Influence on Strength of in Situ Concrete Due to Direction of Coring with Respect to Direction of Pouring

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Abstract – *The evaluation of in situ concrete strength depends on various factors like mix proportions, curing condition & direction of coring with respect to direction of pouring. The available guidelines in various international standard with regards to evaluation of in situ concrete core strength spell out the various factors like l/d ratio, diameter of core, moisture in concrete & damaging factor during drilling of core. However, the standards are silent about the factor of direction of drilling with respect to direction of pouring, whereas the direction of drilling has significant influence on strength of concrete. The direction of drilling influences the strength of concrete as the direction of loading would be parallel or perpendicular to the weak ITZ of aggregate & hydrated bulk cement paste. The flaky, elongated & larger size of coarse aggregate has the tendency to occupy their position in paste parallel to their weak axis which leads to the formation of thin water film of 10-50 micron around the aggregate. The formation of water film around the aggregate leads to formation of weak ITZ. So when load is applied parallel to the ITZ low strength has been noticed, as compared to, when the loading is perpendicular to ITZ it results in higher strengths. The direction of drilling influences the strength of concrete by about 10-14%. The strength of concrete taken by drilling of core perpendicular to the direction of pouring is maximum 14% higher than the strength of concrete core taken by drilling parallel to the direction of pouring.*

Key Words: Interfacial transition zone (ITZ), Water cement ratio, Paste volume, Flaky, Elongated, Compressive Strength.

1. INTRODUCTION

The assessment of in situ concrete strength is one of the most important criteria for evaluation of RCC structure's residual life & real health condition of structures. However actual assessment of strength of in situ concrete depends on many factors like l/d ratio of core sample, diameter of core sample, moisture in concrete & damaging factor during drilling of core. The available standards for evaluation of in situ concrete core have very little focus on direction of drilling although the direction of drilling has significant impact on strength of core. The direction of drilling influences the strength of concrete as the larger size of aggregate in concrete & higher proportion of elongated & flaky aggregate, the greater will be the tendency to form water film around the aggregate surface, thus weakening the interfacial transition zone. This phenomenon is commonly known as bleeding. The flaky, elongated & larger size of coarse aggregates have the tendency to place their position in bulk cement paste perpendicular to the direction of pouring which leads to formation of thin water film of 10-50 micron around the aggregate. Due to formation of water film around the aggregates, it leads to increase in w/c ration in ITZ area. So when the load is applied parallel to the ITZ shear bond failure may occur & low strength may be noticed. However, while loading is in the direction perpendicular to ITZ results of higher strengths are observed as compared to parallel application of load. Thus the direction of drilling influence the strength of concrete from 10-14%.

2. INTERFACIAL TRANSITION ZONE

The microstructure of concrete comprises of following three phase.

1. Aggregate phase.
2. Bulk cement paste.
3. Interfacial transition zone.

The microstructure of concrete is not an inherent feature of the material because the two constituents of the microstructure, namely hydrated cement paste and interfacial transition zone, are subject to transformation with time, environmental humidity, and temperature. As the aggregate phase is strongest amongst all the three phase of concrete, thus there is minimum impact of aggregate on strength of normal concrete. However interfacial transition zone is the weakest phase among all the three phase & thus it effects the strength of concrete significantly. It is thus considered the strength-controlling phase in concrete. It is because of the existence of the transition zone that concrete fails due to shear bond failure at substantial lower stress level than the strength of either of the two main components.

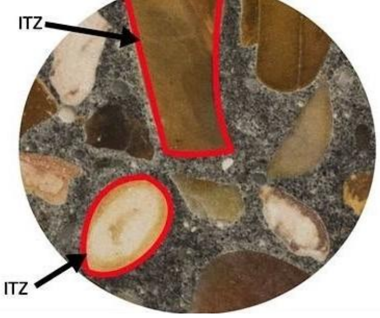


Figure 1:Interfacial tranzition zone in concrete

3. MATERIAL USED FOR EXPERIMENT

The materials used for experimentation in this research include different grade of concrete of C-16/20, C-20/25, C-25/30, C-30/37 and C-40/50 with OPC cement (CEM-I, 52.5 N as per BSEN-197-1), fine aggregate (FM=2.7 as per ASTMC-33), Coarse aggregate (Crushed Basalt stone aggregate) of 19mm nominal size and Polycarboxylate ether based high range reducing admixture. The mix used for various grade of concrete are tabulated below.

Table-1: Mix proportions of various grade of concrete.

Mix Ingredient	Ingredient quantity for different grade of concrete in kg/cum				
	C-16/20	C-20/25	C-25/30	C-30/37	C-40/50
Cement	315	339	377	438	472
Water	173	169	169	175	170
Coarse Aggregate	1085	1195	1175	1142	1133
Fine aggregate	780	663	652	685	680
HRWRA	0	0	0	3.5	3.77
w/c Ratio	0.55	0.5	0.45	0.4	0.36

Table-2: % of various component of different grade of concrete

Mix properties	% of various component of different grade of concrete				
	C-16/20	C-20/25	C-25/30	C-30/37	C-40/50
Total Agg % by mass	79.26	78.35	77.36	74.77	73.74
% Coarse Agg by mass	58.18	63.93	64.04	62.51	62.49
% Fine Agg by mass	41.82	36.07	35.96	37.49	37.51
Cement % by mass	13.39	14.45	15.63	17.93	19.2
Paste Volume in cum	0.27	0.28	0.29	0.31	0.32

Table-3: Physical properties of Coarse Aggregate.

Test parameter	UOM	Tested Results
Nominal maximum size of aggregate	mm	
Sp Gravity	-	2.8
Dry rodded bulk density	Kg/cum	1675
Water Absorption	%	0.42
Crushing strength	%	16.32
Impact value	%	11.41
Flakiness Index	%	21.22
Elongation Index	%	23.5
Gradation as per ASTMC-33	-	Satisfactory

Table –4: Physical properties of Fine Aggregate

Test parameter	UOM	Tested Results
Fineness Modulus (FM)	-	2.7
Sp Gravity	-	2.64
Water Absorption	%	1.58
75 micron passing % by mass	%	1.82

3.1 Experimental Setup & Sample preparation

To evaluate the influence of direction of drilling on strength of concrete 50 mm diameter core had taken by drilling of core by both parallel & perpendicular to the direction of pouring from a cube of 150 mm x 150 mm x 150 mm sizes. For each grade of concrete total 6 specimens had taken from total 3 different cubes. From each cubes one specimen collected along the direction of pouring & one specimen perpendicular to the direction of pouring, thus in totality 3 specimens were collected along the direction parallel to the direction of pouring & 3 specimens were collected through the direction perpendicular to the direction of pouring. During sampling the procedure was followed as per ASTM C42 [7], [8], [9]. The specimen collected from different cubes samples were finally prepared as per the aspect ratio of L/D=2, [6][9]. The final diameter of core specimen collected is 44 mm & length of the specimen were kept as 88 mm.

Figure 2:Drilling of Core sampling from cube samples.

Figure 3:Core specimens collected from cube samples.

Figure 4: Core samples at various direction of drilling i.e. H-Horizontal direction of drilling (Perpendicular to the direction of pouring) & V-Vertical direction of drilling (Parallel to the direction of pouring) for different grade of concrete.

4. Results & Discussions

The strength of in situ core samples of concrete are shown in Table-5 & Figure-6. The variation in strength of different grades of concrete core sample collected by drilling in parallel to the direction of pouring & by drilling in perpendicular to the direction of pouring reveals that there is 10-14% higher strength is noticed for core samples collected by drilling parallel to the direction of pouring. The reasons behind the lower strength for sample collected by drilling perpendicular to the direction of pouring is because the direction of loading is parallel to the interfacial transition zone of vertically aligned aggregate & bulk paste. Similarly, for core sample collected by drilling parallel to the direction of pouring the strength is slightly higher than sample collected by horizontal drilling because the loading direction is perpendicular to the direction ITZ. The experimental results also exhibit that the % of variation is reduced with increased amount of paste volume & decrease in total aggregate content of the mix. Thus from the Figure-4&5 it is evident that the samples which were collected by drilling horizontally i.e. the direction of drilling was perpendicular to the direction of pouring, the majority of the aggregates were found vertically aligned on samples & due of which during loading for test the direction of loading became parallel to the direction of ITZ. Hence it exhibits lower strength. While in the other case when drilling is done parallel to the direction of pouring it has been found that majority of the aggregate were in flat direction thus during testing the direction of loading became perpendicular to the ITZ of aggregate & paste structure. Thus for loading parallel to the weakest ITZ leads to lower strength than for loading perpendicular to weakest ITZ & this is because of the tendency of flaky, elongated & larger size of coarse aggregate to occupy their position in paste parallel to their weak axis leading to formation of thin water film of 10-50 micron around the aggregate[1]. The formation of water film around the aggregate leads to localized increased of w/c ratio of paste structure & thus increase in capillary pore leading to formation of weak ITZ [2].

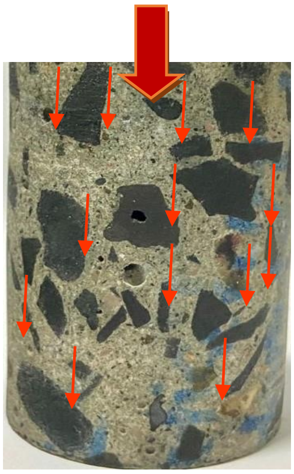


Figure 5: Loading direction parallel to weakest ITZ between aggregate & paste structure when direction of drilling is Perpendicular to the direction of pouring.

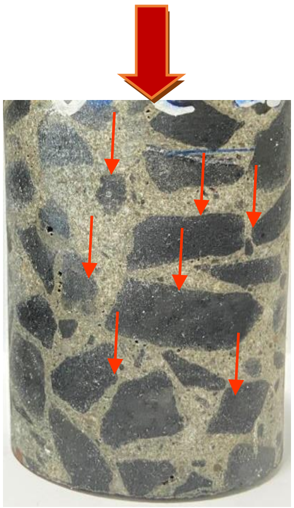


Figure 6: Loading direction perpendicular to weakest ITZ between aggregate & paste structure when direction of drilling is parallel to the direction of pouring.

Table-5: Av strength of concrete core along different direction of drilling with respect to direction of pouring.

Direction of drilling	Av Strength of 6 nos core specimens in Mpa at 28-days for different grade of concrete				
	C-16/20	C-20/25	C-25/30	C-30/37	C-40/50
Parallelel to the direction of pouring	19.72	24.85	26.69	32.88	42.74
Perpendicular to the direction of pouring	17.75	21.88	23.43	28.93	38.79
% Variation in strength	11.10	13.57	13.91	13.65	10.18

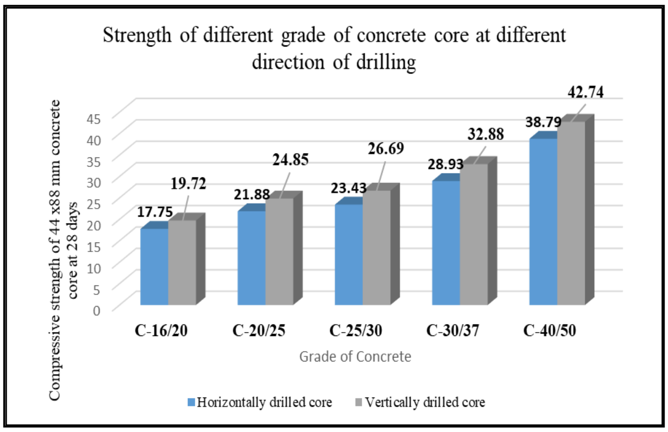
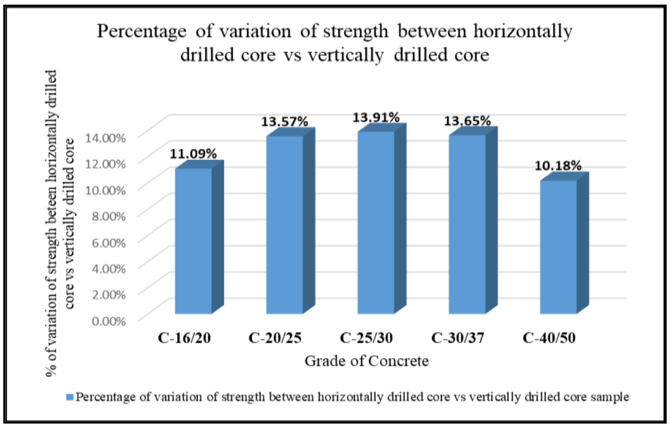


Figure 7: Av strength of different grade concrete core along different direction of drilling with respect to direction of pouring.



5. CONCLUSIONS

The following conclusions can be drawn out from the present research work as follows.

- The direction of drilling has significant influence on strength of core if the coarse aggregate used in the mix are prominent % of flaky & elongated aggregate.
- If the direction of loading is parallel to the interfacial transition zone of aggregate, then concrete will fail earlier as compared to the scenario when the loading is perpendicular to the transition zone of aggregate.
- The strength of vertically drilled core is 10-14% higher than the strength of horizontally drilled core.
- The variation of strength again depends on the paste volume i.e. higher the paste volume lower is the variation & lower is the paste volume higher is the variation level.
- With increase in paste volume the strength of the core is also increases for concrete of normal strength up to C-40/50 grade.

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