The Study of Concrete Mixture Performance to Support the Non-Destructive Testing Evaluation

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Abstract. An experimental program is conducted which three type of concrete mixtures are made to express the different in quality of concrete. Each type of concrete mixture will be consisting of two type of specimens, i.e., Ø100mm x 200mm in height and Ø150mm x 300mm in height. Each set will be 30 specimens, so the total specimens are 180. All the specimens will be tested in the standard age of 28 days. All of them will be tested as follow: (1) Rebound hammer test, (2) ultrasonic pulse velocity, and (3) compressive test. The Ø100mm test specimens having correlation ranged from 90% to 95% against Ø150mm test specimens. The rebound number of Schmidt hammer test having good correlation to the compression strength since it has the $R^2$ of 0.8259, so that the regression value to be 0.9088. The ultrasonic pulse velocity reading also having good correlation to the compression strength since it has the $R^2$ of 0.8006, so that the regression value to be 0.8946. The combine between rebound number, ultrasonic pulse velocity against the compression strength, after being normalize and analyse using nonlinear dynamic regression, having the good correlation since it has the $R^2$ of 0.9843 and so that the regression value to be 0.9921. The chart produced from the nonlinear dynamic regression can be used directly to predict the concrete compression strength from the rebound number and the reading of ultrasonic pulse velocity.

1. Introduction

Concrete (reinforced concrete) is still one of the selected materials for construction purposes. Concrete is ubiquitous in modern construction and has earned this position through characteristics that no other construction material possesses.

Concrete and the materials we used in combination with it are no exception. One of the main factors in the evolution of construction technologies has been driven by the need to use materials that are capable of lasting for long periods of time – that are durable. This is one of the reasons for concrete’s success – it is a strong and largely chemically inert material that can potentially last for centuries. However, the relative immaturity of concrete construction as a technology has meant that much of the concrete building stock has experienced unexpected problems with inadequate durability performance within the design service life. Moreover, there has been a growing trend among governments and the operators of structures to extend the service life of structures for economic and practical reasons: The emergence of unexpected durability problems has meant that the last few decades have been a learning process for engineers involved in concrete construction: it has been estimated that the annual cost of repair of concrete structures in Europe is more than $20 billion[1].

Stresses on a structure can take many forms: sustained or intermittent, cyclic, or random in nature. Stresses are significant from a durability perspective because they lead to cracking, whether caused by
overload of a structural element, creep under sustained loading (which leads to the formation of micro cracks) or fatigue under cyclic loading. These cracks offer a route for harmful substances to make their way into the interior of concrete with relative ease. This aspect of concrete deterioration is not addressed in detail here (except for cracking resulting from volume change). However, the influence of cracking on the ingress of water and gases, and the impact on durability, is addressed[2].

To address the quality of concrete (in the term of durability), ones must assure that the hardened concrete is in the manner as it is designed. To achieve this goal, it can be obtained many ways, but they can be grouped into destructive testing and non-destructive testing. When we do test on the lab, the destructive testing is one selected method since it gives many useful information. But, if we deal with the existing construction or even newly built construction, sometimes we cannot just do the destructive testing because of several reason. In that situation, the non-destructive testing take place besides the destructive testing. One must aware that the use of non-destructive testing not instantly replace the destructive method. The use of non-destructive testing is just one method to investigate the quality of concrete, but it still needs the support from destructive testing. So that, the support of adequate laboratory data obtained from destructive testing is a mandatory for non-destructive testing. This is the goal of this research, so that the use of destructive and non-destructive testing to investigate the quality of concrete can be more superior[3–5].

2. Methodology
This is an experimental research, which mean all the specimens must be test in accordance with specific standard and regulation. Three kind of test were conducted, namely (1) ultrasonic pulse velocity test, (2) Schmidt hammer test, and (3) compression test. Data from the test must be carefully gathered, selected, and analysed to give appropriate result. Statistical approach is commonly used to analyse the data, and if there are data need to be extracted, it must be selected with statistical approach as well. The well-known procedure of Chauvenet’s Criterion[6–8] is used to handle this situation.

![Figure 1. The research workflow](image-url)
3. Result and Discussion
The cement used on this research having specific gravity of 3.06 which is lower than the range of common Portland cement characteristics of 3.15 (in common). The fineness modulus of the cement is 0.97. The fineness of cement affects hydration rate, and in turn, the strength. Increasing fineness causes an increased rate of hydration, high strength, and high heat generation. Bleeding can be reduced by increasing fineness. However, increased fineness can also lead to the requirement of more water for workability, resulting in a higher possibility of dry shrinkage. The increased surface area-to-volume ratio will ensure a more available area for water-cement interaction per unit volume.

The fine aggregate used on this research with the water content of saturated and surface dry of 1.35%. The level of fine aggregate impurities has found to be 3.10%, less than maximum permitted of 5%. The fine aggregate has the density of 1.68 gr/cm³ and the fineness modulus of 2.72 which is at the range of fine aggregate. ASTM C 33 requires the FM of fine aggregate to be between 2.3 and 3.1. The higher the FM, the coarser the aggregate. Fine aggregate affects many concrete properties, including workability and finish-ability. Usually, a lower FM results in more paste, making concrete easier to finish. For the high cement contents used in the production of high-strength concrete, coarse sand with an FM around 3.0 produces concrete with the best workability and highest compressive strength.

The coarse aggregate used on this research have the water content of saturated and surface dry of 3.20%. The coarse aggregate has the density of 1.41 gr/cm³ and the abrasion level using Los Angeles test having 45.38%. The compressive test for each low, mid, and high strength concrete for both Ø100mm and Ø150mm specimens as follows:

![Figure 2. All Type Concrete Quality of 3" Specimens Against 6" Specimens](image-url)

It can be seen than all the specimens having approximately identical slope between 6” specimens against 3” specimens, in the value approximately 90% to 95%. It means that if somehow, we have a field specimen taken from the core drill about the same diameter of 3” and the ratio of height and diameter about 2:1, and then have compressive test on it, so that the specimens will have 90 to 95% the same compressive strength if we use the specimens of 6”. This value is approximately close to the ACI requirement if we want to use small specimen to represent the compressive strength of the concrete.

For all concrete specimens from all quality, the chart shows the correlation between the rebound number against the compressive strength. The exponent-type curve fitting was chosen since it possesses the closest to the data and give the higher regression value of R² of 0.8259 and give the value of R of 0.9088.
For all concrete specimens from all quality, the chart shows the correlation between ultrasonic pulse velocity reading against the compressive strength. The exponent-type curve fitting was chosen since it possesses the closest to the data and give the higher regression value of $R^2$ of 0.8006, and so the value of $R$ of 0.8946.

**Figure 4.** UPV vs Compression Test

The measurement of non-destructive testing will be more complete when three aspects (the rebound number, the UPV reading, and compressive strength) are combined to be one. For that, a particular chart a produce to help the investigator easily examine and predict the compressive strength of the concrete. On this research, after all the data have been normalize, the combination of those aspects can be given in the form of chart as follow:
The result from the original graph to the fitted one giving the $R^2$ value of 0.9843 with R value of 0.9921. From the last graph, the investigator then can easily predict the compressive strength of the concrete from the rebound number and UPV reading.

4. Conclusions
The $\varnothing$100mm test specimens having correlation ranged from 90% to 95% against $\varnothing$150mm test specimens. It means that if we have small specimens with $\varnothing$100mm, with the height to diameter equal 2:1, we can conclude that the specimens will have 90% to 95% compressive strength if it was $\varnothing$150mm test specimens. The above founding is in line with the ACI standard, which allows to use the small specimens if it is not possible to gain the large specimens.

The rebound number of Schmidt hammer test having good correlation to the compression strength since it has the $R^2$ of 0.8259, so that the regression value to be 0.9088. It can be used to directly correlate between the rebound number and the predicted compression strength. The ultrasonic pulse velocity reading also having good correlation to the compression strength since it has the $R^2$ of 0.8006, so that the regression value to be 0.8946, which is slightly the same to the rebound number. It is also can be used to direct correlate between the ultrasonic pulse velocity reading and the predicted compression strength.

The combine between rebound number, ultrasonic pulse velocity against the compression strength, after being normalize and analyse using nonlinear dynamic regression, having the good correlation since it has the $R^2$ of 0.9843 and so that the regression value to be 0.9921. The chart produced from the nonlinear dynamic regression can be used directly to predict the concrete compression strength from the rebound number and the reading of ultrasonic pulse velocity.

5. References
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