QUALITY ASSESSMENT OF TRUCK MIXED CONCRETE IN SAUDI ARABIA

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ABSTRACT. Currently there is a trend of eliminating truck mixing mechanism of concrete production from major construction contracts in Saudi Arabia. Such a shift is liable to produce far reaching effect on concrete industry in the Kingdom. This paper presents an experimental study of strength and uniformity aspects of the concrete produced by the truck mixing mechanism. The experimental work comprises strength tests according to BS 5328 and uniformity tests according to ASTM C94 and BS 3963. Results indicate that, with adequate control on mixing performance factors such as mixing time and drum speed, the truck mechanism complies with strength and uniformity requirements. The paper suggests improvements in test procedure to enhance the uniformity of concrete produced by the truck mixing mechanism and exercise control on operator performance so that strength variability can be reduced.

1. INTRODUCTION

Truck type mixing technique for concrete production (TMM) is recommended by most international standards. Currently, many major project specifications in the Kingdom do not permit production of concrete by TMM. Some major owners like oil companies in the Kingdom are considering to omit TMM from their project specifications.

The major draw back of TMM is the manual control that it employs for production of quality concrete. The other draw back of TMM is that mixing time and speed are manually controlled and hence subject to variation whereas they are automated in CMM.

Elimination of TMM from the standards and project specifications will undermine the stakes of the ready-mix-concrete industry in the Kingdom.

2. SCOPE AND OBJECTIVES

The experimental work comprises strength tests according to BS 5328 [1] and uniformity tests according to ASTM C94 [2] and BS 3963 [3]. The objective of this study is to assess the truck mixing mechanism in terms of concrete strength and uniformity.

3. SETUP OF TMM

The truck unit was equipped with a mixer suitable for mounting on self propelled chassis and capable of mixing the materials and agitating the mixture during transit. The truck mixer had a maximum speed of 21 rpm, while the production speed was set to 14 rpm. After addition of water a mixing time of 3 minutes was used for the normal production.

4. PROBLEMS OF TMM

The major draw back of TMM that it requires an enhanced control for production of quality concrete. According to accepted TMM norms, the slump is checked visually by the batching operator whereas in the case of central mixing mechanism (CMM), this is accomplished instrumentally. The other draw back of TMM is that the mixing time and speed are manually controlled in TMM and hence subject to variation whereas they are automated in CMM. Low control on mixing efficiency related factors in TMM can adversely affect the uniformity of the concrete in a batch. For example, high mixing speed in a batch of high slump may lead to formation of dry balls, and insufficient mixing time or low mixing speed may result in segregation and improper dispersion of cement over the bulk of the batch.

5. EXPERIMENTAL PROGRAM

The experimental part of the study comprises two main tests: concrete strength according to BS 5328 [1] and uniformity test according to ASTM C94 [2] and BS 3963 [3].

5.1 Concrete Compressive Strength

Concrete strength tests were performed on three industry specified concrete mixes C17, C24 and C35 produced by TMM. The mix proportions of the three grades are listed in Table 1. Forty one batches from each of the three grades were produced by TMM. Two cubes (150x150x150 mm) were sampled from each truck and tested for strength at 28 days. The compliance of strength requirements were checked according to the British Standards 5328 which are: the 28 day individual strength at should be larger than or equal to (f_{cu} - 3 MPa) and the 28 day moving average strength should be larger than or equal to (f_{cu} + 3 MPa)

Table 1 : Mix Proportions of Various Grades of Concrete

Batch Weight/m^3	C17	C24	C35
Cement (kg)	250	310	400
Water (Liter)	170	170	170
Aggregate (20 mm) (kg)	640	640	640
Aggregate (10 mm) (kg)	430	430	430
Sand (Fine) (kg)	850	800	720
Admixture (P509) (liter)	0.8	0.8	1.0

5.2 Concrete Uniformity

The uniformity tests were conducted in accordance with ASTM C94 [2] and BS 3963 [3].

5.2.1 Uniformity Test According to ASTM C94 : Concrete uniformity test according to ASTM C94 [2] was performed on three industry specified concrete mixes C17, C24 and C35 produced by TMM. Each sample was tested for concrete slump, unit weight, air content,

coarse aggregate content and compressive strength at 7 days. The difference in test results of a batch were compared with tolerance limits given in the annex section of ASTM C94.

5.2.2 Uniformity Test According to BS 3963 : According to BS 3963 [3] two types of concrete mixes are required to perform the uniformity test on TMM, the types 2 and 3. The sampling sites were within 2 to 4 kilometer of the plant. Two independent samples were obtained from each of the first, second, third and fourth quarters of a batch at the time of discharge from the drum. Each of the 8 samples from a batch was machine tested by the Rapid Analysis Method (RAM) to determine the cement, fine aggregate, and moisture contents.

6. RESULTS

The strength values and the moving average of four consecutive strength tests are calculated. The values of the moving averages are plotted in Fig.1. The results indicate that the grades C17, C24 and C35 produced by TMM comply with the strength requirements specified in BS 5328. The minimum observed individual strength values are 20.8, 26.0, and 39.3 MPa respectively which are higher than the limiting values. The minimum observed moving averages are 22.1, 27.7, and 41.4 respectively which are also higher than the limiting values. The values of standard deviations obtained are a measure of strength variability and level of control on the production process and as such are compared with standards of concrete control prescribed in Table 3.5 of ACI 214 [4] . The standard deviations of the compressive strength of concrete grades 17, 24 and 35 were 2.3, 2.8, and 1.9 MPa respectively. These values are equal to or less than the ACI recommended standard deviation of 2.8 MPa for the excellent level of concrete control.

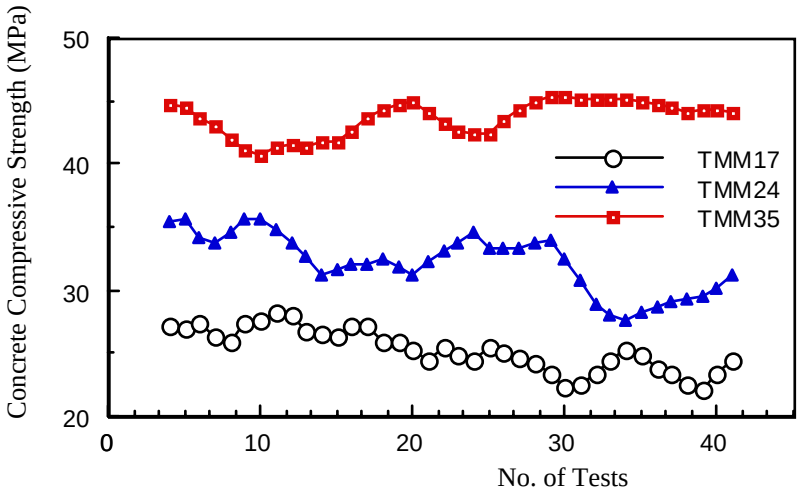

Fig. 1 The moving averages of four consecutive strength tests.

Results from concrete uniformity tests according to ASTM C94 [2] of the three concrete grades indicate that these grades comply with the ASTM C94 limits. Results of uniformity tests for grade C35 are listed in Table 2.

Results indicate that TMM complies with the uniformity requirements of BS 3963 [3]. A summary of these results is listed in Table 3. The BS 3963 uniformity test is quite elaborate and rather costly. It may be pointed out that the testing procedure according to BS 3963

requires about 55.0 m^3 of concrete. These tests are specified to be carried out only when the mixer performance becomes doubtful.

It may be pointed out that the concrete industry, in general, does not exercise quality control observed during this study. As such, the normal production may fall short of the above statistics.

Table 2: Concrete Uniformity Test on Mix C35 According to ASTM C94

Property	Batch 1			Batch 2			ASTM C94 Limits
	Sample (1)	Sample (2)	(1) - (2)	Sample (3)	Sample (4)	(3) - (4)	
Slump (mm)	130	130	0	120	115	5	38
Unit Weight (kg/m3)	2415	2416	1	2385	2393	8	16
Air Content %	1.5	1.8	0.3	1.8	1.6	0.2	1.0
Coarse Agg. %	43.2	44.1	0.9	42.1	42.4	0.3	6.0
7 day Strength (MPa)	40.5	39.1	1.8%	35.1	34.5	0.86%	7.5%

Table 3: Results of Concrete Uniformity Test According to BS 3963

Mix Type	Material	C	D	Max. Limits[1]
Mix 2	Cement Content	0.81	0.56	1.0
	Sand Content[2]	1.02	0.45	2.5
	Moisture Content	0.08	0.10	0.8
Mix 3	Cement Content	0.79	0.44	1.7
	Sand Content[2]	0.84	0.80	2.5
	Moisture Content	0.40	0.08	0.9

1 Limiting values of 0.49 C and 0.89 D.

2 30% fine aggregate content.

7. ENHANCEMENT OF TMM UNIFORMITY

In order to enforce quality control procedure by TMM, a routine procedure for testing of concrete and exercising control on operator performance is essential. Towards this end it is proposed to perform a weekly, random testing of concrete uniformity considering only the concrete slump, the wet density and the 7-day strength as per ASTM C94 uniformity requirements.

8. CONCLUSIONS

Under adequate quality control the concrete produced by the truck mechanism complies with the strength requirements of BS 5328 and the uniformity requirements of ASTM C94 and BS 3963. The standard deviations of the three grades of concrete produced by TMM were 2.3, 2.8 and 1.9 MPa respectively. These values are equal or less than ACI-214 recommended value of 2.8 MPa for excellent level of control. It is suggested that a check on operator performance and enforcement of quality control may be achieved by a weekly, random testing of concrete uniformity considering concrete slump, the wet density and the 7-day strength as per ASTM C94 uniformity requirements. The suggested quality assurance program is inexpensive, effective and can save the truck mechanism from going into oblivion.

REFERENCES

[1] ASTM C94-92, "Standard Specification for Ready-Mixed Concrete," American Standard for Testing Materials, 1992.

[2] BS 3963, "Method for Testing the Mixing Performance of Concrete Mixers," British Standard Institution, England, Jan. 1974.

[3] BS 5328, "Concrete," British Standard Institution, England, 1993.

[4] ACI-214, " Recommended Practice for Evaluation Strength Test Results of Concrete," American Concrete Institution, Detroit, 1977.

Figure 1