Comparative Study of Marshall Stability Test on Dense Bituminous Macadam Layer by Varying number of Blows

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***Abstract*— The utilization of bitumen along with the admixtures in road construction, generally provides many benefits. Construction of roads is a continuous process, as the necessity of highway pavement plays an important role in transportation industry. The purpose of highway pavement is to provide smooth surface over which vehicles can move smoothly from one place to another. In this contemporary world, with increasing population and rapidly increasing manufacturing of vehicles, it has become much necessary to construct more and more roads, in order to satisfy human life.**

The following report consists of details of stability and flow index of bitumen by conducting Marshall Stability of bitumen by varying the number of blows like 50 and 75 blows for different percentage of bitumen i.e. 3%, 3.5%, 4%, 4.5% and 5%. The following report gives the brief description regarding the comparison between different numbers of blows given to the bituminous samples.

Keywords*— *Bitumen; Marshall Stability Test; OBC;

1. INTRODUCTION

Bituminous concrete mix is commonly designed by Marshall method. This test is extensively used in the routine test programmes for the paving jobs. The stability of mix is defined as maximum load carried by compacted specimen at standard test temperature of 60 degree Celsius. The flow is measured as the deformation in units of 0.25mm between no load and maximum load carried by the specimen during the stability test (flow value may be measured by deformation units of 0.1mm).

This test attempts to get the optimum binder content for the aggregate mix type and traffic intensity. This is a test which helps us to draw the Marshall stability vs. % of bitumen. The principle of this test is that Marshall Stability is the resistance to plastic flow of cylindrical specimens of the bituminous mixtures loaded on the lateral surface. It is the load carrying capacity of the mix at 60 degree Celsius and is measured in Kg.

The apparatus needed to determine the Marshall stability of bitumen mixture is

1) Marshall Stability testing machine
2) Balance and Water bath
3) Compaction Mould assembly
4) Specimen extractor
5) Deformation measuring dial gauge
6) Breaking head dial gauge

The sample needed is, from Marshall Stability graph, select portions of the coarse aggregates, fine aggregates in such a way, so as to fulfil the required specifications. The total weight of the mix should be 1200 g.

The mix design should aim at the economical factor with proper gradation of aggregates and adequate proportion of bitumen so as to fulfil the desired properties of mix which are stability, durability, flexibility, skid resistance and workability. Mix design methods should aim at determining the properties of aggregates and bituminous material which would give a mix with these properties. The design of asphalt paving mixtures is a multi-step process of selecting binders and aggregate materials and proportioning them to provide an appropriate compromise among several variables that affect mixture behavior, considering external factors such as traffic loading and climate conditions. In the construction of flexible pavements, bitumen plays the role of binding the aggregate together by coating over the aggregate. It also helps to improve the strength of the road. But its resistance towards water is poor. Anti-stripping agents are being used. Bitumen is a sticky, black and highly viscous liquid or semi-solid which can be found in some natural deposits or obtained as by-product of fractional distillation of crude petroleum. It is the heaviest fraction of crude oil, the one with highest boiling point (525°C) .Various Grades of Bitumen used for pavement purpose:30/40, 60/70 and 80/100.

I.

1.1 BACKGROUND AND RELATED WORK

"Optimum Use of Plastic Waste to Enhance the Marshall Properties". Assist. Prof. Dr. Hamed M. Jassim (IJETT, Vol. 7 -2014)

The vast quantities of plastic waste resulting from the different types and sizes of bottles which are used to contain all types of liquid products such as (Mineral Water, Oils, and detergents ….etc) in municipal solid waste is increasing in the last years due to increase in population, development activities and changes in life style. Thus disposal of plastic waste is amenace and becomes a serious problem globally due to their non-biodegradability and an aesthetic view. This paper focused on Marshall test and index of retained strength to determine the properties of plastic waste particles such as (size, thickness, and percent of content) which provide the ultimate performance of hot mix asphalt. For this purpose plastic wastes were added by six different sizes of particles (passing sieve 3/4" (19.0 mm) to retaining on sieve No.50 (0.3 mm)), four thicknesses (0.2, 0.5, 0.8 and 1.0) mm, and five content percentages (5, 10, 15, 20 and 25) % by weight of total aggregate. On the basis of experimental results, it was concluded that adding plastic waste with fine particles size ,thin thickness and at 15% by weight of total aggregate resulted in improving the Marshall stability and resistance to water damage, as well as they can contribute to relieve some of the environmental problems caused by classical plastic waste disposal means.

"Strengthening of Flexible Pavement using Egg Shell as a Filler". K.Kiruthiha, G.Loshini, M.Thivya, Guide: **Mr.Vignesh Kumar** M.Tech **(IJETT, Vol.21-2015)**
Construction of pavement involves huge outlay of investment. Addition of certain materials like limestone, coconut shell, egg shell, saw dust etc. It may save considerable investment as well as gives reliable performance. This project describes the use egg shell as filler in bituminous pavements in order to fill the air voids. It involves identification of proper mix by obtaining optimum bitumen content (OBC) and optimum egg shell content by determining the Marshall Stability and flow values.

Based on this study, the use of eggshell as filler material in bituminous pavement produce positive result. This shows that eggshell is suitable to apply in the road construction. However, this study proves that the addition of eggshell in the range of 10-15% in bituminous mix with OBC as 6-6.5% gives better strength compared to conventional mix.

Prashantha & Chethan Kumar N T (IJARSE vol.7 (6))
(International Journal of Advance Research in Science & Engineering)
The present study aims in investigating the experimental performance of the bitumen modified with 15% by weight of crumb rubber varying its sizes. Four different categories of size of crumb rubber will be used , which are coarse(2.36 mm- 1.6 mm); medium size(1.6 mm- 1.18 mm); fine (1.18 mm- 600 µm); and superfine (600 µm- 300µm). Common laboratory tests will be performed on the modified bitumen using various sizes of crumb rubber and thus analyzed. Marshall Stability method is used for mix design. Finally a comparative study is made among the modified bitumen samples using the various sizes of crumb rubber particles and the best size is suggested for the modification to obtain best results.

1.2 OBJECTIVE

The main objective of the project conducted is to know the stability and strength of Indian Roads by giving varying number of blows.

The main objectives of the study are-

1) Determine strength variation due to varying number of blows

2) Determine the flow index with the help of Marshall Stability test by varying number of blows

II. MATERIAL

2.1 Bitumen

VG30 bitumen was used in this investigation to prepare the samples. Table 1 shows the test results of basic properties of bitumen.

Table 1: Basic Properties of Bitumen

Properties	Results
Specific gravity	1.02
Penetration	36 mm
Softening point	37°C
Flash point	330°C
Fire point	350°C
Ductility	79 mm
Viscosity	60/70

2.2. Fine Aggregate

Aggregates of size below 4.75 mm as per MORTH Specifications (5th revision) [Anonymous, 2013] were used as fine aggregate. Table 2 shows the test results of basic properties of fine aggregates.

Table 2: Basic Properties of Fine Aggregates

Properties	Results
Specific gravity	2.64
Water absorption	1.45%

2.3. Coarse Aggregate

Aggregates of 20mm as per MORTH Specifications (5th revision) [Anonymous, 2013] down size were used as Course aggregate. Table 3 shows the test results of basic properties.

Table 3: Basic Properties of Coarse Aggregates

Properties	Results
Specific gravity	2.67
Impact value	18.75%
Water absorption	0.39%

III. EXPERIMENT METHODS

3.1. Rothfutch's Method

Sieve Analysis for different materials A, B and C has to be done and percentage finer has to be calculated for each range of particle size for all materials and grain size distribution curves of these three materials are plotted. Desired Gradation lines represent the proportion in which the materials A, B and C are to be mixed. The results from Rothfutch's method are shown in table 5.

Table 4: Results obtained from Rothfutch's graph

IS Sieves	% used	Wt. of Materials (g)
20 mm	25	300
12.5 mm	30	360
6 mm	25	300
S Dust	17	204
Filler	3	36
Bitumen	-	-
Total	100	1200

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3.2. Marshall Stability Test

The Marshall Stability and flow test provides the performance prediction measure for the Marshall Mix design method. The original Marshall Method is applicable only to hot asphalt paving mixes. Marshall Stability of a test specimen is the maximum load required to produce failure when the specimen is preheated to a prescribed temperature placed in a special test head and the load is applied at a constant strain (50.8 mm/minute). While the stability test is in progress dial gauge is used to measure the vertical deformation of the specimen. The deformation at the failure point expressed in units of 0.25 mm (0.01 inch) is called the Marshall Flow value of the specimen.

The 'Marshall Stability' of the bituminous mix specimen is defined as a maximum load carried in kg at the standard test temperature of 60°C when load is applies under specified test conditions. It involves mainly 2 processes:

- Preparation of Marshall Samples
- Marshall Test on samples

3.3. Preparation of Marshall Samples

- For DBM mixes the coarse aggregates, fine aggregates and filler were mixed with bitumen and modifier used according to the adopted gradation, such that each aggregates are weighed and added.
- This will be about 1200 g referring to Rothfutch's graph results.
- Each material is graded, weighed and placed in an oven until a uniform temperature of 60°C is attained.
- Nominal bitumen mix specimen is prepared; Course aggregate is added to a preheated pan and stirred. When they heat up to around 100°C, melted bitumen is added and mixed thoroughly.
- When the mixture shows well coated by bitumen, fine aggregate and cement (filler material) is slowly added.
- The ingredients are heated until they reach 130°C.

3.4. Marshall test on samples

Marshall Stability test is conducted on compacted cylindrical specimens of bituminous mix of diameter 101.6 mm, thickness 63.5 mm. The load is applied perpendicular to the axis of the cylindrical specimen through a testing head consisting of a pair of cylindrical segments, at a constant rate of deformation of 51 mm per minute at a standard test temperature of 60°C. The 'Marshall Stability' of the bituminous mix specimen is defined as a maximum load carried in kg at the standard test temperature of 60°C when load is applies under specified test conditions. The flow value is the total deformation of Marshall Test specimen at the maximum load, expressed in mm units.

In the Marshall method of mix design, each compacted test specimen is subjected to the following tests and analysis.

- Bulk specific gravity (Gb) determination
- Stability and Flow test and
- Void analysis

Bulk specific gravity (G_b) determination

Bulk specific gravities of saturated surface dry specimens are determined.

Stability and flow tests

After determining the bulk specific gravity of the test specimens, the stability and flow tests are performed. Place the specimen centrally on the lower testing head and fit upper head carefully. Fix the flow meter with zero as initial reading. The load is applied at a constant rate of deformation of 51 mm (2 inches) per minute. The total load at failure is recorded as its Marshall Stability Value. The reading of flow meter in units of 0.25 mm gives the Marshall Flow value of the specimen. The entire testing process starting with the removal of specimen from bath up to measurement of flow and stability shall not take more 30 seconds. While the stability test is in progress, hold the flow meter firmly over the guide road and record.

Density and voids analysis

After completion of the stability and flow test, a density and voids analysis is done for each set of specimens. The calculations are given in section 5. Average the bulk density is determined for asphalt content. This average value of G_b is used for further computations in void analysis.

(a) Determine the theoretical density (G_t) for at least 2 bitumen contents nearer to the optimum binder content.

(b) V_v, VMA and VFB are then computed using the standard equations.

Table 5: Marshall Stability and flow values for control mix

Bitumen%	Stability in kg	Flow value in mm
3.0	2300.0	3.60
3.5	2650.0	3.65
4.0	2725.0	3.75
4.5	2825.0	3.80
5.0	2112.5	4.30
5.5	2100.0	4.80
6.0	2087.5	5.00

Table 6: Density and void analysis for control mix

Bitumen%	G_b	V_v	VMA	VFB
3.0	2.272	9.168	15.917	42.523
3.5	2.300	6.9120	14.925	53.688
4.0	2.249	7.9272	15.853	49.994
4.5	2.302	7.420	15.389	51.841
5.0	2.021	7.2905	16.347	55.402
5.5	2.327	10.3793	19.134	45.755
6.0	2.090	8.835	17.741	50.579

Table 7: Marshall Stability and flow values for 50 number of blows

Bitumen%	Stability in kg	Flow value in mm
3.0	1475.0	3.70
3.5	1600.0	3.90
4.0	1725.0	5.05
4.5	1775.0	5.55
5.0	1845.0	5.95
5.5	1275.0	6.40
6.0	1150.0	6.60

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Table 8: Density and void analysis for 50 number of blows .

Bitumen%	G_b	V_v	VMA	VFB
3.0	2.273	9.134	15.886	42.502
3.5	2.272	8.538	16.411	48.032
4.0	2.309	6.396	15.540	60.095
4.5	2.270	7.357	17.468	58.062
5.0	2.195	9.801	20.666	52.591
5.5	2.269	6.112	18.470	67.054
6.0	2.227	7.251	19.379	62.756

COMPARISION OF GRAPHS

1.Stability

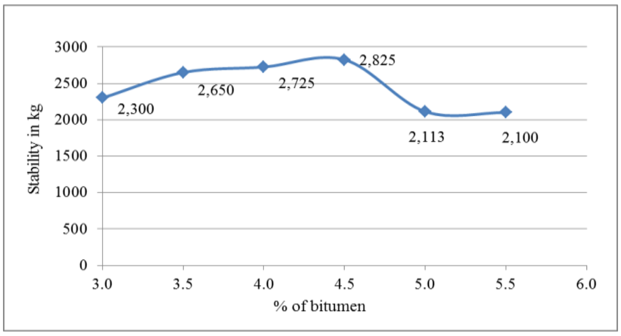

Fig. 1: Marshall Stability for Regular DBM

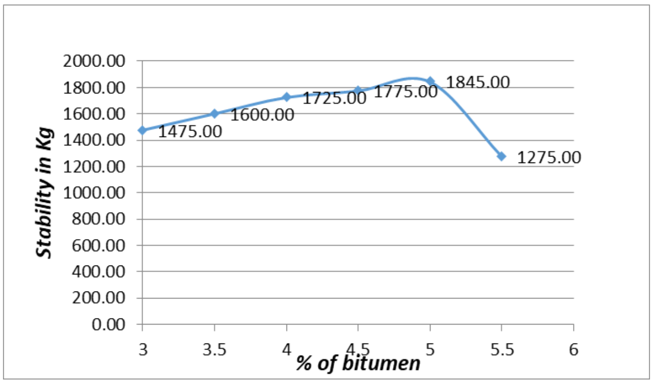

Fig.1.2:Marshall Stability for 50 blows

2.Flow value

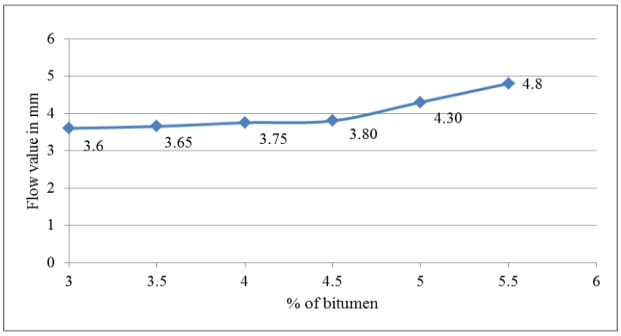

Fig. 2: Flow Value for Regular DBM

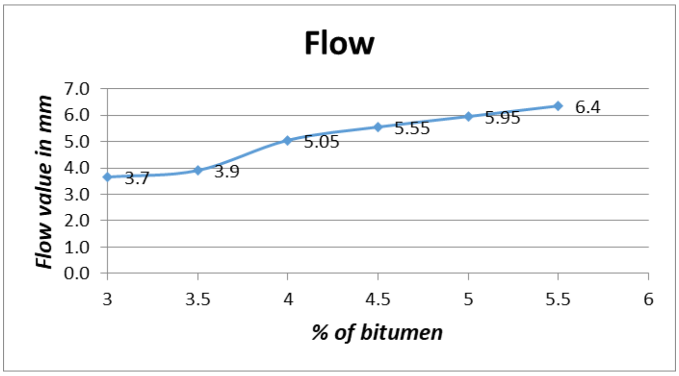

Fig. 2.1: Flow Value for 50 blows

3.Bulk density

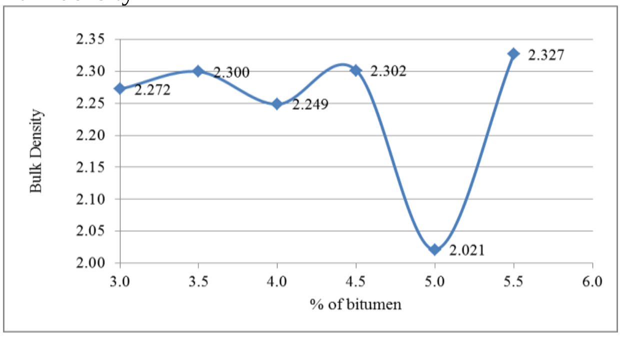

Fig. 3: Bulk Density for Regular DBM

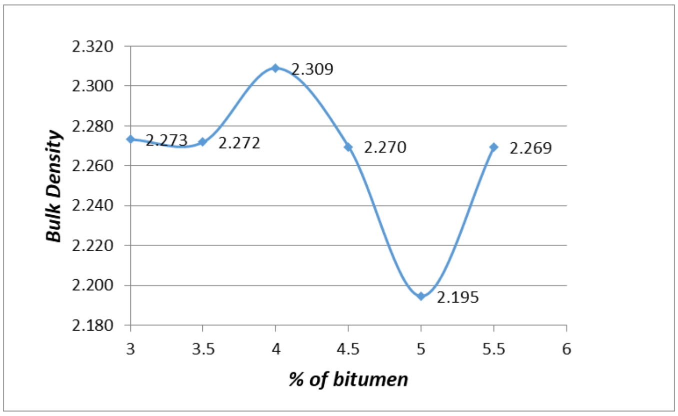

Fig. 3: Bulk Density for 50 blows

4.Volume of voids

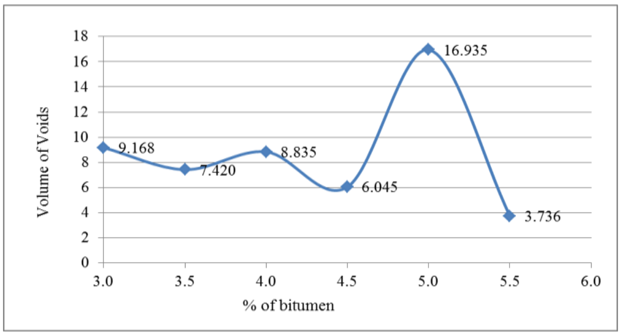

Fig. 4: Volume of Voids in Regular DBM

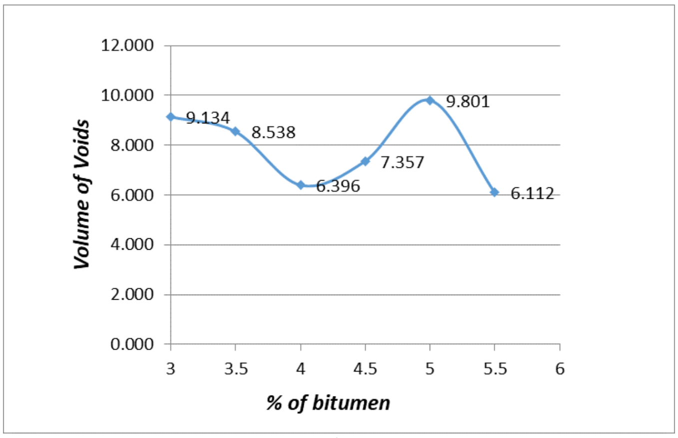

Fig. 4.1: Volume of Voids in 50 blows

5.VMA

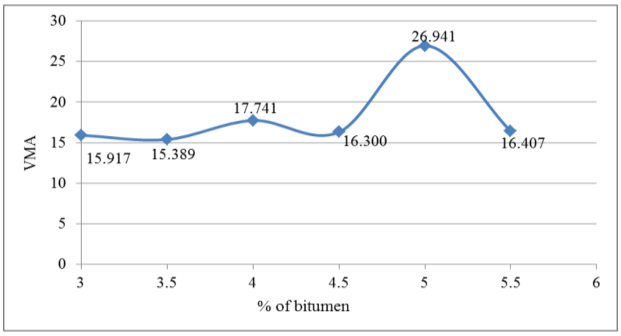

Fig. 5: VMA in Regular DBM

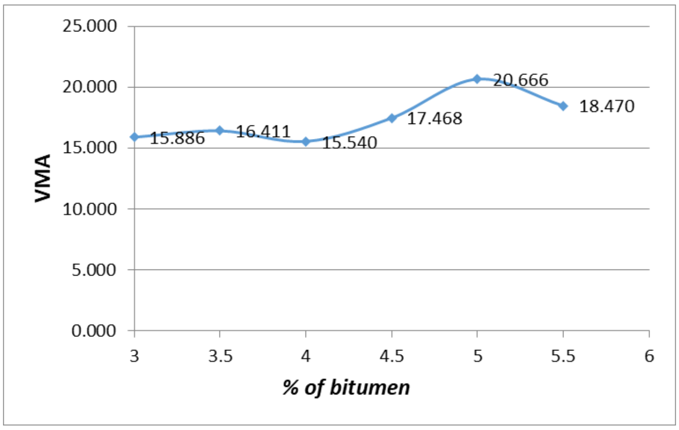

Fig. 5: VMA in 50 blows

6.VFB

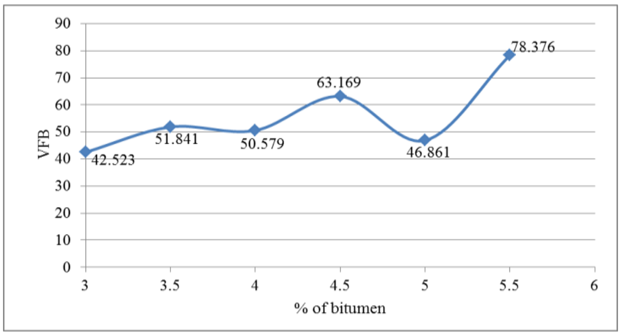

Fig. 6: VFB in Regular DBM

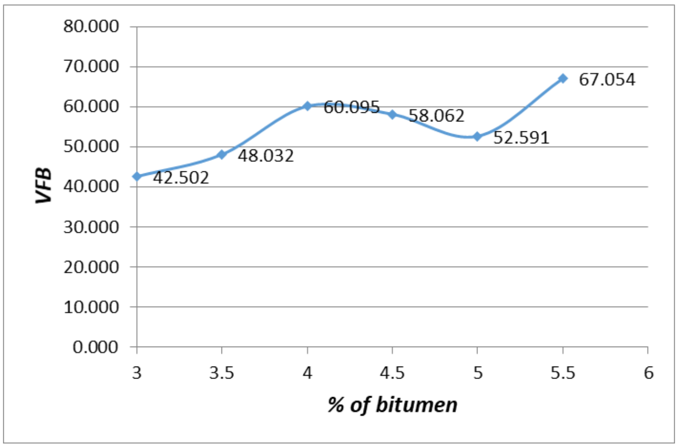

Fig. 6.1: VFB in 50 blows

IV. DISCUSSIONS

It is observed from graphs that with increase in bitumen concentration the Marshall stability value increases up to certain bitumen content and there after it decreases. Thus, the maximum stability was obtained at 4.5% from bitumen% v/s stability graph (Fig.1). The flow value appears to be high in graph 4 at 4.5% of bitumen mix. Marshall Stability value is more in Fig. 1 for 75 blows with 4.5% of bitumen and less in Fig. 1.2 with 5% of bitumen. Flow value for optimum bitumen content (4.5% for 75 blows) in Fig 2 is 5.8mm and flow value for 50 blows is 5.95mm is evident from Fig 2.1 for 5% of bitumen. In both Fig 3 and 3.1, we obtain least bulk density at 5% of bitumen content i.e. 2.021 and 2.195 respectively for 75 blows and 50 blows. Volume of voids is very essential to analyses the extent of deformation after loading. From Fig 4 we observe that volume of voids is 6.045 for 4.5% optimum bitumen content. Similarly, from Fig 4.1, we observe that volume of voids is 9.801 for 5% optimum bitumen content

V. CONCLUSION

On comparing both the results and graphs, we derive that 75 blows are more effective and gives more Marshall Stability values with less percentage of bitumen content.

From the experimental study, the following conclusions can be drawn

1) On comparing the results of 50 and 75 number of blows the stability and flexibility value is more for 75 number of blows
2) By observing graph it can be concluded that 75 number of blows specimen is more Marshall stability value and flow index value.
3) On comparing the results it can be observed that optimum binder content is 0.5% more for 50 number of blows specimen with 75 number of blows specimen.

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