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Research Article

Statistical Evaluation and Comparison of Concrete Produced in Eskisehir with Concrete Produced in Different Provinces in Turkey

Ilker Bekir Topçu[1a], Emir Günaltılı[1b]
[1] Eskişehir Osmangazi University, Faculty of Engineering and Architectural, Dept. of Civil Engineering, Eskişehir 26480, Turkiye
gunaltilie@gmail.com

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ORCID: [a]0000-0002-2075-6361; [b] 0000-0002-0237-1847.

Abstract : In the research, C25/30 and C30/37 class ready-mixed concrete (RMC) produced in Eskişehir in 2022 of the compressive strength test results of concrete specimens taken statistically. The concrete quality was attempted to be evaluated by the C25/30 and C30/37 concrete classes created in different construction sites and building sections in Eskişehir using the results of the compressive strength tests performed on a total of 1355 samples. The previous scientific studies were carried out within the framework of the statistical analysis of the compressive strength results of the C25/30 and C30/37 concrete class samples that were brought to the laboratory from various locations of different construction sites in Eskişehir , within the framework of the standards determined by the quality grades determined by ACI 214R-11 and TS EN 206. In the investigations , the information from the same strength classes that were poured in Eskişehir and different provinces in Turkey on various dates was compared and reviewed.

Keywords : Concrete, ready-mixed concrete, quality control, statistics, compressive strength.

1 Introduction

The most fundamental and significant building material used in modern construction is concrete [1]. Concrete, a material that is often used in construction, plays a significant role in the creation of structures in terms of both the volume it occupies and the desired characteristics, as well as the safety of the structure and the maintenance of its qualities over time [2]. Concrete technology has a long history that began in the 1850s. After the 1970s, ready-mixed concrete (RMC) manufacturing technologies began to be used in Turkey. Turkey's concrete manufacturing processes have evolved in tandem with other technical advancements throughout time, allowing it to construct a more stringent internal quality control system [3]. RMC is the kind of concrete ordered from a concrete factory that uses an automated production method and is made optionally (with cumulative) per the concrete plan set at the building site. It also cuts down labor costs, site inspection expenses, and project duration, which results in cost savings for raw materials, acceptable quality, and economy. Cumulatively, it is delivered quickly and enables quick construction [4].

Precise automated management of aggregate and water according to mix design ensures consistency in quality. With the use of public transportation, a large quantity of concrete may be delivered without wasting cement or aggregates. Since there is no dust issue, there is no pollution. In today's construction applications for massive industrial and residential projects when time is of the essence, RMC is a necessary building material [5]. In a significant portion of Turkey, there is a strong likelihood of an earthquake. Turkey is situated on a tectonically active terrain, as shown by the frequency of earthquakes in recent years. The Turkish Ready Mixed Concrete Association (THBB) guarantees that the concrete produced is easier, quicker, and more affordable, members of the RMC industry supply over 70% of Turkey's yearly total output. The statistical approach should be used since this circumstance will ensure that the generated concrete is uniform and has a suitable number of samples [6]. The lowest concrete class was selected to be C25/30 in the revised 2018 building earthquake code taking into account the seismic factor in our nation [7].

Concrete is often employed in compression loading configurations in civil engineering because its compressive strength is substantially greater than its tensile and/or flexural strengths. The tensile and flexural strengths of concrete are typically in the range of 10 and 15%, respectively, of the compressive strength [8]. Cumulatively, because of its direct connection to the structure of the hydrated cement paste, compressive strength is often used as a gauge of the quality of concrete [9]. Compressive strength is often employed as the foundation for choices on the strength and suitability of concrete members and structures due to these factors [10]. Concrete compressive strength tests are performed to ascertain the degree to which the projects' concrete strength

Table 1: Compressive strength classes for normal and heavyweight concrete

Compressive Strength Classes	Lowest Characteristic Cylinder Strength $f_{ck\ Cyl}$ MPa	Lowest Characteristic Cube Strength $f_{ck\ Cube}$ MPa
C8/10	8	10
C12/15	12	15
C16/20	16	20
C20/25	20	25
C25/30	25	30
C30/37	30	37
C35/45	35	45
C40/50	40	50
C45/55	45	55
C50/60	50	60
C55/67	55	67
C60/75	60	75
C70/85	70	85
C80/95	80	95
C90/105	90	105
C100/115	100	115
C60/75	60	75
C70/85	70	85
C80/95	80	95
C90/105	90	105
C100/115	100	115

requirements have been met and to forecast potential concrete quality values. A composite material like concrete is impacted by a wide range of factors. The right materials and mixing ratios are essential for producing high-quality concrete. Cumulatively, it is crucial for the placing and curing of molds. Utilizing a sound statistical approach and collecting an adequate number of samples are necessary for obtaining accurate information on concrete quality [11, 12, 13, 14, 15].

In this research, the distribution of compressive strengths was looked at using the concrete strength data for 2022 obtained from an RMC plant in Eskişehir. These findings were discovered for the archive in the concrete company's laboratory; they are not official data. Cube samples of 15 cm and aged between 7 and 28 days were used in the experiments, and their strengths were noted. A total of 1340 samples were analyzed in the laboratory, including 1005 samples aged 28 days and 335 samples aged 7 days. As a result, an attempt was made to determine how common RMC classes are in Eskişehir. Cumulatively, the information collected from the concrete business was reviewed in light of its characteristic compressive strength (fck). The TS 500 classification and the Regulation on the Structures to be Built in Disaster Areas have therefore been used to try to determine the condition of the concrete produced by a firm in Eskişehir [16, 17, 18]. A similar study was carried out for the province of Istanbul in 1989 and 1997 according to the test results obtained in the Materials of Construction Laboratory of ITU Faculty of Civil Engineering [15, 19].

2 Scope of Research

The findings of the compressive strength tests performed by bringing samples of the RMC poured at construction sites in the year 2022 and manufactured in different factories around the province of Eskişehir to the concrete and building materials laboratory were examined. It was thought reasonable to split the four sets of samples' concrete compressive strengths into distinct concrete classes and locations. These are the foundation, column, beam, slab that was poured, and 15 cm3 cube strengths that are 7 and 28 days old. Tables 1 and 2 illustrate how these groups are divided. The quality control levels of RMC producers were established by the results of the compressive strength tests on a provincial level by analyzing the strength results in the two groups, histograms, frequency tables, and cumulative frequency curves were drawn, and some statistical parameters were calculated along with these values. In light of other statistical parameters, the compressive strength results of concrete samples from various Eskişehir construction sites were compared with Turkish standards, and a comparison was made between the desired strength values in the project and the actual strength values obtained as a result of the application. An attempt was made to gauge effectiveness.

3 Experiment Results

The compressive strength tests on the 15 cm^3 cube samples obtained by the concrete laboratory during the concrete pouring at the building sites were performed after 7 and 28 days in the curing pool. Table 1 shows that the lowest characteristic of the C25/30 cube concrete sample should be 30 MPa and the lowest characteristic of the C30/37 cube concrete sample should be 37 MPa by TS 500 and TS EN 206. How many groups will be divided according to the strength ranges is found by using the Formula 1 given below. N in the formula indicates the total number of buildings and m indicates the compressive strength range [20].

$$m = 1 + 3.3 \log N \quad \text{or} \quad 2m \geq N \tag{1}$$

Table 2: Relative strength gain of concrete over time

Concrete Age	Age Factor	
	Section	Average
3-day	0.39–0.63	0.51
7-day	0.59–0.86	0.72
14-day	0.77–1.00	0.88
1-month	1.00	1.00
2-month	1.01–1.25	1.11
4-month	1.03–1.34	1.17
8-month	1.04–1.41	1.23
1-year	1.11–1.52	1.28
2-year	1.12–1.49	1.31
5-year	1.12–1.76	1.39

Table 3: 7-day compressive strength of C25/30 concrete poured in foundation

Strength Range (MPa)	Number	Frequency	Cumulative frequency
22.60-24.60	4	0.047	0.047
24.60-26.60	4	0.047	0.093
26.60-28.60	2	0.023	0.116
28.60-30.60	10	0.116	0.233
30.60-32.60	14	0.163	0.395
32.60-34.60	13	0.151	0.547
34.60-36.60	18	0.209	0.756
36.60-38.60	17	0.198	0.953
38.60-40.60	4	0.047	1.000
TOTAL	86	1.000	

The 7-day characteristic compressive strength is anticipated to be around 72% of the 28-day characteristic value (between 59% and 86%) [21], as shown in Table 2 [22]. The 7 and 28-day measurements need to be categorized to statistically examine the strength findings for 2022.

Applying the method (1) shown below [22] determine how many categories should be created according to power ranges. The formula divides each part into classes in distinct numbers, as shown in Tables 3 through 10 and Figures 1 through 4 [23]. As can be seen from Table 2, it is understood that the compressive strength is 72% on average, according to C25/30 produced for 7 days.

During the foundation phase of the ready-mixed concrete company's laboratory, cube samples measuring 15 cm were obtained from concrete produced in the C25/30 quality class. Table 3 provides the results of dividing the compressive strengths determined from the 7-day strengths of the samples obtained according to formula 1 into 9 classes, along with the number of samples corresponding to the groups, frequency, and other frequency data. Table 3 reveals that for 7-day-old C25/30 concrete, the majority of the falls between 28.60 and 38.60. In comparison to the compressive strength anticipated from 7-day concrete, this is a positive outcome. It can be seen that the concrete poured in the Eskişehir region in 2022 is more suitable for the standards, as the 7-day concentration for the C25/30 in the data of Uzunömeroğlu is between 22.00-24.00 [4] and the 7-day compressive strength concentration for the C25/30 in the data of Sofuoğlu is 20.50-28.50 [3].

At the foundation stage of the ready-mixed concrete company's laboratory, 15 cm3 cube samples were taken from the C25/30 class of concrete. After using Formula 1 to figure out the 28-day strengths of the samples, the compressive strength results are shown in Table 4, along with the number of samples in each group, the frequency, and cumulative frequency data. Table 4 shows that the concentration for C25/30 concrete that has been made for 28 days is between 39.30 and 42.30. This is a good result compared to the compressive strength that would be expected from concrete after 28 days. In Uzunomeroğlu's data, the 28-day concentration for C25/30 is between 31.00 and 37.00. In Sofuoğlu's data, it's between 30.25 and 32.50. This shows that the concrete poured in the Eskişehir region in 2022 fits the standards better.

From the foundation phase of the ready-mixed concrete company's laboratory, cube samples measuring 15 cm were obtained from the C30/37 class. The compressive strength findings separated into 5 distinct classes together with the number of samples matching the groups, frequency, and extra frequency data are shown in Table 5 as a result of calculating the 7-day strengths

Table 4: 28-day compressive strength of C25/30 concrete poured in foundation

Strength Range (MPa)	Number	Frequency	Cumulative frequency
28.30-31.30	9	0.035	0.035
31.30-34.30	5	0.020	0.055
34.30-36.30	19	0.074	0.129
36.30-39.30	63	0.246	0.375
39.30-42.30	86	0.336	0.711
42.30-45.30	56	0.219	0.930
45.30-48.30	18	0.070	1.000
TOTAL	256	1.000	

Table 5: 7-day compressive strength of C30/37 concrete poured in foundation

Strength Range (MPa)	Number	Frequency	Cumulative frequency
30.80-32.80	4	0.129	0.129
32.80-34.80	2	0.065	0.194
34.80-36.80	15	0.484	0.677
36.80-38.80	7	0.226	0.903
38.80-40.80	3	0.097	1.000
TOTAL	31	1.000	

Table 6: 28-day compressive strength of C30/37 concrete poured in foundation

Strength Range (MPa)	Number	Frequency	Cumulative frequency
36.10-38.10	7	0.076	0.076
38.10-40.10	15	0.163	0.239
40.10-42.10	23	0.250	0.489
42.10-44.10	22	0.239	0.728
44.10-46.10	10	0.109	0.837
46.10-48.10	11	0.120	0.957
48.10-50.10	4	0.043	1.000
TOTAL	92	1.000	

of the samples obtained according to Formula 1. Table 5 demonstrates that there are few observations since C30/37 strength concrete is not widely used in Eskişehir. The distribution for 7-day-old C30/37 class concrete falls somewhere in the range of 34.80 to 36.80 MPa. In comparison to the strength anticipated from 7-day concrete, this is a positive outcome. It can be noted that the concrete poured in the Eskişehir area in 2022 is more acceptable for the norms, as the 7- concentration for C30/37 in Tuna's data is between 34.00 and 42.00 [24], while in Ateşin's data, it is between 30.00 and 37.00 [25].

15 cm^3 cube samples were obtained from the C30/37 class concrete produced at the foundation stage of the ready-mixed concrete company's laboratory. The compressive strength findings, broken down into 7 separate classes and the number of samples that belong to each group, frequency, and extra frequency data, are shown in Table 6 as a result of the computation of the 28-day strengths of the samples obtained by Formula 1. According to the C30/37 produced for 28 days, Table 6's concentration is between 42.10 and 44.10. As compared to the compressive strength anticipated from a 28-day concrete, this is a satisfactory outcome. It can be seen that the concrete poured in the Eskişehir region in 2022 is more suitable for the standards because the 28-day concentration for C30/37 in Tuna's data is between 37.00 and 46.00 [24] and for C25/30 in Ateşin's data is 35.90-42.80 [25].

Cube samples with the dimensions of 15 cm^3 were taken of the concretes produced in C25/30 class during the column, beam, and slab stages of the ready-mixed concrete company's laboratory. As a result of the calculation of the 7-day strengths of the samples taken according to Formula 1, the compressive strength results divided into 7 different classes are given in Table 7 together with the number of samples corresponding to the groups, frequency, and cumulative frequency data. As can be seen from Table 7, the concentration is between 28.00-34.00 according to the C25/30 produced for 7 days. This is a good result compared to the strength expected from a 7-day concrete. According to Uzunömeroğlu's data, the 7-day concentration for the C25/30 is between 22.00-24.00 [4] and the 7-day concentration for the C25/30 in the data of Sofuoğlu is 20.50-28.00 [3], it is seen that the concrete poured in the Eskişehir in 2022 is more suitable for the standards.

Table 7: 7-day compressive strength of C25/30 concrete poured in Column Beam Flooring

Strength Range (MPa)	Number	Frequency	Cumulative frequency
22.00-25.00	3	0.018	0.018
25.00-28.00	13	0.080	0.098
28.00-31.00	46	0.282	0.380
31.00-34.00	61	0.374	0.755
34.00-37.00	30	0.184	0.939
37.00-40.00	7	0.043	0.982
40.00-43.00	3	0.018	1.000
TOTAL	163	1.000	

Table 8: 28-day compressive strength of C25/30 concrete poured in Column Beam Flooring

Strength Range (MPa)	Number	Frequency	Cumulative frequency
26.50-29.50	6	0.013	0.013
29.50-32.50	9	0.019	0.032
32.50-35.50	55	0.116	0.147
35.50-38.50	164	0.345	0.493
38.50-41.50	149	0.314	0.806
41.50-44.50	67	0.141	0.947
44.50-47.50	25	0.053	1.000
TOTAL	475	1.000	

Table 9: 7-day compressive strength of C30/37 concrete poured in Column Beam Flooring

Strength Range (MPa)	Number	Frequency	Cumulative frequency
29.00-31.00	2	0.021	0.021
31.00-33.00	4	0.041	0.062
33.00-35.00	14	0.144	0.206
35.00-37.00	8	0.082	0.289
37.00-39.00	10	0.103	0.392
39.00-41.00	6	0.062	0.454
41.00-43.00	46	0.474	0.928
43.00-45.00	5	0.052	0.979
45.00-47.00	2	0.021	1.000
TOTAL	97	1.000	

Table 10: 28-day compressive strength of C30/37 concrete poured in Column Beam Flooring

Strength Range (MPa)	Number	Frequency	Cumulative frequency
36.10-38.10	7	0.076	0.076
38.10-40.10	15	0.163	0.239
40.10-42.10	23	0.250	0.489
42.10-44.10	22	0.239	0.728
44.10-46.10	10	0.109	0.837
46.10-48.10	11	0.120	0.957
48.10-50.10	4	0.043	1.000
TOTAL	92	1.000	

In the laboratory of the ready-mixed concrete company, 15 cm^3 cube samples were taken of the concrete produced in the C25/30 class during the column, beam, and slab stages. As a result of the calculation of the 28-day strengths of the samples taken according to Formula 1, the compressive strength results, which are divided into 7 different classes, are given in Table 8 together with the number of samples corresponding to the groups, frequency, and cumulative frequency data. As can be seen from Table 8, the concentration is between 35.50-41.50 according to the C25/30 produced for 28 days. This is a good result compared to the compressive strength expected from a 28-day concrete. According to Uzunömeroğlu's data, 28-day concentration for C25/30 is between 31.00-37.00 [4] and 28-day concentration for C25/30 in Sofuoğlu's data is 30.25-32.50 [3], it is seen that the concrete poured in the Eskişehir region in 2022 is more suitable for the standards.

15 cm^3 cube samples of the concrete produced in the C30/37 class at the stages of columns, beams, and slabs were collected at the ready-mixed concrete company's laboratory. Table 9 includes the results of the Formula 1 calculation for the 7-day strengths of the samples tested, the compressive strength results broken down into 9 separate classes, the number of samples that belong to each group, frequency information, and extra frequency information. As can be observed from Table 9, the C30/37 produced for 7 days has a compressive strength concentration that ranges from 41.00 to 43.00. As compared to the compressive strength anticipated from a 7-day concrete, this is a satisfactory outcome. It can be seen that the concrete poured in the Eskişehir region in 2022 is more suitable for the standards because Tuna's data show that the 7-day concentration for C30/37 is between 34.00 and 42.00 [24] and Ateşin's data show that it is between 30.00 and 37.00 [25].

C30/37 class concrete produced at the RMC company's laboratory was sampled as 15 cm^3 cubes at the column, beam, and slab phases. Compressive strength values, broken down into 7 classes based on the formula 1 calculation of the 28-day strengths of the samples obtained, are shown in Table 10 along with the appropriate sample counts, frequencies, and extra frequencies. The distribution for 28-day-old C30/37-class concrete falls somewhere in the range of 42.10 to 44.10. In comparison to the strength predicted for 28-day concrete, this is a very encouraging finding. The concentration of 28-day for the C30/37 is between 37.00 and 46.00 [24] according to the data of Tuna, while the concentration for the C25/30 is between 35.90 and 42.80 according to the data of Ateşin. As observed in [25], concrete placed in the Eskişehir area in 2022 is more suited to the norms.

4 Evaluation of Results

ACI 214R-11 utilized the values in Table 11 to assess the quality degree of the concrete by the mean compressive strength (X_{mean}) to estimate the quality control degrees of the concretes for which compressive strength data were obtained. The analysis should be conducted using the coefficient of variation value if the mean of the strength series in the Table is less than 25 MPa, and the standard deviation value (SD) if the mean of the series is larger than 25 MPa. In Table 11, V is the coefficient of variation and SD is the standard deviation.

Calculations were done to perform this study while taking into account that table values were established based on the

Table 11: Quality ratings determined by ACI 214R-11 [26]

Degree of Quality Control	$X_{\mathrm{mean}} \leq 25$ MPa for V, %	$X_{\mathrm{mean}} > 25$ MPa for SD, MPa
Very Good	<10.00	<5.00
Good	10.00-20.00	5.00-6.50
Middle	20.00-30.00	6.50-8.00
Weak	>30.00	>8.00

Table 12: Statistical values of C30/37 concrete samples

	Day	Min. Val. (MPa)	Max. Val. (MPa)	Average Strength (MPa)	SD, Standard Deviation (MPa)	V, Coefficient of Variation (%)
Column Beam Slab	7	29.10	46.20	37.66	4.11	16.90
	28	37,60	56.60	44.71	4.14	17.12
Foundation	7	30.80	40.80	35.95	2.43	5.91
	28	36.10	49.10	42.48	3.03	9.19

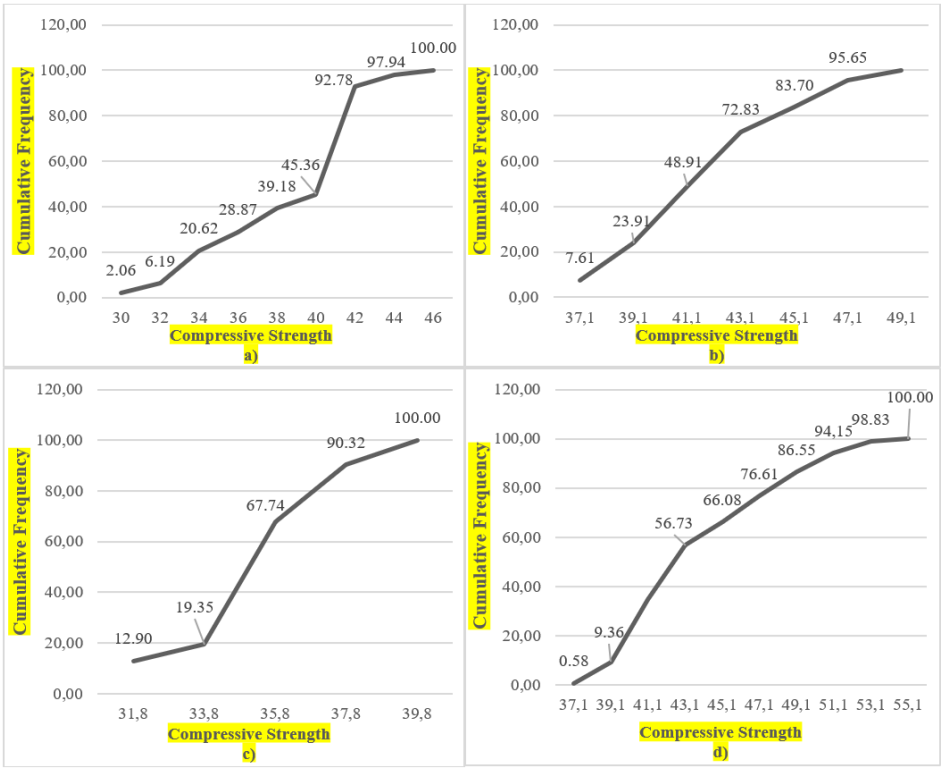

Figure 1: Sample compressive strength cumulative frequency diagram of C30/37 concrete a) 7-day in columns, beams, and slabs b)28-day in columns, beams, and slabs c) 7-day in foundation d) 28-day in foundation.

cylinder sample's compressive strength. The transition coefficient from the 15 cm^3 cubic sample to the ϕ15x30 cm cylindrical sample is 0.78 because of the shape effect [3].

4.1 Evaluation of C30/37 concrete poured on the foundation and Column Beam Slab

The average strength value for 7 days is 35.948 MPa for 31 samples for 7 days and 92 samples for 28 days, according to the statistical parameters prepared based on the results of the samples poured by targeting C30/37 compressive strength in the foundation section of the reinforced concrete building. This SD should be used as a starting point for defining the quality control level, as the strength value is more than the 25 MPa provided in Table 11. As the SD value was less than 5.00 MPa, it was determined that the quality control of the concretes was "Weak" (2.431 MPa). Data from Memiş et al. show that the average minimum strength of a C30/37 concrete sample is 24.49 MPa after 7 days, whereas the average maximum strength is 40.80 MPa.

The computed mean strength was 33.83 MPa, with an SD of 3.7710. According to the C30/37 concrete sample's 28-day strength findings, the lowest strength is 29.15 MPa on average throughout the years, while the maximum strength is 50.28 MPa on average. In this case, we have a mean strength of 40.17 MPa and an SD of 4.0144 MPa [27]. It can be shown that after 28 days the average is 42.479 MPa. This SD figure should be used as a starting point for establishing the quality control level, as the strength value is more than the 25 MPa provided in Table 11. As the SD figure was less than 5.00 MPa, it was determined that the concretes had been manufactured with a **"Middle"** quality control level (3.03 MPa). The likelihood of reaching a certain value may be anticipated and the required parameters for doing so can be determined using the cumulative frequency distribution [25].

The minimum characteristic compressive strength of the cube samples for the C30/37 has been established to be 35 MPa by TS EN 206 and TS 500. Given that the 7-day cube sample strength is generally believed to be equal to 0.72 of the 28-day cube sample strength, the predicted strength value of any 7-day cube sample for C30/37 is 35 x 0.72 = 25.2 MPa. As can be observed in Figure 1, all of the 7-day concrete samples (100%) poured as C30/37 provide, at a minimum, the compressive strength values

Table 13: Quality ratings determined by ACI 214R-11 [26]

	Day	Min. Val. (MPa)	Max. Val. (MPa)	Average Strength (MPa)	SD, Standard Deviation (MPa)	V, Coefficient of Variation (%)
Column Beam Slab	7	22.00	41.40	31.93	3.36	11.30
	28	26.70	47.50	38.74	3.45	11.89
Foundation	7	22.60	39.20	33.17	4.03	16.32
	28	28.30	47.30	40.11	3.66	13.43

specified by TS EN 206 and TS 500. If one uses Figure 1 to determine the compressive strength values in TS EN 206 and TS 500, one can observe that all of the 28-day concrete samples (100%) poured as C30/37 meet the predicted strength of 35 MPa.

When the statistical parameters prepared according to the results of the samples poured by targeting C30/37 in the column, beam, and floor section of the reinforced concrete building are examined, it is seen that the average strength value for 7 days is 37.66 MPa for 57 samples for 7 days and 171 samples for 28 days. This value was derived from the results of the samples poured by targeting C30/37 in the column, beam, and floor section of the reinforced concrete building. Because the value of this material's compressive strength is more than the 25 MPa that is indicated in Table 11, the value of the SD should be used as the foundation for defining the degree of quality control. Since the SD figure was lower than 5.00 MPa, it was determined that the concretes that were manufactured had a **"Middle"** quality control level. This was the conclusion that was reached (4.11 MPa). According to the findings of Memiş et al., the 7-day strength results of the C30/37 concrete sample show that the minimum strength is 24.49 MPa on average over the years, while the maximum strength is 40.80 MPa on average over the years. These figures were derived from the data collected over the course of several years. The mean strength was determined to be 33.83 MPa, while the SD was found to be 3.7710 MPa. According to the findings of the C30/37 sample's 28-day strength test, the lowest strength throughout the course of the years has averaged 29.15 MPa, while the maximum strength has averaged 50.28 MPa. The computed mean compressive was found to be 40.17 MPa, while the SD was found to be 4.0144 [27].

It can be observed that the strength value averaged out over the course of 28 days is 44.710 MPa. Because the value of this material's compressive strength is more than the 25 MPa that is indicated in Table 11, the value of the SD should be used as the foundation for defining the degree of quality control. Since the SD figure was lower than 5.00 MPa, it was determined that the concretes that were manufactured had a **"Middle"** quality control level. This was the conclusion that was reached (4.137 MPa). By utilizing the cumulative frequency distribution, it is possible to estimate the likelihood that a specific value will be exceeded, and it is also possible to compute the required parameters for determining the probability that a certain value will be exceeded [25].

According to TS EN 206 and TS 500, the minimum characteristic compressive strength of the cube samples for the C30/37 has been established to be 35 MPa. This value was arrived at via the use of testing equipment. If the strength of a 7-day cube sample is considered to be equivalent to 0.72 of the strength of a 28-day cube sample, then the predicted strength value of any 7-day cube sample belonging to the C30/37 may be computed as 35 multiplied by 0.72, which is 25.2 MPa. With this strength value, Figure 3, it is observed that all of the 7-day concrete samples (100%) poured as C30/37 substantially provide the strength values in the TS EN 206 and TS 500 standards. These values may be found in these standards. Because it is known that the strength that should be expected for the 28-day strength is 35 MPa, it can be seen that all of the 28-day concrete samples (100%) poured as C30/37 provide the strong values that are specified in the TS EN 206 and TS 500 and are suitable according to the literature [12, 13, 14, 15]. This can be seen by using Figure 3.

4.2 Evaluation of strengths of C25/30 poured on the foundation and Column Beam Slab

When the statistical parameters prepared according to the results of the samples poured by targeting C25/30 in the foundation section of the reinforced concrete building are examined, it is seen that the average strength value for 7 days is 33.169 MPa for 85 samples for 7 days and 255 samples for 28 days. Since this value is greater than 25 MPa specified in Table 11, the SD value should be taken as a basis for determining the quality control level. It was concluded that the concretes produced were produced with a **"very good"** quality control level, since the SD value was less than 5.00 MPa (4.03 MPa). According to the data of Memiş et al., according to the 7-day strength results of the C25/30 concrete sample, the minimum strength is 15.70 MPa on average over the years, and the maximum strength is 34.25 MPa on average over the years. The mean strength was calculated as 28.46 MPa and the SD was 4.0021. According to the 28-day results of the C25/30 concrete sample, the minimum strength is 21.03 MPa on average over the years and the maximum strength is 50.6 MPa on average over the years. The mean strength was calculated as 34.41 MPa and the SD was 4.5779 [27].

It is seen that the average value for 28 days is 40.11 MPa. Since this strength value is greater than 25 MPa specified in Table 11, the SD value should be taken as a basis for determining the quality control level. It was concluded that the concretes produced were produced with a "very good" quality control level, since the SD value was less than 5.00 MPa (3.65 MPa). By using the cumulative frequency distribution, the probability of exceeding a certain value can be predicted and the necessary parameters for the probability of exceeding a certain value can be calculated [25].

According to TS EN 206 and TS 500, the minimum characteristic strength of the cube samples for the C25/30 has been determined as 30 MPa. If the 7-day cube sample strength is accepted as 0.72 of the 28-day cube sample strength, the expected

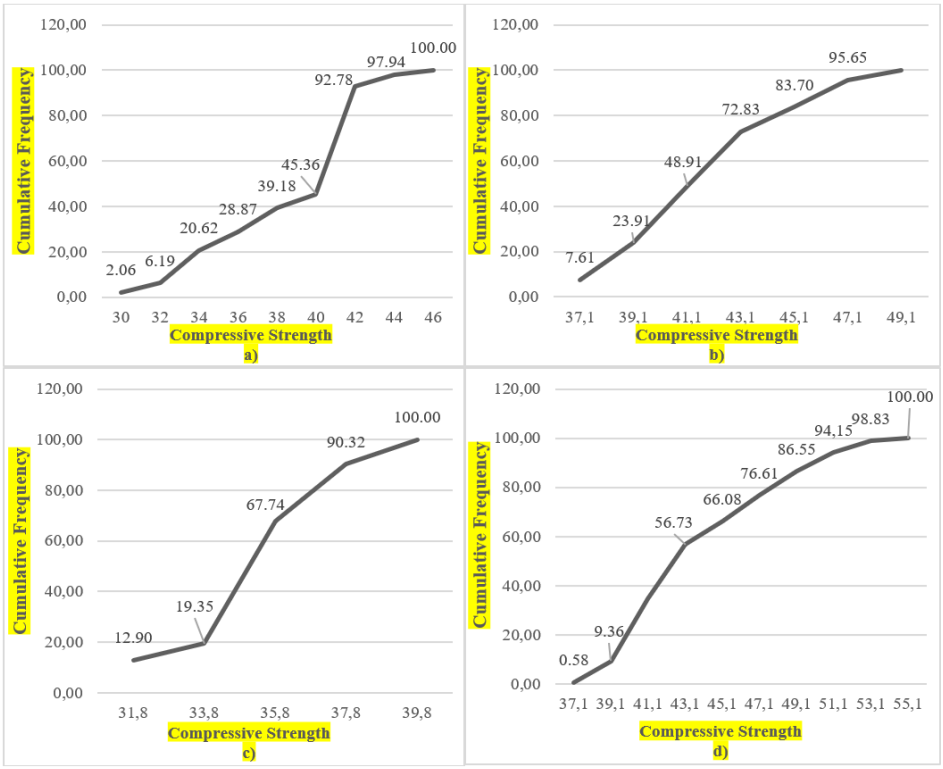

Figure 2: Sample compressive strength cumulative frequency diagram of C25/30 concrete a) 7-day in columns, beams, and slabs b) 28-day in columns, beams, and slabs c) 7-day in foundation d) 28-day in foundation.

strength value of any 7-day cube sample for C25/30 is calculated as 30 x 0.72= 21.60 MPa. Using this strength value, in Figure 2, it is seen that all of the 7-day concrete samples (100%) poured as C25/30 provide the compressive strength values in TS EN 206 and TS 500. Since the expected strength for the 28-day strength is known as 30 MPa, it is seen that 3.52% of the 28-day concrete samples poured as C25/30, based on Figure 2, do not provide the compressive strength values in TS EN 206 and TS 500.

The average compressive strength value for 7 days for 162 samples for 7 days and 489 samples for 28 days is 31.93 MPa, according to statistical parameters created based on the results of the samples poured by targeting C25/30 in the column, beam, and floor section of the reinforced concrete building. The SD value should be used as a starting point for establishing the quality control level since this strength value is more than the 25 MPa provided in Table 11 for that value. Given that the SD figure was less than 5.00 MPa, it was determined that the quality control level used to make the concretes was "Middle" (3.36 MPa). According to Memiş et al. statistics results the lowest strength is 15.70 MPa on average over the years, and the highest strength is 34.25 MPa on average over the years, based on the 7-day strength values of the C25/30 concrete sample. The SD was determined to be 4.0021 and the mean strength to be 28.46 MPa. The C25/30 concrete sample's 28-day strength findings show that the average minimum strength over time is 2.03 MPa and the average maximum strength over time is 50.6 MPa. The SD was 4.5779, and the mean compressive strength was determined to be 34.41 MPa [27].

The average compressive strength over the last 28 days is 38.74 MPa, as can be observed. The SD value should be used as a starting point for establishing the quality control level since this strength value is more than the 25 MPa provided in Table 11 for that value. Given that the SD figure was less than 5.00 MPa, it was determined that the quality control level used to make the concretes was **"Middle"** (3.45 MPa). The likelihood of reaching a certain value may be predicted using the cumulative frequency distribution, and the required variables for the probability of exceeding a specific value can be determined [25].

The minimum characteristic compressive strength of the cube samples for the C25/30 has been established at 30 MPa by TS EN 206 and TS 500. The predicted strength value of each 7-day cube sample for C25/30 is computed as 30 x 0.72= 21.60 MPa if the 7-day cube sample strength is considered as being 0.72 of the 28-day cube sample strength. Figure 2 shows that the compressive strength values in TS EN 206 and TS 500 are essentially provided by all of the 7-day concrete samples (100%) poured as C25/30. As the projected 28-day strength is 35 MPa, it can be observed that all 28-day concrete samples (100%) poured as C25/30 essentially meet the requirements of TS EN 206 and TS 500 for strength and are suitable according to the literature [12, 13, 14, 15].

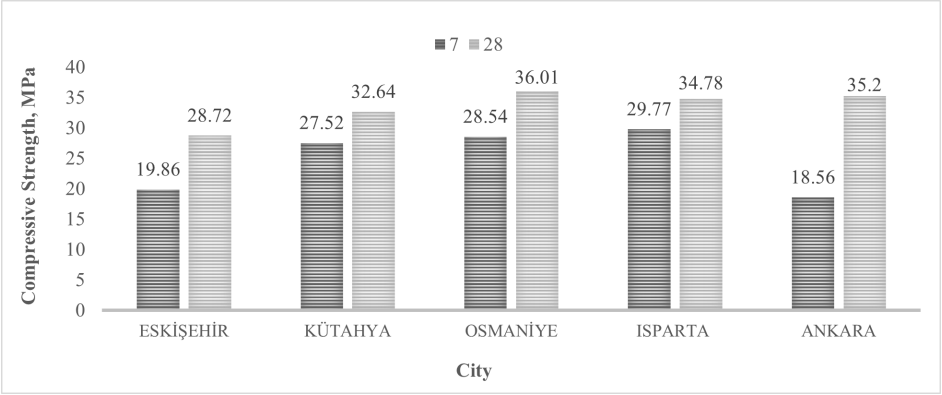

Figure 3: Compressive strengths for a single concrete class of other provinces in Turkey [3, 4, 5, 6, 25, 24, 28]

4.3 Comparison with studies conducted in other provinces in Turkey

Numerous studies on this topic have been conducted in various Turkish provinces. The 28-day average strength value was found to be 34.1 MPa after taking into account the results of the other studies conducted in Eskişehir in 2003, 2005, 2015, and 2021. The 7-day average strength value for C25/30 concrete is 19.86 MPa, the 28-day average strength value is 28.72 MPa, and the 7-day average strength value for C30/37 is 27.61 MPa [3, 5, 6]. When the Osmaniye study from 2017 is analyzed, the 7-day average strength value for C25/30 concrete is 28.54 MPa, the 28-day average strength value is 36.01 MPa, and the 7-day average strength value for C30/37 is 33.85 MPa, with 28 days being the longest period. The calculated result for strength on average was 41.37 MPa [28]. The 7-day strength value for the C30/37 was found to be 27.52 MPa, while the 28-day strength value was found to be 32.64 MPa when the study from Kütahya in 2011 was evaluated [25].

According to Figure 3, the 7-day strength value for the C30/37 was found to be 29.77 MPa, and the 28-day strength value was found to be 34.78 MPa when the study carried out in Isparta in 2022 is evaluated [24]. The average 7-day strength value for the C20/25 concrete class is 23.13 MPa, and the average 28-day compressive strength value is 27.42 MPa, according to the Sinop research done in 2016 for the years 2011, 2012, 2013, and 2014. The average 7-day compressive strength value for the C25/30 concrete class was found to be 28.15 MPa, while the average 28-day compressive strength value was found to be 34.41 MPa. The average 7-day compressive strength value for the C30/37 concrete class was found to be 3.83 MPa, while the average 28-day compressive strength value was found to be 40.17 MPa [27]. The 7-day compressive strength value for the C25/30 was found to be 18.56 MPa when the Ankara study from 2019 was evaluated, and the 28-day compressive strength value was found to be 35.2 MPa [4].

As seen in Figure 4, when the Afyonkarahisar research from 2010 was evaluated, the average 7-day compressive strength value for the C20/25 concrete was found to be 25.46 MPa, and the average 28-day compressive strength value was discovered to be 30.25 MPa. The average 7-day compressive strength value for the C25/30 concrete class was found to be 29.46 MPa, while the average 28-day compressive strength value was discovered to be 37.58 MPa. The average 7-day compressive strength value for the C30/37 concrete class was 36.64 MPa, while the average 28-day compressive strength value was 42.76 MPa [29]. When the Antalya research from 2010 was evaluated, the average 7-day compressive strength value for the C20/25 concrete class was found to be 20.92 MPa, and the average 28-day compressive strength value was discovered to be 27.79 MPa. The average 7-day compressive strength value for the C25/30 concrete class was found to be 25.12 MPa, while the average 28-day compressive strength value was discovered to be 34.31 MPa. The average 7-day compressive strength value for the C30/37 concrete class was 28.08 MPa, while the average 28-day strength value was 39.39 MPa [30].

The 28-day compressive strength value for the C20/25 concrete was found to be 31.26 MPa on average for 3 years (2008, 2009, 2010) when the research from Isparta in 2012 was analyzed in Fig.13. For three years (2008, 2009, 2010), the 28-day compressive strength value for the C25/30 concrete was found to be 35.62 MPa. For three years (2008, 2009, and 2010), the 28-day compressive strength value for the C30/37 concrete has been established at 42.84 MPa [31]. The results of all the tests show that independent of the provinces, the samples collected from recently built buildings are of greater quality than the older ones. The growth of the inspection system and the uniformity of concrete buildings are to blame for this. Cumulatively, it demonstrates that colder regions, like Central Anatolia, have lower compressive strengths. This is because the fast setting of concrete in cold conditions prevents essential hydration products from forming. According to this study, the quality of the concrete poured in Eskişehir in 2022 is higher than it was in earlier years and when compared to other provinces.

5 Conclusions

By examining the 7-day and 28-day test results of C25/30 and C30/37 class concretes poured in the foundation, column, and beam slab at different construction sites in Eskişehir in 2022, it has been observed that they generally meet TS EN 206 and

Figure 4: Compressive strengths for multiple concrete classes of other provinces in Turkey [27, 29, 30]

TS 500 codes. As expected, the 28-day compressive strength results were higher than the 7-day compressive strength results. 74% of the samples examined in Eskişehir were made in C25/30 concrete class. The test results that do not meet the codes were found to be 3.52% only for the 28-day samples in the C25/30 poured on the foundation.

When the average 28-day compressive strength results poured in columns, beams, slabs, and foundations are compared, it is calculated that the concrete poured in the column-beam slab is 5.71% higher. Because the use of vibrator in concrete gives better results in places where it can be done properly. Better settlement occurs due to the comfortable use of vibrators in the columns and as a result of this situation, high strength results are obtained. This is thought to be due to the different arrangement of reinforcements in different structural elements. When the 7 and 28-day compressive strengths of C20/25 and C30/37 concrete poured in different construction sites and different building sections in Eskişehir in 2022 are examined, it is seen that the change is small. This situation shows that both the 7 and 28-day values of the poured concrete have a certain standard according to the pouring places. Good concrete should provide what is expected in terms of strength and durability at the lowest cost. In general, it was concluded that the quality of the concretes produced and sampled in Eskişehir, taking into account the parameters in the codes and regulations, is at a 'good' level.

Finally, with the innovation that came to the building inspection system of 2019, the chipped concrete sample process has started, and the building inspectors have to be on-site during the sampling process. With this application, false reports prepared in laboratories have been prevented, and the sampling process will be instantly controlled by the supervisory institutions and the ministry thanks to the Electronic Concrete Monitoring System (EBIS) and mobile applications [4].

The fact that the sample results are close to each other shows that the calibration of the test equipment of the laboratory where the results are obtained is good and that the codes are complied with in the production of concrete coming from the common concrete plant.

Authors' Contributions

IBT and EG conducted the research together. IBT came up with the idea and explained what needed to be done. EG collected the necessary data and performed the statistical analysis, IBT supervised the studies and evaluated the comments. Both authors read and approved the final draft.

Competing Interests

The authors declare that they have no competing interests.

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