

# QUALITY INSPECTIONS ON READY-MIXED CONCRETE: TURKISH EXPERIENCE

**M. HULUSI ÖZKUL, TÜMER AKAKIN, SELÇUK UÇAR**

## **Abstract**

Many regions of Turkey are in earthquakes zone. Since the most widely used structural system is reinforced concrete, the quality of concrete is much more important in Turkey to build safer structures. Quality of ready mixed concrete in Turkey has been inspected by a 3rd party certification body of Quality Assurance System (KGS), which was established by Turkish Ready Mixed Concrete Association in 1996 as an independent economic enterprise. This body has been issuing “KGS Certificate of Conformity” on voluntary basis. In 2010, a mandatory “G Certificate” was introduced to ready mixed concrete production in Turkey by the government. The Economic Enterprise of KGS became notified body for this legislation and now can issue both KGS and G Certificates to ready mixed concrete plants. In this study, the data obtained from all inspections of KGS in ready mixed concrete industry is analysed with respect to years and the progress in concrete quality seen in Turkey in recent years is evaluated. The detailed certification process under the responsibility of KGS which includes initial type-testing of concrete, the initial inspection and continuous surveillance of the plant and the production control system, an uninformed audit-testing of samples taken at the construction site and conformity evaluation of auto-control samples will be summarised. Non-compliances will be statistically discussed and the overall effectiveness of 3rd party product certification in concrete will be evaluated. Turkey has a growing concrete market; the concrete production in Turkey is the highest in Europe in accordance with 2011 statistics. The production figures and the predictions of concrete production in Turkey will also be given in the paper.

## **Keywords**

3<sup>rd</sup> party certification, inspection, quality, production control, Turkish concrete market.

## **Biographical notes**

M. Hulusi Özkul is Professor in Istanbul Technical University Civil Engineering Department Construction Materials Division. He has been researching reology of fresh concrete, supplementary materials for concrete, polymers in concrete and composite materials. He has been the president of KGS Council since 1996 (KGS Council is the management board of 3rd party certification body called Turkish Ready Mixed Concrete Association The Economic Enterprise of KGS)

Tümer Akakin is Secretary General of Turkish Ready Mixed Concrete Association. He graduated from Boğaziçi University Civil Engineering Department in 1998 and he finished his MSc and PhD degrees in the same university. Since 1998 he has been working in the association.

Selcuk Ucar is Director of Turkish Ready Mixed Concrete Association The Economic Enterprise of KGS. He graduated from Boğaziçi University Civil Engineering Department in 2000 and he finished his MSc degree in the same university. He has been working in the association since 2001.

## 1. INTRODUCTION

The beginning of concrete usage in Turkey goes back to the beginning of the 1900s and has become the most widely used building material over the years. Nearly 99% of the buildings are made by reinforced concrete in Turkey. However, concrete had been produced completely through the conventional methods until the 1980s. The usage of ready mixed concrete has been spread after the 1980s. Currently nearly all concrete production is done in concrete plants and there is nearly at least one concrete plant in each town all over the country.

In recent years, the ready mixed concrete industry has showed a parallel growing with the development of construction industry and Turkey has become the leading country in ready mixed concrete production in Europe [1].

Turkey's gross national income increased with strong development in the last decade from about 200 billion USD to 1000 billion USD. With this increase Turkey became the 16th biggest economy in the World. The economy slowed with the global crisis in 2011, but annual growth is above the average of the World. The growth in construction is contributing in large extend in this development. The growth in construction was 17% in 2010 and in 2011 11%. Construction industry experienced 7 quarters of two digit growth.

In Turkey 500.000 new houses are built every year. The old house stock will be renewed in the following years. 7 million houses will be renewed in the following ten years. Besides increase in housing, there is also increase in infrastructure investments in Turkey. Currently Turkey has 500km of speed rail track and 1700km is under construction or investment. Turkey has been building 8.600MW of hydroelectric power plants currently and 22.700MW is under project. Also Turkey has 500km motorways under construction and 5.000km under project.

Ready Mixed Concrete production in Turkey was 1.5 million m<sup>3</sup> in 1988 and in 2011 it is nearly 90 million m<sup>3</sup>. The production increased about 60 times in nearly 20 years (Fig. 1 and Table 1).

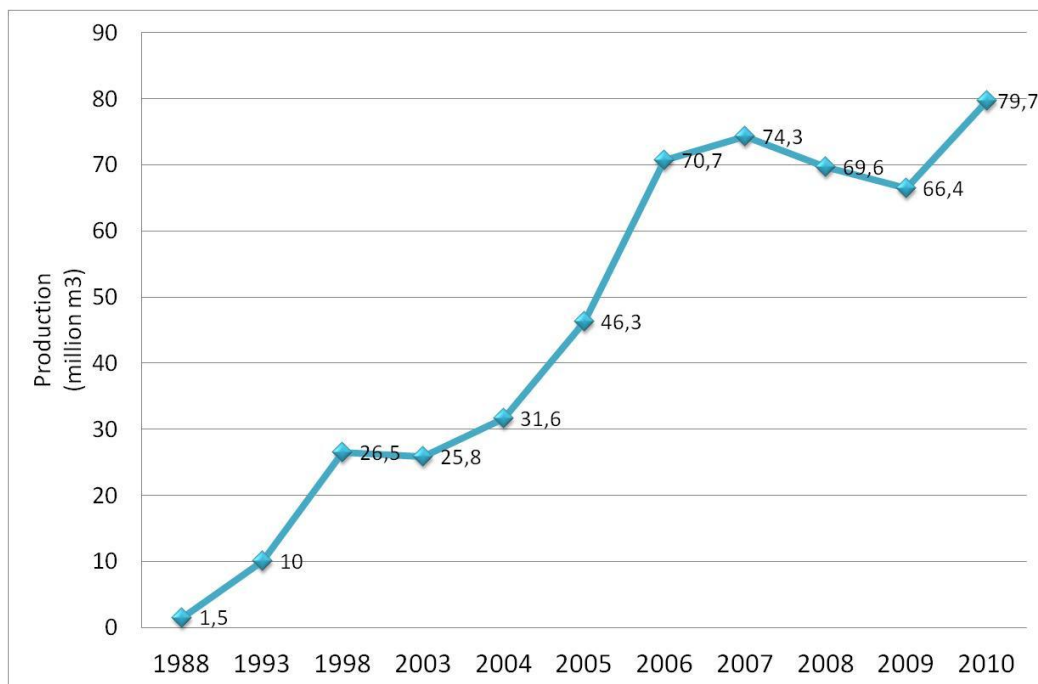


Figure 1. RMC Production in Turkey

Table 1. RMC Plants in Turkey

Years	RMC Firms	RMC Plants	Production (million m <sup>3</sup> )
1988	25	30	1.5
1993	70	110	10
1998	166	341	26.5
2003	238	439	25.8
2004	247	482	31.6
2005	277	568	46.3
2006	409	718	70.7
2007	477	845	74.3
2008	462	825	69.6
2009	467	845	66.4
2010	500	900	79.7

On the other hand, the average concrete grades have been increasing. Obviously the increase in the concrete classes causes increase in the durability of the concrete used. C25 and above concrete classes used in 1998 was less than 5%, but today C25 and above concrete classes is nearly 80% as can be seen in Table 2.

Table 2. Concrete Classes Used in Turkey

Years/ Concrete Class %	C 14	C 18	C 20	C 25	C 30+	≤C20	≥C25
1996	37.5	52.3	6.3	3.3	0.6	96	4
1997	27	51.1	12	7.6	2.3	90.1	9.9
1998	24.4	45.4	18	8.1	4.1	87.8	12.2
1999	22.8	35.9	27.7	10.3	3.3	86.4	13.6
2000	11.5	25.1	41.3	13.2	4.9	77.9	18.1
2001	7	21.3	47.9	18	5.8	76.2	23.8
2002	5.9	21.1	46.9	19.2	6.9	73.9	26.1
2003	4.6	14.7	39.6	25.4	15.7	58.9	41.1
2004	3.3	10.3	40.6	30.7	15.1	54.2	45.8
2005	3.2	8.4	31.2	42.1	15.1	42.8	57.2
2006	2.92	7.66	35.09	36.56	17.77	45.67	54.33
2007	2.85	5.58	26.95	35.25	29.37	35.38	64.62
2008	2.76	6	22.13	38.76	30.84	30.4	69.6
2009	2.44	3.44	23.9	36.1	34.12	29.78	70.22
2010	2.1	2.4	14.6	38.9	41.0	19.1	79.9

The transition from the conventional concrete production to ready mixed concrete increased the concrete quality used in Turkey to an important extent. Ready mixed concrete has made a substantial headway in itself and the plants hardly producing "Concrete 160s," which were the concrete classes of the period, are now able to provide the market continuously with the concrete having compressive strength up to C100s. It is necessary not to perceive quality only as the concrete compressive strength because it is now possible to produce concretes with high performance and different characteristics in line with varied demands.

However, the ready mixed concrete sector has grown so fast that there appeared some inevitable quality problems together with such incredible advancement. Especially, the fact that still many of the ready mixed concrete users by no means demand quality from the producer (the fact that they only pay attention to pricing and some other issues) has started to create a producer profile that addresses to this type of concrete users.

## **2. QUALITY ASSURANCE SYSTEM**

### **2.1. Establishment of the Quality Assurance System “KGS”**

“Quality Assurance System” (shortly named as “KGS”) is a 3<sup>rd</sup> party inspection and product certification mechanism established by Turkish Ready Mixed Concrete Association regarding the concrete and related products. Objectives of establishment are as follows:

- To ensure that ready mixed concrete is produced under continuous inspection,
- To reduce the damages of the unfair competition resulting from the production that lacks quality upon the ready mixed concrete sector.

The first studies regarding KGS were commenced in 1994 and especially in line with the academy-sector cooperation that was conducted at a substantial scale in Turkey’s construction industry as well as the substantial support from the academic people who work in the civil engineering departments and building materials divisions; the first KGS certifications in ready mixed concrete were realized in 1996 [2].

### **2.2. Quality Assurance System’s New Structure**

In 2004, the Quality Assurance System restructured and “KGS Council” has established to manage and execute all activities done in KGS. “KGS Council” has members from most institutions related to concrete. This Council is impartial and independent from R. M. C. Association. In the KGS Council, following institutions are represented:

- T.R. Ministry of Environment and Urbanization,
- T.R. Ministry of Science, Industry and Technology,
- T.R. Prime Ministry Mass Housing Directorate,
- Turkish Scientific and Technical Research Institution,
- Turkish Municipalities Association,
- Chamber of Civil Engineers,
- Chamber of Architects,
- Istanbul Technical University,
- The Middle East Technical University,
- Yildiz Technical University,
- Bogazici University,
- Turkish Union of Construction Industrialists and Employers,
- Turkish Ready Mixed Concrete Association,
- Turkish Prefabricate Association,
- Aggregates Producers Association,
- Admixture Producers Association.

In the organization constituted under the roof of KGS Council, the KGS Directorate that carries out the operations as well as the committees established from the KGS Council’s members and the experts with regard to the issue are available. In addition, KGS’s inspectors are experts in concrete field and mostly academic staff in Turkey.

Together with this structuring, KGS has rendered its working principles compliant with the TS EN 45011 “General Conditions for the Product Certification Institutions” and TS EN ISO/IEC

17021 “Conditions for the institutions meeting the management systems examination and certification” Standards and been continuing its activities since February 2007 as a product certification organization accredited by Turkish Accreditation Agency.

KGS has been granting “KGS Conformity Certificates” in ready mixed concrete on voluntary basis. This certificate is now widely known and accepted by construction industry. In addition to this voluntary KGS Certification, KGS conducts certification for the concrete and concrete-related products within the scope of the mandatory legislation regarding the “G” and “CE” markings that were enacted during the recent years. For concrete, in line with the “Regulation regarding the criteria to which the Building Materials” (shortly G Mark Regulation) that has become mandatory since 01/07/2010, KGS was assigned as the 001 numbered first “notified” conformity assessment body that grants “G Certificate of Conformity”. This assignment was carried out by the Ministry of Environment and Urbanization. Presently, KGS, even when all the products are considered together, is the body that conducts most of the G Conformity Certifications. In addition to “G,” KGS, within the scope of the Construction Products Directive (89/106/EEC), is also a notified body for the “CE Marking” in concrete related products. The fields where KGS is presently conducting inspection and certification are given in Table 3.

Table 3. The certification scope of KGS

<b>Certificate</b>	<b>Product</b>
KGS Certificate of Conformity, G Certificate of Conformity	Ready Mixed Concrete
EC Certificate of Conformity	Cements GGBS Fly Ash Silica Fume
EC Certificate of Factory Production Control	Admixtures Aggregates Bitumen and Bituminous Mixtures Fibres used in Concrete Building Lime
ISO 9001, OHSAS 18001, ISO 14001	All Building Materials

## 2.2. KGS Certification Process in Concrete

The voluntary “KGS Certification” carried out by KGS in the ready mixed concrete sector since 1996 contains the following stages:

- Application and agreement,
- Initial inspection and continuous surveillance of plant and production control system
- Initial type tests,
- Uninformed audit tests of products,
- Evaluation of the results of autocontrol tests of producer,

Subsequent to the application made by the ready mixed concrete plants to KGS, a mutual certification service contract (agreement) is signed. Following this administrative stage, for the system inspection, programming, and production control documentation examination are carried out.

System inspections are carried out by the well known concrete experts and academicians as KGS auditors on the plant and on the production control system established by the ready mixed

concrete producers. System inspection is not only conducted initially, but also in subsequent years at least once a year attaching the same importance as the first inspection. In the system inspection, following sections are scrutinized:

- Production Control System: Production control manual and other documents are evaluated prior to and during the inspection. The structures like organization, authorization, responsibility etc. are examined.
- Laboratory: According to the status of the plant, laboratory conditions, required minimum equipment availability, and their calibrations are examined.
- Constituent materials: Plans of the tests and inspection that must be conducted on the aggregates, cement, additives, fibres, water, admixtures as well as the applications are controlled.
- Concrete Mix Designs and Trial Concretes: The concrete mix designs made according to different conditions and trial concretes are scrutinized and the correctness of the conditions during the production such as water correction etc. are examined.
- Production Processes and the Control of the Concrete Characteristics: Fresh concrete test and inspections like consistence, temperature, density, and entrained air are scrutinized. The correctness of the conformity assessment activities conducted on concrete is controlled.
- Personnel, Equipment and Plant: Material storage, personnel competence and efficiency as well as the development activities and subcontracted services are scrutinized.
- Mixing and Transport: Conformity of the mixing performances of batching system, mixers and truck mixers are examined.
- Equipment Control Processes: Test and inspections conducted on the production, weighing and stocking equipments are examined.
- Records: Check is conducted on all the records like the information on the dispatch list, delivery ticket, and order forms etc.
- Weighing of the Concrete Components for Mixture: Compliance with the weighing correctness and the compatibility with the tolerances are scrutinized.
- Nonconforming Product and Responsibility of the Management: Nonconforming product control activities conducted both on the fresh and hardened concrete are scrutinized.

Within the first inspection or scope expansions, for each concrete class, a sample is taken from the batch or load and subjected to the initial type tests. The initial system inspection and initial type tests are evaluated by the KGS Certification Committee and in the event that the plant has no nonconformity or it is determined that the current nonconformities have been overcome with corrective actions, a "KGS Certificate of Conformity" is drawn up for the plant. The validity period of the KGS Certificate of Conformity is one year on condition that the certificate is not suspended for the reasons like audit tests etc. or cancelled and the reference conditions, production process or production control system is not modified. In the event that at the end of one year, by way of a system inspection conducted again in the plant, the non-conformity is unavailable/overcome, validity period of the certificate is extended for one year.

Audit tests are done without notice, focused on the final check of the products produced by a ready mixed concrete plant. They are conducted subsequent to certification. Audit tests are conducted for each ready mixed concrete plant at least three times a year.

In such tests conducted by the KGS Audit Test Team established through the competent and educated personnel, followings are carried out:

- Visiting the construction site to which the plant supplies concrete without notice and by tracking a truck mixer,
- Conducting the compressive strength and consistence analysis by taking a sample (and specimens) from the truck mixer,
- Conducting the exposure class analyses from the mix designs of the concrete from which the sample is taken,

- Dividing the specimens into three groups as one group for audit test, one group for auto control test of plant and the last group as witness, and transferring the each group to the respective laboratories (TRCCA's lab. for audit test)
- Testing and evaluating the samples on the 28<sup>th</sup> day regarding the compressive strength.

In the audit tests, concrete compressive strength is evaluated according to spot sample test criteria given in EN 206-1 Annex B. Audit tests are conducted for each ready mixed concrete plant at least three times per year.

The results of the producer's autocontrol tests are collected by KGS and checked to conform to the statistical and single result conformity criteria given in EN 206-1 Article 8. The number of evaluations is at least two per year. The representativeness and the accuracy of the results are evaluated using audit test results.

If the results in audit test or producer's auto control test are not conforming the single result or statistical conformity criteria, a complaint plus warning is issued. The next audit test or auto control test evaluation is conducted during the month after issuing. If non-conformity has been experienced in in a plant two times within a one year period of time, that plant's certificate is suspended, and, in the event of three non-conforming results, the certificate of the plant is withdrawn.

### 3. EVALUATION OF THE INSPECTION RESULTS

There is important amount of data obtained from the all inspections and tests carried out for the KGS Certification of Conformity. It was thought that such data will illuminate the overall evaluation of the quality within the concrete sector. Hence the system inspection and audit test data were examined.

#### 3.1. KGS Audit Tests' Data Analysis

The compressive strength is evaluated in the KGS Audit Tests that are presently conducted there times annually in uninformed manner at site in accordance with the EN 206-1 Annex B by way of ensuring the following two conditions:

$$\begin{aligned} \text{Mean of 2-4 results } (f_{cm}) &\geq f_{ck} + 1 \text{ MPa} \\ \text{Any individual test result } (f_{ci}) &\geq f_{ck} - 4 \text{ MPa} \end{aligned}$$

If any of these two conditions is not provided, the audit test is assessed to be "non-conforming". The ratios of the nonconforming results to the total tests as per years are given in Fig. 2.

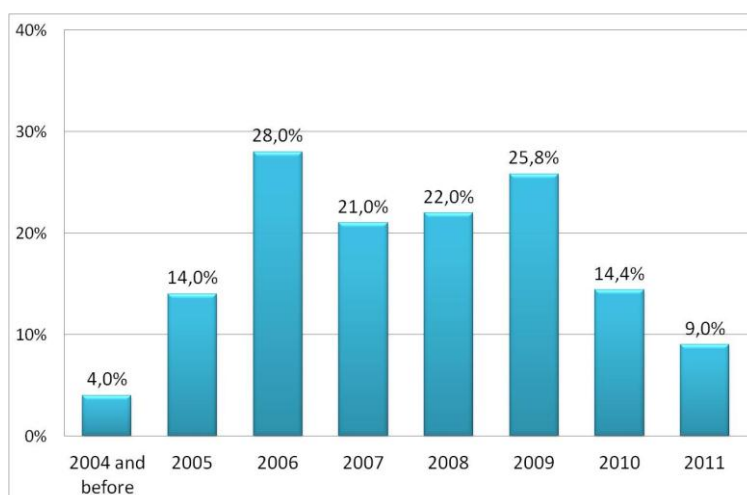


Figure 2. The ratio of the non-conforming audit test results to the total tests- per years



As can be seen in the audit tests given in Figure 2, , the highest non-conforming result ratio is obtained in 2006, continued over 20 % levels until 2009 and showed a decreasing trend together with 2010. The years when the non-conforming ratio is high stand out in general as the years in which the concrete productions are intense. However, during the last two years, a serious fall was experienced in the non-conforming ratios contrary to this determination. Despite the fact that the number of the audit test increased to three annually as of 2010, it is pleasing that the audit test ratio has decreased.

In addition, it must be underlined that the 4% ratio in and before the year of 2004 belongs to the period in which the audit tests are not conducted in uninformed manner and they must not be evaluated in the same fashion as the other years.

The ratio of average deviation that the non-conforming results in the audit tests from the limits in EN 206-1 Annex B article was given in Figure 3.

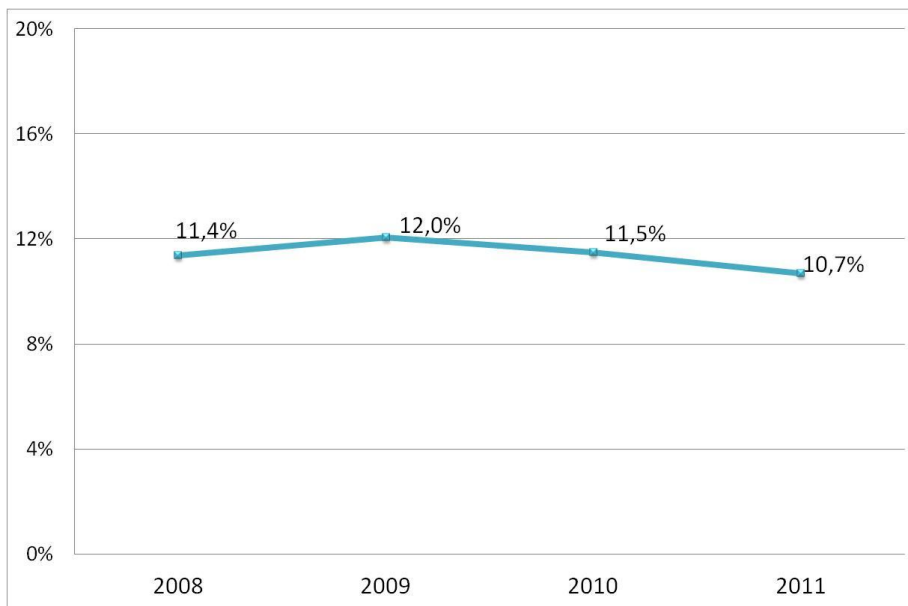


Figure 3. Deviation of the non-conforming results from limit – Average as per years.

The percentages of deviation of the compressive strengths obtained in the last four years during the audit tests from the required limits given in EN 206-1 are close to each other (about approximately 11%). 95% of the non-conformities stem from the inability to provide the first condition that is 1 MPa higher than the class strength of 3 test result averages.

When the non-conformities encountered in the audit tests carried out during 2008-2011 period are compared according to the seasons, the result given in Figure 4 appears.

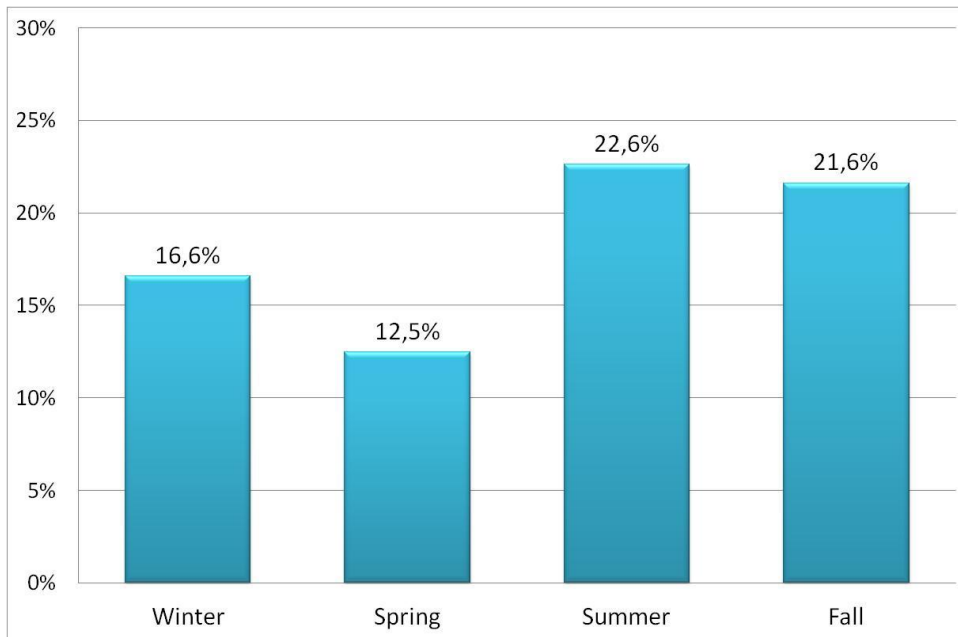


Figure 4. Non-conforming audit test result ratios as per seasons– Between 2008-2011

When the non-conformities of the audit test results as per seasons are scrutinized, it was seen that the most of the non-conformity is seen in the summer months. This ratio falls during the winter and spring seasons. This result, as can be seen from Figure 2, demonstrates the increase of the non-conformity ratio in the periods in which the production is intense.

Audit tests have been carried out without notice since June 2004. The compressive strength class of the concrete inspected during these inspections carried out by the KGS Audit Test Team without notice is not predetermined. Therefore, multiple numbers of the data obtained from the KGS Audit Tests were thought to reflect the production ratios of the concrete classes as per years in Turkey. These results are shown in Figure 5.

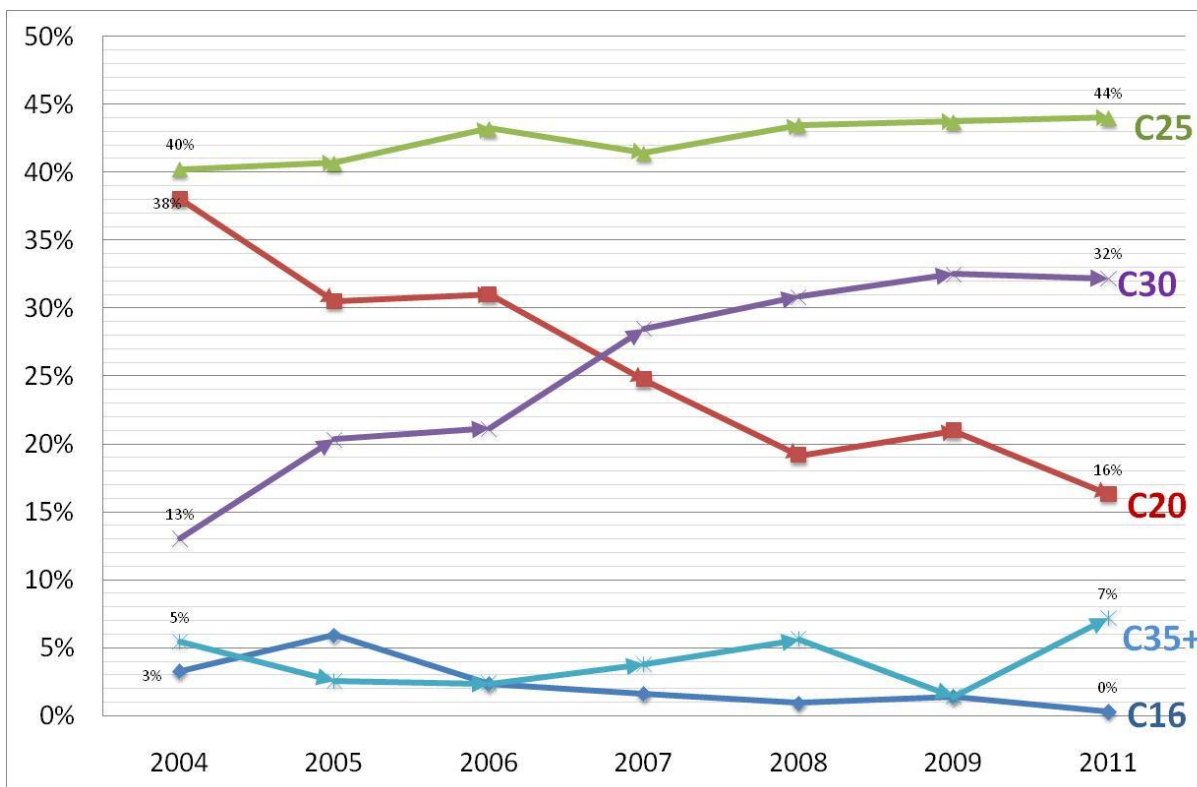


Figure 5. The concrete compressive strength classes encountered in the audit tests– As per years

In Figure 5, it is seen that especially C20/25 production has decreased more than two times in 2011 with respect to that of 2004; on the contrary C30/37 production has increased more than 2 times within the same time period. C16/20 was never encountered in 2011 during the audit tests. The highest concrete strength class encountered by now in the KGS Audit Tests is C65/80.

The non-conformities classified with respect to concrete classes determined in the KGS Audit Tests are shown on Figure 6.

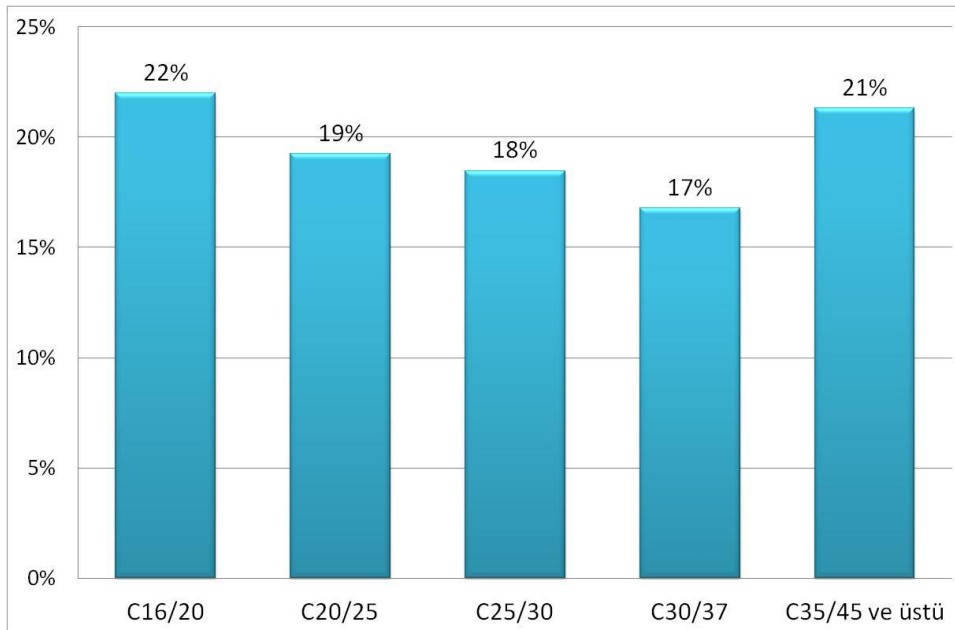


Figure 6. The non-conforming result ratio as per the concrete classes– Between 2008-2011

It is pleasing that the non-conformity ratio in the C25/30 and C30/37, the most widely produced concrete classes in Turkey, are relatively lower than the other classes.

### 3.2. Data Analysis of the KGS System Inspections

The complete 2011 KGS System Inspections were taken through a detailed data analysis. Especially both the nonconforming and the successful matters were determined during this analysis.

In the KGS System Inspections, two types of determinations are made as “nonconformity” and “observation”. “Nonconformity” means that one of the rules required to be complied with regarding the production control system designated in the KGS Certification Guide; and the certification resolution is not made by the KGS Certification Committee without conducting the corrective actions in the issues considered to have nonconformity. “Observation” means the determinations that must be corrected until the next periodical system inspection even though they do not pose prevention to the certification.

By way of conducting a scrutiny between the nonconformities detected during the system inspections the percentages of the important matters where the nonconformities are seen in production control system with respect to the total nonconformity number are seen on Figure 7.

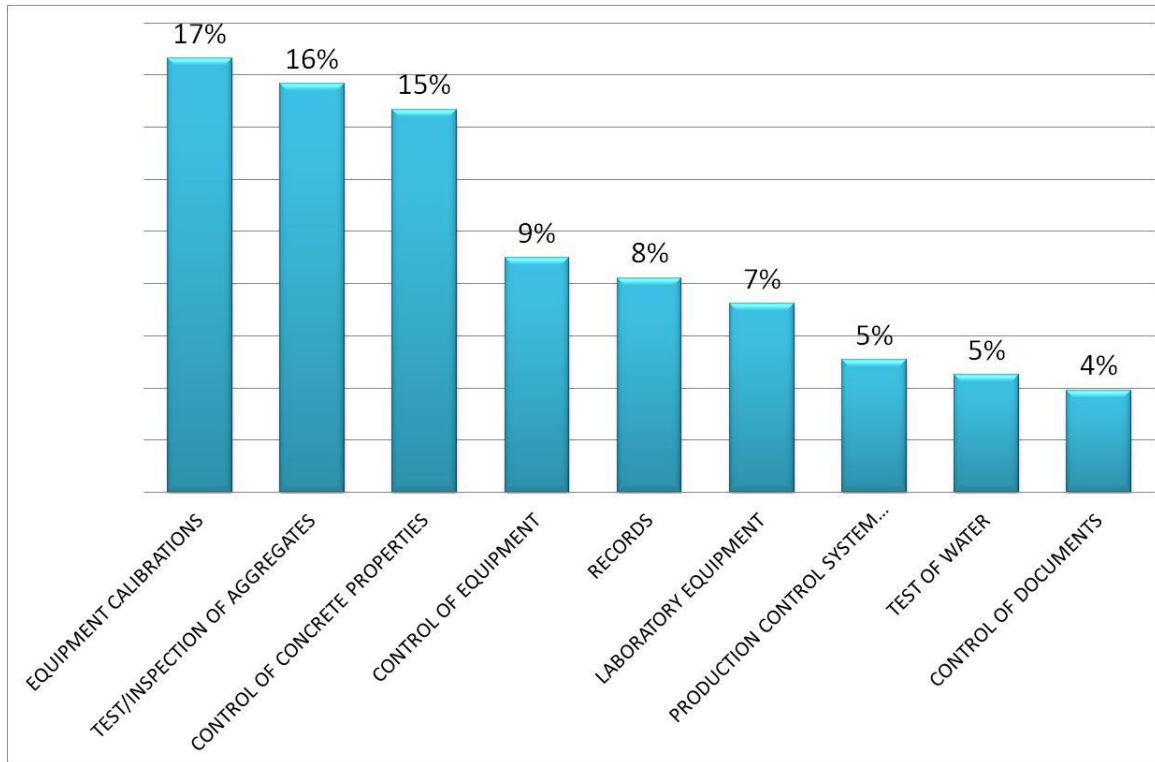


Figure 7. The ratio of the nonconformities detected in the system inspections

As it can be seen in Figure 7, in the system inspections conducted at the ready mixed concrete plants, the most highly encountered nonconformities are the calibration deficiencies in the test equipments, presence of the missing test results in the aggregates as well as the deficiencies in the control of the production and concrete characteristics.

The calibration deficiencies in the test equipments are observed in general in the manner that the calibration frequencies are not complied with. Any inaccurate measurement conducted in the laboratory established by the ready mixed concrete plant within the scope of the production control system in order to control itself can result as a punishment of even a properly conducted production. In the system inspections of the previous years, the calibration nonconformities were not even in the first three line of the list, and this fall, instead of improvement, is thought-provoking [3]. The only improvement in this issue compared to the previous years is that the concrete compressive strength tools have become examinable in accordance with the EN 12390-4 Standard.

In the aggregates, it is seen that the tests and inspections conducted by the concrete plant in its own laboratory are generally conforming; however the tests that must be conducted by the aggregate producers are not fully conducted or conducted in inappropriate frequencies. It is required that especially the alkali-aggregate reactivity measurements must be carried out in a substantial sensitivity.

The most outstanding of the nonconformities determined in the control of the concrete characteristics section is that the water corrections in the concrete mix designs are not carried out in a correct manner because of the inappropriate frequency of moisture content test. Even though during the recent years, the plant automation systems have been able to correct the mixture designs automatically and appropriately subsequent to the water content inflow of the aggregates, in some plants, this adjustment is tried to be made by the plant operator with the slump or mixer ampermeter readings that need to be only the final control. This condition causes that both the plant's standard deviations increase due to the inability of the concrete characteristics to become in the desired measurements and that different problems are encountered due to the input of excess or missing concrete. Another nonconformity determined in this section is that specifically some of the daily tests that must be conducted in the fresh concrete (exp. density measurement etc.) are not carried out in the appropriate frequency.

Insufficiency of the number of the laboratory personnel and/or the deficiencies in their competences is thought to be the cause of such condition.

In the KGS System Inspections, during the years, some very successful achievements were obtained in the following subjects:

- Plant equipment, automation systems, raw material scales,
- Batching and delivery documents,
- Statistical concrete conformity control.

The plant equipments and automation systems have demonstrated very important developments in Turkey during the recent years and gave birth to the fact that the plants conducted the productions with very high efficiency and that they had almost no problem regarding the compliance with the production control system conditions.

Similar condition also applies to the batching and delivery documents. It is seen that presently, in the batching and delivery documents of almost all ready mixed concrete plants, the desired information is available.

Another successful area is that the concrete compressive strength conformity assessment is tracked by establishing a correct system. Presently, even the smallest ready mixed concrete plant with KGS is able to carry out statistical assessment in more efficient and competent manner compared to many factories in different sectors whose quality control is conducted in Turkey.

#### **4. DISCUSSION & RESULTS**

Although it is a very young sector, the ready mixed concrete industry in Turkey has grown very fast and reached the highest level of production between the European Countries. In this rapid growth, it is possible to have problems in respect of quality inevitably. It is a key point that concrete is subject to quality inspection and certification at the production location in order to overcome such problems. In the concrete field that has become a part of culture in Europe for many years, 3<sup>rd</sup> party voluntary certifications are tried to be continued in Turkey since 1996 by way of KGS. However, the perception of quality in Turkey is unfortunately not like in the European countries. The concept of quality control was poor in concrete sector before KGS; but with KGS the consumers and contractors have seen the examples of good production the demand for quality is increasing. However there is more distance to reach a collective conscious since only 350 plants gained KGS Certification out of total 900 ready mixed concrete plants.

In ready mixed concrete sector, mandatory G Marking was launched in 2010. However, this mandatory marking has not yet created the expected impact and preventing the continuation of the old, insufficient applications.

In ready mixed concrete sector, continuous improvements are being carried out regarding the KGS Certifications. In order to make more effective certification, views of all the actors, primarily KGS Scientific Advisory Committee, and the institutions certificated as well as the inspectors are taken and the data stated in this study are evaluated at the end of each year. Accordingly, KGS certification criteria are improved and the different activities that will reduce the setbacks in the ready mixed concrete sector such as training etc. are tried to be implemented.

This study shows that there have been positive developments in the concrete quality during the recent years. However, there are still many issues that must be corrected. It is seen that the important reason of the nonconformities in system inspection is not the technical deficiency in the equipments but the deficiencies in the personnel structure and/or number. It is obvious that the need for trained personnel in this issue is substantial.

Ready mixed concrete is not understood to be a very valuable product in the majority of the construction industry and it is only viewed as any material sold by expressing the compressive strength class. However, a sensitive production processes subject to many production control phases that can never be encountered any other building material are available behind it. In addition, even after the completion of the building, it continues to be the most important product. Therefore, it is required that concrete must not be viewed as any product that can only be expressed by its compressive strength class and that the users are illuminated about the fresh and hardened concrete characteristics as well as the inspection that must be conducted.

In the ready mixed concrete sector, in the KGS inspections, different applications will be initiated regarding the enhancement of quality during the future periods. There will be effective assessment factors launched that are much more beyond the standard conditions, with which the plants will be able to envisage their production qualities. The objective is to move forward all the plants with the KGS Compliance Certificate.

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