blended bitumen for road construction and maintenance." (2012).

10. Al Hossain, Abdullah. "Study on the rheological properties of polymer modified bituminous binder and mixes." (2006).
11. Islam, M. S., "A Study on the Prospects of Using Polymers in Bituminous Binder and Mixes", (2003).
12. Nagabhushana, M. N. "Right grade of bitumen for flexible pavements-Indian Perspective." All India Seminar on Highway Development: Design, Construction operation and Repairs, Indian Concrete Institute & institution of engineers (India), Lucknow Nov, 2008, 2008.
13. Wright, Paul H., and Radnor Joseph Paquette. *Highway engineering*. 1987.
14. Rahman, Md Nobinur, et al. "Experimental Behavior of Waste Polyethylene and PVC on the Compressive Strength of Bituminous Mixes."
15. Ztable. Retrieved from:  
<http://www.stat.ufl.edu/~athienit/Tables/Ztable.pdf>  
[Accessed 05/09/2017]
16. Bitumen Standards. Retrieved from:  
<http://rahabitumen.com>  
[Accessed 05/09/2017]