Analysis the Effect of Moisture

by Civil Engineering Department Mataram University

Analysis the Effect of Moisture Content of Normal Concrete Using Hammer Test

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Abstract. The Hammer test as one of non-destructive concrete strength test should in a non-moist structural condition to produce a high accuracy reading. Since, the strength is only taken from the concrete surface which can be affected by moisture and does not represent the overall properties of the concrete samples. For this reason, hammer test is necessary to compare between the destructive test using a Compression Testing Machine (CTM) a standard concrete strength test and Hammer test. This research used normal concrete with the concrete strength target of 20 MPa, with variations in moisture measured at 0 day, 1 day, 2 days, 3 days, 4 days, 5 days, 6 days, 9 days 14 days and 21 days after removal from curing chamber, as well as the dried samples with 2 days oven to obtain low moisture. The concrete strength test includes compressive and split tensile strength using a cube sample with 15 cm size. The result shows that the compressive strength value of the Hammer test is lower than the CTM test of 12.34 MPa at 40% moisture, and the difference is higher as the moisture of the concrete surface increases. At various moisture content, the ratio of split tensile strength towards the compressive strength ranges 9.94% - 13.65%.

INTRODUCTION

As a building material, concrete is good at withstanding compressive stress, but it is weak in withstanding tensile stress [1]. Although the tensile strength of concrete is low, it is very important for in-depth analysis and to determine the magnitude of cracks that occur in the concrete. Therefore, testing the concrete strength, both compressive and tensile, really needs to be done after the concrete has hardened, and this is useful to determine whether the structure is following the planned design or not.

The concrete strength depends on many factors, including the proportion of the mixture that forms it, temperature, and moisture [2]. The concrete strength in moist conditions needs to be tested as an initial effort in planning the structure to be built and evaluating the existing one. According to [3], concrete structures are often under varying conditions of moisture, which have a significant impact on the results elastic modulus of concrete.

One of the most widely used concrete strength testing includes hammer test and destructive methods [4]. The destructive test is destroying the object, where the object is pressed until it breaks using Compression Testing Machine (CTM), and the actual quality strength of the concrete is obtained. However, in some cases, the CTM is seen as less practical because it must be done in the laboratory so it is considered to use hammer test.

The non-destructive test that is often implemented in the construction world is the Hammer test. According to Sulistya [5], the Hammer test is ideally used in non-moist structural conditions so that the resulting reading has a high accuracy degree compared to the moist conditions. The strength of concrete is reduced the most, and its structure is known for the more developed interface between crystal grains and phase boundaries and the universality of nano

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pores in its structure [6]. The tensile strength of ultra-high performance concrete is of decisive importance for certain applications in machine tool manufacturing or textile concrete [7].

The Hammer test as one of non-destructive concrete strength test should in a non-moist structural condition to produce a high accuracy reading. Since, the strength is only taken from the concrete surface which can be affected by moisture and does not represent the overall properties of the concrete samples. For this reason, hammer test is necessary to compare between the destructive test using a Compression Testing Machine (CTM) a standard concrete strength testing tool. You need to state here what the actually purpose of your study.

THEORETICAL FRAMEWORK

In their research, according to [8] concluded that temperature and moisture have a major role in influencing the concrete properties. Higher temperatures and a higher degree of saturation will result in lower strength of concrete in compression, stress, and modulus of elasticity. Research on the non-destructive test using the Hammer test, and compression test, aims to obtain a correlation equation with various concrete parameters such as aggregate, cement, and others has been conducted [9].

The nondestructive test can be applied to both old and newly constructed structures. For newly constructed structures, the main application tends to be quality control or the resolution of doubts about the quality of materials or construction. Testing the existing structures is usually associated with structural strength assessment according to Agency, IAE. 2002 [10].

Destructive Test

The object is tested for its strength until crushed for mechanical properties. The concrete must be designed in mixed proportions to produce the required average compressive strength construction (*f'c*). At the construction implementation stage, the concrete for which the mixture has been designed must be produced in such a way to minimize the frequency of the concrete having compressive strength lower than *f'c* as required as shown in Eq (1).

$$f'c = \frac{P}{A} \tag{1}$$

Where,

f'c = Compressive strength (MPa)
P = Maximum load (N)
A = Compressed area (mm2)

Hammer Test

The non-destructive test is more practical and more effective because it can be done directly in the field without having to bring the test object to the laboratory [11].

According to [12], In civil engineering, the most commonly used non-destructive test is the Hammer test. Hammer test is a tool for checking the quality of concrete without damaging the concrete itself. It is very sensitive to the conditions on the surface and variations in the hardness of the concrete surface

Split Tensile Strength

According to Neville [13], a concrete cube can be tested for its split tensile strength using the Equation (2). Where ɑ is the side of the cube which is the center of resistance to the load.

$$\sigma t = \frac{2P}{\pi a^2} \tag{2}$$

With,
σt = concrete cube split tensile strength
P = maximum load
α = side length of the cube

Moisture

Concrete moisture is the free moisture content in the concrete pores which can evaporate anytime. The changes in moisture cause the concrete to become wet or dry along with changes in the water content on the concrete surface which can affect its mechanical properties [14].

RESEARCH METHODS

This research used normal concrete with the concrete strength target of 20 MPa [15]. The specimens consist of 66 concrete cubes measuring 15 cm x 15 cm x 15 cm with an age of 28 days. The Hammer test is based on the standards [16, 17]. The concrete compressive strength test is carried out based on Indonesian Standard [18] and the splitting tensile strength test is based on British Standard [19], concerning method for determination of splitting tensile strength, wherein the split tensile strength test of the concrete cube, the cube is loaded continuously without any jerking with a constant loading speed at the midpoint of the surface of the concrete cube.

RESULTS AND DISCUSSION

Results of Concrete Moisture Test

Figure 1 shows that the longer the lifting process in the concrete, the lower the percentage of moisture in normal concrete. From day 0 to 1 day of the removal, there is a significant decrease in the percentage of moisture (from 80.52% to 70.89%), and on day 3 to 21, there is a low decrease in moisture.

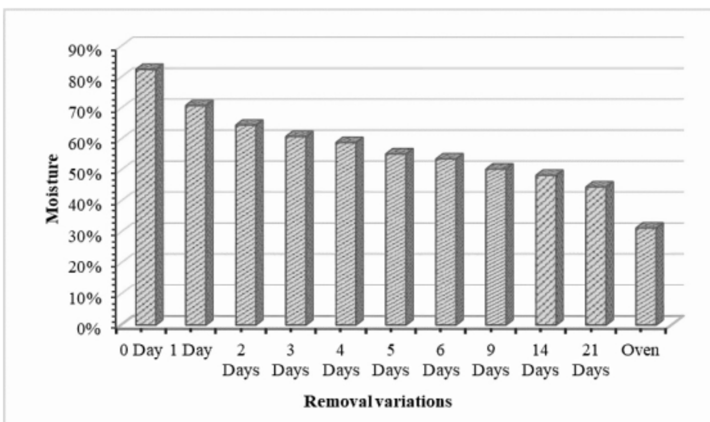

FIGURE 1. Results of concrete moisture test

Relationship between Hammer Test and CTM

The increase in the percentage of moisture results in a reduction of the value of the compressive strength at the age of 28 days, both the compressive strength of the concrete tested using the Hammer test and CTM. Figure 2 describes the relationship between the Hammer test and CTM with 11 moisture variations from day 0, 1, 2, 3, 4, 5, 6, 9, 14, and 21 after removal from curing chamber as well as one variation of the specimen after being dried for two days to get the lowest moisture percentage.

Figure 2 Relationship between the compressive strength of CTM and Hammer test. It shows the difference between the Hammer compressive strength test and CTM at the age of 28 days from day 0 to 21 along with the testing on dry concrete conditions.

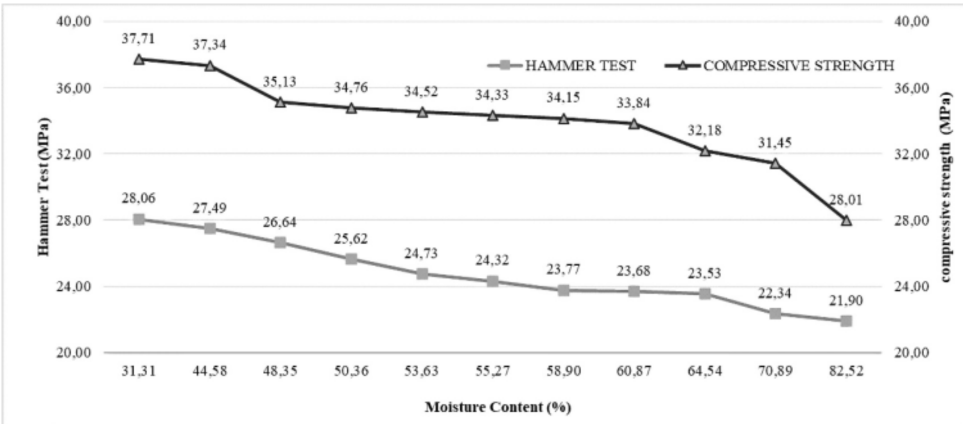

FIGURE 2. Relationship between the hammer test and CTM

Relationship between the Compressive Strength of Hammer Test and CTM

The difference between Hammer and CTM compressive strength test at 28 days from day 0 to 21 of the testing along with the testing on the dried concrete conditions can be seen in Table 1.

TABLE 1. Difference between compressive strength of Hammer test with CTM

Moisture Content %	Compressive strength Hammer Test (f'ch) MPa	Compressive strength CTM (f'c) MPa	Deviation MPa
A	B	C	C-B
40	24.76	37.10	12.34
50	22.58	35.19	12.61
60	20.41	33.27	12.86
70	18.23	31.36	13.13
80	16.05	29.44	13.39

The increase in the percentage of moisture in the Hammer test and CTM results in an increase in the difference in compressive strength obtained. In Table 1, at 40% moisture content, the Hammer test value is lower than CTM of

12.34 MPa, and the difference will also increase along with the increasing percentage of moisture on the concrete surface.

From Table 2 shows the relationship between splitting tensile strength value for each variation of moisture. This table indicated that the splitting tensile strength value at 82.52% moisture, there is a decrease in the surface dry control factor (31.31%), and the average split tensile strength is not significant against the influence of moisture.

The split tensile strength ratio values from 9.94% - 13.65% to the compressive strength of the concrete due to the influence of moisture variations.

TABLE 2. Comparison between split tensile strength with compressive strength of CTM test

Moisture Variation	Compressive Strength (*f'c*) MPa	Split Tensile Strength (*ft*) MPa	Comparison *ft* with *f'c* %
31.31%	37.71	3.96	10.51
44.58%	37.34	3.73	9.98
48.80%	35.13	3.49	9.94
50.36%	34.76	3.58	10.29
53.63%	34.52	3.54	10.25
55.27%	34.33	3.52	10.25
58.90%	34.15	3.50	10.25
60.87%	33.84	3.49	10.32
64.54%	32.18	3.59	11.14
70.89%	31.45	3.68	11.70
82.52%	28.01	3.82	13.65

CONCLUSION

From the results of the research, some conclusions can be drawn as follows:

1. The compressive strength value of the Hammer test is lower than the Compression Testing Machine of 12.34 MPa at 40% moisture, and the difference is getting higher as the moisture of the concrete surface increases.
2. At each increase in the proportion of moisture by 10%, there is a decrease in compressive strength of 8.79% for the compressive strength of the Hammer test, and 5.16% for the compressive strength of the Compression Testing Machine. Based on these two decreases, because CTM is a compressive strength test that reviews the actual state of the overall properties of the concrete, so the effect of decreasing compressive strength due to the moisture level observes the decrease that occurs in the CTM test results.
3. At various moisture variations, the ratio of split tensile to the compressive strength ranges from 9.94% - 13.65%.

REFERENCES

1. Guang,L., "The Effect Of Moisture Content On The Tensile Strength Properties Of Concrete", A Thesis of Master Engineering from The University Of Florida, (2004)
2. S. Hannachi and M.N. Guetteche, "*Application of the Combined Method for Evaluating the Compressive Strength of Concrete on Site* Open Journal of Civil Engineering, 2 (1), pp. 16-21, (2012).
3. G. Zhang, C. Li, H. Wei, M. Wang, Z. Yang and Y. Gu, "*Influence of Humidity on the Elastic Modulus and Axis Compressive Strength of Concrete in a Water Environment"*, Materials, 13 (24): 5696, pp. 1-14, (2020).

4. A. Brencich, G. Cassini, D. Pera, and G. Riotto, "Calibration and reliability of the rebound (Schmidt) hammer test," CivilEngineering and Architecture, vol. 1, no. 3, pp. 66–78, (2013).
5. S. Sulistya, *Procedure for Hammer Testing and Ultrasonic Pulse Velocity,* Civil Engineering Department, Bandung Polytechnic, (2014).
6. G. Slavcheva and A.T. Bekker, "*Temperature and Humidity Dependence on Strength of High Performance Concrete*", Solid State Phenomena, 265, pp. 524-528, (2017).
7. M. Kalthoff, M. Raupach and T. Matschei, "*Influence of High Temperature Curing and Surface Humidity on the Tensile Strength of UHPC*", Materials, 14 (15): 4260, pp. 1-31, (2021).
8. S.N. Shoukry, G.W. William, B. Downie and M.Y. Riad, "*Effect of Moisture and Temperature on the Mechanical Properties of Concrete*", Construction and Building Materials, 25, pp. 688-696, (2011).
9. M. Mahmoudipour,"*Statistical Case Study on Schmidt Hammer, Ultrasonic and Core Compression Strength Test Results Performed on Cores Obtained from Behbahan Cement Factory in Iran",* 5th International Workshop of NDT Experts, (2009).
10. Agency, IAE, "*Guidebook On Non-Destructive testing Of Concrete Structures Training Course Series* ",No.17. Australia: Industrial Aplication and Chemistry Section, (2002)
11. Boundy C. A. P, Hondros G.,"*Rapid field assessment of strength of concrete by accelerated curing and Schmidt rebound hammer*", Journal of the American Concrete Institute, January 1964, pp. 77-83, (1964)
12. A. Brencich, R. Bovolenta, V. Ghiggi, D. Pera and P. Redaelli, " *Rebound Hammer Test, An Investigation into Its Reliability in Applications on Concrete Structures*" University of Genoa, Genoa 16145 Italy, (2020)
13. A.M. Neville, "*Properties of Concrete, Fourth and Final Edition*", Prentice Hall, (1999).
14. X. Chen, W. Huang and J. Zhou, "*Effect of Moisture Content on Compressive and Split Tensile Strength Concrete"*, Indian Journal of Engineering & Materials Sciences, 19, pp. 427-435, (2012).
15. ACI Committee 228, "*In Place Methods to Estimate Concrete Strength*", American Concrete Institute", (1998)
16. ASTM C 805, "*Standard Test Method for Rebound Number of Hardened Concrete",* ASTM International, West Conshohocken, PA, (2018)
17. SNI 03 – 4430-1997, "*Testing of Concrete Structural Elements using Concrete Hammer Type N and NR*", Indonesian National Standard Agency, (1997)
18. European Union, EN 12504-2: "*Testing of Concrete in Structures – Part 2: Non-destructive Testing - Determination of Rebound Number"*, European Union, Brussels, Belgium, (2012)
19. British Standard, "*Testing Concrete Part 117 Method for Determination of Tensile Splitting Strength",* Amendment No.1, (1989)

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