Strengthening Concrete columns in concrete condominium building

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Summary

This paper presents a live design of a new fourteen story luxury condominium building in Union City, New Jersey, USA. Because of a misreading of the design drawings, the contractor poured lower grades of concrete than designed for certain crucial columns. This resulted in about 12 columns being built with less than 85% of the design strength. To obtain the necessary in-place compressive strength of the built concrete columns, they were enlarged using a combination of surface doweling and form-and-pump installation technique.

Keywords: FRP, column enlargement, design column strength, column enlargement, doweling and form-and-pump installation technique

1. Project Profile

Jarmel Kizel Architects and Engineers, Inc. was responsible for designing a new fourteen story multi-family condominium building in Union City, New Jersey. The building is located at 3312 Hudson Avenue. It contains one and two bedroom condominium units. There are a total of approximately 155 units. The residential portion of the building consists of 13 levels built upon a 2 level parking garage. The lower level of the garage is below grade and the main level of the garage is the building's first floor. There are approximately 117 parking spaces. The building is currently under construction and is expected to be in use in July 2008.

2. Design Process

The building has a plaza area and a main residential area. The Plaza area is 2 stories above ground and one level below ground. There are two elevator shafts located in the north end and south end of main residential area. The structural design of the concrete columns in the parking garage is limited by the number of parking spaces required by the client. Slender but higher strength concrete columns were designed to maximize the available space in the parking garage level. The column concrete design strength is varied upon the design. A RAM Model was built to help the preliminary design.

3. Problem in the Construction Phase

Because of a misreading of the design drawings, the contractor poured lower grades of concrete than were specified for certain crucial columns. This resulted in about 20% of the columns being built with less than the designed strength. To obtain the in-place compressive strength of the built concrete columns, testing consisting of partial depth concrete cores were drilled and Windsor probe tests were performed. Those columns meeting ACI-318 tolerance of 85% of design strength requirement were left unchanged (20.3.2 ACI 318-99); the rest of the columns needed to be fixed.

4. Solutions

4.1 Column Enlargement to strengthen the columns

In order to achieve the designed strength for those defective columns, the first solution considered was to use fiber reinforced polymer (FRP). The behavior of fiber reinforced polymer (FRP)-

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confined concrete columns has been extensively studied and the method is widely used in the USA. It has become the most efficient way to strengthen concrete structures. Unfortunately, in this project, the columns needing to be strengthened had a high aspect ratio of the column sections (B/H) of 3.0 or higher. This exceeds the limit allowed by ACI 440 for FRP confinement. So the FRP may not have been effective in confining the columns.

By working with "Structural Preservation Systems" Group, a second approach for strengthening the columns with lower strength was found. This was to enlarge the column section to increase the compressive strength of columns and thus their axial load carrying capacity. A combination of adequate surface preparation, doweling, and use of form-and-pump installation technique ensured a composite behavior of the existing column with the new enlargement, and therefore load sharing. In this way, the defective columns were able to achieve the desired capacity.

As there were many limitations for enlarging columns due to geometry and floor layout at the parking garage level, column strengthening was achieved by increasing the size of the columns on a varying number of sides depending upon the availability of space. The axial strength increase was conservatively based on the new concrete section alone. The additional longitudinal steel bars were not included in the axial column strength calculations. However, all additional longitudinal steel bars were doweled to the top and bottom slabs to make sure that they are capable of resisting axial and bending forces for overloading conditions.

4.2 Structural Calculations for Column Enlargement

This approach may induce additional bending on the column due to eccentricity that can be addressed in the design of the enlargement. Calculation was made to determine the adequacy of an enlarged column to support the factored design axial load (Pu) and bending (Mu). New column eccentricity (ΔMux or Δ Muy) were verified by the calculations including P-M diagrams for the enlarged columns that were generated using PCA column software. These diagrams were used to evaluate the adequacy of the columns for bending. Dowels were provided to ensure adequate shear transfer at column/enlargement interface to achieve a composite behavior. The result by Calculation and computer analysis showed that the proposed enlargement for the column had enough capacity for the factored axial load and bending moment.

Column enlargements were placed using the form-and-pump technique to ensure fully bonded enlargement and adequate shear stress transfer along the existing/new concrete interface.

5. Testing the Design solution

Once the design was finalized, enlargement was accomplished using a combination of surface doweling and form-and-pump installation technique. Full-scale tests were conducted on each column on 28 days breaks of concrete by Structural Preservation Systems Group to validate its effectiveness. The results showed that all of the repaired columns strengths are now at least 10% higher than the design strength. Therefore, the defective columns were able to achieve the desired capacity by using column enlargement.

6. Reference:

[1] Column Strengthening Using Section Enlargement Design Package
Structural Preservation Systems Hawthorne, NJ, 2007