Interradiations between Young’s modulus, compressive strength, Poisson’s ratio, and time for early age concrete

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Abstract

Regular strength concrete specimens were tested for Young’s modulus (E), Poisson’s ratio (ν), and compressive strength (f’c) during the first 25 days of curing. The purpose of this testing included a refined version of the existing ACI relationship between Young’s modulus and compressive strength that is specified to the batch of concrete used. Likewise specific to the batch, a time-independent Poisson’s ratio of 0.186 was found. Further results include relationships between compressive strength and time as well as between Young’s modulus and time.

Introduction

An emerging technique of early age strength monitoring involves the use of high frequency resonant oscillations of piezoceramics to determine Young’s modulus, and from it, early age compressive strength. Such a method is the focus of Thomas TK’s Kallache 2006’s senior design project. In correlation with TK’s work, this project refines existing values and relationships of material properties vital to relating piezoceramic signals to Young’s modulus, and compressive strength. The two most important such relationships are the relation between Poisson’s ratio, typically around 0.2, and time and stress in the equation to prevent the wrong to Young’s modulus and the relation between Young’s modulus and compressive strength based on the following ACI equation: E = 57,000(f’c)^0.5

Results

The experimental values for Young’s modulus, Poisson’s ratio, and compressive strength were averaged for the two cylinders tested on the same day. This averaging created 12 data points, one for each testing day. Figures 5-9 represent the calculation of such after material relationships from this data set.

Conclusions

The aforementioned results will not meet the two major goals of this project: to refine the existing ACI relationship between Young’s modulus and compressive strength to more accurately represent the specific batch used for TK’s piezoelectric experiments and to determine the Poisson’s ratio vs. time relationship for the same batch of concrete.

The 186 result for Poisson’s ratio fell right into the expected region around 0.2, and the experimental Young’s modulus compressive strength relationship of E=57,000(f’c)^0.5 closely followed the theoretical value of E=57,000(f’c)^0.5. This slighter larger constant multiplier for the experimental result is a product of the test cylinder’s consistently breaking below expected compressive strength. There are several reasons this could have occurred. It could have been made using a cement instead of mix ratio. The mix ratio is particularly pliable for the quality of the mix in the wet phase. Even if the cement was mixed properly, there likely might factor inside the casting process such as inefficient mixing. Another factor hindering itself to the load failure was uneven top and bottom surfaces of the test cylinders. Several better concrete cylinders during the Young’s modulus test before the problem was solved by sanding.

Additional errors also contributed to the loss of this optimal fit to the compressive strength vs. age and Young’s modulus vs. age graph. Test days 9, 23, and 25 had particularly strong concrete, while days 11-19 had particularly weak concrete. This may be due to the inconsistent distribution of aggregates between the cylinders. Because the cylinders are so small there are more susceptible to such inconsistencies having a noticeable impact. Other possible errors include inconsistencies and casting, especially when TK was in Spain.

In all, this project was successful in refining two relationships, which help a fellow student. More important and worthwhile was the project use as a learning experience about the basics of concrete and exposure to E691 level research.

Procedure

The experimental protocol involved sixteen days of testing, spanning 25 days. Forty concrete cylinders were cast using the procedure outlined in ASTM C192: 34 “Wax by inch” cylinders for elastic modulus, Poisson’s ratio, and destructive compressive testing. 1 “wax by twelve” cylinder filled with the piezoceramic, matching system, and 6 regular cylinders for back-up. For the first seven days, two regular cylinders were tested each day using ASTM C490, and ASTM C1231 to determine the elastic modulus and Poisson’s ratio (test setup shown in Figure 3) as well as the compressive strength of the concrete mix chosen in Figure 2. For the next 21 days, three cylinders were tested roughly every other day.

Selected References

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For further information

Please contact Ryan P. Carmichael. More information on this and related projects can be obtained at http://www.swarthmore.edu/carmichael/RyanP/Courses.html.

Figure 1: Test setup for determining Young’s modulus and Poisson’s Ratio.
Figure 2: Test setup for determining compressive strength.
Figure 3: Determination of the batch-specialized relationship between Young’s modulus and Poisson’s ratio.
Figure 4: Determination of the batch-specialized relationship between Poisson’s ratio and time.
Figure 5: Determination of the batch-specialized relationship between compressive strength vs. age.
Figure 6: Determination of the batch-specialized relationship between Young’s modulus and time.
Figure 7: Determination of the batch-specialized relationship between Poisson’s ratio and time.