Scope of Work
Establishing Inspection Periods and Preliminary Recommendations for Preventive Measures for Mid-Rise Buildings Near Coastal and Inland South Florida Environments

Florida Department of Business and Professional Regulation
Florida Building Commission

and

Civil and Environmental Engineering Department, Florida International University

Project Leader: Atorod Azizinamni

1. Introduction

Following the collapse of the Champlain Towers South in Surfside, Florida, several research and planning activities relating to many aspects of the challenges surrounding the building collapse have been undertaken under the direction of Dr. Atorod Azizinamini Briefly these activities include:

a) Development of overall strategies for first-level review of plans, especially for mid-rise buildings, to identify structures that require in-depth structural assessment. The major elements of this quick check that could be carried out in a matter of hours include checking the foundation layout, reviewing the lateral load resisting system, and performing a quick review of conformity to the ACI 318 building code used in reinforced concrete design, especially with respect to connections between flat slabs and columns;

b) Development of possible strategies that can add to the structural redundancy of the buildings in non-seismic regions, and follow the general design and construction philosophy used in seismic regions—namely that the structure could sustain damage even beyond repair, but must not collapse;

c) Development of retrofitting methods to strengthen structurally deficient columns in mid- to high-rise buildings using Ultra-High Performance Concrete (UHPC). It should be noted that Florida International University (FIU), among several other universities, has developed non-proprietary UHPC that costs $400 to $800 per cubic yard. The recipe for developing such UHPC is available to the public.

d) Development of procedures for protecting concrete structural elements from corrosion, using UHPC; and

e) Development of rapid in-situ, non-destructive testing methods that can assess the quality of concrete in less than 30 minutes. To this end, the PI has developed a test method based on the developed pressure response of the concrete with the application of liquid at a high

pressure (about 200 psi). Work is underway to relate the results to Standard ASTM Rapid Chloride Permeability and Freeze/Thaw tests.

Carbonation of concrete and ingress of chloride are the most common factors responsible for the observed corrosion of reinforced concrete elements in buildings in Florida. The incidence of carbonation-induced corrosion depends on many factors, among them the presence of concrete pore water, concrete quality, grade of steel, and concrete cover depth.

Project Objectives: The main objective of the proposed project is to establish the scientific basis for the development of protocols for the first and subsequent inspection intervals of Mid to High-Rise Buildings. This study will concentrate on establishing the inspection period that is based on carbonation of concrete. FIU has carried out significant studies on chloride-induced corrosion. The outcomes of these chloride-induced corrosion studies will be considered where possible, in the development of project deliverables, described later. Another major objective of this project is to make the first step in providing preliminary recommendations for taking preventive measures, in the form of wrapping concrete columns prone to corrosion due to concrete carbonation with UHPC. Figure 1 compares corrosion rates of steel in normal strength concrete and UHPC. The horizontal axis represents time after application of compounds capable of starting corrosion, and the vertical axis shows the rate of corrosion. The higher corrosion rates (on the vertical axis) result in a greater degree of damage over time. From data shown in Figure 1B, one could note that the durability of UHPC is superior to that of Normal Strength Concrete. In fact, ingress of chloride through UHPC is about 100 times slower than through Normal Strength Concrete.

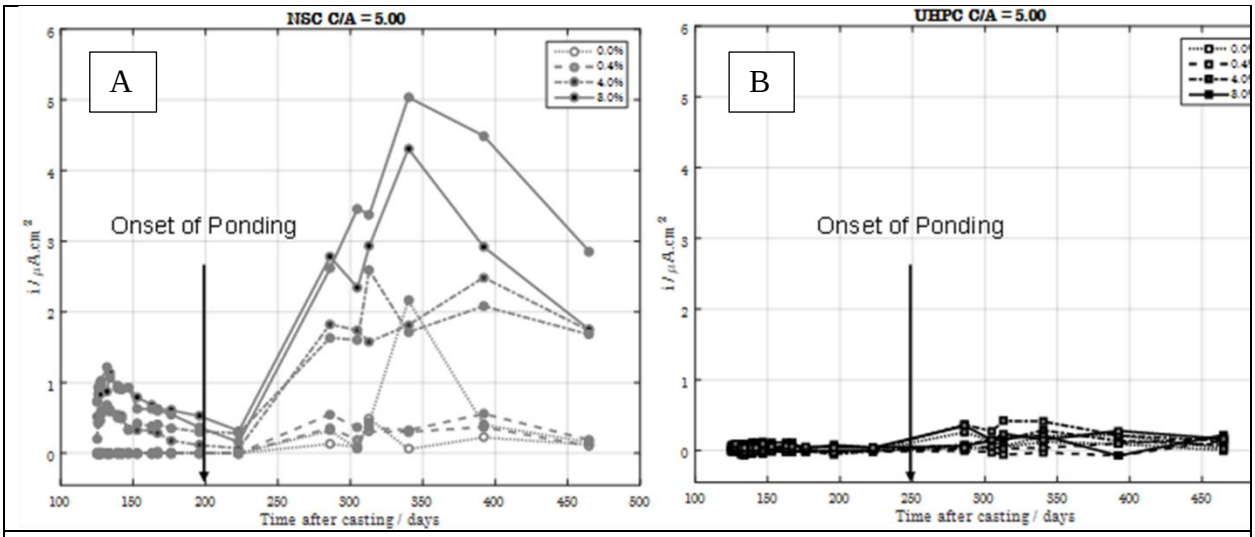

Figure 1. Durability comparison of normal strength concrete and UHPC

2. Scope of Work

Task 1- Conducting tests on large scale column test specimens for establishing time to corrosion due to concrete carbonation- **Without Applied Axial Load**

Four concrete column test specimens are under construction at FIU under the supervision of the PI. Funds for conducting structural testing of these concrete columns are provided from elsewhere.

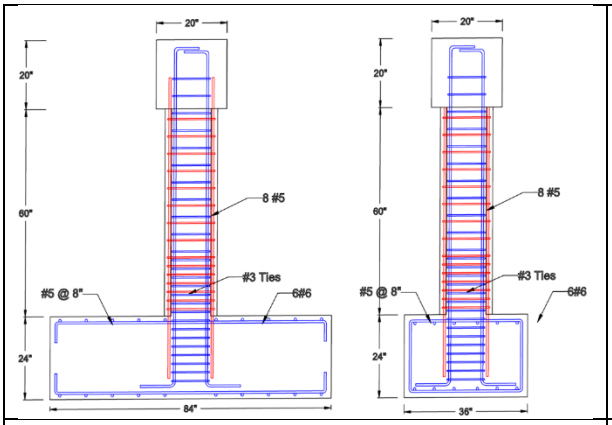

Figure 2. Test columns

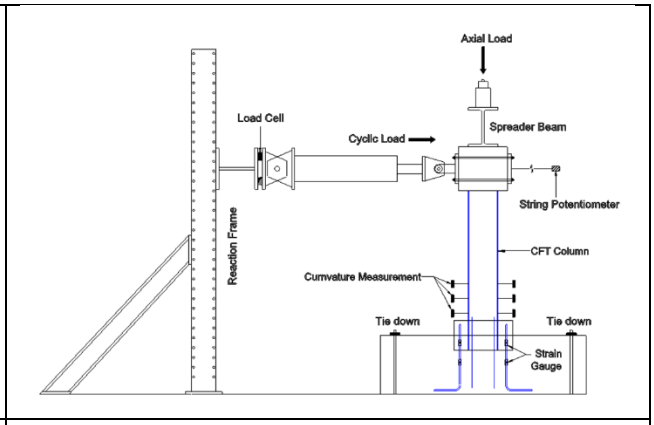

Figure 3. Loading of test specimens

Figures 2 and 3 shows the test specimen and loading plan, which consists of applying an axial load, representing the dead and live load present on the columns, keeping it constant and then applying a lateral load in cyclic manner, representing wind loads.

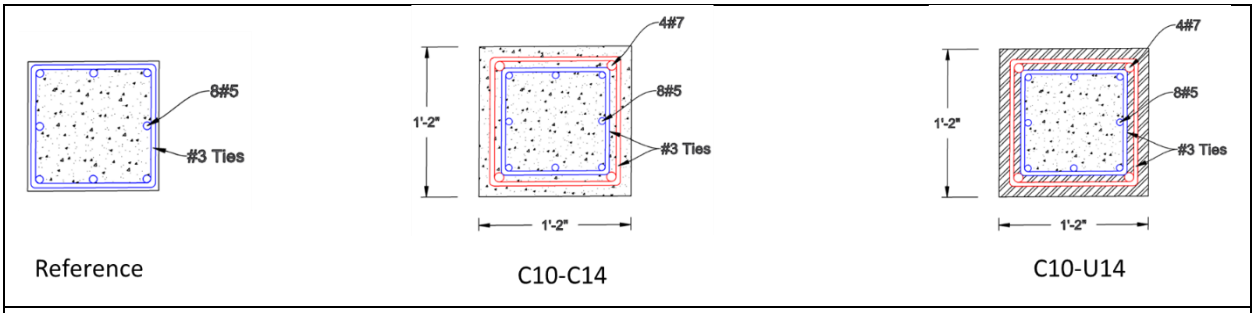

Figure 4. Cross sections of the test specimens under construction

Figure 4 shows the cross section of column test specimens that will be ready for testing by late August, 2022. In Figure 4, the reference column represents the condition of a column that is deficient and needing upgrade. The C10-C14 column represents the reference column upgraded using normal strength concrete. The C10-U14 column represents the reference column upgraded using UHPC.

Before applying the constant axial and cyclic lateral load to the test specimens, durability tests will be carried out to establish the rate at which carbonation can occur for the reference column, column retrofitted using normal strength concrete, and column retrofitted using UHPC. The length of the carbonation test will be limited to two weeks. Specific chamber with carbon dioxide inlet will be placed around the columns for period of 2-weeks to expedite carbonation. Under Task 4, described below, small-scale carbonation tests will be conducted to complement these large-scale test specimens.

Task 2- Conducting tests on large-scale column test specimens for establishing time to corrosion due to concrete carbonation- **With Applied Axial Load**

Tests described in Task 1 will be repeated, after the constant axial load is applied. The constant axial load will be kept for two weeks before applying lateral loads. Concrete carbonation tests will be carried out during those two weeks. It is believed that the presence of axial load, which is closer to real world condition, might help to increase time to corrosion due to concrete carbonation.

Task 3- Relation to quick durability test developed by PI
For all the tests to be conducted under Tasks 1 and 2, liquid pressure test developed by PI will also be conducted.

Figure 5 shows the apparatus for a newly developed FIU durability test that can be conducted in less than 30 minutes. Figure 6. Shows two concrete cylinders after conducting test. The left cylinder is made of UHPC and right-hand side cylinder is made of normal strength concrete. The discoloration on top of the normal strength concrete cylinder indicates the depth through which liquid under pressure penetrated.

Figure 5. Test apparatus for newly developed FIU durability test

Figure 6. Test cylinders tested

Task 4- Small-scale test to establish concrete carbonation time
The time duration for conducting carbonation concrete tests on large test specimens described under Tasks 1 and 2 will be limited to two weeks because of other project limitations. To complement tests under Tasks 1 and 2, a series of concrete carbonation tests will be carried out on small concrete specimens. These tests may take three months to complete. Several concrete specimens will be cast and will be cured for 28 days. The set of small-scale specimens will be divided into two groups. In the first group, the concrete specimens will not be axially loaded. In the second group, similar concrete specimens will be axially loaded after 28 days. The small-scale specimens in both groups will be placed in an accelerated carbonation chamber similar to the one

shown in Figure 7. At two-week intervals, specimen will be removed from the chamber and will be prepared to measure the carbonation depth over time (two-week intervals). At each time of measurement, carbonation depths will be measured in the laboratory, the concrete specimens will be split and cleaned, and 1% phenolphthalein solution in 90% ethyl-alcohol will be sprayed on the fresh-cut surface. When the solution is sprayed on a broken concrete surface, the carbonated portion remains colorless (concrete color) and the non-carbonated portion turns to dark purple as shown in the example in Figure 8. Detail description these tests will be provided in the draft final report.

Figure 7. Example of accelerated carbonation chamber

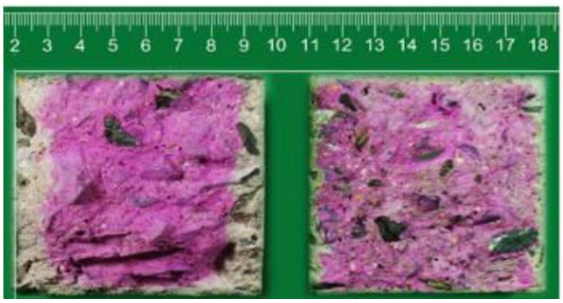

Figure 8. Example of concrete carbonation depth, showing more carbonation on the left

Task 5- Development of recommendations
Using the results of tests conducted, recommendations will be made for the inspection period of reinforced concrete that is based on concrete carbonation, as well as preliminary recommendation for taking proactive steps in preventing corrosion using UHPC wrap.

3. Staffing

The project will be led by Dr. Atorod Azizinamini. Dr. Azizinamini is internationally known structural engineer and has conducted more than $40M research as PI and recipient of White House award. Participants will include Dr. Joe Colaco, Professor of Practice at FIU. Dr. Coloco is a well-established High-Rise Building Designer and has been involved in the design of many notable high-rise buildings around the world, including the John Hancock building in Chicago, Illinois. Also participating in the project will be Mr. Larry Griffis, designer of movable roof for Marlin and Dallas Cowboys stadiums and many high-rise buildings around the world. Mr. Griffis is Professor of Practice at FIU. He is also Vice President with Walter P Moore in Houston, Texas. Dr. Kingsley Lau, Associate Professor at FIU, and Dr. Ankitha Prakash, Research Assistant Professor at FIU, will also participate in conducting of described work. Four Graduate students working on related projects and funded by other sources will partially assist the project in its experimental phase.

4. Method of Payment

A purchase order will be issued to FIU. This project will start on the date of execution of the purchase order and notice to proceed and will conclude, about year later, on July 31, 2023. This purchase order will not exceed $125,000.00 and shall cover all costs for labor, materials, and overhead. Payment will be made for the study after the Program Manager and the Florida Building Commission's Hurricane Research Advisory Committee have approved the final report. Additionally, the Contractor agrees to provide additional documentation requested by the Program Manager to satisfy all payment and audit requirements.

5. Deliverables

a. An interim report shall be prepared and delivered no later than January 27, 2023. The interim report shall cover the progress of Tasks 1, 2, 3, and 4. This report will constitute as a progress update in detail and will include description of any issues that might be affecting the project goals and objectives.

   In addition, the interim report shall be formally presented to the Florida Building Commission's Hurricane Research Advisory Committee at a time set by the Contractor and the Department's Program Manager. The due date could be extended with the approval of the Department's Program Manager.

b. Toward the conclusion of the project, a draft final report will be prepared and submitted by May 5, 2023 for review and comments, by the Research Advisory Committee. The draft final report will include:
   a- Recommendations for inspection periods based on concrete carbonation,
   b- Preliminary recommendations on procedures for assessing durability of concrete columns in mid- to high-rise buildings that uses FIU durability test, and
   c- Preliminary recommendations on taking proactive measures to protect concrete columns against carbonation induced corrosion using UHPC.

In addition, a formal presentation will be made to the committee at a mutually agreed-upon date and time. Comments received will be incorporated into the draft final report and the final report will be submitted by July 31, 2023.

6. Financial Consequences

FIU will be solely responsible for the satisfactory performance of the tasks and completion of the deliverables as described in this Scope of Work. Failure to complete the tasks and deliverables in the time and manner specified in Sections 2 and 5 shall result in a non-payment of invoice until corrective action is completed as prescribed by the program or contract manager.

7. Program Manager

The Program Manager for this project is Mr. Mo Madani, at Mo.Madani@myfloridalicense.com.

Mr. Madani's phone number is 850-717-1825.