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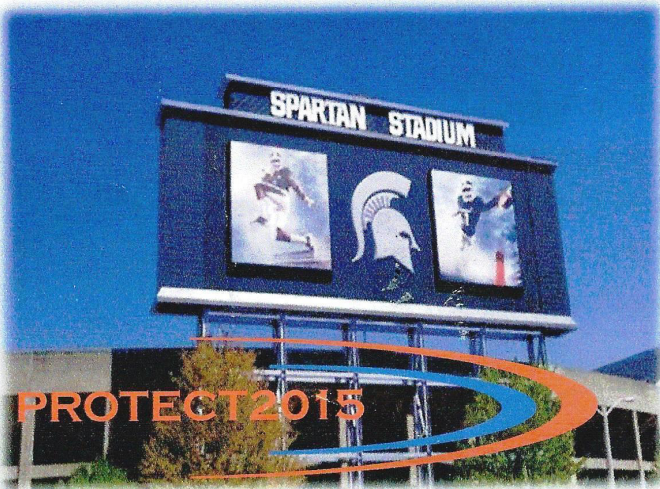
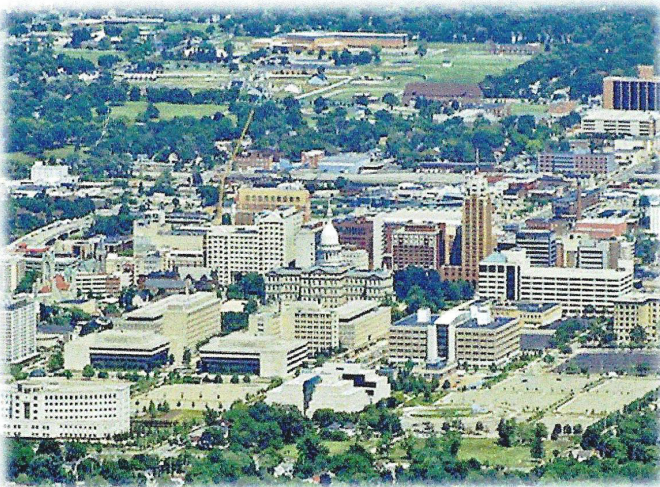
PROTECT2015

Michigan State University

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and Strengthening of Structures under Extreme Loading**



ABSTRACT

The Distribution Center Las Vegas (Medellin – Colombia) is the principal storage and distribution center of the big retail company in Colombia. The project has an area of 646.000,0 ft² and was built in year 2005 (Figure 1). Some years ago, in 4 hours, a conflagration destroyed 430.000,0 ft² of the warehouse (Figure 2). Being centralized the distribution; all activities of the retail company were severely affected and were necessary, after three months of investigations and redesigns, to begin the reconstruction work.

The whole building was divided in 3 blocks (Figure 1 and Figures 3 and 4). The dimensions are indicated in the figures. The height of the columns and walls was variable between 33 ft and 46 ft. For the reconstruction was necessary to consider the most severe specifications to protect the new building against fire. So it was necessary to build new fire walls, 40 ft height supported in the old and new additional frames using the existing deep pier foundations and much of these were unable to resist additional loads. Many of the piers become new loads that were twice the initial loads and for this reason were necessary to strengthen 61 piers (Piers excavated by hand and cast in place).

Medellín is located in an earthquake prone area, with an PEA=0.2 and PEV=0.2.



Figure 1. Distribution Center during the initial construction (Notes: 1. the middle and north warehouses were destroyed by the big fire. 2. For dimensions see figures 3, 4)



Figure 2. Warehouse after the fire

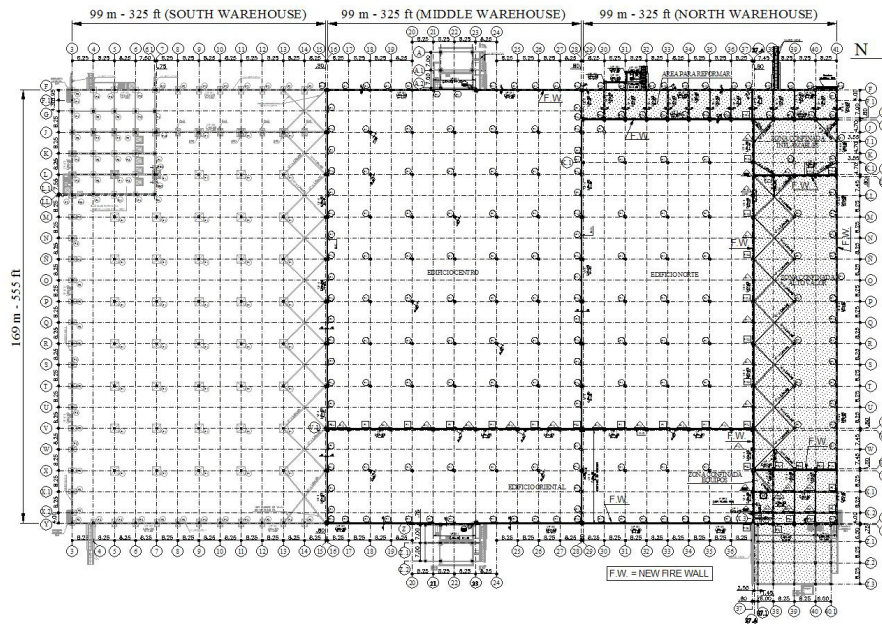


Figure 3. General Plant

Remark: Dotted areas correspond to mezzanine slabs in level 16.40 ft

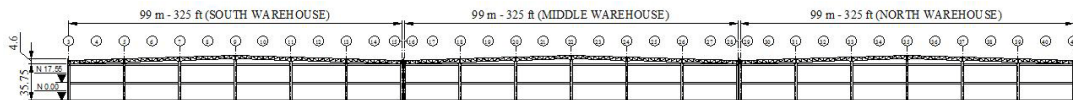


Figure 4. Elevation

INTRODUCTION

Accordingly the recommendations from [1] and following the "Evaluation Methodology" included in figure 1.1 of that publication, several procedures were undertaken to determine the severity of the damage in the different areas of this large warehouse.

PRELIMINARY INVESTIGATION

As structural designers of this warehouse, we had all plans and relevant documents needed, not only for this preliminary investigation, but for the detailed investigation too.

The determination of the severity of the damage required a vast experience which was supplemented with the recommendations given in [2]. To achieve this goal some field tests was made and a table (see table I) for the visual inspection was used.

With the help of this information, 215000 ft² (20000 m²) were given to service one month after the great fire. For the most severed damaged areas a detailed inspection was made.

TABLE I. Data table for Visual Inspection (Damage Level)

Structural Element	Description	Damage Level			
		1	2	3	4
Column Beam Slab	Smoke				
	Color of Concrete				
	Peeling				
	Exposed Steel				
	Loss of Cover				
	Buckled Steel				
	Micro cracking				
	Cracking				
	Deflection				

DETAILED INVESTIGATION

The detailed investigation focused in additional field observations, laboratory testing and a detailed analysis and evaluation.

To understand the difficulties to get the required additional field information perhaps it is important to analyze the figure 5 that depict the real situation found in site: debris all around, varying degrees of damage depending on the presence of racks and the stored wares. Previously to the detailed investigation it was necessary to wait for the permission of the insurance companies and then to proceed to clean all debris. Only when all the conditions were appropriate, it was possible to begin the detailed investigation.

Of the greatest importance was the detailed visual inspection because she gave relevant information about which areas must be demolished or may be rehabilitated. As an example, from the detailed analysis of the situation depicted in figure 6, it was possible to gain very important information because the color of concrete in the surface indicates how high the temperature was and removing the cover it was possible to determine how deep penetrate the temperature in the structural member and it was possible to make an initial appreciation of the damage in the steel too.



Figure 5. Varying degrees of damage



Figure 6. Assessment of fire damage with the concrete color



Figure 7. Extracting concrete cores



Figure 8. Taken of samples of steel for laboratory testing

After that, in the structural members that passed the detailed visual inspection, was necessary to proceed to take some cores (see figure 7) and samples of the steel (see figure 8) for laboratory testing. In figure 6 is noteworthy to see, that was no evidence from a slip between the steel and the concrete, in other words, the adherence was not impaired.

The use of NDT such as pulse velocity tests likewise provided very useful information about the strength of the concrete.

For the detailed analysis and evaluation, the recommendations of [3] are very valuable.

DEMOLITION WORK

The detailed investigation concludes that the mayor part of the central and north areas of the warehouse must be demolished. Although the construction materials and the construction methods have no objection, the very high temperatures over 1112 °F (600 °C) were very destructive for the structural elements and for this reason a controlled demolition of the structure using explosives were made. Only the bakery could be repaired using extensively external reinforcement (FRP) accordingly the recommendations from [4], [5] and epoxy injection [6] (see figure 9).

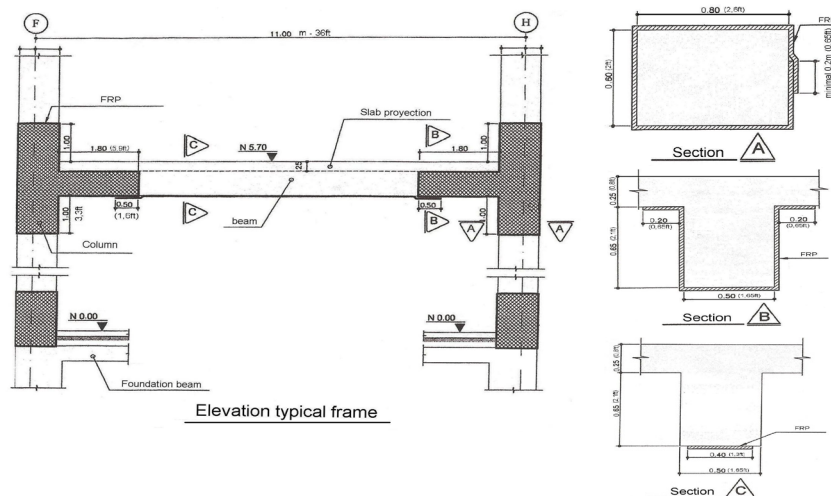


Figure 9. Typical FRP reinforcement of damaged frames

RECONSTRUCTION WORK

For the reconstruction of the warehouse, important changes were made specially to consider the most stringent fire provisions. This provisions required important challenges for the structural design.

Although in some areas new small slabs were required, the big structural problem arises from the new fire walls (from 1 hr to 4 hr) accordingly the flammability of the materials that should be stored. The heavy firewalls with heights ranging between 30 ft (9.0m) and 40 ft (12.0 m), represented a big structural problem, not only of cause of their self weight and seismic considerations but after all because all the new columns required for the new firewalls should be placed very close to the existing ones, which were founded in belled caissons with a shaft diameter of 4 ft (1.2 m) and varying bells accordingly the acting loads. The diameter of the bells were good for the initial loads but not for the final ones, that were approximately twice of the original ones.

For this reason was necessary to enlarge the bells (see figure 10) and to use a variety of corbels anchored with epoxy resins. The figures 11 to 13 show one example of the variety of solutions that should be implemented to attain the new stringent safety requirements. The figures 14 and 15 show the construction works required to the enlargement of the bells and the anchoring of the corbels for the new columns.

The figures 16 and 17 shown some construction stages related with the strengthening of foundations and the anchoring of the corbels reinforcement.

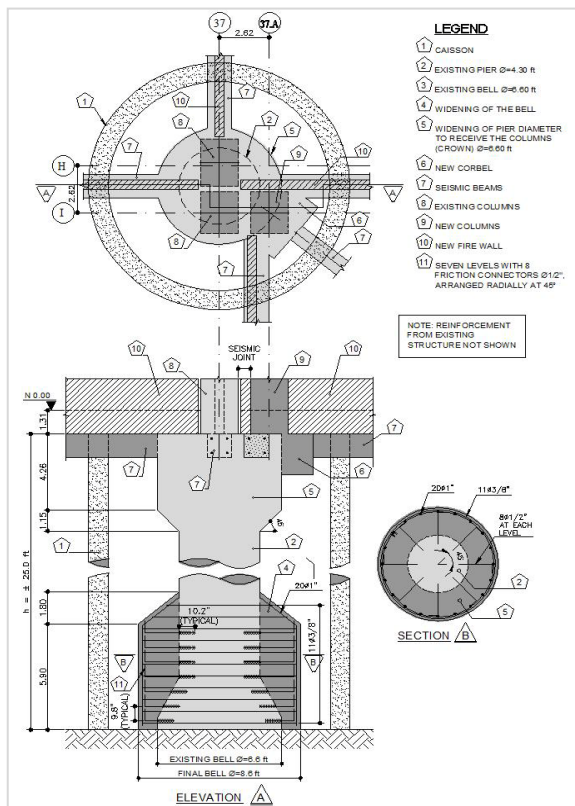


Figure 10. Widening of the bell (Plant and elevation)

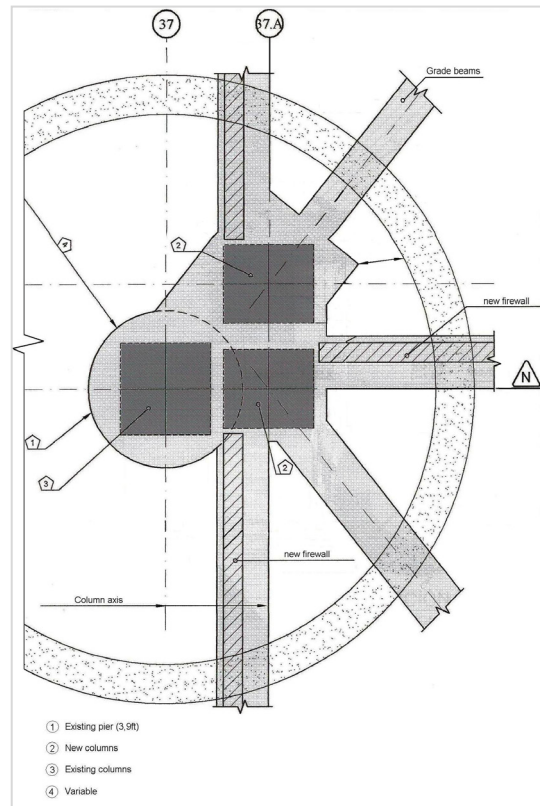


Figure 11. Detail showing new corbels, columns and fire walls

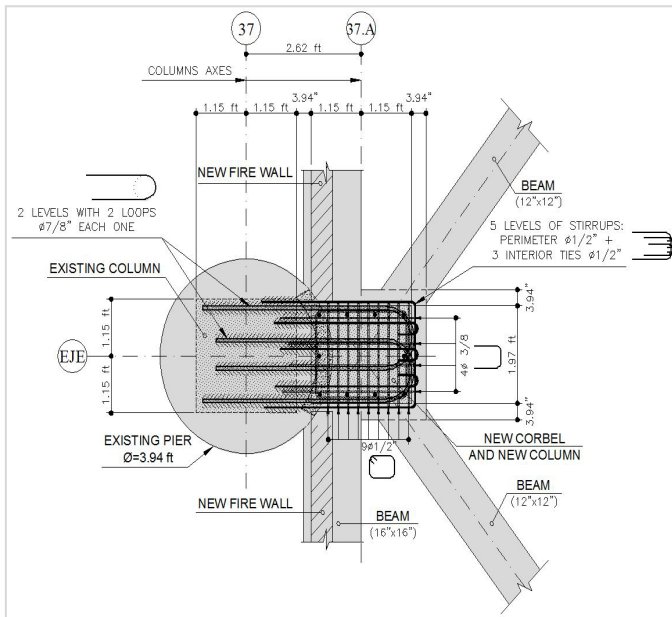


Figure 12. Pier with one corbel

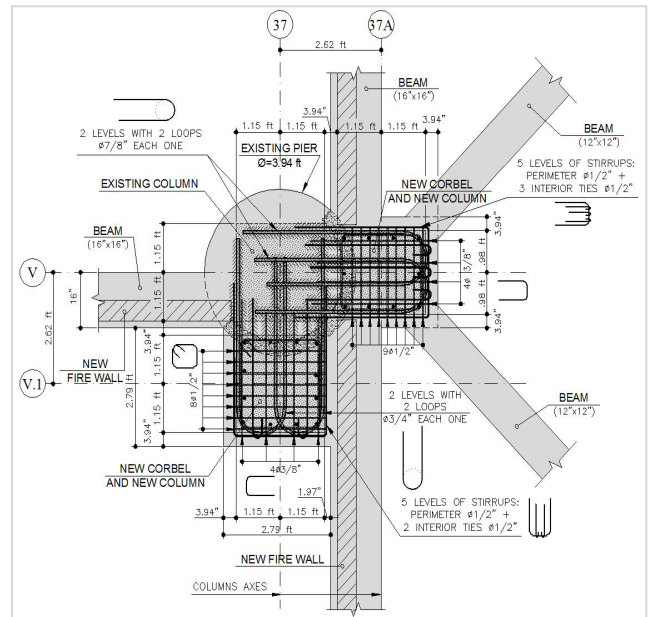


Figure 13. Pier with two corbels



Figure 14. Construction of bell enlargement



Figure 15. Placing of the new bell reinforcement



Figure 16. Epoxy anchoring of the reinforcement for the new corbels

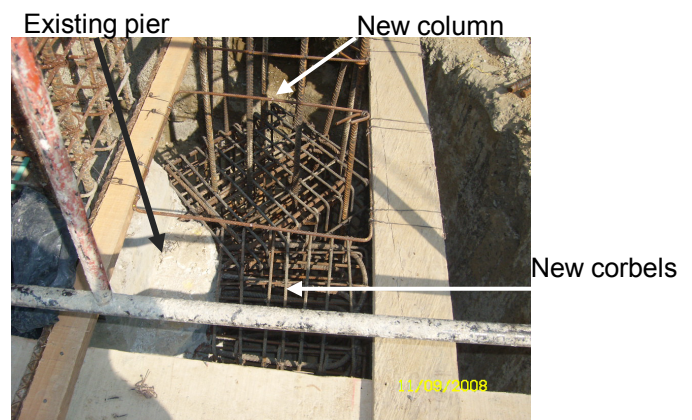


Figure 17. Placing of the new column reinforcement

SLABS ON GROUND

A word is required in connection with the slabs on ground. This were 8" thick and were reinforced with steel fiber with a ratio $l/d=80$ and a concentration of 35 lb/yd³ (21 kg/m³) for light dynamic loading. The joints were spaced every 18ft (5.5m) in both directions. As joint reinforcement were used rectangular load plates and diamond-shaped load plates.

The behavior of this type of slab on ground was very bad and it was necessary to replace it completely.

CONCLUSIONS

A heavy fire caused varying degrees of damage in the structure of a big warehouse. After a detailed investigation some areas might be used shortly after the fire, but other ones must be demolished and reconstructed. Difficult provisions were stated for the reconstruction which required an important design and construction work.

REFERENCES

1. ACI Committee 364.1R-07, "Guide for Evaluation of Concrete Structures before Rehabilitation", American Concrete Institute, Farmington Hills, Michigan.
2. ACI Committee 201.1R-08 "Guide for Conducting a Visual Inspection of Concrete in Service", American Concrete Institute, Farmington Hills, Michigan.
3. ACI Committee 437R-03 "Strength Evaluation of Existing Concrete Buildings", American Concrete Institute, Farmington Hills, Michigan.
4. ACI Committee 440R-07 "Report on Fiber-Reinforced Polymer (FRP) Reinforcement for Concrete Structures" American Concrete Institute, Farmington Hills, Michigan.
5. ACI Committee 440.2R-08 "Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures" American Concrete Institute, Farmington Hills, Michigan.
6. ACI Committee 503.7-07 "Specification for Crack Repair by Epoxy Injection" American Concrete Institute, Farmington Hills, Michigan.

Cover:

Strengthening and Repair of Las Vegas Distribution Center after a severe fire

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