# Rehabilitation of Plaza De Diego Building in San Juan, P.R. using CFRP

by M. Ehsani

**Synopsis:** Carbon Fiber Reinforced Polymer (CFRP) products have been used to strengthen a variety of structures. They offer very high tensile strength and offer unique advantages in projects where access is limited. This paper presents the retrofit of a high-rise building in San Juan, Puerto Rico which was necessitated as a result of change in use. Unidirectional carbon fabrics and plates were used to strengthen the floor beams and slabs in flexure. The location of the floor (on the $12^{th}$ story) and the fact that the partition wall frames were already installed provided unique challenges to this project and limited the strengthening alternatives. The project was completed in time and within budget. Field tests on the installed materials demonstrated that the FRP system met or exceeded the strength values claimed by the materials supplier.

Keywords: beams; carbon fabric; carbon plates; floors; high-rise buildings

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## INTRODUCTION

In recent years, the older sections in many large metropolitan areas have undergone renovation. Such revitalization efforts often lead to change of use in many buildings. That will in turn require rehabilitation of these structures so that they can safely resist the new increased loads.

This paper focuses on the retrofit of the Plaza de Diego Building, formerly known as Professional Building. The building is located at 310 de la Avenida De Diego, in the Santurce area of San Juan, Puerto Rico. It is located next to the South Tower of the Minillas Government Center and is just at 5 minutes from the Luis Muñoz Marín International Airport. The Art Museum of Puerto Rico is nearby and the Plaza de la Cultura (Culture Plaza) between the North and South Towers has just been rehabilitated. An aerial view of the structure is shown in Fig. 1.

As part of the revitalization plan for the Santurce area, this building was to be made larger by adding an additional floor to the top ($12^{th}$) floor. Therefore, the top floor, which was originally designed for roof live loads, had to be strengthened to resist the higher live loads from the new floor.

## STRENGTHNEING WITH CARBON FRP

The 12 story Plaza de Diego Building is a cast-in-place reinforced concrete building. As stated earlier, addition of a new floor to the building required that the roof level be strengthened to resist the larger loads imposed by a floor. In addition, there was a small reinforced concrete structure on the roof; that structure had to be enlarged to form a new penthouse level. This modification required that the roof of the small structure also be strengthened.

### Strengthening the Concrete Beams

The $12^{th}$ floor roof consists of 7.5-in. (190-mm) high joists that include a 2-in. (51 mm) thick slab. The web of the joists tapered from a width of 5 in. (127 mm) at the bottom to approximately 8 in. (203 mm) at the top. Each joist was reinforced with two No. 6 (19-mm) Grade 40 (280 MPa) bars. The joists were typically 17 ft - 4 in. (5.28 m) long. Calculations showed that the joists were strong enough and did not require any retrofit.

The joists were supported at the ends on wide concrete beams. The beams spanned 24 feet (7.31 m) and were 16 in. (406 mm) high and 24 or 36 in. (610 or 915 mm) wide. The total thickness included a 4-in. (102 mm) thick slab. Calculations showed that the beams were overstressed by a factor ranging from 59% to 82% in flexure and they required strengthening. Shear capacity of the members was adequate.

Initially, consideration was given to strengthen the beams with conventional methods, such as the use of new steel beams to carry part of the loads. However, as shown in Fig. 2, there were a number a pipes and utility conduits present that would interfere with such installation. Additionally, transportation of the steel beams to the 12th floor was not an easy task and would have added significant cost to the construction. A further challenge was due to the fact that framing for partition walls was already installed on the entire floor (Fig. 3). This imposed to major difficulties. First, it limited access to the underside of the concrete beams. It also made the handling of any steel beams on the floor very difficult.

Prior to strengthening, the existing cracks that were found in several of the beams were injected with a low-viscosity resin. Figure 4 shows the crack injection. The beam surfaces were then grinded with diamond discs.

Strengthening of the beams was carried out by either using a unidirectional carbon fabric or 3-in. (76-mm) wide carbon plates. The plates have a thickness of 0.05 in. (1.3 mm) and tensile strength in excess of 310 ksi (2140 MPa). The unidirectional carbon fabric had a density of 22 oz per square yard (745 g/m$^2$) and a guaranteed strength of 4750 pounds per inch width of fabric (831 N/m). The fabric was supplied in 50-in. (1.27-m) wide rolls that could be cut to desired widths in the field.

Although the FRP supplier does have special equipment to saturate the fabrics, considering the relatively small size of this project, it was decided to perform this task by hand. Working tables were assembled on the 12th floor and after the two-component saturating resin was mixed, it was poured on top of the fabric. The resin is easily worked into the fabric with a putty knife (Fig. 5). A two-component high-viscosity tack coat is also mixed in the field and a 40-mil thick (1-mm) layer is applied to the surface of the beam. The saturated carbon fabric (or the carbon plate) is then applied to the beams. The fabric is pressed to make sure that it is bonded properly and any trapped air is removed. Figure 6 shows a typical installation.

Among the salient advantages of FRPs is its versatility. There were instances where the partition walls were already framed to the bottom of the beam (Figs. 7 and 8). The small thickness of the carbon fabrics made the installation much easier in such cases. The upper channel of the partition walls was removed and the fabric was bonded to the underside of the beam. If the partition wall ran along the bottom of the beam (Fig. 8), after the installation of the carbon fabric, steel angles were used to connect the channel to the sides of the beams; this prevented damaging the carbon fabric. In the latter case, this provided a further advantage in that it did not require the removal of the partition wall and the insulating material that was already in place.

There were a few locations where the bottom of the beams were partially covered by existing partition walls (Fig. 9). Instead of applying a 36-in. 915 mm) layer of carbon fabric to this beam, two layers of fabric were applied. The first layer was 30 in. (760 mm) wide and it was bonded directly to the beam; the next layer of fabric was 6 in. (152 mm) wide and it was bonded to the first layer of fabric.

**Strengthening the Slab**

In addition to the above beams, there was a 72-ft wide (21.9-m) section of slab that spanned 8 feet (2.44 m). This slab was also reinforced with 6-in. (152-mm) wide carbon fabrics placed at 12-in. (305-mm) on center. Figure 10 shows a portion of the retrofitted slab.

**Construction**

Nearly 1200 square feet (110 $m^2$) of carbon fabric and 120 feet (36 m) of carbon plate were used for this project. The construction process moved very smoothly and the local crew carried out the project successfully.

During the surface preparation phase of the project, because most of the partition walls were already in place, there was a concern about ventilation on the floor. This was addressed by using breathing masks, vacuum and by limiting the workers' shifts and it did prolong the project somewhat. A crew of five and a supervisor completed the installation phase of the project in 4.5 days. However, additional time was needed for surface preparation.

## MATERIALS TESTING

To ensure quality of the installed system, three pull tests were performed and the results exceeded the 200 psi (1.38 MPa) limit set by ACI 440. In addition, samples of the saturated fabric were prepared and sent to a laboratory for testing. The fabrics had a tensile strength of 6000 pounds per inch width (1050 N/m) which is well above the guaranteed value of 4750 lb/in. (831 N/m) provided by the FRP supplier. These tests were carried out by Jaca & Sierra Materials Testing Laboratories in Trujillo Alto, Puerto Rico.

## SUMMARY AND CONCLUSIONS

Strengthening of the 12$^{th}$ floor of the Plaza de Diego in San Juan, Puerto Rico is presented here. Unidirectional carbon fabric and plate were used to strengthen the floor beams and slabs. The system proved to be quite effective and allowed installation in an area where access was very limited. The project was completed in a timely manner and within budget.

## ACKNOWLEDGMENTS

The design of the FRP system and the FRP materials for this project was provided by QuakeWrap, Inc., Tucson, Arizona. QuakeWrap also provided on-site training for the General Contractor, Omega Engineering S.E. (San Juan, Puerto Rico) that carried out the installation.

Figure 1 – Aerial View of the Plaza de Diego Building


Figure 2 – Utilities limited access to the underside of the beams

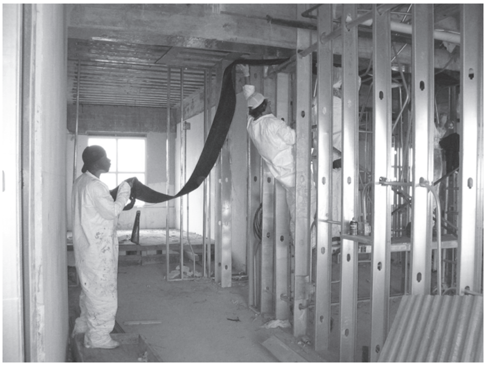

Figure 3 – Partition wall framing limited access throughout the floor

Figure 4 – Crack injection prior to strengthening of beams

Figure 5 – Saturating of carbon fabrics by hand

Figure 6 – Saturated fabric is bonded to the beam surface covered with tack coat

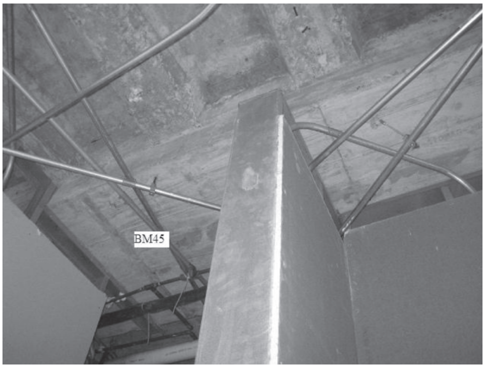


Figure 7 – Partition wall framing crossing the beam axis


Figure 8 – Partition wall framing running along the beam axis

Figure 9 – Two layers of fabric were used when the tension face of the beam was not fully accessible

Figure 10 – Strengthening of slab with carbon fabric