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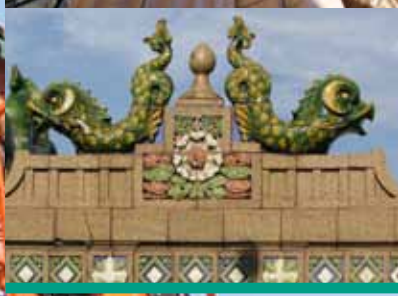

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Regaining the Client's Trust

Using science-based data instead of just verbal assurances, a contractor is able to test validity of concrete repairs without resorting to large-scale demolition

By Andy Schrader, M.S.C.E., E.I.

When a client questions if construction repairs are being performed correctly, it can be useful to address their concerns using third party testing to separate fact from fiction. Such was the case at 440 West Condominium located in Clearwater, Fla. In this case, non-destructive testing (NDT) was used to examine an elevated concrete slab, find the areas most likely to be deficient and pinpoint those areas for physical examinations. Costly and time-consuming demolition of concrete repairs was averted.

This structure consists of a 94,000 ft^2 (8,372 m^2) foot parking garage located beneath an 11 in. (27.9 cm) thick, elevated conventionally reinforced concrete slab and two 16-story towers. The slab has both an upper and lower mat of rebar. The conservative 1970s design methodology used on the slab equates to significantly greater amounts of rebar than is seen in new construction.

Overhead concrete repairs were being performed inside the parking garage using the shotcreting method. Quality control tests for the shotcrete material included taking concrete cores of the repair area to test the bond strength between the repair material and the virgin concrete.

Two of these corings revealed voids (air pockets) in the repair material on top of the lower rebar mat. The owner became concerned that all of the repairs in the parking garage might have voids. Although the contractor speculated that these voids were isolated instances caused by the extensive amount of rebar in the slab, the owner was not convinced. It would have been possible to have the contractor chip out multiple repairs to demonstrate that

Testing firm employee performs Pulse Velocity Test

the voids were not widespread. However, the time and expense involved in that undertaking would have been considerable. The extremely dense nature of the shotcrete material would also make demolition difficult. With this in mind, the engineer recommended non-destructive testing as a way of locating additional voids in the slab (if any) and determining the extent of the problem.

High frequency ground penetrating radar (GPR) was tried first to locate the voids. However, the large amount of reinforcement created radar shadows which made it impossible to examine the area above the rebar. This technique was abandoned.

Impact Echo (IE) technology (detailed in ASTM International C1383) was examined next with an out-of-state testing company. Impact echo technology can measure the time it takes for sound waves to travel through the slab as well as the frequency of the reflected waves to find discontinuities. This method appeared promising although the proposal was rejected due to budget constraints.

Drilling into suspect area to test for voids

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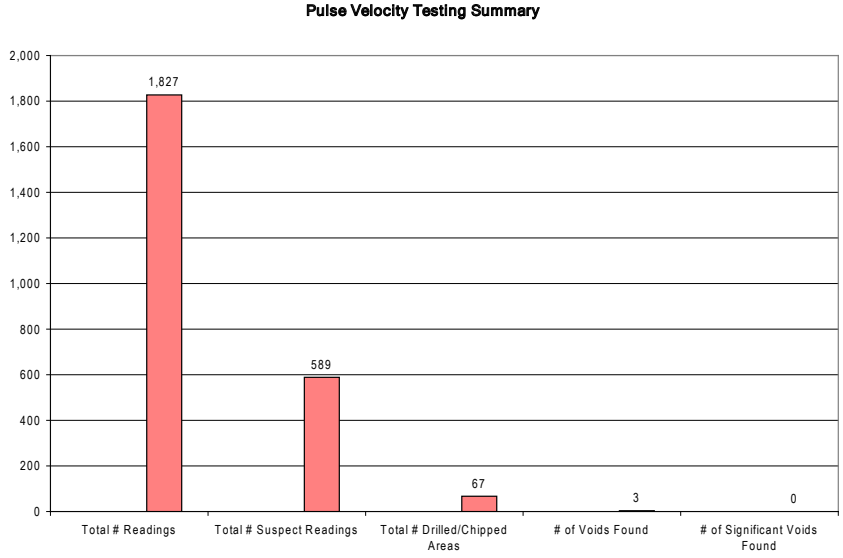
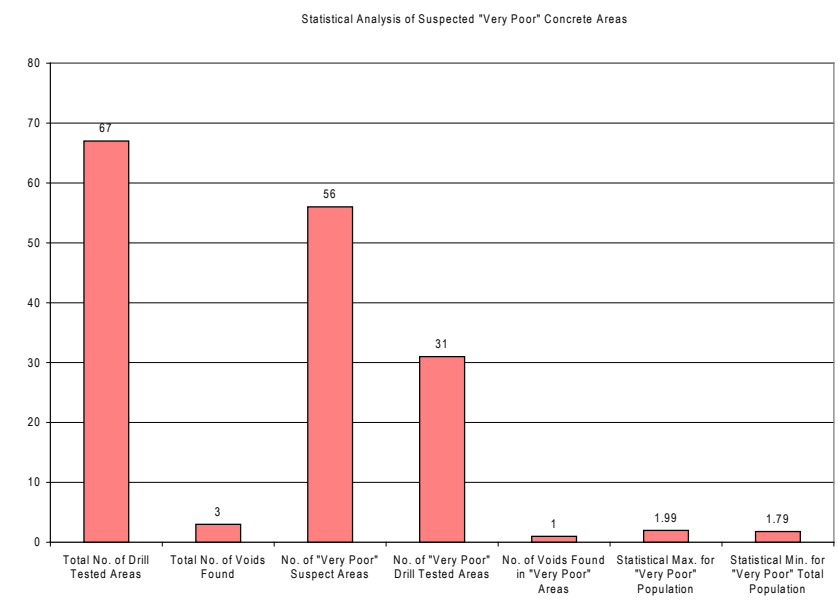
Rebar in concrete repair area which has been exposed for physical testing





A proposal from a local testing company using pulse velocity testing (PVT) was finally approved. Pulse velocity testing is defined in ASTM International C597-02. It uses an electro-acoustical transducer to generate stress waves in the concrete. The speed that these waves travel can indicate the presence of voids or cracks. Unusually long transit times may indicate that the waves have traveled a farther distance to bypass cracks or voids.

The testing firm was given a drawing showing the concrete repair areas and asked to test many of the areas. A 12-inch testing grid was drawn on the concrete repairs and the slab was tested at each one of those points. Areas where longer transit times were measured were marked as "suspect" locations. It is prudent to verify non-destructive data with selective physical explorations. In this case many of the suspect locations were further examined through discrete destructive exploration.

Results

About 1,800 discrete points were tested using the Pulse Velocity Method. Of these, about 600 were marked as suspect using criteria from American Concrete Institute's (ACI) Manual of Concrete Inspection. Sixty-seven of those suspect areas were examined using 3/8" diameter hand held drills. One additional void of structurally insignificant size was found. All other tested areas appeared to consist of dense, well-bonded repair material.

From a statistical standpoint, greater than 50 percent of the physical examinations took place in areas with suspected "Poor" concrete quality as defined by ACI. The remaining physical examinations took place in locations suspected as "Very Poor" quality. These locations are in the lowest

Overhead concrete repairs were being performed inside the parking garage at 440 West in Clearwater, Fla. using the shotcreting method.

10th percentile of velocity readings, and are those most likely to contain a void. Using a 10 percent acceptable margin of error with a 90 percent confidence level, statistical analysis of the data from areas most likely to contain voids suggested a maximum of two voids, both structurally insignificant, in the entire population.

When attempting to produce statistically significant data, it is important to know the required sample size. The size varies based on the desired margin of error and confidence level. For litigation purposes, 5 percent margin of error with a 95 percent confidence level is typically appropriate. General testing such as that discussed in this article may use lower confidence levels. Look up www.macorr.com and click on "Sample Size Calculator" to experiment with different testing criteria.

All voids were located in a single area of the parking garage, which is the first area the contractor used the shotcrete technique of concrete placement. Testing was concentrated more heavily in this area since the voids were first discovered here. We know that the contractor modified his shotcrete technique and equipment while working in Area One. This may have improved the quality of the shotcrete application in later work areas.

Based on the physical evidence produced by drilling and chipping into the slab, the engineer recommended to the owner that no further action be taken to look for voids. The owner, equipped with factual hard data, agreed.

Analysis

Although a large number of areas were marked as "suspect," actual voids were only found in a handful of locations. One explanation is that site-specific conditions affected the pulse velocity testing, resulting in artificially low readings. At 440 West, the elevated slab is a very efficient design. That is, the concrete is stressed somewhere toward the upper limit of what is acceptable. This causes cracks in the concrete, evidenced by significant spider cracking seen above column locations. Smaller cracks will occur in the concrete as well, though not necessarily above columns.

Cracks are known to translate through new concrete repairs. Therefore recent repair areas may have inherited the cracking which is present in the virgin concrete. It is known that even micro-cracks can affect the signal velocity. Therefore, it is possible that the significant cracking observed at 440 West may have been responsible for producing some false positives.

The testing company stated that the selection criteria used for "suspect" areas may have been overly conservative for the given site conditions. Additionally, they feel that the relative freshness of the repair material was partly responsible for the unusually low readings. More mature concrete repairs would be expected to demonstrate velocities at least 20 percent greater than that of fresh concrete.

In spite of that, the Pulse Velocity Method still appears to have been the right choice for the given situation. It allowed the contractor to regain the client's trust using science-based data instead of just verbal assurances, without resorting to large-scale demolition.

About the Author

Andy Schrader is an engineer with Karins Engineering Group, Inc., consulting engineers with offices in St. Petersburg, Sarasota, Ft. Myers and Ft. Lauderdale and specializing in the design and restoration of buildings. He is a member of the American Society of Civil Engineers and earned bachelor's and master's degrees in civil engineering from the University of South Florida.