Predicting the Mechanical Features of Cement Mortar Using Destructive and non-Destructive Tests

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Abstract. In this paper a prediction purpose of the mechanical features for cement mortar by using a non-destructive method on cement mortar instead of a destructive method. As well as comparing the different origins of all aspects of cement “manufacturing” between Iraq and Saudi cement. For this purpose, mortar mixture, cubical specimens of 7cm³ sizes were prepared weights used for making one cube of cement mortar are 185g of cement, 555g of standard sand and the percentage of used water is 49% of the weight of the cement determining which one is likely to be the best type from the perspective of tests that have been conducted on both types.

1. Introduction

Cement is a fine and gray substance that has cohesive and adhesive features in the presence of water so that the substance can bind concrete materials together and adhere to reinforcement steel and the rebar. Cement is the essential construction material that is used for cohesion and adherence between the concrete materials in building construction and civil engineering. The initial setting time for the cement should not be less than 45 minutes while the final setting time should not be less than 10 hours [1].

The main components of the raw materials used in the manufacturing of the Cement are Silica Fume, Limestone; Iron ore and other materials (clay materials) [1-3]. The clay provides chemical compounds, including calcium and aluminum silicate. As reported in previous scholarly research most of the concrete properties are influenced by the cement and to some durability properties of cements are determined through cement mortars [4]. Destructive testing, the specimen being only one time on the same samples. Along these lines, many test substrates are required through these kind of tests to acquire a result. While, a nondestructive test can be carried out on the same specimen without any disturbance effect [4-6]. The Ultrasonic inspection Techniques have been applied on concrete since 1940s [4]. The Ultrasonic techniques can be classified as [uniformity, determination of dynamic (pulse) modulus of elasticity, strength estimation, determining hardening characteristics, durability assessment, crack detection, appraisal of the effect of fire exposure, and establishing an acceptance criteria] [4-7].

The main goal of this research was to use the ultrasonic pulse velocity, to investigate the relationship between the UPV of cement mortars and their strength characteristics as evaluated during destructive testing at different ages and to make an attempt to evaluate the effects of different cement types and origins on ultrasonic pulse velocity.
2. Test Strategies

2.1 Destruction Test
It is the test in which the model destruction process happens, so it is used in test models only as shown in Figure 1. No buildings can be tested without making models of the building that is intended to be constructed (Core test).

![Compression strength testing device (Destruction Test)](image)

Figure 1. Compression strength testing device (Destruction Test)

2.2 Non-destructive testing
Are the tests in which the process of testing the models occurs without destroying the models so they can be used after testing. It can be used to test pre-fabricated buildings without destroying it.

2.3 Devices used in non-destructive tests
Ultrasonic Frequency Speed Device: Frequencies that are sent by the device are ultrasonic frequencies which can be heard by humans, such waves are considered as a type of high frequency (It ranges between 100 kilocycle/second - 100 megacycle/second) in which waves emerge from one arm and received by another arm. Then, using these frequencies sent from the arm from the stress waves, the device evaluates the kind of concrete it is. Sending and reading should be impeccably accurate as it is sending frequencies in one direction and there is a measurable indicator for the time that is taken by the frequencies after emerging from one branch of the device, passing through the concrete and receiving it in the other direction of the other branch of the device. Therefore, the velocity of these frequencies can be known as shown in Figure 2.

Hammer test: This kind of testing has worked on the relationship between the steel hammer reaction during the collision with concrete on one side and the compression strength of the concrete on the other side.
Figure 2. Non-destructive testing

2.4 The working modality of the project
Two types of cement were used, the first type is a sulphate salt resistant cement, and the other type is the ordinary cement. These two types are from two different origins and have been used to make comparisons between them.

2.4.1 Casting the specimen
The required quantities for making three (3) cubes of masonry cement, “cement mortar”, have been prepared separately using a ratio of one part cement to three parts sand (1:3) based on weight. Weights used for making one cube of cement mortar are 185g of cement, 555g of standard sand and the percentage of used water is 49% of the weight of the cement.

Mold joints as well as its base contact surfaces are coated with a thin layer of oil to keep water from leaking while shaking the mold. In addition the interior of the mold is coated with a thin layer of oil. Place the mold on the cement mortar vibrator and securely attach it as shown in the Figure 3.

Figure 3. Machine's Control Panel: "Cement Mortar Machine"

Mix cement and dry sand with water on a non-porous surface for 1 minute. Then add and mix the mixture for four minutes. All mixing equipment and tools should be clean and the temperature of the cement, sand and room should be within 20 ± 2 º. The mixture directly placed in the mold and then leave it for 2 minutes on the cement mortar vibrator. Remove the mold from the cement mortar vibrator and place it in a humid atmosphere of at least 90%, while covering the surface of the mold with a non-porous sheet such as a canvas that is hydrated with water or polythene to prevent the evaporation of water. It should be left for 24 hours. The cubes will be removed from the mold after 24 hours and mark them, immersing process with clean water at a temperature of 20 ± 2 º will be applied to them and leave them for the specified period of (3-7 days) see Figure 4.
2.5 Testing method (Non-destructive)
Remove the cubes from the water at the examination time. Wipe excess water from the surface and remove any superficial surface to make the surface flat, so that it does not give a variable reading. Immediately examine the three saturated and dry surface cubes in order to set the pressure strength after three days. Then examine three other cubes under the same conditions after 7 days, provided that it is calculated from the end of the molding process.

Figure 5 illustrates the testing molds using non-destructive methods with an ultrasonic velocity measuring instrument, where the sides of the mold are obliterated on both sides while putting the frequency sender and receivers on opposite sides, ensures that the wet mold does not affect the examination process. The less time these frequencies take for a given distance, the better this mold is, which means that this model is faster and more intense than others.

It should be put on one side of the scanner, the non-smooth face should not be used for the mold's faces. Also, do not use anything on the cube sides except for steel sheets. One of the surfaces of the scanner should be placed on a ball rest to adjust the endurance process.

Table 1 presents the mean compressive strength of cubic specimens at 3, and 7 days. As expected, the compressive strengths generally increases with increasing testing age.
Table 1. Calculations and practical results of non-destructive tests

| Cement type            | Origin          | Test Age (days) | Wave Round Trip Time | Compressive Strength (MPa) |
|------------------------|-----------------|-----------------|-----------------------|---------------------------|
| Ordinary cement        | Iraqi Sulaymaniyah | 3               | 17.5                  | 13.9                      |
|                        | Saudi Eastern Province | 7               | 16.9                  | 16                        |
|                        |                  | 3               | 17.3                  | 14                        |
|                        |                  | 7               | 16.7                  | 17.5                      |
| Resistant to sulphat salts | Iraqi Sulaymaniyah | 3               | 18.3                  | 10                        |
|                        | Saudi Eastern Province | 7               | 17.80                 | 11.6                      |
|                        |                  | 3               | 18                    | 10.9                      |
|                        |                  | 7               | 17.95                 | 11.2                      |

2.6 Testing method (Destructive)
The compressive strength of 7-cm cubical specimens were determined at 3, 7 days of mortar age using a universal testing machine. The test procedure for cubic specimens were in accordance with ASTM C109/C. The calculated results are shown Figure 6 and Table 2.

Table 2. Calculations and practical results of destructive tests:

| Cement type            | Origin          | Test Age (days) | Compressive Strength (MPa) |
|------------------------|-----------------|-----------------|---------------------------|
| Ordinary cement        | Iraqi Sulaymaniyah | 3               | 14.06                     |
|                        | Saudi Eastern Province | 7               | 16.6                      |
| Ordinary cement        | Saudi Eastern Province | 3               | 14.3                      |
|                        |                  | 7               | 17                        |
| Resistant to sulphat salts | Iraqi Sulaymaniyah | 3               | 10                        |
|                        | Saudi Eastern Province | 7               | 12                        |
|                        |                  | 3               | 10.3                      |
|                        |                  | 7               | 11.6                      |

Figure 6. Testing specimen (Destructive method)

2.7 Cement Softness Tests
Both resistant and ordinary cement types showed the same results, as the water drop time was 65 seconds; this indicates that softness criterion appears to be similar in both types.

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\text{Softness criterion} = \frac{\sqrt{\text{time}}}{\sqrt{92}} \times 377
\] (1)
Softness criterion = 377 * $\sqrt{\frac{65}{92}}$

= 316.887 m²/kg

Figure 7. Fineness of Cement-Balanced with an accuracy of 0.001g

3. Conclusions
Testing results have shown that both cement types from different origins are similar, as the differences between them are small. However, the most significant point in the test is whether it is possible to use a non-destructive test rather than a destructive one. It has been noted that the results of non-destructive tests gave the same results or were similar to the results of destructive tests as shown in the non-destructive test table, meaning that a non-destructive examination can be used instead of a destructive examination. This research may provide an opportunity for the next generation to re-examine the process. However, several mixtures of cement mortar should be made with different percentages of water ratio to obtain a working scale for the study to get a special cement mortar curve from non-destructive tests. It was also observed that there is a linear relationship between the compressive strength and the non-destructive test, as the age of mortar increases. It is highly recommended to determine the properties of cement mortars under the effect of specimen dimensions.

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