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EFFECT OF REBAR ON COMPRESSIVE STRENGTH OF CONCRETE CORES

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ABSTRACT
Concrete coring is used for determining compressive strength of hardened concrete of elements to evaluate low-strength-test-result concrete or to understand concrete placing quality of existing structure. In safety evaluation of existing structures that need rehabilitation and retrofitting, it's necessary to have some information about existing concrete. The best and most accurate method to determine compressive strength of existing concrete is coring. Rebars always make difficulty in coring of reinforced concrete structures. Sometimes it is not possible to core from plain concrete areas. There are serious considerations for effects of rebar on compressive strength of concrete cores in some countries. There is no strength correction for the effect of rebars in ACI and also in Iranian related codes and specifications. There is only an Concrete Society equation in publication no.207 of BHRC based on result corrections of cores contained rebars perpendicular to cores longitudinal axes. This correction does not exceed 10%. Dealing with such problems in a project and because there was sureness about strength of placed concrete, but strength of cores was highly lower and it was not possible to obtain plain core as there was heavy rebar concentration, it was necessary to study rebar effects on core strength. In this research, strength of cores of an element contained rebars and plain ones were compared to evaluate above mentioned equations. Also some cylindrical samples were made and tested with placed rebars. In addition if the core has uncut rebars, there will be no significant reduction in its strength. It seems that cutting of rebars in coring process has little effects on concrete quality. It is due to cracks formation between concrete and rebars that reduce the concrete strength.

Keywords: compressive strength, core, rebar, reinforced concrete, structure

1. INTRODUCTION
If any strength test of laboratory-cured cylinders falls below fc′ by more than the given values or if tests of field-cured cylinders indicate deficiencies in protection and curing, steps shall be taken to assure that load-carrying capacity of the structure is not jeopardized [1].

If the likelihood of low-strength concrete is confirmed and calculations indicate that load-carrying capacity is significantly reduced, tests of cores drilled from the area in question in accordance with "Method of Obtaining and Testing Drilled

Cores and Sawed Beams of Concrete" (ASTM C 42) shall be permitted [1,3,4].

If by structural analysis, again it can not be accepted, ordinary solution to accept concrete structurally and according to strength criterion, especially in Iran, is coring critical parts of concrete structure [3,4].

Nondestructive tests of the concrete in place, such as by probe penetration, impact hammer, ultrasonic pulse velocity or pull out may be useful in determining whether or not a portion of the structure actually contains low-strength concrete. Such tests are of value primarily for comparisons within the same job rather than as quantitative measures of strength. For cores, if required, conservatively safe acceptance criteria are provided that should ensure structural adequacy for virtually any type of construction [1].

Some specific consideration such as preparing suitable diameter and height, not contacting with reinforcements if possible, positioning critical areas, and some non destructive tests such as rebar locating test, impact hammer and ultrasonic pulse velocity are needed for coring.

In any case, if rebars are closely spaced or rebars positions can not be determined, rebars will be cut and core will contain them.

Rebar existing in the core has always been debatable subject. Some consider that rebar increase sample strength; others believe that strength will be reduced when rebar exist; the others believe in very low effect of rebar presentation [6].

In some codes and standards like ACI, ASTM, EN, Iranian Concrete code and other Iranian codes, there is no consideration for rebar effect on core, therefore there is not any correction for core test result [1,2,3,4].

In some European countries there is no correction, but BS 1881:1983 and Concrete Society presented corrections for rebar existing in concrete cores [6].

Equation (1) generally works for samples that rebar are parallel to ends of sample.

$$StrengthCorrectionFactor = 1 + \frac{3\sum_{i=1}^{n}\left(d_{r,i}h_i\right)}{2d_cL} \qquad (1)$$

Where, $d_{r,i}$ is rebar diameter, d_c is core diameter, h_i is rebar axis distance to next core surface and L is core length[5].

In equation (1), effects of rebar depend on diameter, location and number of rebar, but this correction does not exceed 25% of core strength [7].

If it is possible, the best solution is obtaining cores from plain concrete areas. Perhaps rebars cutting leads to adverse effects on structural strength, concrete quality and core strength [6].

Existing no quality control in precast concrete beams construction for bridges of a road in the South of Iran, supervisor selected coring as only practical solution for quality control of concrete of these beams. Compressive strength of cores was astonishing because there was enough confidence in strength of placed concrete, but strength of cores was too low. Accordingly, it was necessary to study rebar effects on core strength.

2. EXPERIMENTAL PROGRAM AND MATERIALS

To determine rebar effect on concrete core strength, two groups of concrete beams is used. In the first group, there are beams without rebar, and beams with rebars were the second group (Figure 1). The concrete that is used for construction of each group, is similar and also with same consolidation and curing conditions. By coring plain beams and determining their strengths, it is possible to compare results. In some beams, one, two and even three rebar was placed. Beam is a concrete block with dimension of 15× 15×60 cm and core is a cylinder with 10cm diameter and 15cm height (Figure2 and 3). As shown in Table 1, two different kinds of concrete mix proportion were used in this research. Nominal maximum size of aggregates was 20 mm.


Figure 1. Rebars placement in beams

Figure 2. Coring of beams

Figure 3. Cored beams

Table 1: Details of Mix Proportions

Mix No.	Cement kg/m^3	SilicaFume kg/m^3	W/C	Sand (SSD) kg/m^3	Coarse Aggregate (SSD) kg/m^3	Fresh Concrete Density kg/m^3	Slump mm.	HRWRA Admixture kg/m^3	Air Content %
1	370	30	0.4	925	850	2328	120	3.2	2.4
2	400	-	0.43	980	775	2328	140	2.8	2.1

Concretes without rebar are determined by CP and ones with rebar by CR. Three cores were prepared for each mix proportion. Rebar sizes are 10, 12, 16, 20, 32 mm diameter and different rebar arrangement, as shown in table 2, was used. These arrangements tried to be same as real rebar arrangements in real beams.

In another part of this research, some cylindrical samples with mix proportion no.2 and with or without rebar were prepared. Rebars placed in some samples are shorter than sample diameter and they are not cut. After 28-day same curing, tests were fulfilled. Cylindrical samples with rebar are distinguished with P and ones without rebar with letter R.

3. EXPERIMENTS RESULTS AND ANALYSIS

28-day Compressive strength results of cores in saturated state after capping as well as weights, number, diameter and arrangement of rebars are presented in Table 2. Also corrected strength of cores with rebar by using Concrete Society equation (mentioned above) is presented in this table.

Also results of cylindrical samples with and without rebar are shown in table 3. Cylindrical samples are with 150 mm diameter and 300 mm height.

According to Tables 2 and 3, in all cores with rebar there is a reduction of 25 to 60 percent than cores without rebar.

It seems that existing of rebars results in weakening of cores. In cylindrical samples, existence of rebar has reduced sample strength 16 to 24 percent.

After core breaking-up, it observed that usually rebar were separated from adjacent concrete matrix (Figure 4).

It also seems that in addition to weak connection resulting from bleeding that water gathers under rebar, act of rebar cutting weakens connection of rebar and concrete.

Cores strength variation does not follow any rule and there is much variation.

Cores strength correction result from Concrete Society equation does not show good proximity to strength of cores without rebar except CR-2-1, CR-2-2 and CR-2-4 cores.

Results of cylindrical samples with rebar after correction by Concrete Society equation show better correlation with samples without rebar. This demonstrates that rebar cutting weakens concrete samples.

Figure 4. Separation of rebars after compression test of cores

Table 2: Concrete Cores Test Results

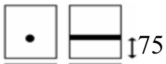
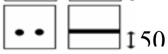
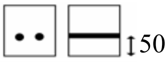
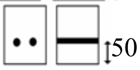
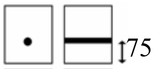
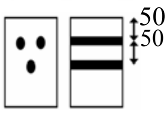
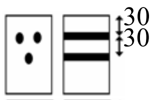
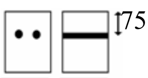
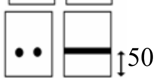
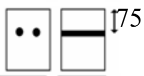
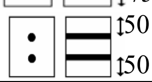
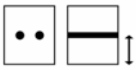
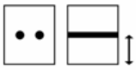
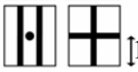
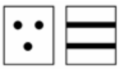
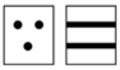
Core No.	Rebar quantity and diameter(mm)	Rebar location (mm)	Core weight (kg)	Measured compressive strength (kg/cm^2)	Corrected strength by Concrete Society equation (kg/cm^2)
CP-1-1	-	-	2.240	490	-
CP-1-2	-	-	2.235	461	-
CP-1-3	-	-	2.235	475	-
CR-1-1	1Φ32		2.380	260	322.5
CR-1-2	1Φ32		2.365	231	286.5
CR-1-3	1Φ12 1Φ20		2.370	260	301.5
CR-1-4	1Φ12 1Φ20		2.375	212	246
CR-1-5	2Φ16		2.380	360	417.5
CR-1-6	2Φ16		2.375	320	371
CP-2-1	-	-	2.220	375	-
CP-2-2	-	-	2.235	404	-
CP-2-3	-	-	2.280	388	-
CR-2-1	1Φ32		2.310	303	375.5
CR-2-2	1Φ32		2.325	303	375.5
CR-2-3	1Φ32		2.310	245	284
CR-2-4	1Φ32		2.310	303	375.5
CR-2-5	2Φ10 1Φ20		2.360	231	277
CR-2-6	2Φ10 1Φ20		2.320	274	323
CR-2-7	1Φ12 1Φ20		2.330	260	301.5
CR-2-8	1Φ12 1Φ20		2.330	144	178.5
CR-2-9	1Φ16 1Φ20		2.300	216	255
CR-2-10	1Φ16 1Φ20		2.315	122	155
CR-2-11	2Φ16		2.325	260	322.5
CR-2-12	2Φ12		2.320	231	259

Table 3: Cylindrical Concrete Samples Test Results

Sample No.	Rebar quantity and diameter(mm)	Rebar location (mm)	Measured compressive strength (kg/cm²)	Corrected strength by Concrete Society equation (kg/cm²)
P-2-1	-	-	342	-
P-2-2	-	-	328	-
P-2-3	-	-	323	-
P-2-4	-	-	337	-
R-2-1	1Φ16 1Φ12	 150	253	288.5
R-2-2	1Φ16 1Φ12	 150	267	304.5
R-2-3	2Φ16 1Φ32	 150	252	-
R-2-4	2Φ16 1Φ32	 150	257	-
R-2-5	2Φ16 1Φ32	 100 100	279	338.5
R-2-6	2Φ16 1Φ32	 100 100	266	322.5

CONCLUSION

According to obtained results and their analysis, following conclusions can be deduced.

1. The equation given by Concrete Society does not predict the core results accurately.
2. Compressive strength of core with cut rebar is always less than corresponding strength of core without rebar.
3. It appears that strength reduction due to existence of rebar in cores is between 25 to 60 percent. This reduction in cast cylindrical samples is about 16 to 24 percent.
4. It seems that rebar cutting leads to weakness in cores compressive strength due to crack formation between concrete and rebars.
5. There is not reliable relationship for correcting compressive strength results of cores with rebar. But in limited cases, correction of Concrete Society equation can give acceptable results.
6. Strength reduction of cast cylindrical samples with rebar is usually less than that of concrete cores.

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REFERENCES

1. ACI Committee 318, “Building Code Requirements for Structural Concrete (ACI 318-05)", *ACI Manual of Concrete Practice, Part3, 2006.*
2. ASTM, "Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete", ASTM C42-99, Book of ASTM Standards, Concrete and Aggregates 04.02., 2000.
3. State Management and Planning Organization, "Concrete Code of Iran", Office of Technical Affairs Deputy, Iran, 2000, 94-96 (in Farsi).
4. Ministry of Housing and Urban Development, "Iranian National Building Code", Part 9, Iran, 2006, 94-96 (in Farsi).
5. Concrete Society Technical Report no.11, "Concrete Core Testing for Strength", Concrete Society, London, 1976.
6. Neville, A.M., “Properties of Concrete”; Forth Edition, Wiley & Sons, New York, 1996 (Translated into Farsi by Famili, H.).
7. Ramezanianpour, A.A., Hamidian, M.R., "Non-Destructive Testing of Concrete Core Tests", BHRC, Tehran, 1994 (in Farsi).