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Research Article

Evaluation of the Quality of Ready-Mixed Concrete Used in Building Controlled Structures after Electronic Concrete Monitoring System

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ABSTRACT

It is of great importance that the buildings are built as earthquake resistant in our country where there is an earthquake risk. Iron and concrete designs are at the forefront of the determining parameters in the earthquake resistance of buildings. With the widespread use of ready mixed concrete system in our country, great improvements have been achieved in concrete quality. The quality of concrete is directly related to its production properties as well as its compressive strength. Accordingly, the production of high-quality and high-quality ready-mixed concrete in the construction sector has come to the fore in recent years. According to the building inspection law that came into force, the sensitivity of building inspection organizations on the strength of concrete classes has also increased.
The Electronic Concrete Monitoring System (EBIS), in which concrete samples are monitored electronically for the first time in the world, was put into use in order to prevent abuses in the ready mixed concrete inspections of the buildings. Although the results obtained show that there is no problem in the compressive strength results of the ready mixed concrete used in the buildings under construction control, the points to be considered in concrete quality were encountered and these issues were emphasized.

1. INTRODUCTION

Turkey is located on a tectonically active ground. This mobility has made itself felt especially with the earthquakes that have occurred in recent years. As the recent earthquakes have shown once again, the importance of concrete quality is of great importance in terms of building safety. Primitive concrete production levels at the construction site, which are of great importance for concrete production in Turkey, have reached the level of ready-mixed concrete production with the quality assurance system [1].

The concrete produced by mixing the materials, which are combined in the desired proportions under computer control, in the concrete batching plant or mixer and delivered to the consumer as “fresh concrete” is called “Ready Mixed Concrete”. Consistent quality is ensured by precise computerized control of water and aggregate according to the appropriate design of the mixture. High volumes of concrete are obtained without wasting cement and aggregate due to bulk transportation. It does not cause pollution as there is no dust problem. Ready-mix concrete is an indispensable building material for the giant industrial and housing projects required by today's construction practices.

The absolute volume of concrete consists of 70% aggregate (sand, gravel, crushed stone), 20% water and 10% cement. Ready-mixed concrete aggregate is a collection of unbroken or crushed grains of non-organic, non-organic, natural or artificial material, usually not exceeding 100 mm in size, brought together with the binding material consisting of cement and water mixture in concrete or mortar making [2].

The process of determining the quality of ready-mixed concrete consists of 5 basic stages. These are; Design, Production, Transportation, Placement, Maintenance and Curing. While the first three stages are performed by the ready-mixed concrete producer, the last two stages are performed by the consumer.

The communiqué, which is based on taking samples from the fresh concrete mixture in the buildings inspected within the scope of the building inspection law, conducting experiments, creating reports according to the readings, monitoring and supervision of the stages, officially entered into force on December 25, 2018. According to the communiqué, which sets out the laws and rules governing the sampling of the concrete mixture in buildings and the reporting of the samples by subjecting them to various tests, the “Electronic Concrete Monitoring System (EBIS)” was put into effect by the Ministry of Environment and Urbanization. With EBIS, concrete samples can be monitored electronically thanks to special chips placed in concrete samples at the construction site.

The chips record electronically when concrete samples will be subjected to the crushing test, when reliable quality casting will take place, which relevant engineer will control the test, and in which laboratory the concrete quality will be checked.

With the chip system, if the people in the building query the parcel number, they will have all the information about the concrete quality of their houses. In addition to this information, it is possible to access historical construction images and information on how many times the construction has been inspected. Citizens can see images of the construction stages of the construction, control information, information about the contractor company, which engineer controlled the construction, and the problems experienced in the past.

The Ministry started to actively implement EBIS in all provinces across Turkey. EBIS enabled electronic monitoring of concrete quality at construction sites. The system, which was first used in pilot provinces, has started to be implemented throughout Turkey with positive results. The chips in question are created by Aselsannet AŞ. through R&D studies using Radio Frequency Identification (RFID) tags. The main purpose of the transition to this system by the Ministry is to prevent losses, errors and leakages that may be made in applications, especially by building inspection laboratories, and to prevent counterfeiting.

It is aimed to control concrete in building constructions in a healthier and safer way, and in this context, the country is moving closer to its goal of creating better quality and livable cities by offering its citizens the opportunity to live in buildings that are safer against earthquakes. Taking samples of concrete, which is one of the most important principles of residential areas created to ensure the safety of life and property; sampling, witnessing the sample, taking the samples out of the construction site and keeping the curing processes under supervision are carried out electronically with EBIS. A safe sampling phase is created by preventing errors, losses and leaks that determine the quality of concrete in the production environment, construction site and laboratory areas.

With the chip system, the location, time of concrete sampling, concrete result report data, personnel involved in the test and technical personnel who witnessed the concrete sampling are electronically audited in provincial, district, laboratory or building inspection systems. During the collection of the concrete sample from the construction site, different location verifications are made by the personnel officer of the laboratory organization to ensure that the concrete sample is taken from the correct building construction, and in this case, the fresh concrete sample is taken; It eliminates the possibility of non-participation of both the laboratory organization officer and the relevant engineer of the building supervision organization. The goal of EBIS is to control the curing process, to control the time of leaving the construction site, to accurately report the crushing results and most importantly to check whether the fresh concrete sample complies with the standards [3].

The aim of this study is to introduce the Electronic Concrete Monitoring System (EBIS), to investigate why such a system is needed today, to evaluate whether the strength values recorded before and after this system are statistically different and to evaluate the positive / negative issues experienced in the current application of the system. The evaluation of this system (EBIS), which is applied in Turkey for the first time in the world, will be carried out at the scale of Elazığ province. The compressive strength results of concrete samples taken from different construction sites in Elazığ will be compared with Turkish standards in the light of other statistical parameters. A comparison will be made between the desired strength values and the actual strength values in the project and an idea will be obtained about the concrete quality and production technologies obtained as a result of the application.

2. LITERATURE REVIEW

Topçu, İ. B., and Ateşin, Ö. (2013) tested the compressive strength of C30/37 concrete at various construction sites in and around Kütahya in 2011. Approximately 1023 experimental results were used to determine the status of concrete quality in Kütahya province. As a result, it was observed that the C30/37 concretes sampled in Kütahya province conformed to the standards. With this study, according to the inspection records in 2011, concrete is produced in accordance with the standards and economical in Kütahya province [1].

Güçlüer, K., Günaydın, O., Tekin, Ö.F., and Şahan, M.F. (2017) examined aggregates, the main ingredient of composite concrete, which contains materials of different origins in the structure and has a wide range of uses. In the study, the effects on the mechanical properties of concrete test specimens produced with aggregates obtained from 4 different aggregate quarries were investigated by destructive and non-destructive test methods. Comparisons were also made among themselves. As a result, the intended results were achieved with different aggregate types. The strength differences between each other were interpreted according to all effects. According to the ultrasonic values measured for the aggregates, the concrete class was found to be of good concrete quality [2].

Mehta, P.K., and Monteiro, J.M.P. (2006), in their study, describe the important applications of concrete and examine the reasons that have made concrete the most widely used building material in the world today. The basic components of modern concrete are described. A brief description of the main types of concrete is given. The properties of concrete such as strength, elastic modulus, toughness, dimensional stability and durability are examined. Recently, it has been observed that the strength classes have increased with the recycling materials used by developing the cement industry. It is stated that more reliable and better quality concrete is produced with the increase in strength classes [4].

Öztoprak, B., Sözen, Ş. and Çavuş, M., (2018) examined the quality of ready-mixed concrete and the status of concrete plants in Bolu province. It is thought that ready-mixed concrete plants negatively affect the quality in terms of machinery, equipment and personnel. As a result of the studies, it was stated that there is a need to improve quality control methods. According to the results obtained; it was determined that there were deficiencies in machinery - equipment, tools, laboratory equipment, production control, work organization and following current technologies [5].

Ergün and Başaran (2010) aimed to statistically analyze the quality change in the quality control of concretes produced in different ready-mixed concrete plants in Afyonkarahisar between 2009 and 2010. The compressive strengths of concrete samples from three different ready-mixed concrete producers were evaluated at Kocatepe University Construction Laboratory. Considering the data of the last two years, the improvement in concrete quality in Afyonkarahisar city center was revealed and according to the results obtained, it was determined that there was a positive development in terms of reinforced concrete structures. It has been observed that the quality level in ready-mixed concrete plants is above good, but there is no production of high concrete classes [6].

Doğan, S. (2020) examined the effects of EBIS on building performance. It was stated that there were problems such as loss, error, fake report and unfair competition while taking concrete samples and it was determined that these problems were eliminated with EBIS. In the study in question, it was stated that reports prepared without sampling were prevented with EBIS and the quality of ready-mixed concrete increased [7].

3. MATERIALS AND METHODS

Within the scope of this study, the ready-mixed concrete quality of the buildings under building inspection control in Elazığ province before and after EBIS will be evaluated. Concrete compressive strengths of 15*15*15 cube specimens produced in C20, C25 and C30 standards taken from building inspection companies in Elazığ were comparatively analyzed before and after EBIS.

According to the circular issued by the General Directorate of Construction Works of the Ministry of Environment and Urbanization of the Republic of Turkey on 13.04.2022, the number of samples taken in construction laboratories according to the poured m^3.

To summarize the system in general, an RFID concrete chip is placed in each sample to be taken in accordance with the standards by the laboratory personnel from the ready-mixed fresh concrete arriving at the construction site and scanned and recorded on EBİS software. The samples taken in accordance with the relevant standards are scanned again by the laboratory personnel with EBİS mobile software during the removal from the construction site. After these processes are completed, the exit from the construction site is realized.

Concrete sample reports of the buildings under building inspection control in Elazığ province were examined and samples with similar standards were identified and the data of these samples before the chip system were obtained from the building inspection companies operating in Elazığ. Similarly, concrete samples produced after the chip system were obtained from building inspections and their 7 and 28-day compressive strengths were examined comparatively.

The samples brought by the laboratory personnel are scanned again via EBIS mobile software before curing. The daily temperatures and daily relative humidity rates of the curing pools and curing rooms of the samples are transmitted to the EBIS Central Monitoring Software via sensors by the organization where EBIS services are received.

Figure 1. Part of Sampling Processes.

With the QR code application, each mixer sent to the site by the concrete producer will be labeled with a concrete mixer label and the relevant concrete producer will create a QR code and the delivery note information will be included in this code. The QR code will be read and recorded by the laboratory personnel at the construction site during sampling. The delivery note QR code includes serial number, shipment time and date, concrete quantity, 7 and 28 day strength ratios, water and cement ratio, aggregate size, vehicle license plate, additives and fiber information. In this way, it will be prevented that mixers without a label code will be poured at the construction site. Some of the Sampling Processes are shown in Figure 1.

With the "Communiqué on Monitoring and Supervision of the Processes of Sampling, Testing, Reporting and Reporting of Fresh Concrete for the Buildings Supervised under the Law No. 4708 on Building Supervision" published in the Official Gazette dated March 24, 2020 and numbered 31078, ready-mixed concrete producers are obliged to use mixer labels and delivery notes with QR codes. However, due to the pandemic, it has been implemented as of November 2020. [8]

3.1. Research findings and discussion

Within the scope of this study, the ready-mixed concrete quality of the buildings under building inspection control in Elazığ province before and after EBIS will be evaluated. Concrete compressive strengths of 15*15*15 cube specimens produced in C20, C25 and C30 standards obtained from building inspection companies in Elazığ were comparatively analyzed before and after EBIS.

According to the circular issued by the General Directorate of Construction Works of the Ministry of Environment and Urbanization of the Republic of Turkey on 13.04.2022, the number of samples taken in construction laboratories according to the spilled m3 calculation is given in Table 1.

Table 2. and Table 3. show the 7 and 28-day data statistically. In Table 2, 7-day pre- and post-EBIS data are evaluated on concrete batching plant basis, while in Table 3, 28-day pre- and post-EBIS data are evaluated on concrete batching plant basis.

When analyzed on company basis, according to the standard deviation and coefficient of variation ratio, it was observed that Company C produced better quality concrete than the other companies in concrete class C25/30 after EBIS.

Table I
DETERMINATION OF SAMPLE NUMBERS

Criterion 1 Amount of Concrete Poured (m^3)	Criterion 2 *Area Of Concrete Poured (m^2)*	Number of Transmixers to be Sampled (Number)	7 Daily (Qty)	28 Daily (Qty)	Total Number of Samples (Number)
0-24	-	2	2	6	8
25-100	450	3	3	9	12
101-150	451-650	4	4	12	16
151-200	651-850	5	5	15	20
201-250	851-1050	6	6	18	24
251-300	1051-1250	7	7	21	28
301-400	1251-1450	8	8	24	32
401-500	1451-1650	9	9	27	36
501-600	1651-1850	10	10	30	40
>600	>1850	For each additional 200 m^3 volume or each additional 200 m^2 area, 1 is added to the above numbers.	For each additional 200 m^3 volume or each additional 200 m^2 area, 1 is added to the above numbers.	For each additional 200 m^3 volume or each additional 200 m^2 area, 3 is added to the above numbers.	For each additional 200 m^3 volume or each additional 200 m^2 area, 4 is added to the above numbers.

Table II
7-DAY STATISTICAL DATA BEFORE AND AFTER EBIS.

		BEFORE EBIS			AFTER EBIS		
		A	B	C	A	B	C
C20/25	Average	23.53	23.24	26.29	-	-	-
	Minimum	19.70	19.90	22.90	-	-	-
	Maximum	34.30	29.70	31.50	-	-	-
	Standard Deviation	2.69	2.42	2.39	-	-	-
	Coefficient of Variation (%)	11.43	10.42	9.09	-	-	-
C25/30	Average	28.19	26.68	26.16	32.13	32.19	33.73
	Minimum	23.50	22.10	22.60	27.30	28.90	30.10
	Maximum	32.00	33.00	30.10	44.00	38.30	38.00
	Standard Deviation	2.09	2.70	2.09	3.44	2.48	1.57

	Coefficient of Variation (%)	7.40	10.11	7.98	10.69	7.70	4.65
C30/37	Average	32.40	32.61	32.88	40.99	35.49	43.29
	Minimum	28.70	29.40	29.90	37.10	30.80	34.10
	Maximum	35.10	36.00	36.30	46.40	43.50	48.10
	Standard Deviation	1.52	1.97	1.55	2.11	2.74	2.76
	Coefficient of Variation (%)	4.70	6.04	4.71	5.15	7.71	6.37
C35/45	Average	-	-	-	43.35	41.70	41.34
	Maximum	-	-	-	40.00	39.80	37.90
	Maximum	-	-	-	46.50	44.10	47.00
	Standard Deviation	-	-	-	1.77	1.10	2.39
	Coefficient of Variation (%)	-	-	-	4.09	2.63	5.77

Table III
28-DAY STATISTICAL DATA BEFORE AND AFTER EBIS.

		BEFORE EBIS			**AFTER EBIS**		
		A	**B**	**C**	**A**	**B**	**C**
C20/25	Average	30.34	31.06	37.26	-	-	-
	Minimum	26.80	27.40	30.90	-	-	-
	Maximum	38.80	37.00	42.00	-	-	-
	Standard Deviation	2.35	2.63	2.36	-	-	-
	Coefficient of Variation (%)	7.75	8.46	6.35	-	-	-
C25/30	Average	36.22	35.28	33.77	41.94	44.97	45.32
	Minimum	31.00	24.60	31.00	31.30	37.30	42.10
	Maximum	41.80	41.00	37.30	51.90	51.60	49.90
	Standard Deviation	3.75	4.05	1.54	5.31	3.59	1.39
	Coefficient of Variation (%)	10.36	11.47	4.55	12.65	7.98	3.07
C30/37	Average	42.65	43.24	42.18	50.03	43.06	51.62
	Minimum	37.60	39.10	38.90	48.20	39.70	42.50
	Maximum	47.50	50.40	48.60	53.80	51.40	56.00
	Standard Deviation	2.56	2.72	1.90	1.40	2.60	2.67
	Coefficient of Variation (%)	6.00	6.29	4.50	2.79	6.04	5.17
C35/45	Average	-	-	-	49.21	49.04	50.75
	Minimum	-	-	-	46.70	44.50	46.70
	Maximum	-	-	-	51.20	53.10	55.80
	Standard Deviation	-	-	-	1.15	1.78	2.33
	Coefficient of Variation (%)	-	-	-	2.34	3.62	4.60

While better results were observed in concrete class C25/30 after EBIS, larger coefficient of variation and standard deviations were observed in concrete class C30/37. When the coefficients of variation and standard deviation in C30/37 concrete classes are analyzed, it is seen that the ratios increased after EBIS throughout the company. In C30/37 concrete class, Company A has a worse rate compared to the 7-day data, while Company A has a better rate compared to the other companies

In Elazığ, while the compressive strengths of the samples before EBIS were normal and above normal according to concrete classes, higher strength values were observed after EBIS. Electronic Concrete Monitoring System (EBIS) was found to have positive effects on concrete quality.

4. CONCLUSION

The evaluation of whether the transition from an uncontrollable system until recently to EBIS, which is managed by a centralized system, has changed in terms of concrete quality and application quality constitutes the basis of the problem addressed in this study. In this study, the ready-mixed concrete quality of building supervised structures before and after EBIS was evaluated in Elazığ province. In the examinations made, before EBIS, fake reports were issued in the construction laboratory and the samples were not subjected to the required tests. The curing pools are insufficient with the increasing work intensity in certain periods. With EBIS, the risk of creating a fake report in the fresh concrete sample taken from the construction site has been eliminated and it is aimed to increase the quality of concrete. The control of the samples is carried out not only by laboratory personnel, but also under the supervision of the Presidency of Defense Industry.

In the study in question, there are no C20 data after EBIS and no C35 data before EBIS. With the 2018 earthquake regulation, the lowest concrete class was C25. For this reason, C20 data after EBIS are not available. Before EBİS, concrete samples of C35 concrete strength classes could not be obtained. Since C35 concrete class was a high concrete class before EBIS, it was observed that it was not preferred by contractor companies.

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Mehmet Emiroğlu, graduated from Fırat University, Faculty of Technical Education, Department of Construction Education in 2004. He completed his master's degree in 2006 and his doctorate in 2012 in the Department of Construction Education at Fırat University, Institute of Science and Technology. He graduated from Sakarya University, Faculty of Engineering, Department of Civil Engineering in 2015. In 2017, he was promoted to the rank of Associate Professor at the Interuniversity Board. Mehmet Emiroğlu, who was promoted to the title of Professor in 2024, works in the Civil Engineering Department of Sakarya University Faculty of Engineering