Faculty of Engineering and Technology

Civil Engineering Department

Construction Materials Laboratory

ENCE215

Experiment # 5

“ Destructive test on hardened concrete ”

Instructors :-

Dr. Nizar Assi.

Eng. Yasser Saad

Done By Group #C :-

Mojahed Sabbah 1171996

Date of performing the experiment: 23-10-2019

Date of submitting the experiment: 21-11-2019

- **Table of Contents**

- **Introduction**

Background information

When concrete is used as a construction material it is vitally important to make assurance that the final outcome (the hardened concrete) possesses the specified characteristics. The most significant approach to do so is by measuring the strength of concrete, since the strength of concrete gives an overall idea of other properties such as durability, uniformity, void content, internal structure… etc. The strength of concrete is defined as the minimum stress (force per unit area) that is capable of inducing failure in concrete, in other words it is the stress measured just at the point of failure. However, concrete is a heterogeneous material, which means that properties (including strength) differ by changing the direction of loading, also by the shape of the specimen, hence in order to define strength of concrete as a unique property it has to be related to the type of loading (compressive, tensile or flexural) and the type of specimen (small cube, large cube, cylinder or prism) included in the test.

Compressive strength is usually measured for British cubic molds (100^3 or 150^3 mm^3) or for American cylinder (150 mm diameter * 300 mm height), where each of these samples is subjected to compressive axial compressive loading that is applied to the point of failure of the specimen, in the case of concrete the compressive force is the most important type of strength to be measured.

Tensile strength of concrete is rarely measured directly, since concrete is assumed to not hold tension when designing structures, also because the devices that hold the specimen produce secondary stresses that affect the real value, thus to estimate the tensile strength of concrete conducting the ' splitting tensile test ' could be useful. This kind of test is applied on the cylinder where it is subjected to a compressive stress along its diametral lines, the compressive stress develops transverse tensile stress that could be correlated to the compressive stress using an empirical formula, it is worth mentioning that this kind of testing is needed when using concrete in pavements or airports, where concrete is subjected to bending stresses rather than compressive ones.

Another test related to the tensile strength of concrete is the flexural loading test which is conducted on a prism specimen ($100 * 100 * 500\ mm^3$), in this test the prismatic specimen is subjected to flexural loading that induces bending in the prism, till its failure point, then the rupture (flexural tensile stress) could be calculated using empirical formulas.

It was observed by experimental procedures that the strength of concrete is affected by different factors, the most dominant of which is the ratio of water to cement (W/C), it was found that the lower this value is the higher the strength of concrete is rises, another key factor that governs the strength of concrete is its age, it was found that the strength of concrete rises as it ages, this could explained by realizing that hardening of concrete is caused by the hydration reaction (between cement and water) and this reaction is dependent on time.

Formulas:

1) $$\rho = \frac{W_{SSD}}{W_{SSD} - W_{Sub}}$$

Where:

ρ: density of the specimen.

W_{SSD}: saturated surface dry weight of the specimen.

W_{sub}: water submerged weight of the specimen.

2) $\sigma = \frac{P}{A}$

Where:

σ: compressive strength.

P: failure compressive load.

A: cross-sectional area.

3) $T = \frac{2P}{\pi L d}$

Where:

T: tensile strength.

P: failure compressive load.

L: length of the cylinder.

d: diameter of the cylinder.

4) $R = \frac{PL}{bd^2}$

Where:

R: tensile strength (modulus of rupture).

P: failure compressive load.

L: prism's span length.

b: width of the prism.

d: depth of the prism.

5) $index(small\ \ cube, large\ cube)\ = \frac{strength\ \ of\ \ large\ \ cube}{strength\ \ of\ \ small\ \ cube}$

6) $index(cylinder, large\ cube)\ = \frac{strength\ \ of\ \ cylinder}{strength\ \ of\ \ large\ \ cube}$

Purpose

This experiment aims to measure the strength (compressive, splitting and flexural) of different specimens at different ages for different (W/C), and finding correlations between strength and different factors (W/C and age).

- **Hypotheses**

It is expected that the strength of concrete is directly proportional to the its age, while it is inversely proportional to its (W/C). Also, one assumes that different shapes of specimens would give different compressive strength of concrete even though they are all made of the same materials and that is because concrete is a heterogeneous material. Based on experience concrete compressive strength is expected to be noticeably higher than the tensile strength because concrete is very weak at holding tension.

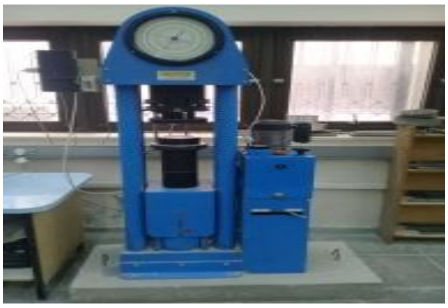
- **Procedure**

1. Four concrete mixes having four different (W/C = 0.5, 0.55, 0.6 and 0.65) where prepared.
2. Two cubical specimens (150 mm) of each (W/C) were molded.
3. six cubical specimans (100 mm) of each (W/C) were molded.
4. One prism (100mm *100mm*500mm) of each (W/C)
5. Three cylindrical specimens (150 mm * 300 mm) were molded.
6. The day after all samples were removed from molds, and then submerged in water to be properly cured.
7. After seven days all specimens were removed out of water and put on shelf to be dried.
8. At the same day (seventh day) eight small cubes (two cubes of each ratio), were tested for density (SSD and submerged weights using balance), and then crushed using the compressive crushing machine by putting the specimen at the center of the plate and then applying the axial force by the machine and recording the force at failure.
9. Step (7) was repeated at the fourteenth day and at day 28.
10. At day 28 the big cubes (eight cubes) were crushed using the compressive crushing machine (two smooth faces were chosen) and the failure forces were recorded.
11. Also at day 28 eight cylinders were tested for the compressive strength, the rough surface was capped using a rubber cap and then vertically put inside the compressive machine with the capped surface from bottom, and the failure forces were recorded.

12. Also at the same day four cylinders (one of each ratio) were tested for the splitting tensile test, where each cylinder was put horizontally inside the compressive machine using where the diametral line was loaded, and at failure the forces were loaded.
13. Also at the same day one prism of each ratio were tested using the flexural test. On the prism, two lines were marked at 5cm offset from each side, then another two lines were marked at 13.3 cm offset from the previous two lines.
14. The prism was put inside the flexural machine the bottom steel bases on the 5cm lines and the top two steel balls at the 13.3 cm, then the load was applied by the upward and downward movement of the lever arm until failure, the forces were recorded at failure point.

- **Instruments**

Apparatus and Tools:



Fig(1): Compressive crushing machine (large)

Fig(2): Compressive crushing machine (small)

Fig(3): Crushing machine (prism flexural test)

Fig(4): Crushing machine (splitting tensile test)

Fig(5): Trowels

Fig(6): Electronic balance

- **Data & Calculations:**

Table (1): compressive strength of 10mm cubes at different days 7, 14 and 28 for W/C of 0.5, 0.55, 0.6 and 0.65												
No	W/C	Cast Date	Test Date	Age	Mold	Dimensions (cm)	SSD Weight (gm)	Submerged Weight (gm)	Volume (cm^3)	ρ (gm/cm^3)	P (KN)	σ (Mpa)
1	0.50	17/9	24/9	7	cube	10*10*10	2370.45	1349.45	1021.0	2.32	200.3	20.03
2	0.50	17/9	24/9	7	cube	10*10*10	2373.95	1347.90	2239.0	1.06	188.8	18.8
3	0.50	17/9	1/10	14	cube	10*10*10	2303.45	1284.00	1019.4	2.25	262.9	26.29
4	0.50	17/9	1/10	14	cube	10*10*10	2269.15	1251.65	1017.5	2.23	268.0	26.80
5	0.50	17/9	15/10	28	cube	10*10*10	2241.90	1238.75	1003.15	2.23	294.5	29.45
6	0.50	17/9	15/10	28	cube	10*10*10	2222.20	1232.00	990.2	2.24	294.4	29.44
7	0.60	24/9	1/10	7	cube	10*10*10	2290.80	1290.15	1000.6	2.28	198.6	19.86
8	0.60	24/9	1/10	7	cube	10*10*10	2291.80	1294.25	997.55	2.29	204.6	20.46
9	0.60	24/9	8/10	14	cube	10*10*10	2226.95	1225.30	1001.6	2.22	279.2	27.92
10	0.60	24/9	8/10	14	cube	10*10*10	2240.15	1235.00	1005.1	2.23	277.2	27.72
11	0.60	24/9	23/10	28	cube	10*10*10	2214.35	-	-	-	328.2	32.82
12	0.60	24/9	23/10	28	cube	10*10*10	2208.80	-	-	-	318.5	31.85
13	0.55	17/9	24/9	7	cube	10*10*10	2271	1285	986	2.30	242.0	24.2
14	0.55	17/9	24/9	7	cube	10*10*10	2336	1316	1020	2.29	240.0	24.0
15	0.55	17/9	1/10	14	cube	10*10*10	2275	1272	1003	2.27	170.0	17.0
16	0.55	17/9	1/10	14	cube	10*10*10	2263	1272	991	2.28	172.0	17.2
17	0.55	17/9	15/10	28	cube	10*10*10	2171	1175	996	2.18	226.0	22.6
18	0.55	17/9	15/10	28	cube	10*10*10	2165	1177	988	2.19	220.0	22.0
19	0.65	24/9	1/10	7	cube	10*10*10	2278	1276	1002	2.27	180.0	18.0
20	0.65	24/9	1/10	7	cube	10*10*10	2307	1291	1016	2.27	196.0	19.6
21	0.65	24/9	8/10	14	cube	10*10*10	2297	1278	-	-	140.0	14.0
22	0.65	24/9	8/10	14	cube	10*10*10	2246	1245	-	-	140.0	14.0
23	0.65	24/9	23/10	28	cube	10*10*10	2178	1178	1000	2.18	204.0	20.4
24	0.65	24/9	23/10	28	cube	10*10*10	2100	1114	996	2.12	208.0	20.8

Sample calculations of specimen number one:

$$\rho = \frac{W_{SSD}}{W_{SSD} - W_{Sub}} = \frac{2370}{2370 - 1349.45} = 2.32 \ gm/cm^3$$

$$\sigma = \frac{P}{A} = \frac{200.3 * 1000}{100^2} = 20.03 \ MPa$$

Table (2): compressive force of 150mm cube and the cylinders at 28 days for 0.50, 0.55, 0,60 and 0.66 (W/C)

No.	W/C	Date of casting	Date of test	Age of test	Type of mold	Dimensions (cm)	P (KN)	σ (MPa)
1	0.50	17/9	15/10	28	Cube	15*15*15	640	28.4
2	0.50	17/9	15/10	28	Cube	15*15*15	660	29.3
3	0.60	24/9	23/10	28	Cube	15*15*15	747	33.2
4	0.60	24/9	23/10	28	Cube	15*15*15	735	32.6
5	0.55	17/9	15/10	28	Cube	15*15*15	590	26.2
6	0.55	17/9	15/10	28	Cube	15*15*15	565	25.1
7	0.65	24/9	23/10	28	Cube	15*15*15	515	22.8
8	0.65	24/9	23/10	28	Cube	15*15*15	525	23.3
9	0.50	17/9	15/10	28	cylinder	15*30	324	18.34
10	0.50	17/9	15/10	28	cylinder	15*30	320	18.11
11	0.60	24/9	23/10	28	cylinder	15*30	300	16.99
12	0.60	24/9	23/10	28	cylinder	15*30	312	17.66
13	0.55	17/9	15/10	28	cylinder	15*30	242	13.70
14	0.55	17/9	15/10	28	cylinder	15*30	140	7.93
15	0.65	24/9	23/10	28	cylinder	15*30	184	10.42
16	0.65	24/9	23/10	28	cylinder	15*30	200	11.32

Sample calculation for cubic specimen No.1:

$$\sigma = \frac{P}{A} = \frac{640 * 1000}{150^2} = 28.44 \ MPa$$

Sample calculation for cylindrical sample No.9:

$$\sigma = \frac{P}{\pi(\frac{d}{2})^2} \frac{324 * 1000}{\pi 75^2} = 18.34 \ MPa$$

Table (3): cylinder Splitting tensile strength values at 28 days for W/C of 0.50, 0.55, 0.60 and 0.65								
No.	W/C	Date of casting	Date of test	Age of test	Type of mould	Dimensions (cm)	P (KN)	T (MPa)
1	0.50	17/9	15/10	28	cylinder	15*30	192	2.72
2	0.60	24/9	23/10	28	cylinder	15*30	192	2.72
3	0.55	17/9	15/10	28	cylinder	15*30	80	1.13
4	0.65	24/9	23/10	28	cylinder	15*30	128	1.81

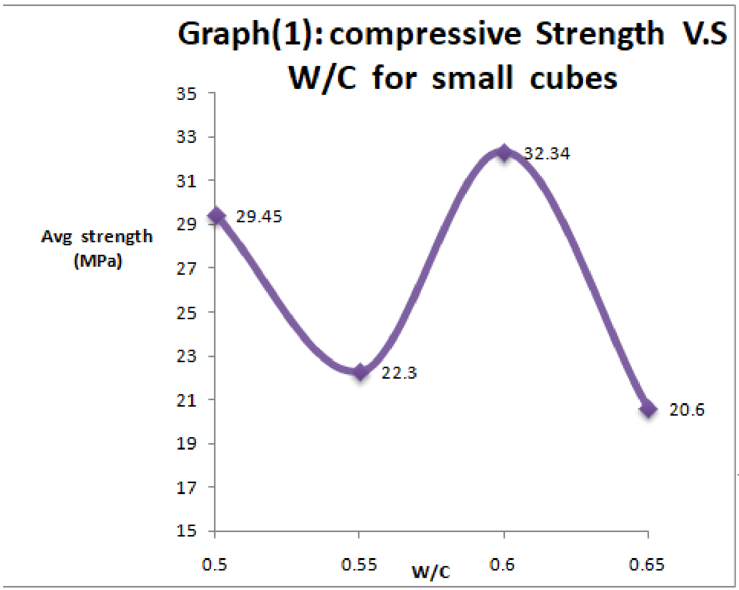
Sample calculation for specimen No.1:

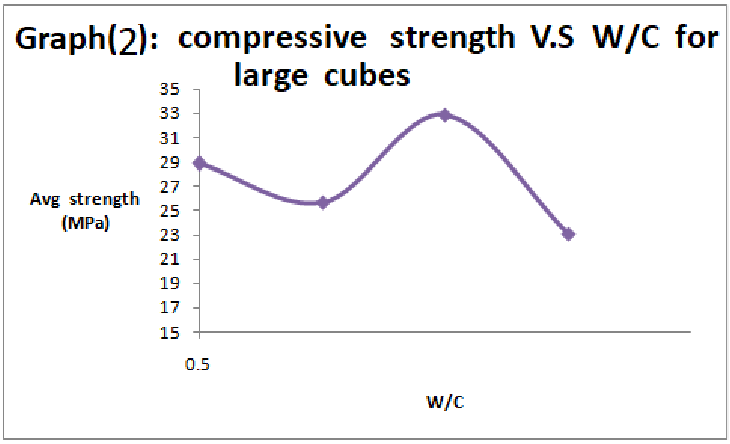
$$T = \frac{2P}{\pi L d} = \frac{2 * 192 * 1000}{\pi * 300 * 150} = 2.72 \ MPa$$

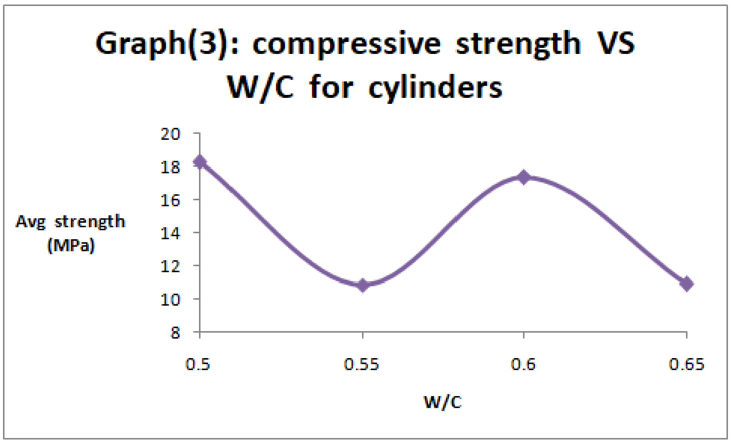
Table (4): flexural tensile test values at 28 days for prismatic specimen for W/C 0f 0.50, 0.55, 0.60, 0.65								
No.	W/C	Date of casting	Date of test	Age of test	Type of mold	Dimensions (cm)	P (KN)	R (MPa)
1	0.50	17/9	15/10	28	Prism	10*10*50	5.16	2.58
2	0.60	24/9	23/10	28	Prism	10*10*50	4.45	2.23
3	0.55	17/9	15/10	28	Prism	10*10*50	1.06	0.53
4	0.65	24/9	23/10	28	Prism	10*10*50	0.89	0.45

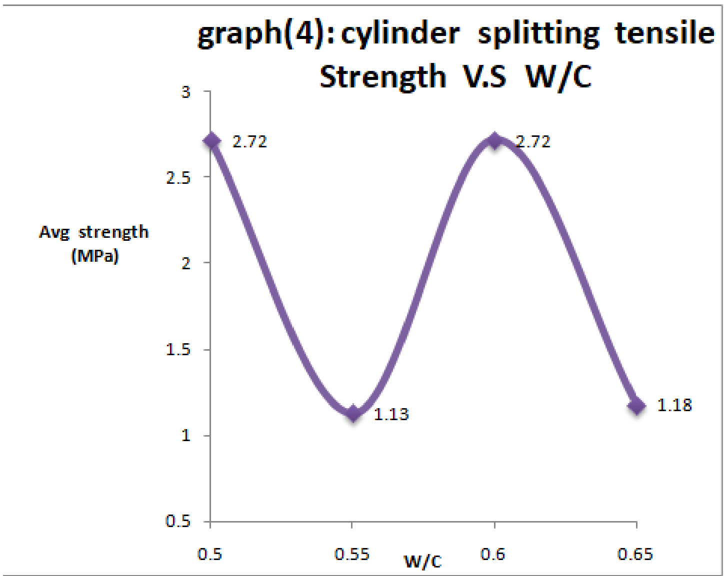
Sample calculation for specimen No.1:

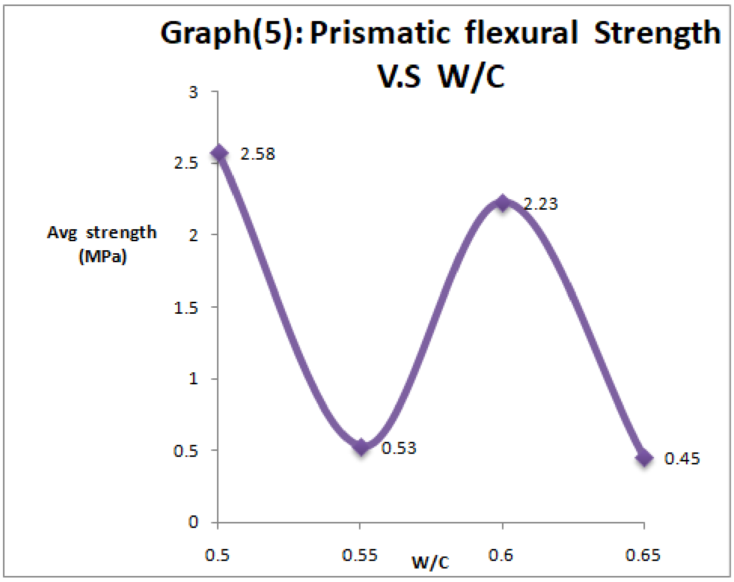
$$R = \frac{PL}{bd^2} = \frac{5.16 * 1000 * 500}{100 * 100 * 100} = 2.58 \ MPa$$

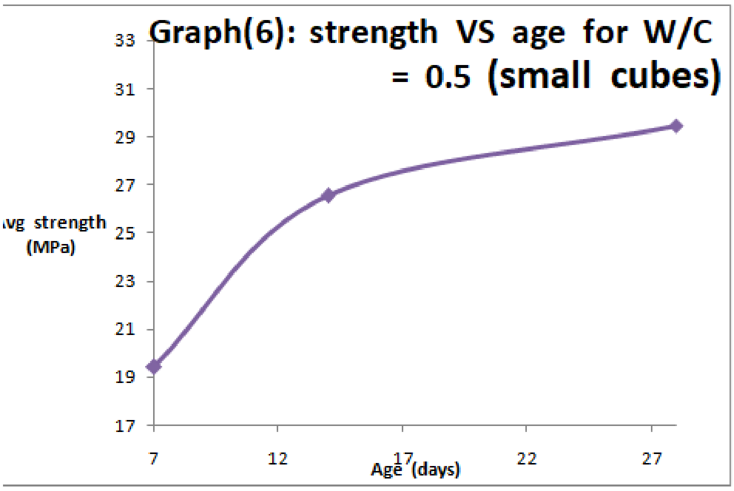

Graph(1): compressive Strength V.S W/C for small cubes
Avg strength (MPa)
35
33
31
29
27
25
23
21
19
17
15
29.45
22.3
32.34
20.6
0.5
0.55
W/C
0.6
0.65

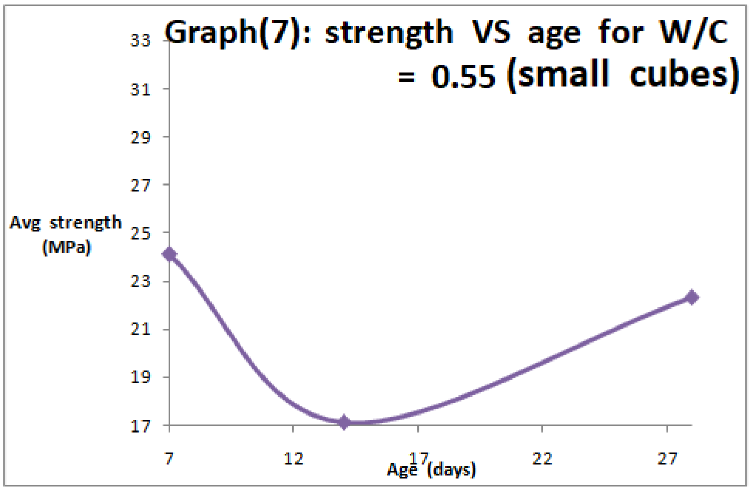

Graph(2): compressive strength V.S W/C for large cubes
Avg strength (MPa)
35
33
31
29
27
25
23
21
19
17
15
0.5
W/C

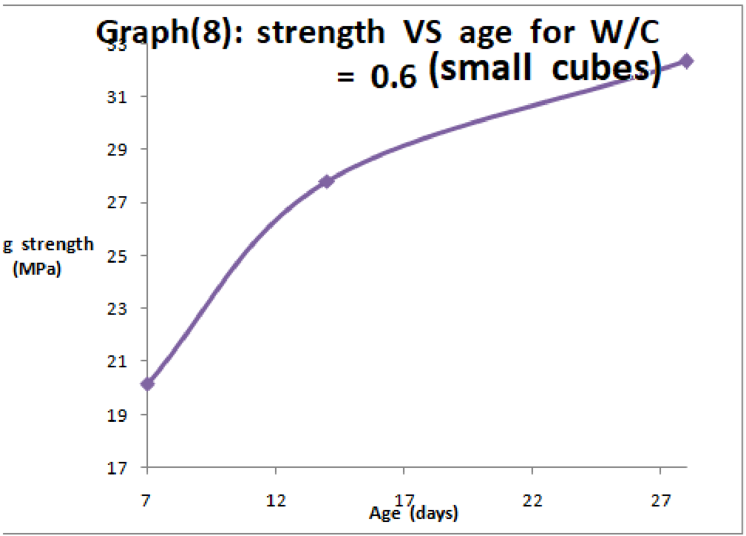

Graph(3): compressive strength VS W/C for cylinders
Avg strength (MPa)
20
18
16
14
12
10
8
0.5
0.55
0.6
0.65
W/C

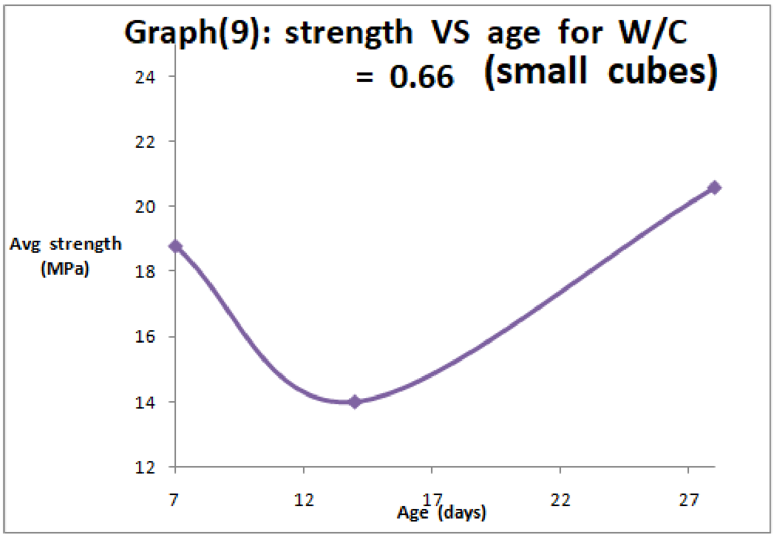

graph(4): cylinder splitting tensile Strength V.S W/C
Avg strength (MPa)
3
2.5
2
1.5
1
0.5
2.72
1.13
2.72
1.18
0.5
0.55
W/C
0.6
0.65


Graph(5): Prismatic flexural Strength V.S W/C
Avg strength (MPa)
3
2.5
2
1.5
1
0.5
0
2.58
0.53
2.23
0.45
0.5
0.55
W/C
0.6
0.65









Table(5): index between large and small cubes for different W/C				
W/C	0.5	0.55	0.6	0.65
Index(large cube,small cube)	97.9%	115%	101.7%	111.9%

Table(6): index between cylinder and large cubes for different W/C				
W/C	0.5	0.55	0.6	0.65
Index(cylinder, large cube)	63.2%	42.18%	52.7%	94.3%

- **Results & Conclusion**

The results of different strength values and densities are shown in the tables and graphs.

It is not possible to conclude a clear and direct relationship between the strength and W/C from the previous graphs, because the values vary in an alternating rhythmus more like a sinusoidal function, while on real ground the relation should be always increasing, and this contradicts the hypothesis.

On the other hand for the strength V.S age graphs, graphs (6 and 8) give the accurate relation, where the strength always increases with time, so there is mutuality with the hypothesis for these two graphs.

The cubical index is 106.6% in average, where the actual index should be around 97.5%. The cylindrical cubical index is 63.1%, while the actual index, it is noticeable that the obtained indices deviate highly from the actual ones due to large errors.

A lot of errors may have happened while performing the experiment, such as poor compaction which leaves voids that weaken concrete, poor batching for concrete components which manipulates the W/C, bad capping for cylinders, temperature also has a role in controlling the hydration reaction.

- **References**

1. Department of concrete constructions (2006) concrete Production and Testing: Construction Inspector’s Training Manual. Washington State, Department of concrete. Environmental and Engineering Program, Construction office.

2. https://theconstructor.org/building/concrete-compressive strength-test/1358/?fbclid=IwAR0Bm89wilGozpszFxhqQuPu-WJ0GCbILwYJPGHOcE_mmZ8ZqxZEWibOIP8