The Impact of Limestone and Plastic Additives on Concrete

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The proposed experiment will compare the compressive and tensile strength properties of mixes with varying proportions of limestone, plastic fibers and concrete. The specific materials to be implemented throughout this research are Portland Cement Type I/II, 3.5 MPa Limestone, and Re-Bind Concrete Binding Fibers. Materials characterization testing includes Fourier-transform infrared spectroscopy (FTIR), Laser Diffraction particle size analyzer (Shimadzu SALD 2300), and Energy Dispersive X-Ray Fluorescence Spectrometer (EDX-7000). Physical performance testing includes Compression Testing (ASTM C39), Splitting Tensile Strength Testing (ASTM C496), and Slump Testing (ASTM C143). Two different molds are used for physical testing including 3x6 in plastic cylinders and 2x2 in stainless steel cubes.

The experiments will be conducted in a concrete lab with instruction from certified lab technicians. The instruments used in this study consist of a few different categories that include material characterization, concrete mix design, and physical performance testing.

The *Nanoparticle Analyzer and X-ray Fluorescence (XRF)* are two other material characterization tests that use non-destructive analytical techniques to determine the elemental composition of materials. XRF analyzers determine the chemistry of a sample by measuring the fluorescent (or secondary) X-ray emitted from a sample when it is excited by a primary X-ray source. A third instrument used within material characterization is the *Fourier-transform infrared spectroscopy (FTIR)*, an analytical technique that identifies organic, polymeric, and inorganic materials by using infrared light. These different techniques were all chosen because of the availability in the civil engineering research lab. It was hoped that a *Scanning Electron Microscope (SEM)* would be used to examine a cured sample of the mixed concrete under an intense microscope. *SEM* operates by scanning an electron beam over a given surface in order to create a magnified picture. This technique was chosen since there is an *SEM* present in the mechanical engineering department. However, the mechanical engineering lab technician reported that the equipment was broken and would not be repaired for the remaining of the 2019-2020 academic year.

A concrete mix design test includes the *Slump Test* (ASTM C143), which checks the workability of a freshly made concrete mixture. This simple procedure will be helpful in understanding how the plastic fibers affect a mix design when compared with the control group. This test is also widely known and practiced throughout the industry and comes with specific timelines that dictate the concrete's usefulness. Physical testing includes the *Compression Testing (ASTM C390),* which measures the concrete's strength in its hardened state after the sample is prepared and cured for a set period of time in a water bath. Compressive strength is concrete's most defining property and comparing the compressive strengths to a control sample is indicative of the mixture's integrity. Another physical test includes the *Splitting Tensile Strength Testing (ASTM C496)*, which measures the concrete's tensile strength in its hardened state after the sample is prepared and cured for a set period of time in a water bath. Hardened concrete fails under tensile loads, the *Split Tensile Strength Test* provides information about how a concrete mixture will behave when flexural stress is applied from indirect tensile stress. Due to difficulty in applying uniaxial tension to a concrete sample, this is an indirect method of determining the tensile strength of concrete.

Before dry-batching the materials and preparing the concrete, a mix design schedule was created. Because of the labor and materials capabilities of the civil engineering department and research team, only 2 different mix designs should be completed in any given work session. Even though only a few of the mix designs were completed, the anticipated proportions are as follows:

- 100% cement/sand
- 99.5% cement/sand, 0.5% plastic
- 100% limestone
- 99.5% limestone, 0.5% plastic
- 74.75% cement/sand, 24.75% limestone, 0.5% plastic
- 49.75% cement/sand, 49.75% limestone, 0.5% plastic
- 24.75% cement/sand, 74.75% limestone, 0.5% plastic

With these 7 different mix designs, 3 cylinders were required for any one type of testing for any given time period. It was decided that for compression testing, 3 sets (1, 7, 28 days) would be used and for tensile testing, 1 set (28 days) would be used. Ultimately, this worked out to require 12 cylinders worth of testing for any 1 given mix design.

When carrying out this experiment, the procedure involved includes dry-batching materials while using a large kitchen mixer to mix the portland cement, sand, limestone, and water. It should be noted that the order in which materials are added makes a significant difference, since the cement-water combination acts as a binding and hydrating reaction. When mixing, the cement should be added, followed by the water. After these two materials mix for 1 minute, then the sand should be added in ⅓ proportions and 30 second intervals. After all of the sand is added, if the mixture contains limestone, it should be added in ⅓ proportions in 30 second intervals. After all of the materials are added, the large kitchen mixer should continue for 2 minutes to ensure a uniform and homogeneous mixture. If plastic is being included, the mixture should be removed from the kitchen mixer, transferred to a smaller steel bowl, and hand mixed in with a spatula for 2 minutes until the mixture is uniform. Make certain to clean the kitchen mixer spatula and bowl in between batches to guarantee that no materials are left behind, as additional dry and/or wet materials can drastically change a mix's properties.

After the concrete was mixed with the desired materials, 3 x 6 concrete cylinders molds and 2 x 2 steel square molds were poured for testing. These molds were greased with form oil spread onto a paper towel before any concrete was poured into them. ASTM C31 is followed for making concrete cylinders, where concrete is added in ⅓ amounts, rodded 25 times throughout the cylinder, and pounded with a closed fist 4 times on each the north, south, east, and west direction. When filling the cylinder with the last ⅓, the concrete should bubble over the top, and be rolled off cleanly with the rod after undergoing rodding and pounding. For the purposes of this experiment, all of the completed cylinders were subject to 1 minute on the vibrating table to ensure that air bubbles were removed. Cylinders were then wiped down and marked. It is important to mark the cylinders with their proper date of creating and mix design number, as it can be easy to confuse cylinders at later dates.

After the concrete cylinders air dried for 1 day, they were de-moulded and placed in curing buckets with cold water. Both the cylinders and the curing buckets should be re-labeled with the concrete mix design and date of creation information. Curing is done to enhance the hydration process that concrete undergoes to achieve desired strength. Water curing prevents the moisture loss from the sample by providing a constant source of moisture. Curing also reduces cracks, increases abrasion resistance, and improves microstructure. 1, 7 and 28 day compressive and 28 day split tensile strength tests will be completed. With the hopes of eliminating some degree of error, 3 molds were used for one type of testing.

It is also predicted that the addition of limestone will increase the physical strength of the concrete in the early stages of curing. It is also predicted that because plastic is added in such a small amount, the results between the plastic mix and the control mix will be similar. The tensile strength of the concrete mix is expected to improve due to the addition of the plastic fibers. The quantifiable results from the slump, compression, and split tensile tests will allow for comparison.

Next Steps:

Future testing should consider additional material characterization instruments available in the Wentworth laboratory. *Gas Chromatography-Mass Spectrometry (GC-MS)* is used for its ability to understand complex mixtures and trace organic contamination. The GC-MS can analyze the dry concrete mixture and the resulting mixed concrete sample (Tomoto, Moritoshi 2008). Other future testing can also experiment with material proportions, such as using higher or lower values for the plastic fibers than the proposed 0.5%. Utilizing other SCM’s should be considered in future testing to examine the relationship between concrete, limestone, plastic and materials such as fly ash, ggbs, and silica fume.