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Abstract –*Among all the concrete characteristics, the compressive strength is known as the most important feature and therefore, it is often utilized to quantify the quality of concretes. The assessment of concretes strength in existing constructions is important during their service life. Thus, in addition to destructive evaluation of strength, many non-destructive techniques have been adopted to assess the concretes strength. Ultrasonic Pulse Velocity (UPV) is one of the non-destructive techniques that involve measuring the speed of ultrasonic wave through concretes to predict concretes strength. According to the Griffith's theory, the strength of the material is greatly affected by the defects' existence (for example, small cracks). These cracks can be current prior to the application of any loading or could create throughout the load application. The presence of micro-cracks in concretes that generate due to the applied load may affect the UPV test results in comparison with unloaded concretes. An experimental investigation is conducted in order to assess the impact of the applied of load (ultimate load) on the measured ultrasonic wave velocity and compared with the results of compressive strength from destructive test. A total of thirty (150 mmx150mm) cube specimens have been utilized with water to cement ratios (0.45). These cubes have been examined in ultrasound without any loads and then they have been tested in the same way with applied ultimate load which is approximately equal to half of the required design load (failure load) and then inspected or tested in the normal way (destructive test). In order to assess the compressive strength of concretes using (UPV), loading condition is considered in order to study the impact of the applying load. In addition, the water absorption has been examined for thirty concretes samples under the impact of the applied loads (20%, 40% and 60%). The results of non-destructive tests of concretes samples under the influence of imposed loads (60%) have showed to be less by compressive strength 5 MPa than the results obtained from testing of unloaded concretes samples through the resulting equation and comparing them to the equation from previous research. This is consistent with the water absorption test of the specimens under the imposed loads (60%) where Absorption values have been greater than concretes models without applied loads.*

***Keywords**: Compressive strength, Ultrasonic Pulse Velocity, non-destructive techniques and failure load*

Nomenclature

ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
C	Capillary absorption coefficient ($g/(m^2h^{0.5})$)
CO_2	Carbon dioxide
F_{cu}	Compressive strength (MPa)
IQS	Iraqi Standard
L	Path length, (mm)
NDT	Non-destructive test
M_0	Dry Mass (g)
M_1	Wet Mass (g)
MPa	Mega Pascal
S	Surface area
T	Transit time (s)
V	Ultrasonic pulse velocity (km/s)
W	Capillary absorption performance (g/m^2)

I. Introduction

The concretes are composite materials that contain adherence intermediate inside which elements of aggregate (sand and gravel) are implanted.

Nondestructive test (NDT) methodologies are used to identify hardened concretes properties. Nondestructive test techniques are important to concretes construction for several purposes, i.e. quality controlling of new buildings, troubleshooting of difficulties with new construction; condition assessment of aged concretes for rehabilitation purposes and quality controlling of concretes repairs [1]. Nondestructive testing technologies are improving and research continues to enhance current techniques and create new approaches.

Depending on Griffith's hypothesis, the existence of flaws (for example, microscopic cracking) has a significant impact on the material's strength. These cracking might exist before the applications of any load and might occur throughout the application of any load. [2].

Non-destructive testing may be utilized to verify both new and aged concrete and it may be utilized on both old and new buildings, with the most common applications being quality controlling or the persistence of concerns about the materials or quality construction. The use of nondestructive testing on existing structures is often linked to the determination of structural dependability or appropriateness. [3].

Non-destructive tests involve a wide range of parameters, including strengths, elastic modulus, and, density, as well as surfaces hardness, surface absorption, and reinforcement position. In some cases, skill of workmanship quality and structural integrity can also be verified by the ability to identify voids and cracks [4].

Because the ultrasonic pulse cannot travel through air, the existence of a cracking (flaw) or voids on the track will increase the path length and the weakening so that a longer crossing time will be registered. In the case of sound material, the resulting UPV will be the lowest. This idea or knowledge will be applied only to cracking or voids that are not filled with water [5]. This fact has been studied and it has been decided that while cracks filled with water cannot be detected during the ultrasonic test. Cracked and honeycombed concretes of low pulse velocity will perform likewise [6].

Bungey has shown that the micro-cracking of concretes will be enough to interrupt the path taken by the ultrasonic pulses and, the result pulse velocity may be estimated to drop because of interruption of path length when the compressive strength more than of 50% of the cube crushing strength [7].

The presence of fractured concretes increases the time of travel that affects in a lower UPV. The influences affect the intensity of pulse velocity affiliation water to cement ratio, voids, grading type, aggregate size, and content, the concretes age, moisture condition, compaction, curing temperature and path length [8].

The pragmatic relationship should be recognized on test specimens in the laboratory. It is commonly approved that there is no single relationship between strength of concretes and UPV. Several types of factors may affect one restriction only causing the presence of different relationships.

Raouf and Samurai have found out an experimental relationship to approximation concretes compressive strength [9].

$$Compressive\ strength\ of\ concretes = 2.8\, e^{\,0.58V} \quad (1)$$

Earlier studies have inspected the water absorption of normal concretes in several situations [10-18]. The mix proportion of concretes has a clear impact on the capillary water absorption. Besides, the water absorption of normal concretes with imposed damage has also a direct impact. For example, Gonen has obtained the influence of freeze-thaw damage on the absorption actions of normal concretes [19], and Wang has explored the impact of applied loading on the capillary absorption performance of normal concretes [20], which demonstrates that the imposed freeze-thaw damage and load damage cause the additional rise in the water absorption of normal concretes. The grouping of water absorption and executed damage should be well thought out carefully in the assessment and design of concretes durability.

This paper has been constructed to consist of the following sections. The experimental program of the paper is presented in section II. Then the results and discussion are presented in section III. Finally, the conclusions are presented in section IV.

II. Experimental Program

II.1. Program of investigation

The main objective of this research is to obtain a more realistic relationship for estimating the compressive strength of concretes by having real applied loads on the concretes structural section that is examined or tested by UPV method or in a sense, to know the impact of the real applied loads on the concretes section during the testing of non-distractive method.

This study deals with the extent of the impact of the actual loads present in the concretes parts on the results of non-destructive tests of these sections and compares them to the results of non-destructive tests without these existing loads. Two groups of concretes models have been casted with 30 specimens for each group. In the first group, which includes casting and examining the specimens after 28 days, the specimens are tested by non-destructive method and examined by destructive method. In the second group, which includes casting and testing concretes specimens after 28 days, the models are examined by non-destructive method after applying 60%

of the actual loads (ultimate loads) and are examined by destructive method.

The absorption of water of concretes specimens has been tested in case of unloaded and loaded (0, 20, 40 and 60)% of ultimate load. Water absorption test has been approved out according to the ASTM C1585. First, specimens have been dried in the drying oven for 24 h where the temperature has been saved around 105°C, and then the specimens have been located and cooled at chamber temperature.

Full details and information about material and mixes, mixing procedure, casting and curing and testing are carried out on sample in order to attain the aim of this study.

The last group of specimens has been subjected to the carbonation by applied CO_2 gas on the specimens that applied (0%, 20%, 40% and 60%) of ultimate load. The concretes specimens have been kept until 28 days in the carbonation chamber and then kept in ambient environments inside the laboratory until the age of test carbonation depth.

The concretes specimens (cube specimen with dimension 150x150x150 mm) have been tested at the age of 28 days for compressive strength with and without applied real ultimate loads.

II.2. Materials

Ordinary Portland cement manufactured in Iraq has been utilized. It is conformed to Iraqi specification [IQS 5-1984] type I [21]. The chemical analysis and the physical characteristics of cement are shown in Table I and Table II, respectively.

TABLE I
CHEMICAL COMPOSITION OF PORTLAND CEMENT

Composition	Oxides Content, %	Limit of (IQS NO.5/1984)
SiO_2	20.58	-
Al_2O_3	5.6	-
Fe_2O_3	3.28	-
CaO	62.79	-
MgO	2.79	≤ 5 %
Free CaO	0.9	-
SO_3	2.35	≤ 2.8 %
I.R	0.86	≤ 1.5 %
L.O.I.	1.94	≤ 4 %
L.S.F	0.9	0.66-1.02

TABLE II
PHYSICAL CHARACTERISTICS OF PORTLAND CEMENT

Characteristics	Test result	Limit of (IQS NO.5/1984)
Initial setting time (min)	122	≥ 45 min
Final setting time (min)	193	≤ 10 hrs
Compressive strength (MPa)		
3 days	19	≥ 15 MPa
7 days	28	≥ 23 MPa
Blaine fineness (m^2/kg)	314	≥ 230 m^2/kg

Natural sand from Al-Abadiy region has been utilized for concretes mixes of this investigation. The sieve analysis of the sand is presented in Table III, while specific gravity, sulfate content, and absorption of utilized sand are shown in Table IV. It conforms to the requirement of (IQS NO.45/1984) [21].

TABLE III
THE SIEVE ANALYSIS OF SAND UTILIZED

Sieve Size (mm)	Cumulative passing %	Limit of Iraqi specification No.45 /1984 (zone 2)
10	100	100
4.75	93	90-100
2.36	75	75-100
1.18	55	55-90
0.6	44	35-59
0.15	10	8-30

TABLE IV
PHYSICAL CHARACTERISTICS OF SAND UTILIZED

Characteristics	Test result	Limit of (IQS NO.5/1984)
Specific gravity	2.6	-
Sulfate content %	0.21	≤0.5%
Absorption %	0.8	-
Fineness Modulus	3	-

Natural graded coarse aggregate with maximum size of 19mm has been utilized from Al-Nibaey region. The sieve analysis of the course aggregate is presented in Table V, while specific gravity, sulfate content and absorption of coarse aggregate are summarized in Table VI. It conforms to the requirement of (IQS NO.45/1984) [21] .

TABLE V
THE SIEVE ANALYSIS OF COARSE AGGREGATE

Sieve Size (mm)	Cumulative passing %	Limit of Iraqi specification No.45 /1984 (zone 2)
10	100	100
4.75	93	90-100
2.36	75	75-100
1.18	55	55-90
0.6	44	35-59
0.15	10	8-30

TABLE VI
PHYSICAL CHARACTERISTICS OF COARSE AGGREGATE

Characteristics	Test result	Limit of (IQS NO.5/1984)
Specific gravity	2.61	-
Sulfate content %	0.01	≤0.1%
Absorption %	0.21	-
Bulk density kg/m^3	1620	-

Tap water has been utilized for both mixing and curing of concretes in this work.

II.3. Mix design

Normal concretes with a compressive strength of 28 MPa at 28 days have been designed according to the American Method ACI 211-1-2005 as shown in Table VII.

TABLE VII
MIX PROPORTION OF NORMAL CONCRETES

Materials (kg/m^3)	Content
Cement	368
Fine aggregate	785
Coarse aggregate	972
Water	185
(Water/cement) ratio	0.50

The molds have been cleaned, gathered, and lubricated before use. The typical concretes have been cast in three layers in molds, with every layer crushed utilizing a vibrating table for a sufficient amount of time to remove any trapped air. The samples have been demolded the following day and put in water to cure at a temp of (24+ 3) C until the day of testing (28 days).

II.4. Testing of Specimens

The UPV test has been accomplished according to BS 4408:Part5 [22] using the portable ultrasonic concretes tester. The time of passage of an ultrasonic pulse, transitory through the concretes to be evaluated, is measured using the UPV technique. An electronic circuit for producing pulses and a transducer for converting electrical pulses into mechanical energy with a vibration frequency have made up the pulse producer circuit. In order to ensure a proper connection, the transducers are greased. The time it takes for the pulse to travel from its first conception to its response has been measured using technological techniques. Then the pulse velocity is computed by dividing the length of the concrete route by the transmission duration:

$$V = \frac{L}{T} \quad (2)$$

Where V is the UPV, km/s, L is the path length, mm, T is the transit time.

According to B.S.1881 [23], the compressive strengths test has been completed. A hydraulic compression machine with a capability of 2000 kN has been utilized to perform this test on 15 cm cubes. For each test, an average of three cubes has been utilized. For wet curing, the test has been performed at ages greater than 28 days.

II.4.1. The Capillary Water Absorption Test

Water penetration into concretes occurs mostly by capillary absorption when the concretes are relatively dry. The samples have been produced for absorption under unloaded and loaded conditions (0, 20, 40, and 60 percent of ultimate load). Depending on ASTM C1585, a capillary water absorption test has been authorized [24]. Samples have been initially dried for 24 hours in a drying oven at a temperature of roughly 105°C, after which they have been relocated and chilled at chamber temperature. Eventually, a water absorption test has been performed, with the quantity of absorbed water determined at various times. The water absorption test is shown in Figure 1.

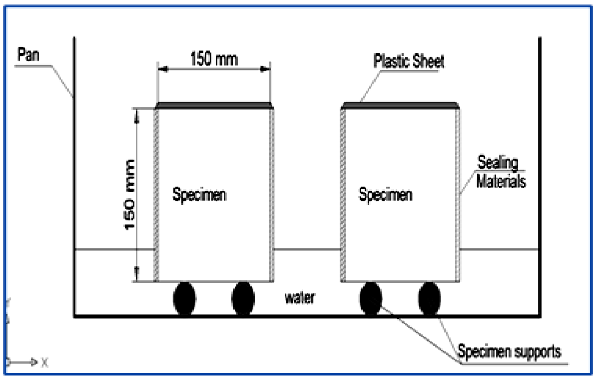

Fig. 1 Water Absorption Test

In a basic way, the capillary absorption performance may be defined. W(g/m^2) represents the mass increase (g) of absorbed water by the surface area S (15 cm 15 cm) in Formula (3). C stands for the capillary absorption coefficient, g/(m^{2}h$^{0.5}$), which may be determined using Equation (4) [25]. The water permeability of cementbased materials may be determined by the quantity of absorbed water and the capillary absorption coefficient.

$$W = \frac{m1-m0}{S} \quad (3)$$

$$C = \frac{W}{\sqrt{t}} \quad (4)$$

II.4.2. The Carbonation Curing Test

Fig. 2 shows the parts and the device of a MDF wood box with dimensions 1500 * 500 * 500 mm that has been utilized. A basic carbonation chamber has featured one intake for Carbon dioxide from a tank and one exit for vacuum air from the box and the release of any pressure inside the box. In order to keep a moisture of 60 ± 5 percent, a saturated NaCl solution has been utilized. Nevertheless, during the accelerated test, the observed humidity has ranged from 50% to 80%, with temperatures ranging from 20 to 27 degrees Celsius..

Fig. 2. Carbonation chamber.

The samples have been tested on a steel mesh in order to prevent contact with the saturated NaCl solution, and the chamber has been filled with Carbon dioxide every two days (by letting the exhaust valve to open whereas Carbon dioxide has been pumped via the input valve) and has been tightly sealed in order to achieve a 100 percent Carbon dioxide levels.

Furthermore, a device that measures the concentration of CO_2 Inside the box along with measuring the temperature and humidity was used as shown in Fig. 2. The device is very important to give notification when the concentration of CO_2 decreases.

The depth of carbonation is usually assessed by spraying phenolphthalein indicator on the surface of newly split concretes, as suggested by RILEM CPC-18, among several suggested ways to detect the carbonation depth of concretes (1988). The pink hue will totally fade from the carbonated region, indicating a pH magnitude of less than 9.5. For carbonation depth measurement, concrete specimens with varied applied loads of (0 percent, 20percent, 40percent, and 60percent) of ultimate load have been created (the same concrete samples have been utilized for absorption). For 28 days, they have been kept in an unpressurized room with a 10-50 percent CO2 atmosphere. After 28 days, the samples have been removed from the chamber and the following procedures have been followed in order to track the carbonation depth advancement.

After the samples have been removed from the chamber, each one has been cut from the top to the bottom utilizing a machine saw to concrete them. The sectioned surface has been cleansed of dust, and a phenolphthalein indicator has been used to determine the depth of carbonation around the perimeter of the half sample. The average result of two measurements taken 90o apart on the disk has been used to determine the depth of carbonation. Additional measurements have been added in certain instances, particularly for specimens, in order to determine the minimal depth of carbonation.

III. Results and Discussions

III.1. Compressive strength and UPV

The results of the compressive strength and UPV tests of normal concretes cubes (unloaded cubes) are shown in Tables VIII, while Table IX presents the results of the compressive strength and UPV tests of normal concretes cubes (loaded cubes with 60% of ultimate loads).

After the tests have been completed and the findings have been obtained, the data has been statistically evaluated using the Microsoft Excel computer software version 10. All the spreadsheets have the same fundamental functions as Microsoft Excel. In order to organize data managements such as arithmetic operations, a grid of cells organized in numbered rows and letter-named columns are utilized.

Fig. 3 shows the relationship between the compressive strength and velocity without loaded cubes. A computer program (Excel version 10) has been modified to obtain the equation of the expected relationship between velocity and compressive strength (fcu).

$$Fcu = 2.82\ e^{0.578*V} \quad (5)$$

Fig. 4 shows the relationship between the compressive strength and the velocity with loaded cubes (60% of ultimate loads). A computer program (Excel version 10) has been improved to obtain the equation of the expected relationship between velocity and compressive strength (fcu).

$$Fcu = 1.9562\, e^{0.6165*V} \quad (6)$$

TABLE VIII
CHEMICAL COMPOSITION OF PORTLAND CEMENT

No	Velocity (km/s)	Compressive Strength (MPa)
1	4.13	30.5
2	4	27.1
3	3.92	26.81
4	4.01	28.22
5	3.88	23.5
6	3.89	25.28
7	3.63	23.7
8	3.77	25.21
9	3.62	22.4
10	4.08	29.85
11	3.86	22.93
12	3.7	25
13	3.99	29.2
14	3.98	30.32
15	3.6	23.66
16	3.75	23.1
17	3.91	28.6
18	3.85	25.2
19	3.87	27.5
20	3.63	21.31
21	3.77	27.77
22	4.05	29.7
23	3.82	27.11
24	3.96	27.05
25	3.74	24.85
26	4	30.04
27	3.89	27.54
28	3.53	21.38
29	4.11	29.92
30	3.87	28.82

Fig. 3 shows the relationship between the compressive strength and the velocity without loaded cubes. A computer program (Excel version 10) has been modified to obtain the equation of the expected relationship between velocity and compressive strength (fcu).

TABLE IX
CHEMICAL COMPOSITION OF PORTLAND CEMENT

No	Velocity (km/s)	Compressive Strength (MPa)
1	3.98	23.5
2	3.9	21.1
3	3.77	20.81
4	3.86	20.22
5	3.73	19.2
6	3.72	20.5
7	3.78	21.7
8	3.79	20.1
9	3.89	21.32
10	3.93	21.4
11	3.76	20.7
12	3.92	22.6
13	3.84	21.88
14	3.83	19.32
15	4.03	22.8
16	3.8	20.45
17	3.76	20.72
18	3.73	17.53
19	3.7	17.7
20	3.8	20.95
21	3.77	17.83
22	3.83	20.24
23	3.97	21.59
24	3.81	21.7
25	3.79	20.77
26	3.8	21
27	3.74	18.65
28	3.82	20.3
29	3.82	22.9
30	3.83	21.8

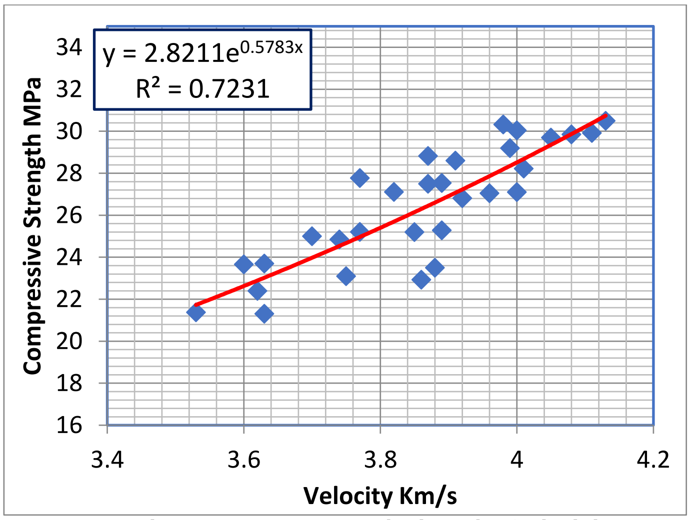

Fig. 3. Velocity - compressive strength relationship (Unloaded cubes)

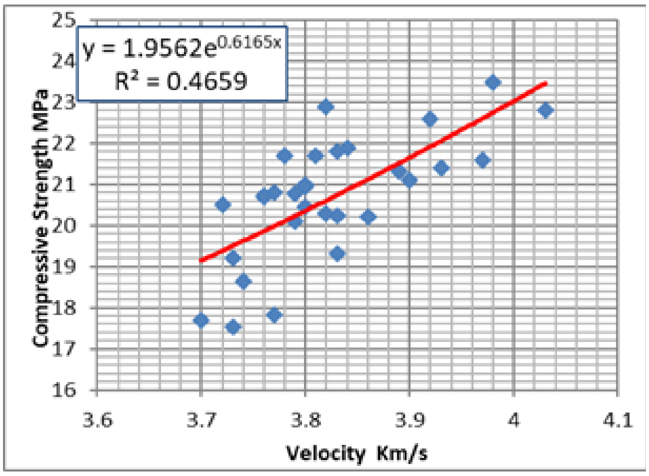

Fig. 4. Velocity - compressive strength relationship (loaded cubes)

The results and the equation have been observed by testing the non-destructive models after the applied load of 60% of ultimate loads, where the transmission speed of the ultrasonic pulse has been slightly less than the results obtained without applying the loads (60% of ultimate load). This is because the impacted loads generate micro-cracks and macro-cracks in the concretes. Only the macro cracks obstruct Ultrasonic pulse transmission and thus slightly lower the values of ultrasonic results and higher decrease in destructive compressive strength of concretes due to micro and macro cracks.

III.2. Water Absorption

Through the results of examining the concretes cubes by the non-destructive test, and in order to reveal the impact of the applied loads (20%, 40% and 60% of ultimate loads) on concretes members on the results of the testing as a result of generating microscopic cracks in concretes, it is necessary to conduct a water absorption test for concretes, especially for loaded concretes, because of its great impact to identify defects or flaws and microscopic cracks generated as a result of loading. This supports what is found in the specifications ASTM C 1585 – 04, which states that the water absorption of concretes depends on a number of factors, among which there are microscopic cracks.

Table X and Figs. 5 and 6 show the results of water absorption of concretes specimens with loaded case (20%, 40% and 60% of ultimate load) and unloaded case.

Depending on the results obtained, with an increase in the applied loads, the percentage of water absorbed by concretes increases, especially at the applied loads of 60%, where the absorption rate of concretes has been 726 g/m^2, because the applied or imposed loads cause the occurrence of microscopic cracks that open channels between the voids in the concretes and thus increase Absorption. This is in line with the results of a non-destructive test using ultrasound pulse velocity, where the imposed loads are about 20% of ultimate load. The results of the water absorption of the concretes do not differ much from the specimens without loads because the loads are very small and cannot cause microscopic cracks or damage to the concretes.

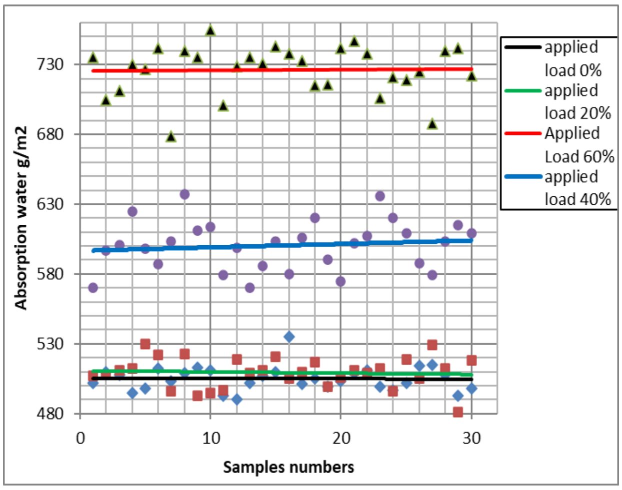

Fig. 5. Water Absorption of Thirty Specimens with Different Applied Loads

III.3. Carbonation Depth Measurement Results

The results of carbonation depth measurement are presented in Table XI and Table XII.

All the concretes specimens have been subjected to CO_2 curing for 28 days. For the specimens applied load 0% of ultimate load, the average value of 30 specimens taken 90º from each side has been 4.81 mm. The specimens with applied load 60% of ultimate load recorded average readings had 12.03 mm of carbonation depth and for specimens with applied load 20% and 40% of ultimate load carbonation depths have been 4.89mm and 7.93mm , respectively.

TABLE X
WATER ABSORPTION RESULTS WITH DIFFERENT APPLIED LOADES

No	Water Absorption g/m²			
	Applied load			
	0%	20%	40%	60%
1	502	507	570	735
2	510	508	597	705
3	508	511	601	711
4	495	512	625	730
5	498	530	598	727
6	512	522	587	742
7	503	496	603	679
8	509	523	637	740
9	513	493	611	735
10	511	495	614	755
11	493	497	579	701
12	490	519	599	729
13	502	509	570	735
14	507	511	586	731
15	510	521	603	743
16	535	505	580	738
17	501	510	606	733
18	505	517	620	715
19	499	499	590	716
20	503	506	575	742
21	509	511	602	747
22	511	509	607	738
23	499	512	636	706
24	497	496	620	721
25	502	519	609	719
26	514	505	588	725
27	515	529	579	688
28	508	512	603	740
29	493	481	615	742
30	498	518	609	722

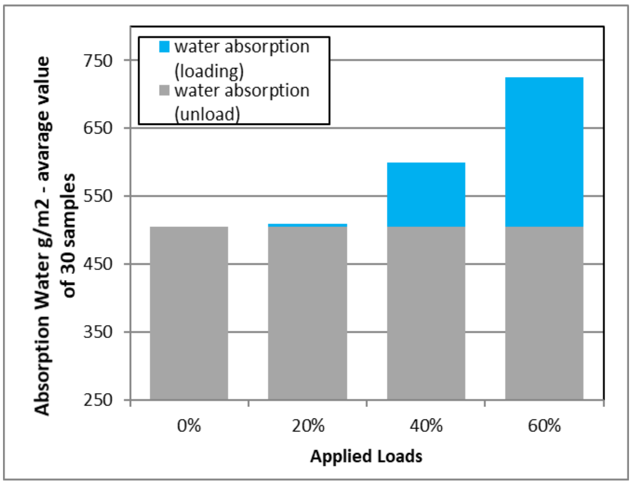

Fig. 6. Average Values of Water Absorption with different Applied Loads

When comparing the results of CO_2 gas penetration of the non-imposing specimens with the specimens that are subjected to 60% of the ultimate load, it is clearly seen that the CO_2 gas penetration depth of the specimens on which the loads are 60% of the ultimate loads is 7.22mm more and this is due to the occurrence of microscopic cracks in the concretes (as results of applied load of 60%) that lead to gas penetration Deeper as shown in Table(9). At the same time, the penetration of carbon dioxide gas into the concretes leads to reacting of the CO_2 gas with $Ca(OH)_2$ and forming $CaCO_3$ from to fill concretes voids and decreasing the gas penetration.

TABLE XI
MIX PROPORTION OF NORMAL CONCRETES

Applied load	Average of Carbonation Depth mm
Unloaded 0%	4.81
Loaded 20%	4.89
Loaded 40%	7.93
Loaded 60%	12.03

TABLE XII
CARBONATION DEPTH MEASUREMENT WITH DIFFERENT APPLIED LOADES

No	Carbonation Depth (mm)			
	Applied load			
	0%	20%	40%	60%
1	5.12	6.77	7.21	11.50
2	4.15	5.71	6.30	12.91
3	6.20	3.82	7.89	13.35
4	3.80	5.89	8.52	12.78
5	4.26	3.55	8.66	10.65
6	5.87	4.12	7.56	11.62
7	6.35	3.53	8.44	13.58
8	5.71	4.40	7.34	13.82
9	4.14	5.71	6.39	11.58
10	5.02	3.36	8.29	10.55
11	5.37	6.11	7.98	10.38
12	3.38	5.95	8.87	9.95
13	6.23	4.29	8.00	10.39
14	4.52	4.00	7.57	11.20
15	3.13	5.76	8.73	13.70
16	3.23	5.50	8.11	13.75
17	4.89	3.84	8.53	11.85
18	3.51	4.83	9.13	12.11
19	6.80	6.11	7.56	12.60
20	5.37	4.21	6.78	11.82
21	5.09	5.73	7.59	10.70
22	3.78	4.55	8.78	13.61
23	5.36	5.30	7.48	11.93
24	4.51	6.36	8.06	13.83
25	5.23	3.17	8.23	10.78
26	3.85	4.43	6.58	12.66
27	5.65	3.81	8.77	10.59
28	6.18	5.78	7.88	12.21
29	3.80	6.03	8.05	10.73
30	3.75	4.12	8.85	13.79

IV. Conclusion

According to the obtained experimental results, the following conclusions have been found out.

The results have showed that the relationship of the normal concretes cubes examined in destructive and non-destructive test after the age of 28 days without applying any loads on it has been very close to the equation obtained from other researchers. Concerning the concretes specimens loaded with 60% of the ultimate load, the relationship between the results of the destructive inspection and the non-destructive test after applying 60% of the ultimate load has been different so that the obtained formula gives results for concretes strength less by 20 to 25% from the results of the equation (3) for concretes cubes without loads. The decrease in compressive strength results is due to the fact that the process of applying the load by 60% of the ultimate load corresponds to the actual load present for the concretes parts of the structure during the destructive examination, which works to create macro cracks in the concretes, and since the non-destructive of concretes (UPV Test) depends on the transmission of the ultrasonic pulse in the homogeneous concretes medium (without cracks) it is faster as cracks generated from obstructing the transmission of ultrasonic pulse in concretes, and thus the velocity values will be lower than in unloaded concretes and therefore the resulting equation is more accurate than other ones for previous research. Moreover, the results of non-destructive tests of concretes samples under the influence of imposed loads (60%) have showed to be less by (compressive strength 5 MPa) than the results obtained from testing of unloaded concretes samples through the resulting equation and with comparing them to the equation from previous research. The water absorption results of the specimens under the imposed loads (60%) have been greater than concretes without applied loads. By using the carbonization test, it is clearly noticed that the process of applied loads at 60% of the ultimate loads leads to microscopic cracks in the concretes, and this is obvious through the penetration of carbon dioxide gas to a greater depth. This proves that the concretes are exposed to loads of 60% of the ultimate loads. The results of non-destructive test of concretes are lower than the ones of concretes without imposing loads.

Reference

[1] ACI Committee 228, Nondestructive Test Methods for Evaluation of Concrete in Structures, 2004.

[2] A.M. Neville, " Properties of Concrete," *Longman Group, Ltd.,4th and Final Edition, 2000.*

[3] IAEA: International Atomic Energy Agency, "Guidebook on Non-destructive testing of concrete structures", Vienna, *2002*.

[4] J.H. Bungey, and S.G. Millard, "Testing of Concrete in Structures", Blackie Academic & Professional, an imprint of Chapman & Hall, Third Edition, *1996*.

[5] O. Kroggel, "Ultrasonic examination of crack structures in concrete slabs". Proc. Faults and Repairs 93, Eng. Technics Press, Edinburgh, 3, *1993*.

[6] H.N. Tomsett, "Ultrasonic pulse velocity measurements in the assessment of concrete quality". *Magazine of Concrete Research, 32, No. 110, 1980.*

[7] J.H. Bungey, "The validity of ultrasonic pulse velocity testing of in-place concrete for strength". NDT International, IPC Press, Dec. *1980*.

[8] V.M. Malhotra and N.J. Carino, "Handbook On Non-destructive Testing of Concrete" Boca Raton London New York Washington, D.C, *2003*.

[9] Z.A. Raouf and M. Samurai, "Nondestructive testing of concrete" Edition No. 1, Shariga, *1999*.

[10] H. M. Al-Baghdadi, A. A. Shubbar and Z. S. Al-Khafaji, "The Impact of Rice Husks Ash on Some Mechanical Features of Reactive Powder Concrete with High Sulfate Content in Fine

Aggregate". *International Review of Civil Engineering (IRECE), 12, No. 4, 2021.*

[11] Z. A. Hasan, M. S. Nasr and M. K. Abed, "Combined effect of silica fume, and glass and ceramic waste on properties of high strength mortar reinforced with hybrid fibers". *International Review of Civil Engineering (IRECE), 10, No. 5, 2019.*

[12] Z. A. Hasan, M. K. Abed and M. S. Nasr, "Studying the mechanical properties of mortar containing different waste materials as a partial replacement for aggregate". *International Review of Civil Engineering (IRECE), 10, No. 3, 2019.*

[13] M. S. Nasr, I. M. Ali, A. M. Hussein, A. A. Shubbar, Q. T. Kareem, and A. T. AbdulAmeer, "Utilization of locally produced waste in the production of sustainable mortar," *Case Studies in Construction Materials, vol. 13, p. e00464, 2020.*

[14] A. A. Shubbar, M. Sadique, M. S. Nasr, Z. S. Al-Khafaji, and K. S. Hashim, "The impact of grinding time on properties of cement mortar incorporated high volume waste paper sludge ash," *Karbala International Journal of Modern Science, vol. 6*, no. 4, *2020.*

[15] M. S. Nasr, A. A. Shubbar, Z. A.-A. R. Abed, and M. S. Ibrahim, "Properties of eco-friendly cement mortar contained recycled materials from different sources," *Journal of Building Engineering, p. 101444, 2020*.

[16] M. Vigneshwari, K. Arunachalam, and A. Angayarkanni, "Replacement of silica fume with thermally treated rice husk ash in Reactive Powder Concrete," *Journal of Cleaner Production, vol. 188, pp. 264-277, 2018.*

[17] H. Huang, X. Gao, H. Wang, and H. Ye, "Influence of rice husk ash on strength and permeability of ultra-high performance concrete," *Construction and Building Materials, vol. 149, pp. 621-628, 2017*.

[18] M. S. Nasr, Z. A. Hasan, M. K. Abed, M. K. Dhahir, W. N. Najim, A. A. Shubbar and Z. D. Habeeb, "Utilization of High Volume Fraction of Binary Combinations of Supplementary Cementitious Materials in the Production of Reactive Powder Concrete," *Periodica Polytechnica Civil Engineering, vol. 65*, no. 1, *pp. 335-343, 2021*.

[19] T. Gonen, S. Yazicioglu, and B. Demirel, "influence of freezing-thawing cycles on the capillary water absorption and porosity of concrete with mineral admixture, " *KSCE Journal of Civil Engineering, vol. 19, no. 3, 2015.*

[20] L. C. Wang and S. Li, "Capillary absorption of concrete after mechanical loading, " *Magazine of Concrete Research, vol. 66, no. 8, 2014.*

[21] IQS 45, Iraqi Organization of Standard for Natural Aggregate Resources, 1984.

[22] BS 4408: Part 5, Measurement of the velocity of ultrasonic pulses in concrete , British Standards Institution, 2 Park Street , London W1A 2BS, 1974.

[23] B.S.1881: part 116, Method for Determination of Compre-ssive Strength of Concrete Cubes, British Standard Institution: 1983.

[24] ASTM C1585, Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes, ASTM International, West Conshohocken, PA, USA, 2013.

[25] S. A. Kelham, "A water absorption test for concrete," *Magazine of Concrete Research, vol. 40, no. 143, 1988.*

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