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Destructive and Non- Destructive Testing for Concrete in Sudan - A Comparative Study

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Abstract: *The aim of the research contained in this study is to check the applicability of the destructive and non-destructive techniques in concrete , to make such comparison between destructive and non-destructive tests Two grades of concrete were considered, grade 25 and grade 30 N/mm² . For each grade 24 cubes and three beams were casted and tested. Two destructive tests were made(crushing test and tensile strength test) and two non- destructive tests were considered(rebound hammer test and ultra-sonic pulse velocity test). These tests were conducted in different intervals of time from the date of cast (7, 14, 28 and 56 days). Cubes were tested for crushing, hammer and ultra-sonic pulse velocity tests. Beams were tested for tensile strength after 28 days . According to the designated compressive strength after 28 days crushing test show good results, Non-destructive tests is very sensitive to local variations in the concrete (aggregate particles, voids, steel, cracks, experience of the operator,…,etc) (Bungy&Millard,2004)[1] so for as measure of concrete strength this type of test may can not be a reliable test.*

I. Introduction

There are two commonly used structural materials concrete and steel. Steel is manufactured under carefully controlled conditions; the properties of every type of steel are determined in a laboratory and described in manufacturers certificates. But on a concrete building site the situation is totally different(Nevile,1990) [2] .

Concrete is made by mixing cement, aggregate and water but can give bad or good concrete, many factors influence this product , the first factors are the ratio and the quality of the constituents of the mix.

Tests made for quality control to obtain a good concrete which means in the hardened stage high compressive strength, volume stability , durablility , high density, impermeability , high resistance to abrasion , high resistance to impact , good tensile strength and resistance to sulphate , . . . , etc . and at the fresh stage the concrete can be properly compacted , transported , placed and finished sufficiently easily without segregation . The hardened concrete properties mentioned above are seriously affected by its degree of compaction at the fresh stage.

There are two kinds of tests which are done on hardened concrete, these are non-destructive tests and destructive tests.In non-destructive test, the sample is not destroyed and this test is very useful in determining or estimating the strength of existing buildings or structures (detection of cracks, flaws, imperfections, permeability and absorption characteristics of concrete) (Mehta&Monteriro,2006) [3] where as in destructive test a sample is made and then destroyed to find out the strength of concrete. Compression test is the sample of destructive tests, here the non-destructive tests :- rebound hammer test and ultra sonic pulse velocity test.

II. Materials and methods:

2-1 **Materials**: To reach the purpose of this research, an experimental laboratory study was developed using the following materials:

2-1-1 **cement**: Ordinary Portland cement (OPC) Procured from Atbara cement company(sudan) was used through out this research.

2-1-**2 coarse aggregate** : the gravel used in this study is uncrushed with crushing value equals 23%.

2-1-**3 fine aggregate**:the type of the sand used is a coarse sand.

2-1-4 **water**:water from the public main supply was used for the production and the curing of the concrete cubes and beams.

2-2 **Methods**:

2-2-1**variables**:As a primary study two grades of concrete were designed. Concrete grade 25 N/mm² after 28 days and grade 30. Specimens casted and tested at 7 , 14 , 28 , and 56 days.

2-2-**2 specimens determination**: For every grade of concrete 24 cubes and 3 beams were tested ,the dimensions of the cubes are 150mmx150mmx150mm and the beams are 100mmx100mmx500mm (Beatrix&Panarese,2003) [4] so 48 cubes and 6 beams were tested.

2-2-**3 Design of the mix:** The design has been made according to the British standards, the constituent ratios for the two grades are shown in table (1) and table(2).

Table 1 composition of the mix for grade 25N/mm² at 28 days

constituent	**Weight(** kg/m³**)**
Water content	180
Cement	330
Fine aggregate	750 kg/m³
Coarse aggregate	1125 kg/m³

The constituent ratios were kept unchanged for all cubes and beams.
The quantity of each ingredient was calculated on the basis of 1 cubic meter using the above mix design ratios and by taking the density of fresh concrete as 2385 kg/m³.

Table 2 Composition of the mix for grade 30N/mm² at 28 days

constituent	**Weight(** kg/m³**)**
Water content	180
Cement	360
Fine aggregate	740
Coarse aggregate	1105

The constituent ratios were kept unchanged for all cubes and beams.
The quantity of each ingredient was calculated on the basis of 1 cubic meter using the above mix design ratios and by taking the density of fresh concrete as 2385 kg/m³(BS 1881:Part111,1983) [5].

2-2-**4Testing of the specimens**:

I- cubes after preparing , grinding and weighing tested using ultra- sonic pulse velocity test by a 56.1khz transducers and reference bar, transit time is detected as 3 readings for each cube(BS1881Part203)[6]and (ASTMc597) [7], the cube then fixed at the crushing machine at about 170 KN force the position of the cubes is at right angles to the position as casted , 12 points of the rebound position were detected for every cube(BS1881Part207) [8] , the load applied to the cube is raised by a constant rate within a range of 0.2 to 0.4 Mpa /s till failure and the crushing strength is reported(BS 1881:Part108,1983) [9]. 6 cubes are tested from concrete grade 25 and the other from concrete grade 30 so 48 cubes are tested at 7 , 14 ,28 and 56 days from the date of casting .

II- **Beams testing**: After 28 days from the date of casting, beams after grinding and alignment were tested on there side in relation to the cast position(BS 1881:Part118,1983) [10] at a rate
of increase in stress in the bottom fiber of 0.02 Mpa/s till failure(BS 5328,1997) [11] so 6 beams are tested for the two grades of concrete.

III. Results and discussions:

3-1discussion of compressive strength test results :

Table (3) shows results of compressive strength test for the two grades of concrete at different ages of concrete for more details see figure (1).

Table (3) crushing test results

Test periods days	Compressive strength f_{cu} N/mm^2	
	Concrete grade 25	Concrete grade 30
7	19.15	23.48
14	24.8	27
28	27.6	30.1
56	40,17	43.61

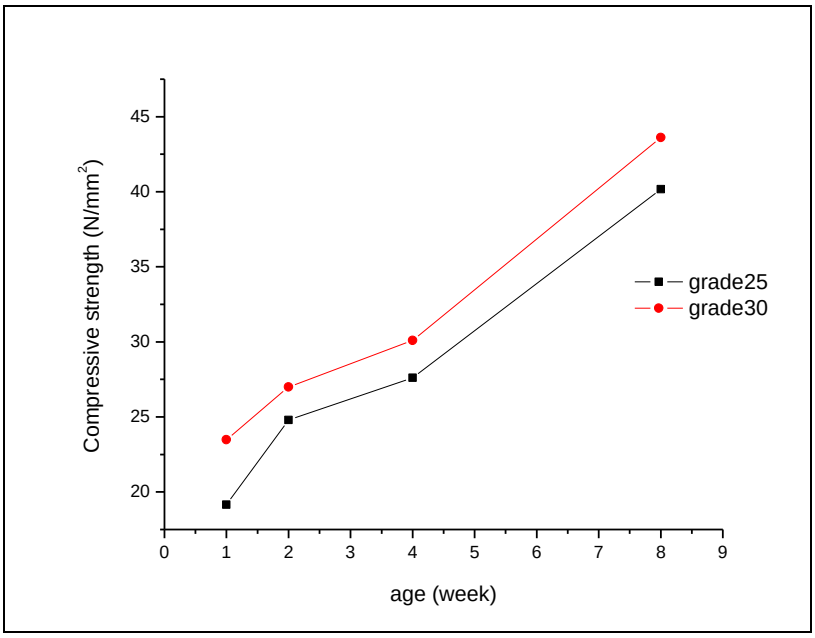

Figure (1) Compressive strength test for the two grades of concrete at different ages.

3-2 Discussion of tensile test results: Tables (4) and (5) shows the results of tensile test on beams tested at 28days and Table (6) shows Percentages of modulus of rapture (tensile strength) from actual compressive strength at 28 &56 days .

Table (4.) Results of tensile test on beams tested at 28 days (grade (25)).

Beam No	Weight (kg)	Failure load p(kN)	Tensile strength (modulus of repture) N/mm²	Average (modulus of repture) N/mm²
1	12.100	80	3.2	3.3
2	12.080	85	3.4	
3	12.080	80	3.2	

Table (5) Results of tensile test on beams tested at 28 days (grade (30)).

Beam No	Weight (kg)	Failure load p(kN)	Tensile strength (modulus of repture) N/mm	Average (modulus of repture) N/mm²
1	12.200	95	3.8	3.5
2	12.270	80	3.2	
3	12.180	85	3.4	

Table (6) Percentage of modulus of rapture (tensile strength) from actual compressive strength at 28 &56 days

	Grades	Percentage of modulus of rapture %
At 28 days	Conc. Grade 25	12
	Conc. Grade 30	12
At 56 days	Conc. Grade 25	8
	Conc. Grade 30	8

3-3 **discussion of hammer test results :**

From table (7) results of hammer test, the estimated compressive strength after 7 days is more or equal to the designated compressive strength, and after 56 days the results were equal for the two grades of concrete.

Table (7) hammer test results

Test periods days	Estimated compressive strength (N/mm²)	
	Concrete grade 25	Concrete grade 30
After 7	28	30.63
14	30.33	31.33
28	33.5	33
56	37.15	36.42

3-4 Discussion of ultra-sonic pulse velocity test results:

From table (8)results of ultra-sonic pulse velocity test, the estimated compressive strength after 7 days is almost 60% of the calculated 28 day compressive strength

Table (8) ultra-sonic pulse velocity test results

Test periods days	Estimated compressive strength (N/mm²)	
	Concrete grade 25	Concrete grade 30
7	16.28	19.5
14	26.8	27.12
28	40.13	41.87
56	43.8	44.5

3-5Comparison between the tests in the designated compressive strength: Table (9) shows the percentages of overall actual compressive strength that found from the designated compressive strength at 28 day. For more details figure (2) shows the actual compressive strength for various tests for concrete grade 25

After one week hammer test show high result which is 112% from the designated compressive strength at 28 day.After 1½ week crushing test and ultra-sonic test show equal results about 90%.After 2½ week crushing test and ultra-sonic test show equal results about 125%.After 6 ½ week crushing and hammer tests show equal results about 140%.

Figure (3) shows the actual compressive strength for concrete grade 30

After one week hammer test show high result which is 102% from the designated compressive strength at 28 day.After 2 weeks crushing test and ultra-sonic test show equal results about 90%.After 2½ week crushing and hammer tests show equal results about 105%.After 5 weeks crushing and hammer tests show equal results about 112%.

Table (9) Percentages of actual cube compressive strength from the designated compressive strength .

Test Periods days	Conc. grades	Compressive strength comparisons(N/mm²)					
		Test result Compr. f_{cu} Test		Hammer test		Ultra-sonic.test	
7	Grade 25	19.15	76.6%	28	112%	16.28	65.1%
	Grade 30	23.48	78.3%	30.63	102%	19.5	65%
14	Grade 25	24.8	99.2%	30.33	121%	26.8	107.2%
	Grade 30	27	90%	31.33	104.4%	27.12	90.4%
28	Grade 25	27.6	110.4%	33.5	134%	40.13	160.5%
	Grade 30	30.1	100.3%	33	110%	41.87	139.6%
56	Grade 25	40.17	160.7%	37.15	148.6%	43.8	175.2%
	Grade 30	43.61	145.4%	36.42	121.4%	44.5	148.3%

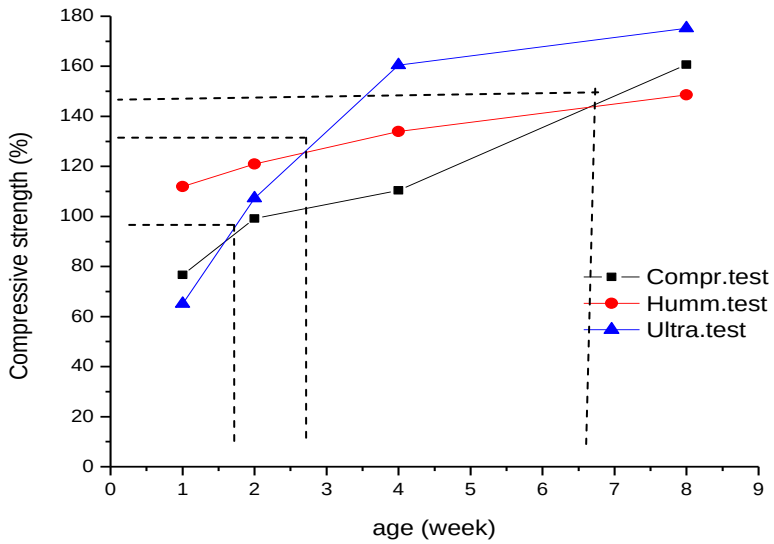

Figure 2 Percentages of actual compressive strength from the designated compressive strength at 28 day for various tests for grade 25

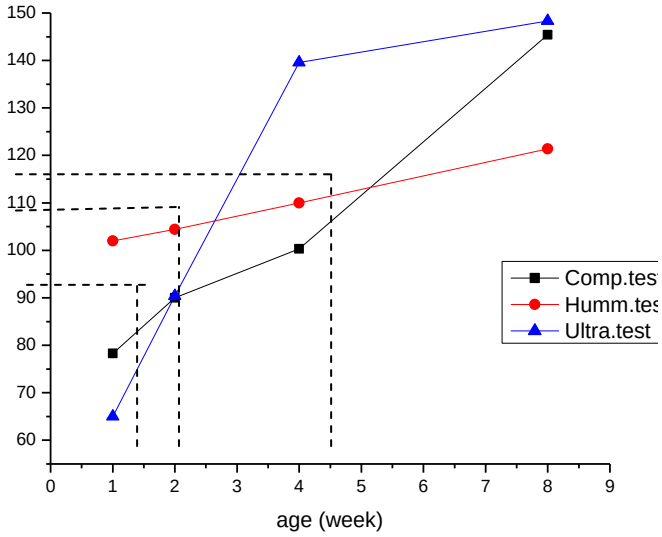

Figure 3 Percentages of actual compressive strength from the designated compressive strength at 28 day for various tests for grade 30

IV. Conclusions

The following conclusions are made based on the results of the present study:

1-According to The designated compressive strength after 28 days crushing test show best results.

2-Destructive tests results more logic and the shapes of the graphs is best than non-destructive tests according to the known concrete graphs.

3-Tensile strength is found to be 8% of actual compressive strength.

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