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# Characterization of concrete samples with different compressive strength using synchrotron X-ray microtomography

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## 1. Introduction

The study of materials' microstructure and its correlation with mechanical properties is in great importance in various scientific and industrial fields. Concrete is one of the most widely used construction materials due to its diversity, durability and cost-effectiveness. Optimizing its properties in particular the compressive strength is essential for enhancing the sustainability and safety of infrastructure projects. The microstructure of concrete plays a fundamental role in determining its mechanical characteristics. In the current state of materials science and construction engineering, research has led to significant advancements in concrete formulation, with the goal of improving strength, durability, and sustainability [1]. Various studies have explored the impact of individual components (such as cement type, aggregate size, and water-cement ratio) on concrete properties [2, 3]. However, understanding the microstructural complexity and their direct influence on mechanical behavior is an ongoing challenge [4, 5]. In this context, our research focuses on investigating the microstructural properties of concrete samples and correlate them with variations in compressive strength.

## 2. Materials and Methods

The primary research objectives of this experiment are to characterize the microstructure of concrete samples and establish precise correlations between microstructural features and variations in compressive strength. To achieve these objectives, we prepared six types of concrete, each type with unique magnitude of cement, sand, water, aggregate1, and aggregate2. The composition of each type was adjusted to ensure a controlled variation in compressive strength. The samples preparation took on established industry standards to guarantee the reproducibility and accuracy of the results.

For each type of concrete, four samples were prepared. Traditionally, compressive strength tests are performed at an age of 7 and 24 days with an estimations of 75% and 100% of the intended strength, respectively. The maximum compressive strength concrete can achieve depends on the hydration process, the curing and environmental conditions and the age of the concrete. In our experiment, for each type of concrete, two samples were used to perform a standard compressive strength tests at an age of 7 and 24 days at An-Najah National University laboratory. Then, the other two samples, were used in the X-ray microtomography imaging experiments.

We collected 3D microtomography images for each type of concrete over the largest possible field of view. Both filtered-white and monochromatic beam modalities were tested, and the scan energy selected based on image quality. The goal is to have enough contrast for accurate quantification of porosities.

The acquired 3D data were investigated using Dragonfly. An example of advanced image processing and analysis able to identify and quantify microstructural features within the samples is shown in Figure 1. This includes image filtration, segmentation and the characterization of cementitious phases, aggregate distribution, pore morphology, and the size and distribution of pores.

Correlations between the observed microstructural characteristics and variations in compressive strength across the six types were investigated.

## 3. Preliminary results and Discussion

During the commissioning period at the BEATS beamline, we had the unique opportunity to collect preliminary data, offering an impression into the potential insights that can be gained through synchrotron X-ray microtomography. While these results are preliminary and require

further validation, they provide valuable indications of the capabilities of the BEATS beamline and the promise of our research.

The preliminary X-ray microtomography images obtained demonstrated remarkable clarity and detail in visualizing the internal microstructure of our concrete sample. Even at this early stage, we could observe distinct features such as cementitious phases, aggregate distribution, and pore size. Figure 1(a, b) illustrates a rendered 3D volume for part of the scanned sample and shows the internal pores size and pores morphology. The high resolution and contrast provided by the synchrotron radiation source allowed us to discern fine-scale microstructural elements that are often challenging to capture with conventional imaging methods.

## 4. Conclusion

Our research is driven by the hypothesis that compressive strength in concrete is primarily influenced by the microstructural characteristics, particularly porosity, pore size, and their distribution within the material. As porosity increases, we expect a decrease in compressive strength due to reduced load-bearing material. Moreover, larger pores and irregularly shaped pores may act as stress concentrators, leading to reduced compressive strength. We also expect to observe differences in the distribution of these features across the different compositions. Our experiment will yield a comprehensive dataset, including high-resolution 3D images of concrete microstructure and a quantitative analysis of microstructural features.

## 5. Acknowledgements

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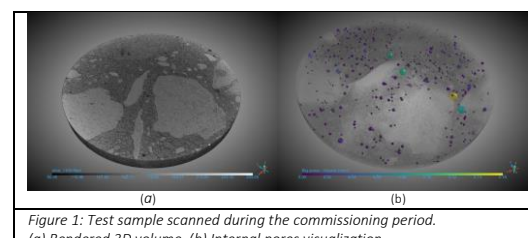


Figure 1: Test sample scanned during the commissioning period.  
(a) Rendered 3D volume, (b) Internal pores visualization.