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Full Length Research Paper

Effect of e-Quality control on Tolerance limits in WMM and DBM in highway construction - A Case Study

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This paper involves a case study which has been carried out to know the effect of e-quality control in Highway construction on the tolerance limits of WMM and DBM. The existing tolerance limits have been kept keeping in view the normal system of quality control and permits higher range of variations for acceptance. This study involves the solution of a real life problem faced by an engineer during the construction of a highway. In this paper, we present a methodology using e-quality control system and updated machinery to see its effect on the tolerance limits of WMM and DBM. To understand the methodology a field case study is presented here.

Keywords: e-control, WMM, DBM, tolerances, GPS, Consumption, VTS etc.

INTRODUCTION

The economic development of a country largely depends on the conditions of roads as these play a vital role in this. With the fast development of the country, the pace of construction of Highways has increased. In this electronic era, with the use of new technologies the riding quality of roads is improving day by day. The modern equipments used in the highway construction such as batch mix type hot mix plant with electronic sensor, cone crusher (integrated stone crushing and screening plant), automatic wet mix plant with moisture content controller, concrete batching and mixing plant with automatic control, paver finisher with electronic sensor, vibratory road rollers/compactor etc. automatically control the quality of product (Bant et al., 2012). With the e-quality control system, the quality and quantity of the work is assured. This system includes all those planned actions that are necessary to provide adequate confidence that the product will meet all the requirements and is conforming to the specifications. It ensures that 100% material has been used as per requirements in a particular stretch of the road. The existing tolerance limits in the existing codes have been kept keeping in view the normal system of quality control and permits higher range of variations for acceptance. Now, in a system where all the activities of a highway construction are electronically controlled and which assures the quality and quantity of the work, the tolerance limits prescribed in the codes needs to be re-looked and revised so as to accept the best work strictly as per standards (Mukherjee et al., 2001).

Preliminaries

In this section, some preliminaries have been presented which will be useful to our main work in next session.

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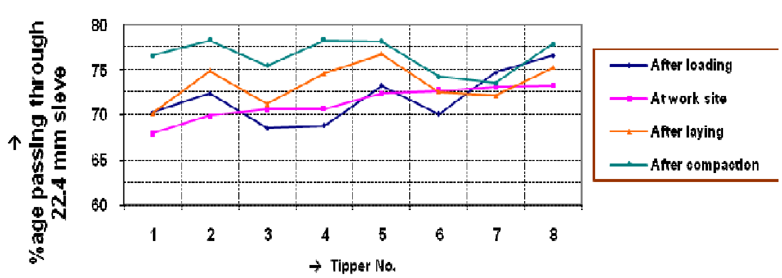
Table 1. (Gradation data of WMM at various stages)

Sr. No.	Tipper No.	Location	Sieve size in mm							
			53	**45**	**22.40**	**11.20**	**4.75**	**2.360**	**0.60**	**0.075**
1.	KA22B5719	After loading	100	100	70.23	54.13	36.06	23.67	14.97	5.06
		At work site	100	100	67.92	55.23	31.26	25.10	16.24	4.37
		After laying	100	100	70.14	52.14	35.49	26.71	15.33	6.11
		After compaction	100	100	76.55	56.42	37.55	28.41	15.83	4.81
2.	TN30L0883	After loading	100	100	72.33	51.22	33.55	23.55	16.55	5.66
		At work site	100	100	69.88	50.88	33.78	20.88	16.55	4.52
		After laying	100	100	74.88	54.88	37.44	28.44	18.33	6.12
		After compaction	100	100	78.22	58.22	37.44	26.88	20.11	5.89
3.	KA22B5715	After loading	100	100	68.52	50.46	28.68	22.74	16.92	5.65
		At work site	100	100	70.62	48.72	34.54	22.82	19.54	4.68
		After laying	100	100	71.22	49.11	34.66	23.11	15.66	5.88
		After compaction	100	100	75.44	54.22	34.56	26.12	14.82	5.41
4.	KA22B5717	After loading	100	100	68.82	55.42	33.62	24.25	18.08	5.66
		At work site	100	100	70.68	53.42	29.74	24.56	18.94	5.08
		After laying	100	100	74.55	56.41	34.78	24.66	13.55	4.98
		After compaction	100	100	78.22	57.09	36.12	25.10	15.14	4.26
5.	TN30L0913	After loading	100	100	73.21	56.42	36.21	24.10	17.03	5.23
		At work site	100	100	72.33	51.60	32.10	23.11	14.06	5.26
		After laying	100	100	76.75	57.44	36.88	26.88	17.56	6.44
		After compaction	100	100	78.14	56.17	37.88	28.22	18.22	5.89
6.	KA22B5716	After loading	100	100	70.06	51.60	34.12	23.60	16.36	4.97
		At work site	100	100	72.63	53.71	35.26	24.12	16.34	3.96
		After laying	100	100	72.55	54.71	34.15	26.32	16.74	4.50
		After compaction	100	100	74.21	53.12	34.25	25.14	17.25	3.96
7.	TN300911	After loading	100	100	74.68	54.18	36.40	22.18	16.80	5.14
		At work site	100	100	73.14	52.60	37.18	22.16	17.18	3.01
		After laying	100	100	72.13	56.44	37.88	23.19	17.58	4.89
		After compaction	100	100	73.52	57.83	38.61	24.34	18.43	5.36
8.	TN30K6610	After loading	100	100	76.55	57.88	37.22	25.31	18.22	3.78
		At work site	100	100	73.25	55.88	37.25	24.33	15.66	2.88
		After laying	100	100	75.22	55.11	35.77	27.33	16.52	5.22
		After compaction	100	100	77.83	55.82	36.45	28.12	16.73	5.88

Graph No.1 : for 22.4 mm sieve size (WMM)



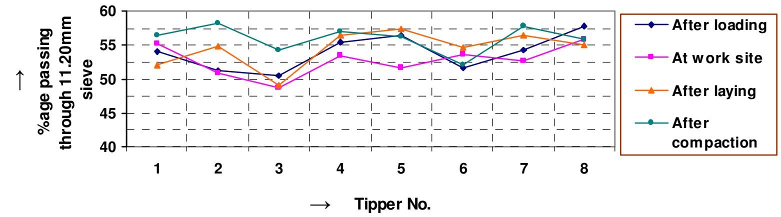
e-quality control system?

In this system, every activity is electronically controlled through the modern equipments having computerized control and the live data is placed on the website along with live photographs in real time in respect of the followings:

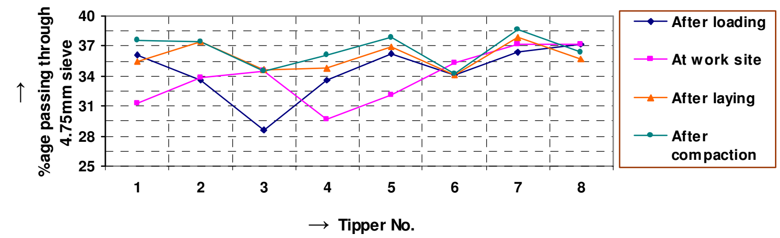
e-control on receipt of bitumen

Generally the bitumen is received from the oil refineries. To control the pilferage of bitumen, the live photographs of the bitumen tankers taken during its weighing on automatic computerized weighing machine are placed in live time on the website with project ID.

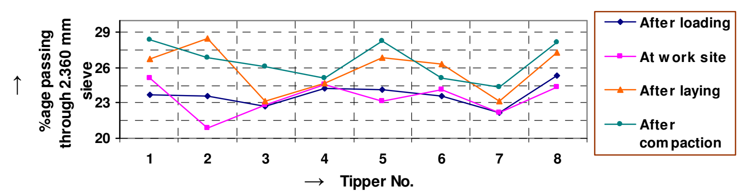
Graph No.2 : for 11.2 mm sieve size (WMM)



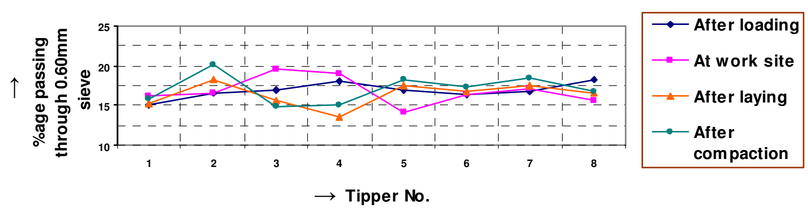
Graph No.3 : for 4.75 mm sieve size (WMM)



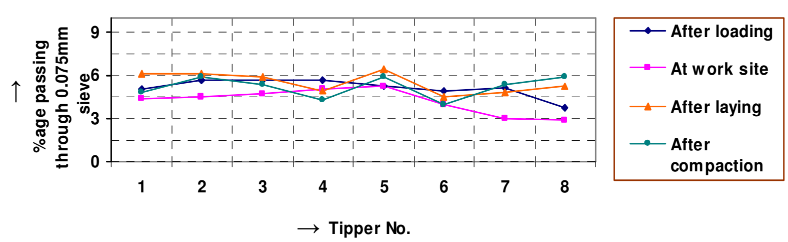
Graph No.4 : for 2.360 mm sieve size (WMM)



Graph No.5 : for 0.60mm sieve size (WMM)



Graph No.6 : for 0.075mm sieve size (WMM)



e-control on mixing of material at plant site

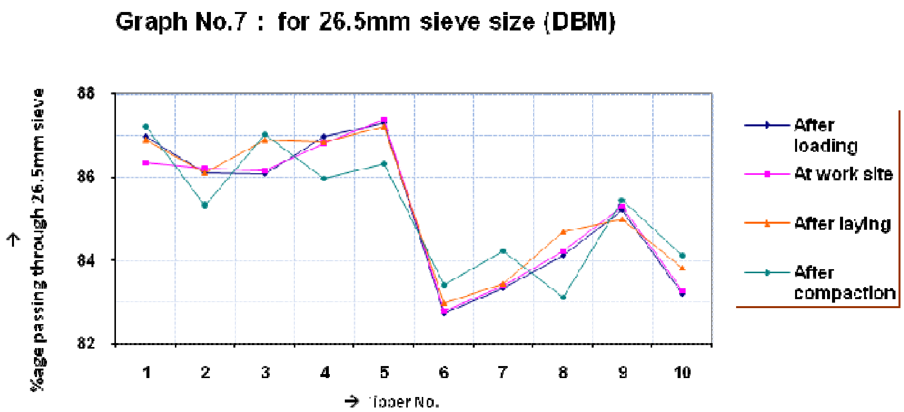
The Batch mix type Hot Mix Plant with electronic sensor (which automatically controls proportion of different fractions and bitumen) is used. The proportions of various ingredients required for DBM are set upon the computer of batch type hot mix plant. The live data with project ID is placed on the website (IRC:90-1985).

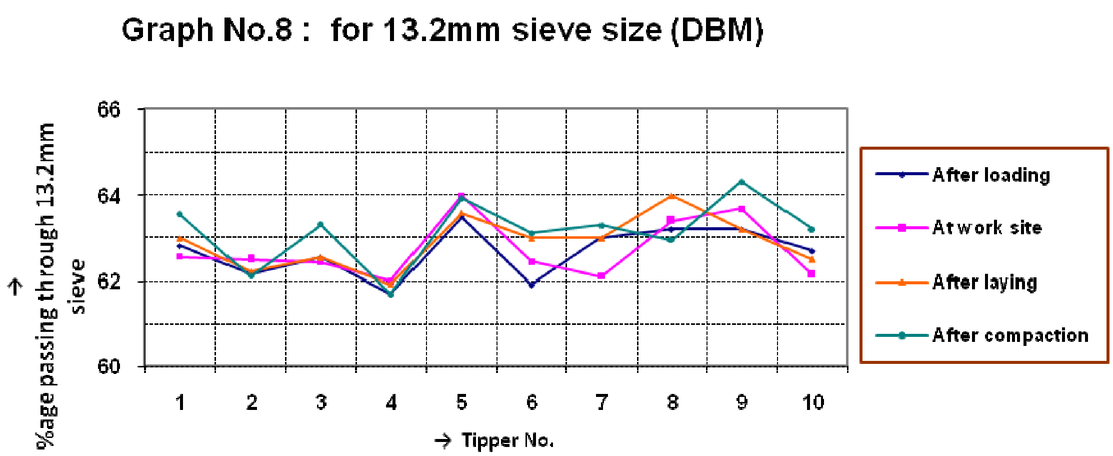
Table 2. (Tolerances for various sizes of aggregates in WMM)

S. No.	Description	% age passing through sieve		Recommended Tolerance Limits
		As per code	As per tests conducted	
1.	Aggregates passing 53mm sieve	100%	100%	100%
2.	Aggregate passing 45mm sieve	95-100%	100%	This sieve size be omitted
3.	Aggregate passing 22.40 mm size	60-80%	67-79%	65-80%
4.	Aggregate passing 11.20 mm sieve	40-60%	50-59%	50-60%
5.	Aggregate passing 4.75 mm sieve	25-40%	30-38%	30-40%
6.	Aggregate passing 2.36 mm sieve	15-30%	20-29%	20-30%
7.	Aggregate passing 600 micron sieve	8-22%	13-21%	12-22%
8.	Aggregate passing 75 micron sieve	0-8%	2-7%	2-8%

Table 3. (Gradation data of DBM at various stages)

Sr. No.	Tipper No.	Location	Sieve size in mm							
			45	37.5	26.5	13.2	4.75	2.36	0.3	0.075
1	KA22B5715	After loading	100	100	86.96	62.80	42.45	33.87	12.51	4.37
		At work site	100	100	86.35	62.55	42.20	33.55	12.01	4.15
		After laying	100	100	86.88	62.98	42.50	37.90	12.89	4.22
		After compaction	100	100	87.22	63.55	39.45	35.22	13.22	3.98
2	TN30K6635	After loading	100	100	86.10	62.15	42.68	33.15	12.90	4.68
		At work site	100	100	86.22	62.48	42.33	33.98	12.52	4.53
		After laying	100	100	86.11	62.20	42.48	33.90	12.68	4.90
		After compaction	100	100	85.30	62.10	41.15	34.90	13.10	5.01
3	KA22B5719	After loading	100	100	86.08	62.53	42.68	33.71	12.81	4.26
		At work site	100	100	86.15	62.43	42.70	33.96	12.53	4.75
		After laying	100	100	86.88	62.53	42.61	33.09	12.09	4.87
		After compaction	100	100	87.02	63.30	41.63	34.09	13.15	4.98
4	KA22B5717	After loading	100	100	86.96	61.68	42.45	33.59	12.68	4.29
		At work site	100	100	86.80	61.99	42.30	33.75	12.99	4.68
		After laying	100	100	86.83	61.92	42.34	33.80	14.01	4.81
		After compaction	100	100	85.98	61.68	43.53	34.30	14.28	5.01
5	TN03L883	After loading	100	100	87.30	63.49	42.55	33.39	11.19	4.20
		At work site	100	100	87.39	63.98	44.43	32.98	11.98	4.69
		After laying	100	100	87.22	63.58	44.12	31.98	12.10	4.70
		After compaction	100	100	86.33	63.92	41.22	34.92	13.80	5.11
6	KA22B5719	After loading	100	100	82.74	61.89	41.44	33.31	14.80	5.50
		At work site	100	100	82.79	62.44	41.31	33.80	14.11	5.10
		After laying	100	100	82.98	62.99	41.98	32.81	14.80	5.00
		After compaction	100	100	83.41	63.11	42.82	33.81	14.11	5.35
7	KA22B5718	After loading	100	100	83.33	62.99	41.55	33.20	13.85	4.60
		At work site	100	100	83.39	62.10	41.36	34.33	14.08	4.81
		After laying	100	100	83.44	62.99	41.55	34.20	12.99	4.88
		After compaction	100	100	84.23	63.29	41.68	32.30	12.68	3.89
8	TN03A7150	After loading	100	100	84.11	63.19	42.91	33.22	12.33	4.78
		At work site	100	100	84.22	63.39	42.98	33.28	12.86	4.50
		After laying	100	100	84.68	63.98	42.22	33.58	13.11	4.80
		After compaction	100	100	83.11	62.94	43.44	33.88	13.88	4.98
9	KA22B5716	After loading	100	100	85.20	63.19	42.88	33.22	12.34	4.62
		At work site	100	100	85.28	63.68	42.20	33.30	12.11	4.20
		After laying	100	100	84.99	63.20	42.28	33.48	12.08	4.68
		After compaction	100	100	85.45	64.32	41.30	34.20	13.08	5.09
10	RJ06G4131	After loading	100	100	83.19	62.68	42.63	33.98	12.85	4.33
		At work site	100	100	83.28	62.12	42.48	33.20	12.10	4.77
		After laying	100	100	83.81	62.48	42.44	33.81	12.63	4.29
		After compaction	100	100	84.11	63.20	43.30	33.13	12.10	4.88





e-control on weighing machine site

As soon as the tipper is filled with the mixed bituminous material, it is brought to the automatic weighing machine to carry out the weight. A camera and GPS instruments are also installed at the weighting machine site and the live data along with photograph is placed on the website.

e-Control on Vehicles

A Vehicle Tracking System along with various devices such as vehicle diagnostic sensors, fuel sensor and Global Positional System (GPS) etc. is attached with each tipper carrying out the material to check the route of the vehicle at all times, fuel consumption per km., kms traveled by the vehicle in a day, working hours of vehicles/day, halt hours of vehicles/day, idle hours of vehicles/day and speed of vehicles etc. (Bant et al., 2012).

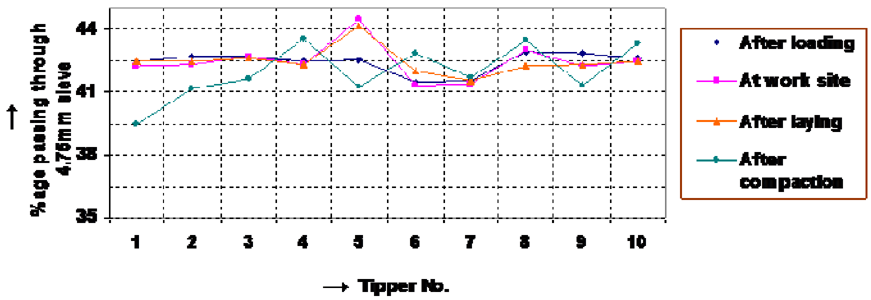
e-Control on Work Site

On the start of the work with a particular tipper on the site, its photograph during unloading in the hopper of the paver is taken and the live data along with location (RD) is placed on website. The same exercise is repeated at the end point where material of this particular tipper finishes. Thus it controls the material used in a particular reach.

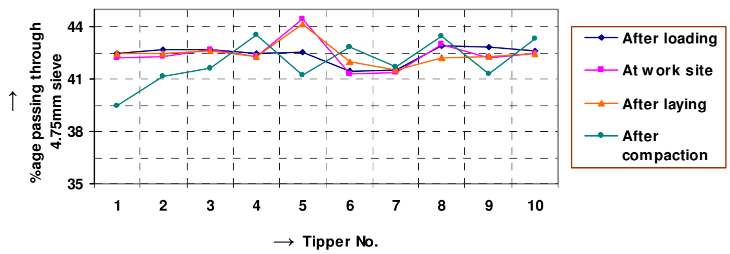
e-control on testing of samples

Every Engineer is given a laptop enabled with GPS and Camera. While conducting the test, the live data is placed on website. It gives the location where test is being conducted along with the photograph of the person conducting the test. Thus, the system checks bogus entries of tests.

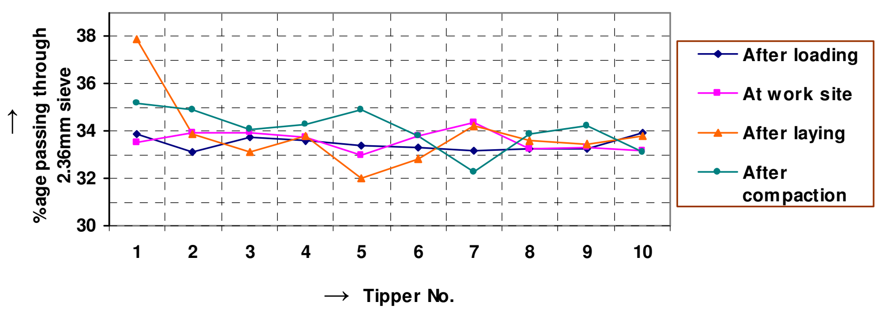
Graph No.9 : for 4.75mm sieve size (DBM)



Graph No.9 : for 4.75mm sieve size (DBM)



Graph No.10 : for 2.36mm sieve size (DBM)



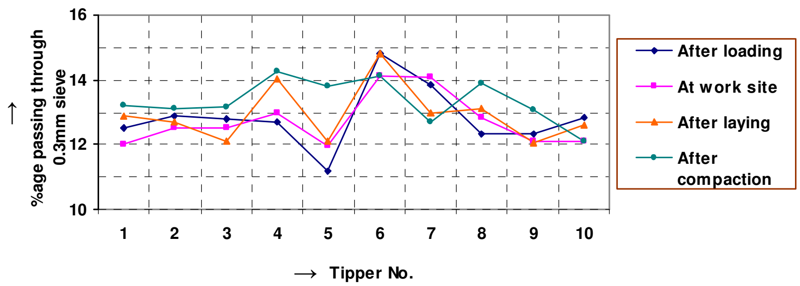
Why change in tolerance limits?

In the codal provisions/specifications, the tolerance limits have been given, so that the contractor can set up the plant to get the percentages of the various ingredients in the actual mix as per job mix formula within the permissible limits of variations and the material is accepted within these tolerance limits (IRC:SP:57-2000). In this electronic age, the modern equipments are used which automatically control the various ingredients of product and check the quality of product. So, in the highway construction where e-quality control system has been adopted, the quality and quantity of the work as per standards is assured (Bant and Srijit,). To upgrade the standards of highways especially in the case of a high speed corridors where a better riding quality is required, the tolerance limits needs to be relooked and revised tolerance limits (lower than the existing) should be allowed.

METHODOLOGY

Firstly, we selected a project to carry out the work in field. The modern equipments such as batch mix type hot mix plant with electronic sensor which automatically controls proportion of different fractions and bitumen, cone crusher (integrated stone crushing and screening plant), automatic wet mix plant with moisture content controller, concrete batching and mixing plant with automatic control

Graph No.11 : for 0.3mm sieve size (DBM)



Graph No.12 : for 0.075mm sieve size (DBM)

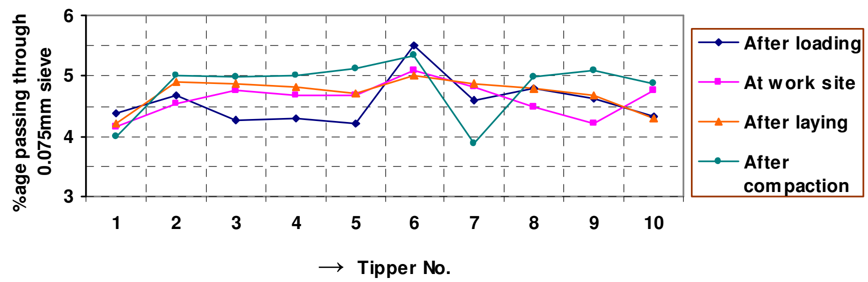


Table 5. (Comparison of Bitumen as per data set on computer, actual tests at plant site & after laying)

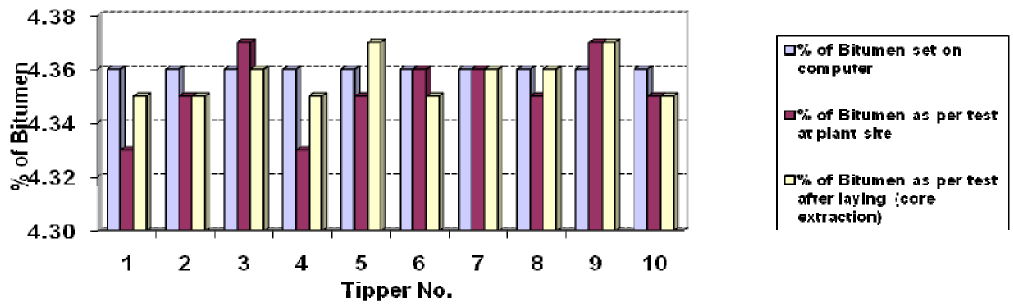
S. N.	Description	KA22 B5715	TN30 K6635	KA22B 5719	KA22B5 717	TN03 L883	KA22B5 719	KA22B5 718	TN03 A7150	KA22B5 716	RJ06 G4131
1.	% of Bitumen set on computer	4.36%	4.36%	4.36%	4.36%	4.36%	4.36%	4.36%	4.36%	4.36%	4.36%
2.	% of Bitumen as per test at plant site	4.33%	4.35%	4.37%	4.33%	4.35%	4.36%	4.36%	4.35%	4.37%	4.35%
3.	% of Bitumen as per test after laying (core extraction)	4.35%	4.35%	4.36%	4.35%	4.37%	4.35%	4.36%	4.36%	4.37%	4.35%
4.	Difference of Sl. No.1 & 2	(-) 0.03%	(-) 0.01%	(+) 0.01%	(-) 0.03%	(-) 0.01%	0%	0%	(-) 0.01%	(+) 0.01%	(-) 0.01%
5.	Difference of Sl. No.1 & 3	(-) 0.01%	(-) 0.01%	0%	(-) 0.01%	(+) 0.01%	(-) 0.01%	0%	0%	(+) 0.01%	(-) 0.01%

etc. are used at site. All the relevant data collected at site at various stages is placed on web site. Various physical tests are conducted to know the variations in different ingredients. To understand the above methodology, let us make a valid case study in a highway construction in India.

A case study

For a valid case study, we select a sanctioned project "Construction of NH-4 (Belgaum-Dharwad section from km.433 to km.515) executed in the State of Karnataka, India" at an estimated cost of Rs.480.00 crores on DBFO (Design, Built, Finance and Operation) pattern. The execution of work is being carried out by National Highways Authority of India according to technical specifications laid down by Ministry of Road Transport and Highways (MoRTandH) (Ministry of Road Transport and Highways, 2001). For the sake of simplicity in presenting our methodology the data is collected at site and evaluated as under:

Graph No.13 – %age of bitumen as per data set on computer, actual test at plant site & after laying - tipperwise



Tolerance limits in Wet Mix Macadam (WMM)

To study the variations at various stages of construction, the material of the same truck/tipper was tested at different stages of construction as under:

(i) Just after loading in the tipper.
(ii) At the time when tipper reaches at work site.
(iii) After laying.
(iv) After compaction.

The data of 8 such tippers is placed below in Table-1 giving the gradation of various ingredients at various stages of construction:

The above data of 8 tippers is further presented in graphs 1 to 6 for %age passing through sieves 22.40mm, 11.20mm, 4.75mm, 2.360mm, 0.60mm and 0.075%mm (the graphs of 53mm and 45mm are not shown as there is no variation).

From the above Table No.1 and Graphs 1 to 6, the variations in %age of aggregates passing through different sieves during various stages of construction are presented below in Table No.2 along with the codal provisions and recommended tolerances:

Tolerance limits in Dense Bituminous Macadam (DBM)

To study the variations at various stages of construction in Dense Bituminous Macadam (DBM), again the material of the same truck/tipper was tested at different stages such as just after loading in the tipper, at the time when tipper reaches to site, after laying and after compaction. The tolerance limits for aggregates and bitumen content are studied as under:

Aggregates

The data collected in respect of 10 tippers is placed below in Table-3 giving the gradation of various ingredients at various stages of construction:

The above data is further presented in graphs 7 to 12 for %age passing through sieves 26.5mm, 13.2mm, 4.75mm, 2.36mm, 0.3mm and 0.075mm (the graphs of 45mm and 37.5mm are not shown as there is no variation).

From the data presented in Table No.3 and Graphs 7 to 10, the variations in %ages of aggregates passing through various sieves during various stages of construction are presented below in Table No.4 along with the codal provisions and recommended tolerance limits:

Bitumen contents

The data collected in respect of bitumen contents in DBM for 10 tippers during various stages of construction is presented below in Table No.5:

The %age of bitumen set on computer at plant site and bitumen found in DBM material during actual testing at plant site and after laying has been shown in a graphical presentation in Graph No.13

From the above Table No.5 and Graph No.13, it is clear that there is a variation in the bitumen contents in the samples in the range from (-) 0.03% to (+) 0.01%.

Thus, the codal provisions for permissible tolerances/variations in bitumen contents which are ± 0.3% seems to be on very much higher side and are recommended for revision as given in Table No.6:

RESULTS AND DISCUSSIONS

The results of the case study shows that with the use of e-quality control system, there is less variation in the %age of aggregates passing through various sieves during various stages of construction and thus lower tolerance limits are required than prescribed limits in the codes. In case of Wet Mix Macadam, the range in variation of various size of aggregates should be reduced as per recommendations given in Table .2. Similarly, in case of DBM, a lower range for variations in various sizes of aggregates is recommended then prescribed in the codes as given in Table No.4. The allowable variation as per codes in case of bitumen contents in DBM which is 0.3% also seems to be very much on excessive side and is recommended as 0.05%. The reduction in the tolerance limits will give a better quality of the product and also a longer life of the road.

CONCLUSION

With the use of e-quality control system, the quality and quantity of the product is assured. The batch mix type fully automated computer controlled hot mix plant with electronic sensor controls the quality and uniformity of the finished product. The other modern equipments also control the quality automatically. So, in a system where all the activities are electronically controlled, the tolerance limits prescribed in the codes seems to be on higher side. These limits were fixed when every activity/gradient was not electronically controlled and has become redundant now. The use of e-quality control system has direct effect on the existing tolerance limits in WMM and DBM and needs to be revised. The revision of tolerance limits in a lower side as recommended in this paper will give the best quality of the finished product to the best of its standards.

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