ULTRA HIGH PERFORMANCE CONCRETE BRIDGE BEAM TESTING AS MONITORED WITH DIGITAL IMAGE CORRELATION

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THE UNIVERSITY OF TEXAS SYSTEM LOUIS STOKES ALLIANCE FOR MINORITY PARTICIPATION

Abstract

The United States Infrastructure is failing drastically. We face the problem of aging infrastructure on bridge designs. Great interest is arising for a more reliable, durable and improved bridge design. There are a number of stories about how bridges failing are in the US, like the I-10 Bridge in Southern California, the I-75 Southbound in Cincinnati, Ohio or the Minneapolis I-35W Bridge over the Mississippi River. Although these bridge failures don't occur daily, it is still a major problem that put millions of lives at risk

The search for a better sustainable bridge design has led to the development of advanced material resources. This search led to the development of Ultra-High Performance Fiber-Reinforced Concrete (UHPFRC). It was first produced by a company named Aalborg in the 1960s and 1970s. This concrete has a cement matrix and a characteristic unconfined compressive strength ranging from 21.75 ksi to 36.26 ksi. It contains a steel fiber which increases the tensile and flexural capacity and it has micro-sized to no pores as a result of its high binder content.

Further research on UHPC is still required to understand its structural behavior and determine its limits and efficiency to our Infrastructural Department. These can be determined by analyzing its behavior when subjected to various, intense amounts of load and environmental conditions.

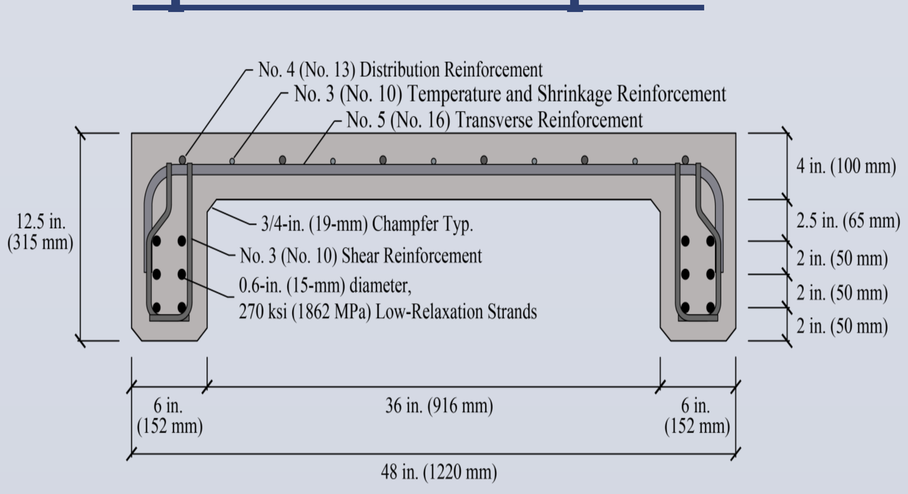
No one can predict what bridge or any other infrastructural system will fail next. America's Infrastructure has a D+ GPA according to the American Society of Civil Engineers which means we need an estimate of $3.6 Trillion by the year 2020 for rehabilitation. Hopefully, Ultra-High Performance Concrete can be the first step into acquiring a more dependable infrastructural system.

Introduction

This report discusses an experiment carried out on the testing of Ultra High Performance Concrete (UHPC) in New Mexico State University. The UHPC beam of 25-feet-long beam was placed on a structural frame which exerted a specified load on it. The amount of stress and strain were recorded using a Digital Image Correlation System (DIC). A beam of High Performance Concrete (HPC) was also tested the same way, and compared with the stress and strain results of the UHPC beam.

The purpose of this experiment was to calculate the compressive strength of the UHPC and HPC beams, i.e., the resistance of the beams to crack or deform under compression from the load applied on it. The experiments were recorded using DIC systems and the images were extracted and analyzed using Aramis software.

Specimen Description



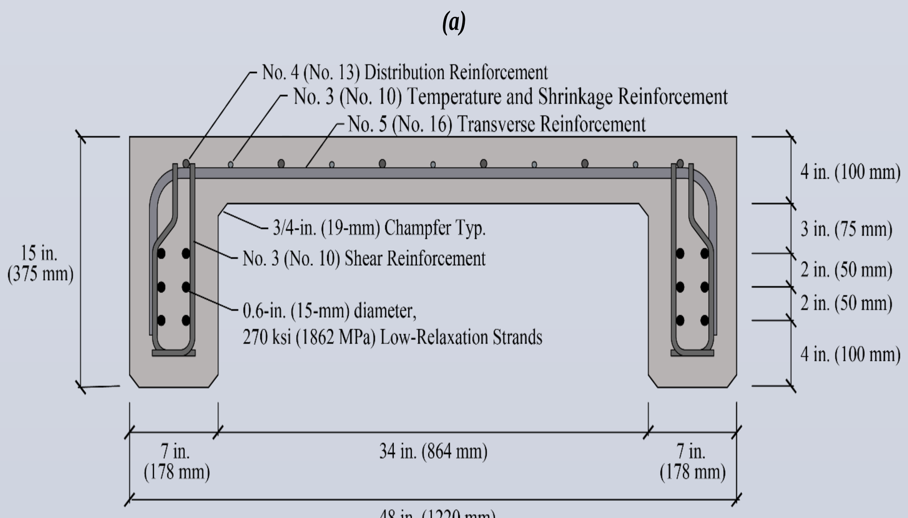


FIGURE 2 Reinforcement layout (a) UHPC cross-section and (b) HPC cross-section

Objectives

The main goal of this research is to evaluate Ultra High Performance Concrete and find out its key structural parameters, such as strains, crack openings and deflection. This research can prove to be extremely helpful in our society in the future, as it could bring about a more broad knowledge and understanding in using UHPC to improve The United States Infrastructural Systems.

While carrying out the experiment, we had a number of objectives important in achieving the main goal. These objectives are;

- Evaluate the behavior of the beam under load.
- Determine the cracking moment.
- Determine the failure moment.
- AnalEvaluate the behavior of the beam under load.
- Determine the cracking moment.
- Determine the failure moment.
- Analyze the strain data using the computer program, Aramis.
- Study the graphs of the strains at the top and bottom of the beam.
- Use the strain data to calculate the neutralyze the strain data using the computer program, Aramis.
- Study the graphs of the strains at the top and bottom of the beam.
- Use the strain data to calculate the neutral axis at each stage.
- Study the graphs of the neutral axis.
- Graph and study the gamma shear deformation of the beam.

Procedure

This experiment was carried out in New Mexico University. The UHPC and HPC Beams that were tested were prepared by creating a random pattern on their surfaces. This patterns are used to measure the displacement distribution of the surface by comparing the images taken before and after deformation.

There were three DIC systems used. They were Hispec, Go-pro and 2M cameras. They were setup with the Hispec monitoring the middle of the beams, the Go-pro monitoring the Shear Spaw and the 2M monitoring the end of the beam. These DIC systems captured deformations in the areas noted in ***Figure 1***.

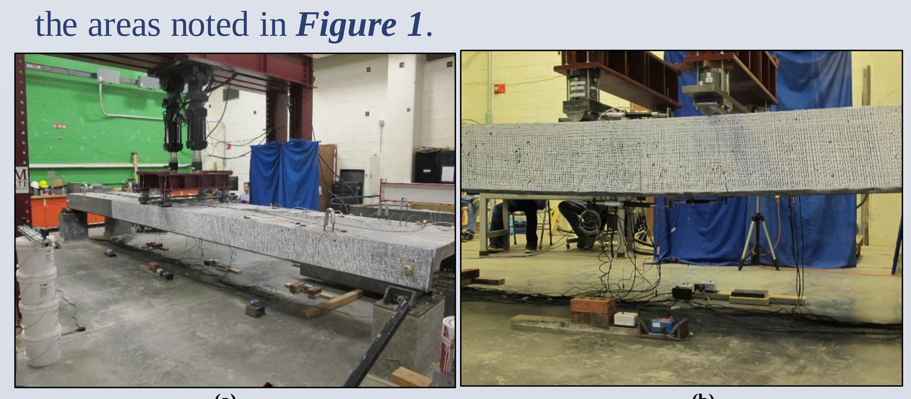


FIGURE 1 UHPC beam with DIC stochastic grid pattern (*a*) prior to testing and (*b*) deflecting under load.

After the pattern dried the following steps were carried out:

- Set the Beam on the Structural Frame.
- Setup the DIC systems.
- Startup Aramis software on the computer and link the cameras to the system.
- Calibrate the cameras using a calibration plate
- Lower loading head to just above the middle of the of the beam
- Apply load at the designated rates.

The beams had a C-shaped cross section and were 25 feet long. The supports were 24 feet apart leaving 6 feet of the beam at both ends overhanging. The load was applied by two hydraulic activators, each located 1 foot from the beam's centerline. ***Figure 2*** shows the cross section of the two beams.

References

Aging Infrastructure: Issues, Research, and Technology. (2010, December 1). Retrieved August 6, 2015.

Braganca, L., Koukkari, H., Veljkovic, M., & Borg, R. (n.d.). Sustainable Construction. Retrieved July 1, 2010.

Ljmu Progress In Utilising Limestone Quarry Waste Dust As Road Base And Subbase Material. (n.d.). Retrieved August 6, 2015.

FIGURE 3 DIC photos for HPC (left) and UHPC (right) for (a, b) 0 kips; (c, d) 10 kips; (e, f) 20 kips; (g, h) 30 kips; (i, j) 40kips; (k, l) 50 kips; (m, n) 60 kips; (o, p) 70 kips; (r) 80 kips.

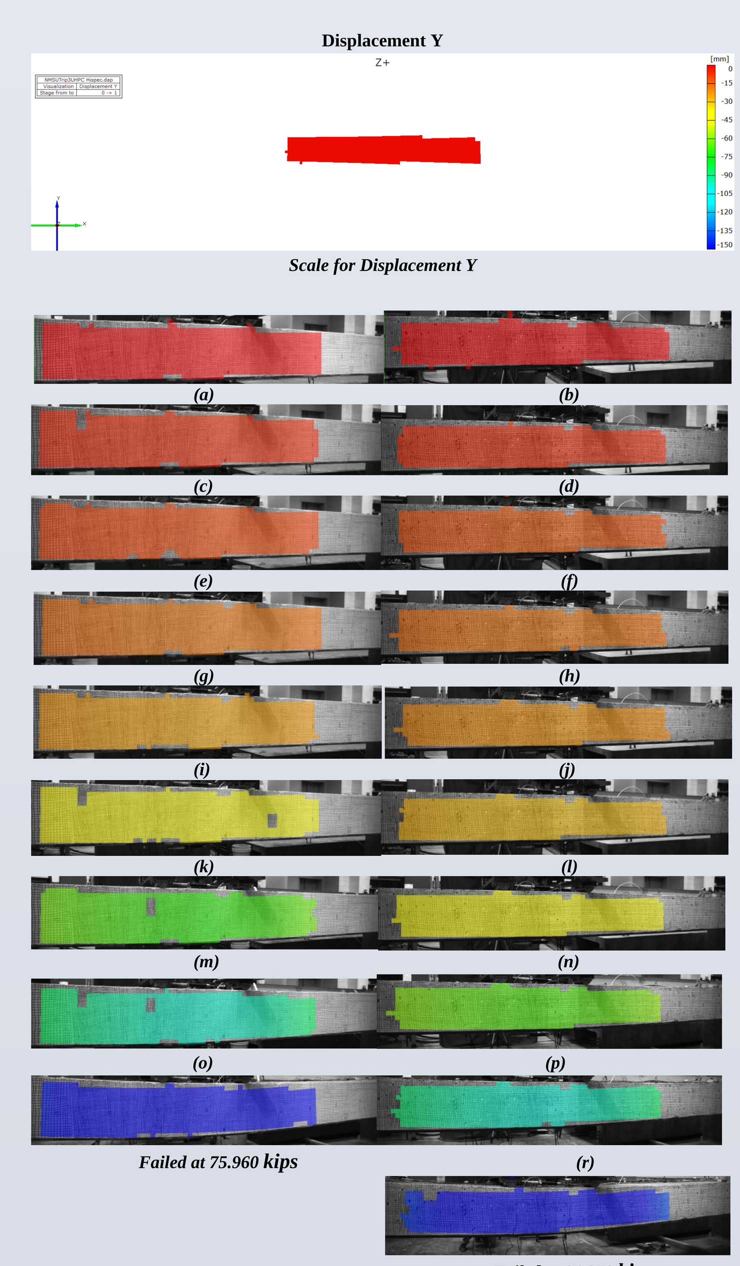


FIGURE 3 DIC photos for HPC (left) and UHPC (right) for (a, b) 0 kips; (c, d) 10kips; (e, f) 20 kips; (g, h) 30 kips; (i, j) 40 kips; (k, l) 50 kips; (m, n) 60 kips; (o, p) 70 kips; (r) 80 kips.

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Results

Figure 4 below shows the graphs of the strain at the bottom and the strain at the top for the UHPC and HPC beams. The first graph, ***(a)***, illustrates the strain patterns in the HPC beam. It tells us that the strain at the bottom and the top increases as the load increased until they both reach a peak of 0.99** and 0.2**.

The maximum strain at the bottom and is expected to be greater than the strain at the top because, when load is applied to the center of the beam, the beam is expected to concave curve opposite and perpendicularly to the external force. This causes material near the top of the beam to be placed in compression along the x-direction, with the lower region in tension. So because concrete naturally has high compressive strength with low tensile strength, the strains at the top where compression is occurring is significantly smaller than that of the bottom where tension is occurring.

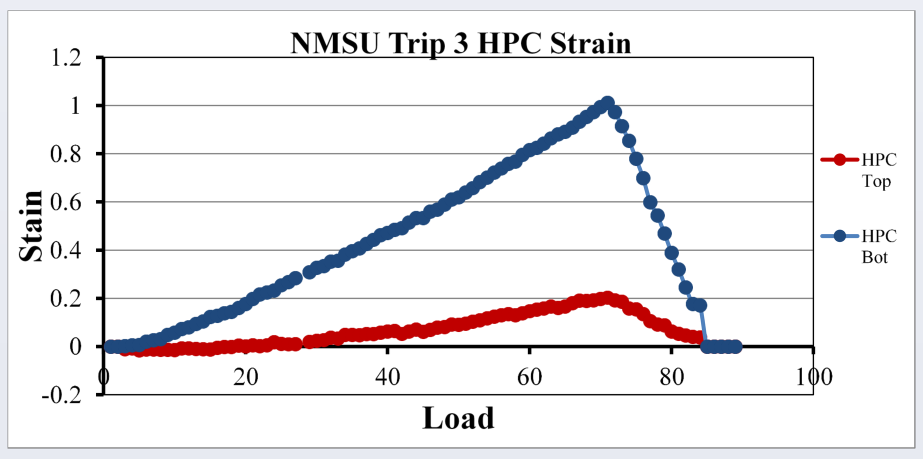

Figure 4 (a)

The UHPC beam acted the same way as illustrated in ***Figure 4 (b)*** below, but in this beam the maximum strained attained was 0.86** at the bottom and 0.08** at the top.

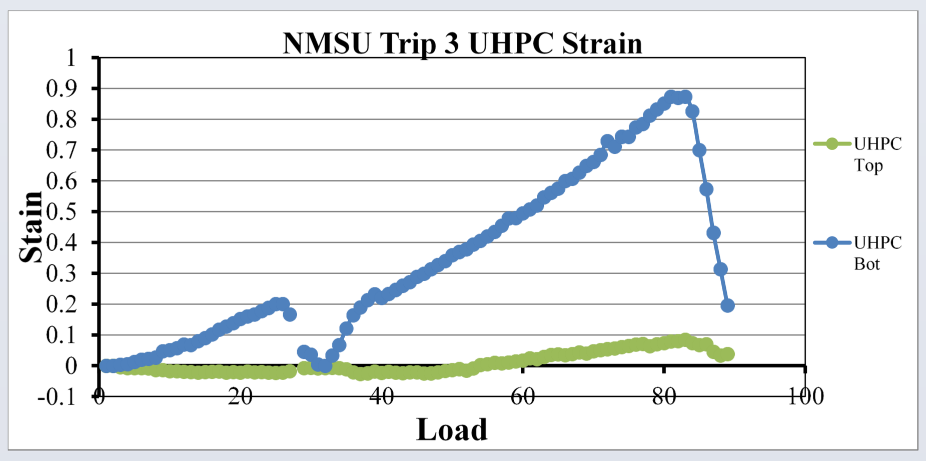

Figure 4(b)

When we compiled the two strain results for the HPC and UHPC beams below in ***Figure 3 (c)***, we observed that the HPC beam's strain at the top and bottom was greater than that of the UHPC. This is expected, and it is because the UHPC contains steel fibers which increases its tensile capacity and that makes it more resistant to strain than the HPC beam is.

As the load on the beams increase, and simultaneously, the compressive region reduce while the tensile region increases, the compressive region becomes significantly small in size which causes the beam to fail. For failure to occure, the neutral axis displaces up in the y-direction until it reaches the top of the beam. At this moment, the beam fails. i.e. neutral axis is the point where compression changes to strain in the beam, at this exact point, stress equals zero.

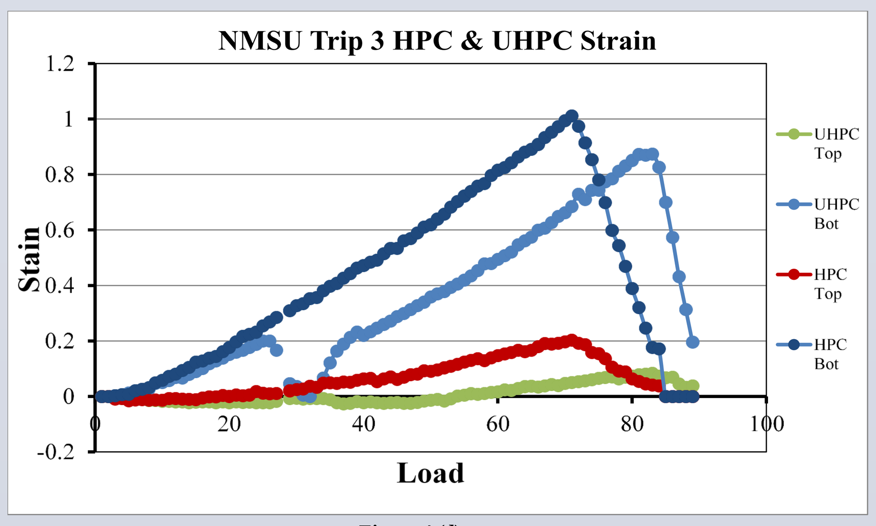

Figure 4 (d)

The results from the UHPC and HPC testing are illustrated below. The pictures were taken at approximately every 10kips applied to the center of the beam. The digital images where captured using the DIC system. The HPC digital images are illustrated on the left and the UHPC digital images on the right.

Below are the images captured from the center of the beam using the HISPEC cameras? The first image labeled "Scale for Epsilon X" shows the scale used for all the pictures in epsilon x. The Epsilon X scale runs from +3000 μm/m to -3000 μm/m.

The second set of images illustrates the initial signs of cracking that occurred in each specimen. It can be seen that the HPC beam first cracked at 41.645 kips, while the UHPC beam first cracked at 55.8252 kips. The appearance of green and yellow indicates the minute strain development as micro-cracking initiates.