

Analysis of Concrete Core Strength With and Without Rebar

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Abstract

Core tests have usually been concerned due to concrete's strength analysis in concrete's industry and occasionally, it turns to a unique tool for testing the strength of concrete structures. Therefore, the core test is provided in most codes. Rebar existence impacts on the results, and some regulations insist that cores should be used without rebar and some others have no prohibition unless by taking into account the correction factor. In the present experimental study, the effective factors on core's strength containing rebar were investigated. To this end, 112 simple concrete beams were created and reinforced with 10 and 16 mm-diameter bars (with the diverse layouts) and with two mix designs, water-cement ratios of 0.4 and 0.55. The beams were operationalized and maintained in environmental conditions. 988 concrete cores of 10 and 7.5 centimeters in diameter, with a length to diameter ratio of 1 and 2 on ages of 14, 28 and 56 days were drilled and their strength was examined. In most occasions, by increasing the value of water/cement from 0.4 to 0.55, strength of cored rebar was reduced compared to the cores without rebar. By increasing the rebar covering, core's strength is reduced. Decrease percentage of one-rebar containing cores is increased by raising the rebar diameter, compared to the cores without rebar. By increasing the rebar's numbers, the strength is reduced. The biggest strength's reduction is occurred in cores with two rebars $\phi 16$, which the strength is reduced 23% compared to the core without rebar. Rebar cores would have bigger strength's decrease with extra-axial compared to the same state without extra-axial.

Keywords:

Cores tests, Strength, Steel Rebar

1. Introduction

The compressive strength of concrete is one of the most appropriate indicators which are analyzed to ensure the concrete's quality during the construction as test samples. These samples which are representing the concrete measure's potential strength, have being prepared, cured and tested based on the specifications and regulations of the relevant standard. On the other hand, determination the real strength of concrete in a structure is not simple, because it depends on type and history of curing, quality and the density of concrete and manner of concreting. Hereupon, the question that is most commonly affects the designers' mind is that whether samples indicate the concrete's strength at the site? Answering to this question is more raised when the strength of standard samples is lower than

the characteristic strength. Furthermore, maybe there is not standard sample with a high lifetime and it's also necessary to determine the present strength of the structure. These situations occur in old structures we want to analyze its strength and durability amount or we want to use it in conditions with higher stress levels or improving its performance by optimization. In such cases, the core test is the most effective and most reliable way to test the concrete's characteristics on the structure (Tuncan et al., 2008). Although this procedure is time-costing and expensive, it provides helpful and reliable bones and results. That's because they are mechanically examined to the destruction stage (Nikbin et al, 2009). In some parts of reinforced concrete, the existence of rebar in drilled cores might be inevitable. Core's strength under the effect of several factors such as diagonal, Ratio (l/d), the humidity amount of core's sample, drilling direction, the existence of the reinforcement rebar, type and size of stone beads, or even concrete's strength amount. Regulations have known several various factors, affecting the core test's results. They only discuss that factors and ignores other factors or they have no reaction against them.

This fact leads to different interpretations of a core's test among the rest of regulation. "Table 1" shows considerable factors on valid regulations such as (ACI¹), (B.S²), (CEN³), (JSCE⁴), (C.S⁵) and (ESS⁶) provided to interpret that core's strength to in Situ concrete strength. As it is observable, for a specific core's strength, the obtained strength is different due to different providing codes. As it can be seen, the effect of rebar on the core's strength is investigated on the C.S, CEN and B.S regulations. "Table 2" shows a series of relations and equations provided in different regulations related to the effect of rebar on the core and its strength (Neville, 1995).

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Table 1: Factors affecting the interpretation of core’s results on various regulations

| List | Standard/Regulation | Edition | Effective Factors | | | | | |
|------|---------------------|---------|------------------------------|-----------------|-----------------------|----------|---------------------------|------------------|
| | | | Length to diameter ratio l/d | Core’s diameter | Rebar inside the core | Humidity | Damage caused by drilling | Coring direction |
| 1 | B.S | 2003 | ▪ | | ▪ | | | ▪ |
| 2 | B.S | 2009 | ▪ | | ▪ | | | ▪ |
| 3 | ACI | 1998 | ▪ | | | | | |
| 4 | ACI | 2012 | ▪ | ▪ | | ▪ | ▪ | |
| 5 | CEN | 1998 | ▪ | ▪ | ▪ | | ▪ | |
| 6 | CEN | 2009 | ▪ | | ▪ | | | |
| 7 | JSCE | 2007 | ▪ | | | | | |
| 8 | C.S | 2013 | ▪ | | ▪ | | ▪ | ▪ |
| 9 | ESS | 2008 | ▪ | | ▪ | | | ▪ |
| 10 | ASTM | 2008 | ▪ | | ▪ | | | ▪ |

Table 2: Relations among different regulations regarding the effect of presence of rebar in core core’s strength

| List | Regulation | The general definition of strength | Correction coefficient of the presence of rebar |
|------|-----------------------|---|--|
| 1 | B.S 2003-2008 | $f_{cu} = (F_{reinf})(\frac{F_l}{d})f_{core}$ $F_l = \frac{D}{1.5 + \frac{1}{\lambda}}$ | $F_{reinf} = 1 + 1.5 \frac{\Phi_{rd}}{\Phi_{cl}}$ |
| 2 | ASTM 2009, ACI 1998 | $F_{cy} = F_{core} \cdot \frac{F_l}{d}$ | |
| 3 | ACI 2012 | $F_c = F_l \cdot F_{dia} \cdot F_{mc} \cdot F_d \cdot F_{core}$ | |
| 4 | CEN 1998 | $f_c = C_{H/D} \cdot C_{dia} \cdot C_a \cdot C_d \cdot f_{core}$ | C _a =1 Core without rebar C _a =1.03 Φ = 10 mm C _a =1.13 Φ = 20 mm |
| 5 | CEN 2009 | $F_{cu} = (F_{Reinf})(\frac{F_l}{d})f_{core}$ $F(\frac{l}{d}) = \frac{D}{1.5 + \frac{1}{\lambda}}$ | $F_{Reinf} = 1 + 1.5 \frac{\Phi_{rd}}{\Phi_{cl}}$ |
| 6 | Concrete Society 2013 | $F_{is} = f_{core} \cdot K_{is} \cdot K_s \cdot K_m$ $K_{is} = 2.5 / (1.5 + [1/\lambda])$ Km= 1.0 if tested dry or moisture condition unknown Km=1.1 if tested wet | $K_s = 1 + 1.5 \frac{\sum \Phi_{rh}}{\Phi_{cl}}$ |

By examining these regulations and standards, it is observed that some of them considered the rebar’s effect and some did not. When the core’s strength transforms to cylindrical and cubic standard samples of strength, on the best form, it shows strength in the place of concrete. Although this seems to be a very simple method for quality examination, but there are still problems regarding

the interpretation of strength’s values. Diameter, length to diameter ratio (l/d), Humidity during the examination, the age of the original sample, the presence of rebar inside the core, alignment of concrete strength and sample hurting caused by drilling are the most important factors affecting the core’s strength. Disagreement on compaction methods and curing between the cores and the standard samples

which transform core's strength to standard sample's strength, make the matter more difficult (Bungey, 1979). Based on the opinion of some researchers (Bartlett & MacGregor, 1994) the cores which are used to examine the strength of concrete should not contain any alloy steel but it's not inevitable in all situations. According to these authors, in this type of cores (steel-contained ones), it is expected that the measured strength is reduced. According to them, the amount of reduction depends on several factors that could be variable from 0 to 20 percent (In the case of large diameter or multiple rebars). When the steel is used in the core, it could be a coefficient to multiply the core strength, or real estimated potential strength which corrects the steel. According to some other researchers, using steel into the core does not reduce the strength in the core (Bartlett & MacGregor, 1994). Studies performed by Malhotra (2004) indicate no strength reduction as well. Although the buried steel seems to affects the strength, but

the information about this topic is not accurate (Bartlett & MacGregor, 1994). Some of the researchers analyzed the effects of some variables (above) on the core's compressive strength. As it is shown in "Table 3", it is again observed that the information is contrastive. Some researchers like Gaynor, considered the presence of rebar as a cause to reduce the core's strength and some else like Petersons and Lewandowski (Gaynor, 1978) considered a significant decrease for rebar-contained core's strength, compared to the ones who have not contained the rebar. According to some of the researchers, it should be tried to examine cores which does not possibly contain rebar. They believe, in the cores that the rebar is perpendicular to the core axis, it's better to remove the rebar by cutting some parts of the core which contains rebar even if the in a decrease in length ratio below 2 (ASTM, 2008).

Table 3: The effect of armature on the core's strength

| Author's name | The average percentage reduction in compressive strength |
|---------------|--|
| Gaynor | 8-13% |
| Lewandowski | Little impact |
| Petersons | Little impact |

Studies were performed in Concrete Association C.S on the effect of rebar on core's strength. 66 cylinders are concreted that some of them did not contain any rebar whilst some had rebar perpendicular to the central axis. Specific position of the rebar had also a little impact on cylinders strength. "Table 4" demonstrates the average strength reduction.

Table 4: Average reduction in strength, by the existence of rebar

| Strength's decrease percentage | Rebar amount | rebar diameter (mm) |
|--------------------------------|--------------|---------------------|
| 8% | 1 | 12 |
| 11% | 2 | |
| 9% | 1 | 25 |
| 13% | 2 | |

The same tests were done on 170 cylinders dimensioned 150×300 mm, some of them include rebar φ10 and φ20 which were placed at different depths and different distances from the axis. After curing, the samples were examined for 26 days in weather and 2 days in water. "Table 5" provides the mean percentage of different reductions in strength (Khoury, 2014).

Table 5: The average reduction in strength due to presence of rebar in different situation

| Rebar Diameter (mm) | Percent reduction in distance from top of the cylinder of strength | | |
|---------------------|--|--------|--------|
| | 50 mm | 150 mm | 250 mm |
| 10 | 1.5 | 2.6 | 3.8 |
| | 3.3 | 1.6 | -0.4 |
| 20 | 3.5 | 11.6 | -0.1 |
| | 10.4 | 8.6 | 5.4 |

As it can be seen in the "Table 5", the experiments results are contradictory and in some cases, the cylindrical strength containing rebar is reduced or in some cases is increased compared to those without rebar. Loo et al. (1989) reported in their experiments that buried transverse rebar(s) are decreasing the cores' strength with height to diameter ratio of 2, but this is less effective when the height to diameter ratio is lower. As an example, height to diameter

ratio of 1, the buried steel has no effect on measured strength, regardless of its position in the core. This effect has been attributed to the stress distribution in the cylinder, with various amounts of ratio of height to diameter. As shown in the "Figure 1", for l/d of less than 1.5 and due to the inhibitory effect of levels of upload testing machine, the measured strength is increasing rapidly.

When l/d is changing between 1.5-4, the strength is affected only a little, and for the l/d amounts between 1.5 and 2.5, the measured strength will be rather 5% less or more than the standard one ($l/d=2$). When the l/d is over 5, the strength is decreased faster, and the effect of slenderness ratio specimens will be appear.

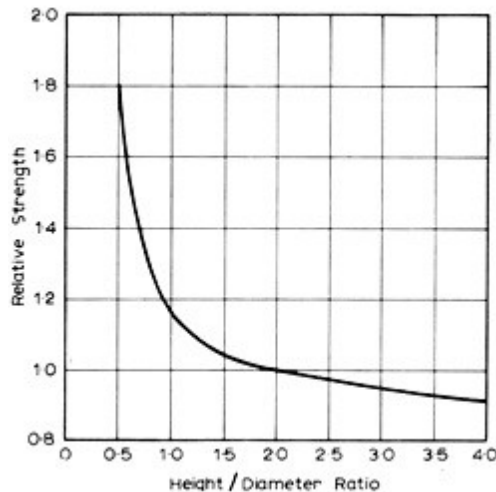


Figure 1: The general pattern's ratio of height to diameter effect on the strength of cylindrical specimens.

When this ratio was 1 or in a cube, there would be no tensile lateral stress on specimens and steel would easily bear the vertical pressure (Dolce, 2006). Teddin et al have also investigated the effect of rebar on concrete cores and in some cases, they have pointed to an increase in strength of cores containing rebar(s) than those without rebar. According to relations in different regulations, it's observed that, firstly, on valid regulations, there are disagreements in interpretation of core tests results and their usage in case that there is steel inside the core. In some regulations like ACI, the existence of rebar in the core is not allowed. Study the effect of steel rebar inside the core on the cores strength, which is the main objective of this study, was investigated in ESS, C.S, CEN and B.S regulations, but it has not been examined in other regulations. Secondly, in the regulations which have provided the effect, the factors such as rebar layout, rebar's distance to bottom of samples, deformed or non-deformed rebar(s), rebar's distance to cylinder's axis etc. which seem to be important factors have not been even considered.

By examining the studies of other researchers, it could be concluded that most of them avoid measuring the cores strength containing rebar or they just studied a special condition of rebar in the core and they have not considered the effective above-mentioned factors or they just considered some of them. Therefore, in this study, not only the effective factors on cores strength containing rebar is being mattered, which are told in valid references, but also

there is an investigation on new parameters on such cores, also there is considering the rebar's existence on concrete cores, the effective factors on pushing strength of these cores and strength's comparing between cores with or without rebar.

According to unavoidability of rebar's existence in extracted cores in structural members due to rebar density and cores dimensions, investigation of factors affecting strength of such cores to determine the actual strength concrete is very important. Because of this, there is a coefficient in some regulations which transforms the strength of such cores. But the effect of coefficients such as rebar(s) arrangement out of the axial rebar in the concrete samples which need further investigations is important. Considering the valid regulations, it is observed that there are inconsistencies in the interpretation of test results cores containing rebar. Also, the reasons of decrease or increase in strength of cores containing rebar compared to those without rebar were not examined. In this study, due to the effective factors on strength of cores without rebar, the effective factors on strength of cores with rebar is also investigated and compared to the strength of those without rebar.

2. Research Method

Concrete mix is made with 28-day strength of 15.4 to 48.1, Megapascal (Mpa). In the mix, the Ordinary Portland Cement and river sand with a maximum nominal diameter of 19 mm was used. For each mix, reinforced and non-reinforced beams with dimensions of 150×150×1000 (mm), and laboratory conditions with a relative humidity of 77% and the average temperature of approximately 22°C were constructed. In reinforced concrete bars, the rebar(s) were placed in tension area. Cores with the diameter of 100 and 75 mm were extracted by drilling the bars perpendicular to the direction of the concreting. The cut core samples were capping by sulfur mortars and the ratio of length to diameter equals 1 and 2. At least, 988 cores with 28 and 56 day age and 3 samples of each age were provided. Producing concrete mixes, cores drilling, cores maintenance, capping process and concrete experiments were performed according to ASTM (Malhotra, 1977 & 2004).

Variables, layouts of rebar(s) inside the core and the way of mixing the mortars to create concrete are provided in "Table 8, 7 and 8", respectively. The way of formatting and placement of the rebar in concrete is demonstrated in "Figure 2" and placement of rebar(s) on the axis inside the cores has shown in "Figure 3".

Table 6: Rebar’s arrangement inside the core

| no | d (cm) | l (cm) | l/d | cover (cm) | φ(mm) | figure | no | d (cm) | l (cm) | l/d | cover (cm) | φ(mm) | figure | no | d (cm) | l (cm) | l/d | cover (cm) | φ(mm) | figure |
|----|--------|--------|-----|------------|---------------|--------|----|--------|--------|-----|------------|---------------|--------|--|--------|--------|-----|------------|-----------|--------|
| 1 | 7.5 | 15 | 2 | | Without rebar | | 21 | 10 | 20 | 2 | 5 | 2φ10 | | 38 | 10 | 10 | 1 | 3 | 2φ16 | |
| 2 | 7.5 | 15 | 2 | 5 | φ16 | | 22 | 10 | 20 | 2 | 3 | 2φ10 | | 39 | 10 | 10 | 1 | 5 | 2φ10 | |
| 3 | 7.5 | 15 | 2 | 7.5 | 2φ16 | | 23 | 10 | 20 | 2 | 5 | φ10-N.T | | 40 | 10 | 10 | 1 | 5 | 2φ10-N.T | |
| 4 | 7.5 | 15 | 2 | 7.5 | φ16 | | 24 | 10 | 20 | 2 | 3 | φ10-N.T | | 41 | 10 | 10 | 1 | 3 | 2φ10 | |
| 6 | 7.5 | 15 | 2 | 7.5 | φ10 | | 25 | 10 | 20 | 2 | 5 | 2φ10-N.T | | 42 | 10 | 10 | 1 | 3 | φ10-N.T | |
| 7 | 7.5 | 15 | 2 | 3 | φ10 | | 26 | 10 | 10 | 1 | | Without rebar | | 43 | 10 | 20 | 2 | 5 | φ16-D | |
| 8 | 7.5 | 15 | 2 | 3 | φ16 | | 27 | 10 | 10 | 1 | 3 | φ16 | | 44 | 10 | 20 | 2 | 3 | φ16-D | |
| 9 | 7.5 | 15 | 2 | 5 | 2φ16 | | 28 | 10 | 10 | 1 | 5 | φ16 | | 45 | 10 | 20 | 2 | 5 | φ10-D | |
| 10 | 7.5 | 15 | 2 | 7.5 | φ10-N.T | | 29 | 10 | 10 | 1 | 5 | 2φ16 | | 46 | 10 | 20 | 2 | 3 | φ10-D | |
| 11 | 10 | 20 | 2 | | Without rebar | | 30 | 10 | 10 | 1 | 3 | 2φ16 | | 47 | 10 | 20 | 2 | 5 | φ10-N.T-D | |
| 12 | 10 | 20 | 2 | 3 | φ16 | | 31 | 10 | 10 | 1 | 5 | φ10-N.T | | *N.T=No Tread= Without tusk *D=DEVIATION=Deviations from axis | | | | | | |
| 13 | 10 | 20 | 2 | 5 | φ16 | | 32 | 10 | 10 | 1 | 5 | φ10 | | | | | | | | |
| 14 | 10 | 20 | 2 | 7.5 | φ16 | | 33 | 10 | 10 | 1 | 3 | φ10 | | | | | | | | |
| 15 | 10 | 20 | 2 | 5 | 2φ16 | | 34 | 10 | 10 | 1 | 5 | 2φ10 | | | | | | | | |
| 16 | 10 | 20 | 2 | 7.5 | 2φ16 | | 35 | 10 | 10 | 1 | 5 | 2φ10-N.T | | | | | | | | |
| 19 | 10 | 20 | 2 | 3 | φ10 | | 36 | 10 | 20 | 2 | 5 | 2φ10 | | | | | | | | |
| 20 | 10 | 20 | 2 | 5 | φ10 | | 37 | 10 | 20 | 2 | 5 | 2φ10-N.T | | | | | | | | |

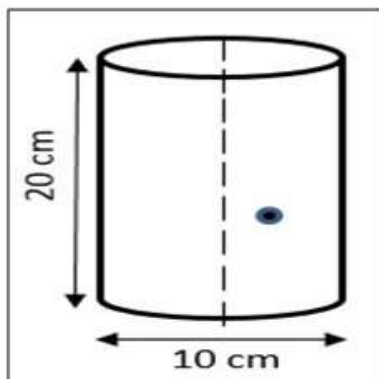


Figure 2: How to formatting and reinforcement the sample **Figure 3:** Cross-axis rebar (s) placement inside the cores with 10cm of diameter

Table 7: Materials used in 1 cubic meter of concrete

| | Gravel (kg) | Sand (kg) | Cement (kg) | Water (lit) | W/C | Slump (mm) |
|-------|-------------|-----------|-------------|-------------|------|------------|
| Mix 1 | 905 | 953 | 380 | 152 | 0.4 | 70 |
| Mix 2 | 985 | 1020 | 250 | 137.5 | 0.55 | 95 |

3. Results and Discussion

“Table 8” indicates the result tests of standard cubic and cylindrical specimens’ compressive strength at the age of 28 and 56 day

Table 8: Compressive strength of standard samples at the age of 28 and 56 days

| Designs | W/C | Curing conditions | (kg/cm ²) Cylindrical samples | | (kg/cm ²) Cubic samples | |
|---------------|------|-------------------|---|-------------|-------------------------------------|-------------|
| | | | 28-day aged | 56-day aged | 28-day aged | 56-day aged |
| First design | 0.44 | 3 humid days | 285 | 331 | 481 | 510 |
| | | Environmental | 241 | 268 | 446 | 485 |
| Second design | 0.55 | 3 humid days | 100 | 121 | 165 | 192 |
| | | Environmental | 71 | 88 | 154 | 170 |

A. The effect of rebar’s presence on concrete cores

1. The cores of 10 cm diameter, included single rebar

The extracted rebar(s) with 10 cm of diameter, which included a single tread rebar with diameters of 10 and 16 cm’s and also without rib, diameter of 10 cm, from created bars were examined of their pushing strength. The results were provided on Diagram 1. Rebar(S) cover at these cores is considered 5 cm. Presence of a single 16” rebar in cores with w/c = 0.4 leads to a 9% decrease in strength compared to core without rebar and in w/c = 0.55, the decrease was more than 2% (Figure 4). It seems that by decreasing w/c, the concrete’s strength against cuts made by drilling is increasing and this, has led to increase in core’s cracks. Also, combining with an increase in the diameter of the rebar and increased rebar strength against the cutting, has led

Aggravated decrease in strength of cores including 16” rebar compared to 10” ones. The experiments shows that around the rebar(s) inside the core with w/c = 0.55 the cracks are lesser compared to w/c = 0.4. It seems that the same reason has led the division of lesser strength cores with or without rebar on cores with w/c = 0.55 compared to the same ones but w/c = 0.4. The results have also cleared that on all conditions, the cores including 10” rebar(s) without tread, has less strength compared to all other cores with the same conditions. It seems this may be due to a lack of friction between steel and concrete around the rebar.

The results has shown that the effect of changing in keeping conditions from “air dried” to “soaked 72h” has not much effect on decrease/increase process in cores’ strength.

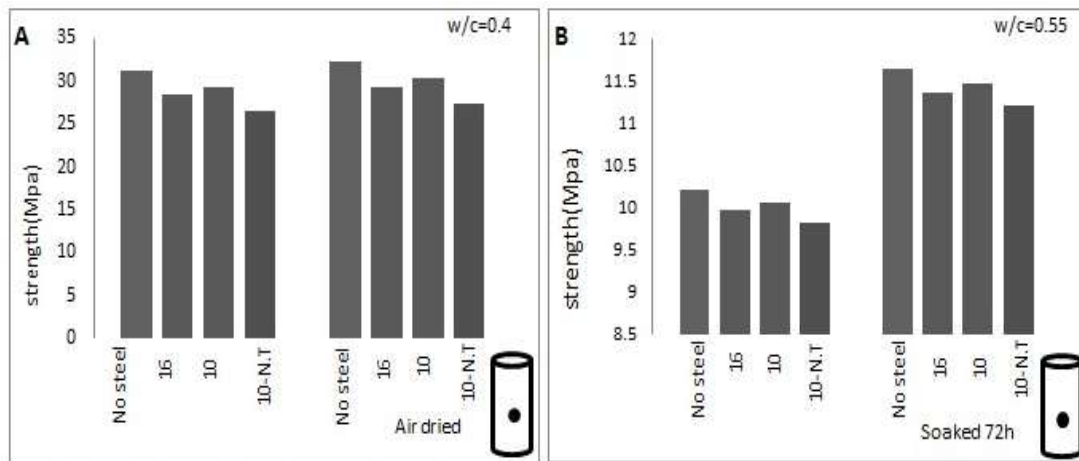


Figure 4: The effect of single rebar on samples with the diameter of 10 cm and 1/d=2 and 5 cm of covering N.T=No Tread

A. Ghazy et al., in concrete cores including rebar(s), investigated some of the effective factors on strength of the core and also compared it to cores without rebar. “Figure 5”

is a comparison between results of the present study and A. Ghazy’s.

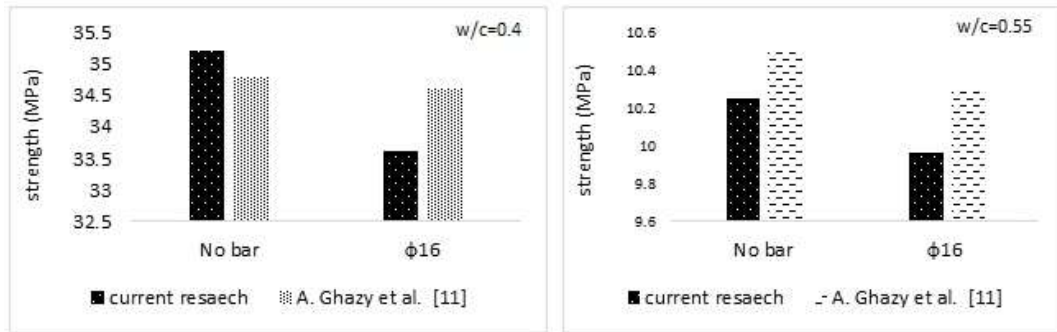


Figure 5: Comparing the results of present study with A. Ghazy et al.'s study results

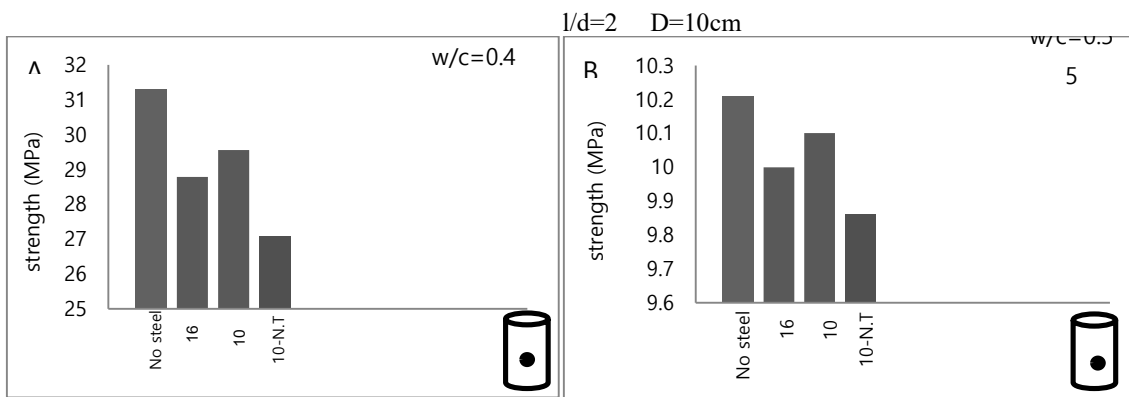


Figure 6: The effect of single rebar φ10 with l/d=2 and 3cm cover N.T= air dried

“Figure 6” indicates the effect of the rebar on the rebar cover in the cores. The tests proved that when the drill reaches to the rebar, the most vibration is applied to the whole part of the core by rebar strength. Therefore, the cracks around the rebars are extended to the above and below the core. It seems that when there is less concrete

under the rebar, there is less cracks and finally concrete damages is reduced and core strength is increased

Fig 7 shows a comparison of cover effect of rebar on strength of cores with 10 cm diameter, which contain 10” and 16” rebar(s). As it can be seen, in cores with 10 cm diameter and by increasing the rebar’s cover on cores containing 10” and 16” rebar(s) the strength is reduced. l/d=2 air dried

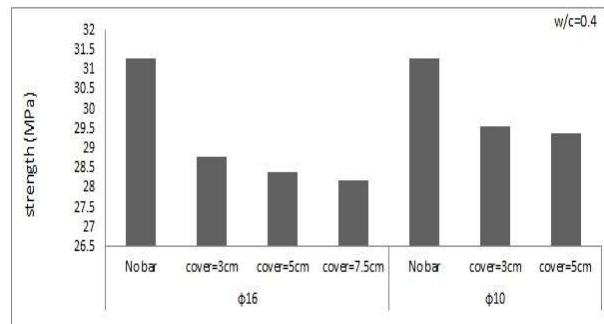


Figure 7: Comparing the covering effect of rebar on strength of cores with 20 cm diameter

2. Cores of 7.5 cm diameter, containing single rebar
Such cores with 7.5 cm diameter containing single deformed rebar with diameters of 10 and 16 cm and also rebar with 10 cm diameter without tread have been tested from created beams. The results are shown in “Figure 8”. Results reveals that in cores containing single rebar φ16, w/c = 0.4 is reduced nearly 12% and w/c = 0.55 is reduced more than 4%. In the same cores containing a single 10” rebar and in w/c = 0.4, a decrease of nearly 10% and in w/c= 0.55 a decrease more than 2% is seen. In cores containing rebar without tread, a division of nearly 28% is happened compared to cores without rebar.

With decrease in diameter (from 10 to 7.5) and due to volume decrease against the rebar volume and decrease

of cement relations near the rebar's area compared to the same core, a faster decrease in volume is happened.

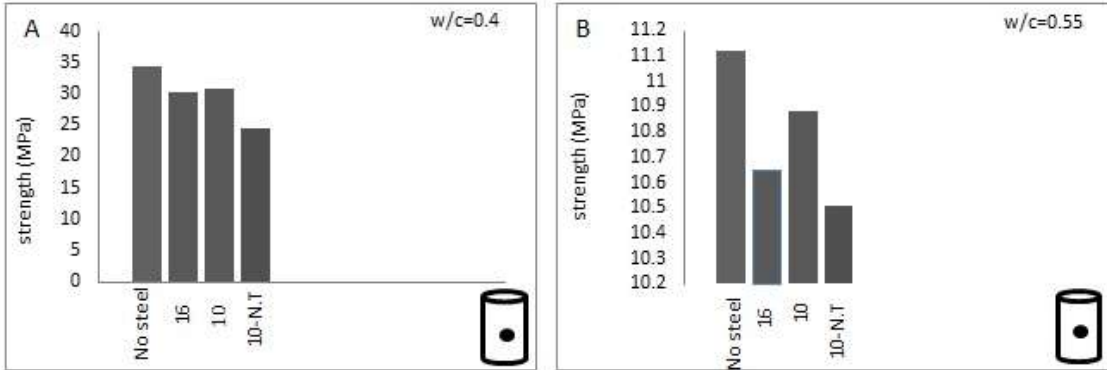


Figure 8: The effect of single rebar in the cores with 7.5 cm diameter and $l/d=2$, the covering is 7.5 cm N.T-air dried

3. 10 cm Diameter cores containing double rebar

“Figure 9” demonstrates the effect of double rebar next to each other on cores with diameters of 10 cm and $l/d=2$ and the rebar(s)’ cover is 5 cm. Results proved that cores containing double 16” rebar and $w/c = 0.4$, the decreasing strength is nearly 23% and in the same cores with double rebar and $w/c = 5.5$, a decrease more than 13% can be seen compared to those without rebar. In cores containing 10” and $w/c = 0.4$, decreasing strength is nearly 17% and in $w/c = 0.55$, more than 10% reduction is seen compared to those

without rebar. It seems that, in cores containing double 16” rebar, due to excessive weakening of the cement matrix around the rebar(s), and especially in the area among the double rebar, strong resistance reduction (32 percent) is happened compared to non-rebar ones. This fact was happened in the same way with less severe (27%) in cores containing double 10” rebar. Results revealed that in the same cores containing 10” double rebar without tread, little difference was observed compared to the same and the Rebar(s) with tread.

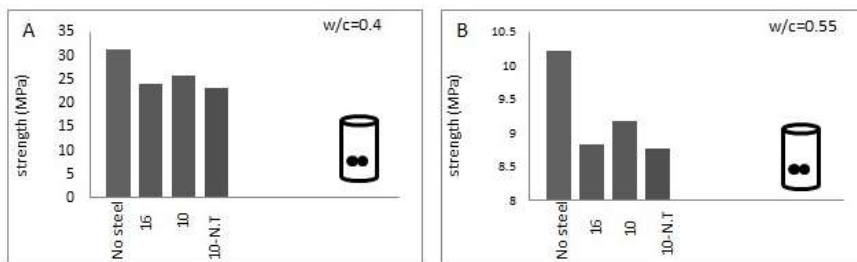


Figure 9: The effect of double rebar on the cross of 10 cm diameter and $l/d=2$ with 5 cm covering N.T air dried

4. Cores with diameter of 10 cm, included cross-axial rebar

In all types of cores containing cross-axial rebar from the main axis of the core (2.5 cm), to the cores without rebar, the decrease in strength is reported. In $w/c = 0.4$ and environmental conditions, in the presence of single 16” rebar, 18% was seen and in $w/c = 0.55$ a decrease more than 13% was reported. In the presence of a single 10” rebar and in $w/c = 0.4$, decrease was approximately 14% and in $w/c = 0.55$, the decrease was over 10%. In the presence of single

10” rebar without tread, in $w/c = 0.4$, an approximately strength decrease of 23% compared to cores without rebar has reported. On the other strength level and curing conditions, the same results as these results are repeated (Figure10). Experiments had shown that the more the rebar strays from the vertical axis to the outer edges, the more the core’s strength is decreased and not only the vertical and diagonal cracks are improving, but also the horizontal ones

do so to the outer edges. This element is more intense in cores containing 16” rebar than the ones containing 10”.

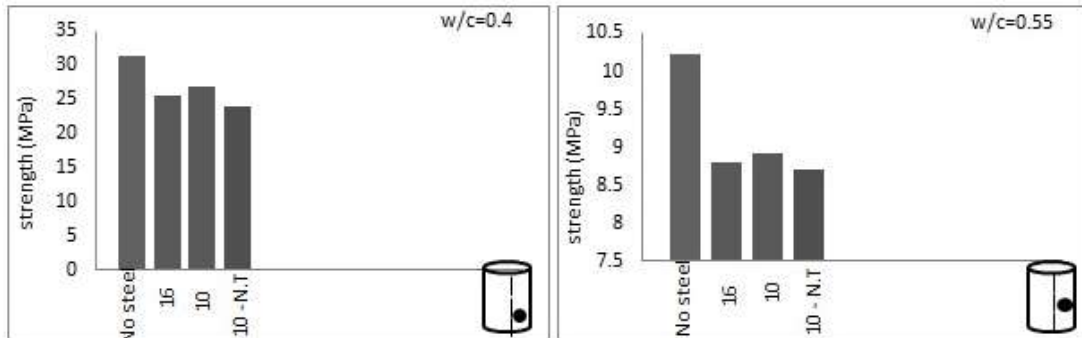


Figure 10: The effect of deviation s from the rebar’s axis in the core of 10 cm diameter
No Tread: N.T air dried

In 5cm of cover. As we can see, in the presence of these two and in w/c = 0.4 a decrease of approximately 14%, and in w/c = 0.55, a decrease of more than 23% is provided. In the presence of two rebar(s) φ10 without tread and in w/c = 0.4, a decrease of approximately 21% was observed and

in w/c = 0.55, a decrease of more than 25% were available. In the most cases, in two rebar(s) φ10, it has a fewer decrease compared to 2 rebar(s) without tread, and also the decreasing percentage of strength in w/c = 0.55 was lower than what it was in w/c = 0.4.

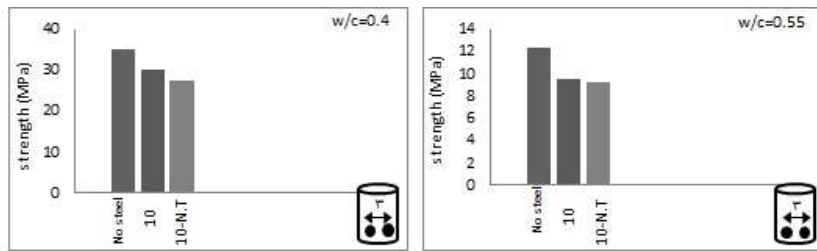


Figure 11: The effect of two rebars with 3 cm distance from each other in the cores of 10 cm diameter and l/d=1 and 5 cm of cover No Tread: N.T air dried

In a same research, Tadayon et al. (2014) had experiments on cores included rebar. “Figure 12” compares

the results of a part of their experiments, specified in cores including double rebar(s), with the present research.

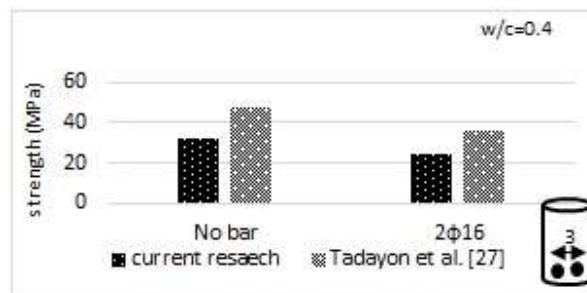


Figure 12: Comparing the results of the present research with the one which is done by Tadayon et al. (Tadayon, 2014).
l/d=2 D=10 cm

5. The samples with the diameter of 10 cm, containing single rebar and with the ratio of length to diameter = 1

In “Figure 13”, which is related to the effect of single rebar on 10cm of diameter and $l/d = 1$ on the 5 cm cover, we can see in the presence of single 16” rebar and in $w/c = 0.4$, the decrease is approximately 5% and in $w/c = 0.55$, a decrease of more than 14% and in the presence of single 10” rebar, on $w/c = 0.4$, an approximate Increase of 2% and on $w/c = 0.55$ a decrease of more than 9% and in the presence of single 10” rebar without tread on $w/c = 0.4$ a decrease of

approximately 9% and on $w/c = 0.55$, a decrease of more than 18% have reported. In the presence of single rebar, the results have sporadically changed and in some cases the strength is increased, while in some other it’s decreased. The results are showing that in the presence of a single rebar, the decreasing rate of strength compared to the same sample with $l/d = 2$ would be lesser, which is the result decrease in time of coring and the damages resulted of this.

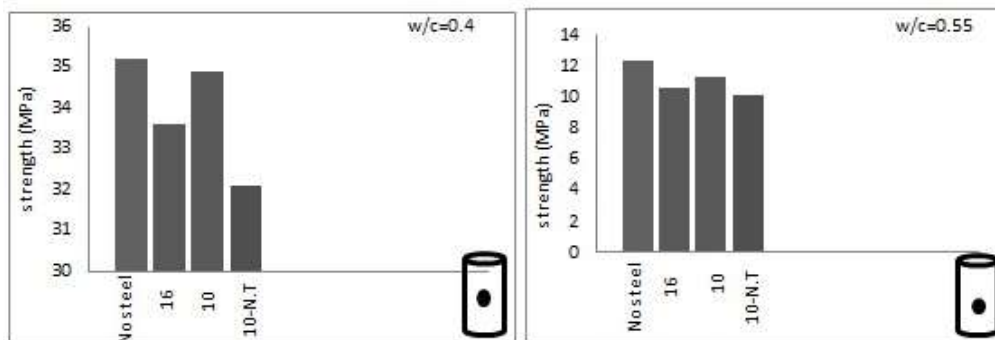


Figure 13: The effect of single rebar on the cores with 10cm of diameter and $l/d=1$ with 5 cm of coverage
No Tread: N.T air dried

As it can be seen in “Table 9”, the results of present researches have shown in no rebar condition, the F_l coefficient, is similar to other coefficients of the rest of ASTM, B.S, ACI regulations carefully, and also its similar to the coefficient determined by A.Ghazy et al. In the cores containing 10 or 16 and $w/c = 0.4$, this coefficient is decreasing 6% compared to the without rebar mode. According to the results, by increasing the w/c to 0.55, the coefficient is increasing approximately 14% compared to the cores without rebar in the cores containing 16” rebar, and on the cores containing 10” rebar the increase is approximately 9%.

In comparison with cores containing single rebar $\phi 16$ with two modes of $w/c = 0.55$ and $w/c = 0.4$, the results shows that w/c is increased in these cores. The coefficient is increasing approximately 14%. It seems that the more the rebar’s volume (compared to the concrete’s), the cores lead to decrease in strength compared to the cores without rebar.

B. The effect of presence of rebar, on the F_l coefficient

This coefficient is determined for the present research and the A.Ghazy et al, in accordance with equation 1 due to cores with or without rebar and both $w/c = 0.4$ and 0.55. The complete results are provided in the “Table 9”

$$F_l = \frac{f_{core}(\frac{l}{d}=2)}{f_{core}(\frac{l}{d}=1)} \tag{1}$$

Where

f_{core} is the strength of core.

The ACI regulation rejects the presence of rebar in core and avoids checking the cores which are containing rebar. Hence, to determine the coefficient F_l , we reject the presence of rebar, in accordance with equation 2. Also in regulations ASTM and B.S, there are fixed numbers of rebar determine the coefficient and reject the direct effect of rebar in determining the coefficient.

$$F_l = 1 - \{0.144 - \alpha f_{core}\}(2 - \frac{l}{d})^2 \tag{2}$$

Where α is $4.3 \times 10^{-4} (\frac{1}{Mpa})$ to determine cores with the strength according to Mega-pascal (Mpa).

The CEN regulation provides the equation 3 to determine the coefficient.

$$F_l = \frac{D}{1.5 + \lambda} \tag{3}$$

Where D is 2.3 for vertically drilled cores (vertical against concreting), λ is the length to diameter ratio (l/d), after providing the end. As it can be seen, CEN regulation also directly rejects the effect of rebar and w/c in determining the coefficient. “Table 9” provides the

coefficient by the mentioned relations of regulation (Concrete Society, 1976).

Table 9: Comparison of the coefficient from the present study to the other sources

| | | w/c=0.4 | | | w/c=0.55 | | |
|------------------|------|---------|------|------|----------|------|------|
| | | No bar | Φ16 | Φ16 | No bar | Φ16 | Φ16 |
| Current Research | | 0.89 | 0.84 | 0.83 | 0.82 | 0.88 | 0.94 |
| A. Ghazi | | 0.88 | 0.8 | 0.77 | 0.8 | 0.85 | 0.91 |
| Standard | ACI | 0.871 | | | 0.861 | | |
| | CEN | 0.8 | | | 0.8 | | |
| | ASTM | 0.87 | | | 0.87 | | |

By comparing the $F_{(l/d)}$ coefficient from the present study to the other references, the presence effect of rebar and w/c in determining the coefficient is clear.

4. Conclusion

According to the empirical comprehensive study, the following conclusions can be derived.

- 1- The rebar's presence in cores is decreasing from 2% to 23%. The least reduction is for the presence of 10" or 16" rebar in the cores of l/d with concrete cover of 5cm and w/c = 0.55 to 0.4, are the changing flow of strength decrease in cores compared to the cores without rebar, which was approximately 10%.
- 2- By decreasing the w/c amount from 0.55 to 0.4, the strength's decrease percentage of cores containing rebar comparing to the ones without rebar is increasing. In cores containing double rebar with 16" diameter, by decreasing w/c from 0.55 to 0.4, the changing flow of strength decrease was approximately 10% compared to the cores without rebar.
- 3- In cores containing rebar, by increasing the concrete coverage, the core's strength is decreased.
- 4- In cores containing rebar, by increasing the rebar diameter, the strength decreasing flow is obvious. The most strength decrease is available by increasing the rebar diameter from 10 to 16 in w/c = 0.4 and equals 6% compared to the cores without rebar (Loo, 1989).
- 5- By increasing the amount of rebar(s) inside the cores, the core strength is rapidly reduced than the cores without rebar.
- 6- With the creation of deviations from axis on rebar(s) inside the core with respect to the central axis, the core's strength is further decreased comparing to the same mode without the deviation.
- 7- The presence of rebar inside the cores of w/c = 0.4 leads to decreasing the coefficient's amount, comparing to the cores without rebar.
- 8- The presence of rebar inside the cores of w/c = 0.55 leads to increasing the coefficient's amount, comparing to the cores without rebar (Wright, 1958).

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