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REHABILITATION OF BUILDINGS AFTER THE 1985 MEXICO CITY EARTHQUAKE

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ABSTRACT

This paper presents an overview of the rehabilitation of buildings damaged by the 1985 Mexico City earthquake and the subsequent structural strengthening carried out to reduce the city vulnerability. Damage assessment, strengthening systems and the most commonly used techniques for shoring and rehabilitation of buildings are discussed.

KEYWORDS

Damaged buildings; damage assessment; shoring; rehabilitation; repair; retrofit; strengthening; Mexico City; vulnerability.

DAMAGE ASSESSMENT

After the 1985 Mexico City earthquake, the authorities of the city requested the owners of damaged building to submit a technical report of the stability of the structure. This report had to be carried out by a structural engineer.

Based on the importance of the damage, the structural specialist determined if major rehabilitation was needed, in such case, a rehabilitation project was required. Finally, the authorities submitted the rehabilitation scheme to the review of private consultants before a construction permit was granted.

This review was well accepted by the designers and only in a few projects there were professional conflicts. This procedure was also used to approve the construction of new buildings.

For the demolition of a building it was also required the submittal of a study that indicates the reasons to demolish and the proposed method. Most of the demolition involved economic and social factors. In some buildings with minor damage in the lower stories, an economical solution consisted of demolition of the upper stories and rehabilitation of the rest.

The qualified supervision of rehabilitation projects was in effect for about three years and was suspended by the new government of Mexico City in 1989. Nowadays the review of projects by the authorities is only an administrative procedure without the intervention of external reviewers.

TEMPORARY SHORING AND BRACING

The 1985 Emergency Regulations required damaged structures to be shored for vertical loads and braced for 25% of the lateral loads estimated according to the new buildings regulations, taking into account the live loads that will exist during construction.

The shoring was usually made with timber (Fig. 1) or steel elements (Fig. 2). In general, the specifications for lateral loads were not accomplished, for economical reasons the temporary bracing used was not significant.

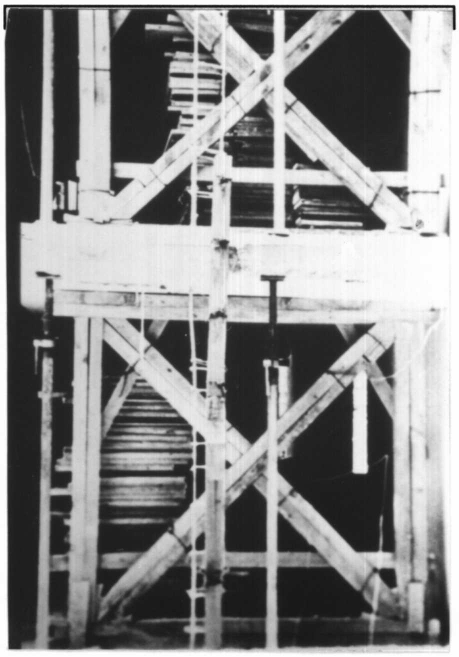

Figure 1. Shoring with timber elements

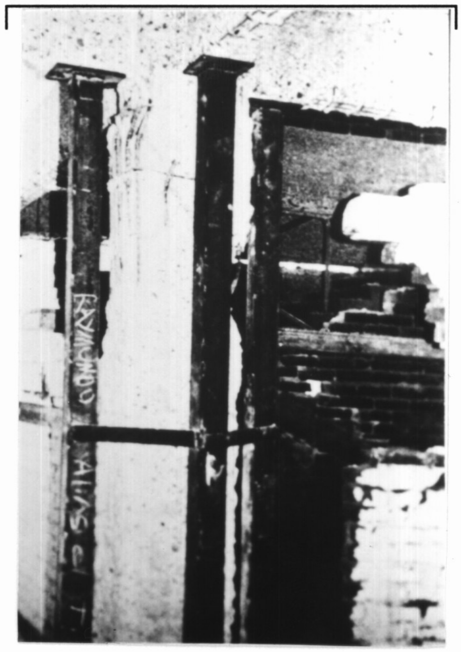

Figure 2. Shoring with steel elements.

DESIGN PROCEDURES

In most of the rehabilitation projects the original structural drawings and calculations were not available, only architectural drawings existed. The lack of adequate information sometimes made it necessary to determine the characteristics of the existing building from measurements and observation at the job site.

The properties of concrete were obtained by means of the combined use of concrete cores and the Schmidt Hammer. The position and number of reinforcement bars were determined by removing concrete cover and in some cases with the Pachometer. When it was not possible to get reliable information the existing reinforcement was usually ignored in the rehabilitation project.

Soil exploration was carried out, specially if settlement or tilting of the building had occurred after the earthquake.

In damaged buildings, the rehabilitation strategy was generally based on an effort to interpret the observed damage and an attempt to correct the associated causes. In undamaged buildings the rehabilitation was focused on strengthening, eliminating irregularities and changing the dynamic characteristics of the structure. The most common objectives were:

Stiffening and strengthening of the structure.
Eliminating discontinuities and irregularities in plan and elevation.

Repair and strengthening of structural elements.
Repair and strengthening of foundation.

Seismic loads were determined by modal analysis and the design spectra of the Emergency Regulations first and the new Mexico City building code afterwards. In many cases a static analysis was considered adequate.

With regard to detailing of the reinforcement steel, it was very difficult to comply with the requirements of the new building regulations in existing buildings. The requirements of the new building code do not make much difference between the existing and new buildings.

REPAIR OF STRUCTURAL ELEMENTS

The most common method of repair damaged structural elements were:

Resin Injections.

Very frequently, epoxy resins were injected in cracks of damaged elements. The equipment used grease guns for wide cracks (Fig. 3) and high pressure injection machines for slender ones.

Replacement of Damaged Sections.

In some buildings, when the longitudinal reinforcement buckled, the ties broke and the concrete crushed, damaged sections were removed and replaced with new materials. Sometimes, hydraulic jacks were used to recover the original geometry of columns.

Figure 3. Crack injection of a damaged slab.

STRENGTHENING OF STRUCTURAL ELEMENTS

The most common techniques used for strengthening structural elements were:

Reinforced Concrete Jacketing.

This technique was extensively used for the strengthening of beams and columns. In some cases it was applied only as a local solution, but in general, the reinforcement was made continuous trough openings drilled in the slabs (Fig. 4).

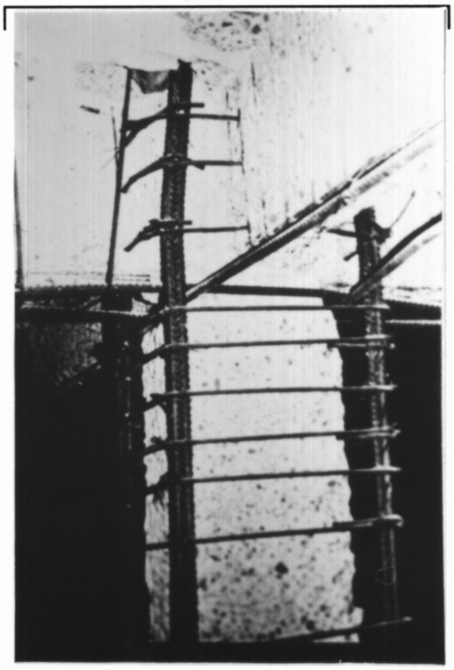

Figure 4. Reinforced concrete jacketing of beams and columns.

Steel Jacketing.

Jacketing with steel angles and straps was a common system to strength columns (Fig. 5). External clamps or steel straps attached with epoxy resins were sometimes used for local strengthening of beams.

Steel elements were also used for the strengthening of the solid area around columns in waffle slabs.

ADDITION OF NEW STRUCTURAL ELEMENTS.

New structural components in damaged buildings was the most common solution for stiffening, strengthening and eliminating discontinuities and irregularities in plan and elevation of structures. The types of structural elements used were:

Concrete Walls.

The addition of new reinforced concrete shear walls (Fig. 6) was the most common practice. Usually, the boundary elements were jacketed along the entire height of the wall.

Reinforced concrete infilled walls with local strengthening of existing columns were also used in some cases (Fig. 5).

Figure 5. Jacketing of column with angles and straps.

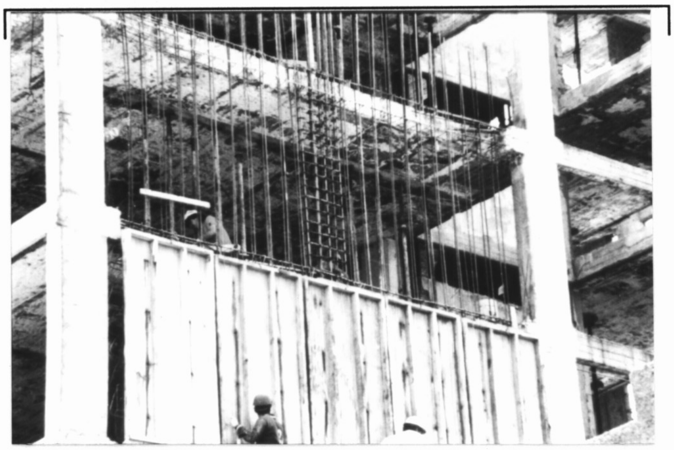

Figure 6. Reinforcement of new shear wall.

Frames and Steel Bracing.

If the use of the building or the concentration of loads on the foundation limited the addition of concrete shear walls, the addition of concrete frames (Fig. 7) or steel bracing (Fig. 8) were the alternatives selected.

Cable Bracing.

Cable bracing has been used for the strengthening of many undamaged low-rise school buildings. The cables are designed to reach their capacities at the same displacement levels, and are postensioned at about 10% of their capacity to prevent sagging.

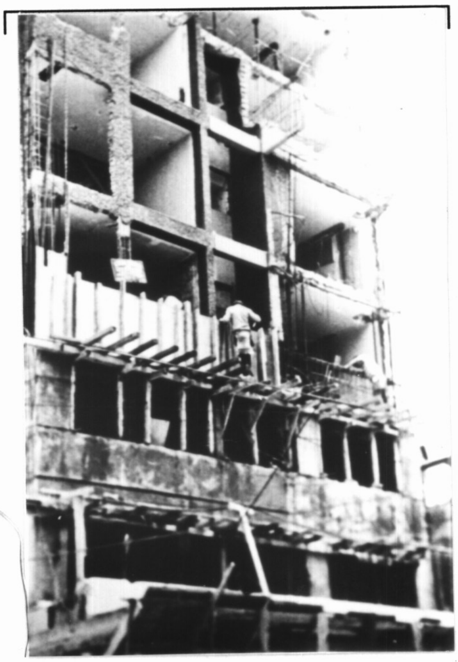

Figure 7. Addition of a reinforced concrete frame.

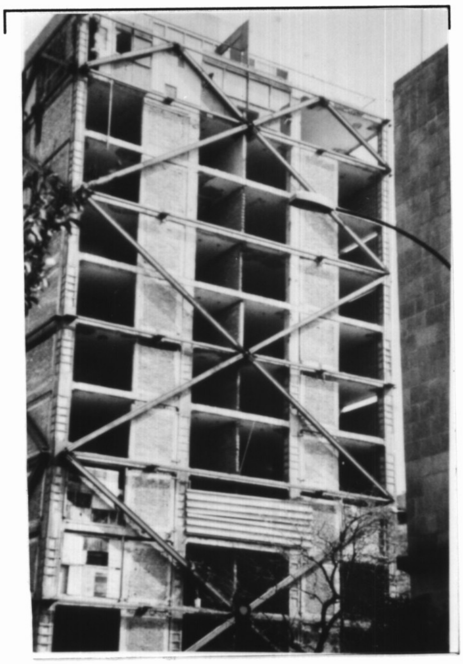

Figure 8. Steel bracing.

FOUNDATIONS

Repair and strengthening of foundations was due to two types of problems: the change of the path load on the foundation and the failure of the foundation itself.

In the first case, the most common practice was the reinforced concrete jacketing of foundation beams and the addition of new piles. Generally segmented concrete piles were used driven by hydraulic jacks (Fig. 9).

If the building had excessive non uniform settlement, the addition of new piles in combination with ballast and excavation was used to control the movement of the structure. In these cases control piles were also used (Fig. 10).

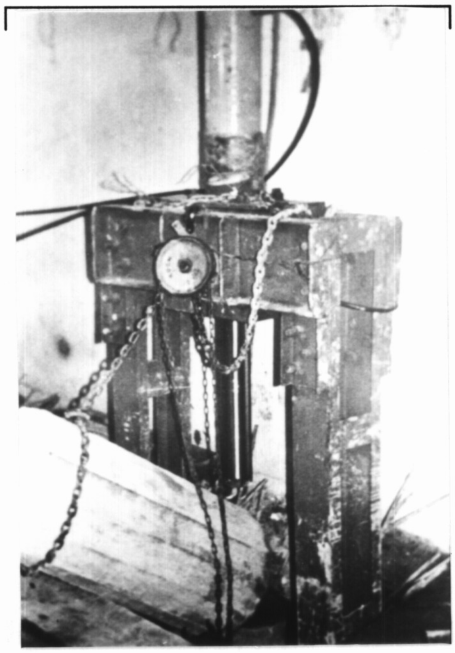

Figure 9. Driving of a concrete pile segment.

Figure 10. Control pile.

CONCLUSIONS

Hundreds of building at Mexico city have been rehabilitated after the 1985 Mexico earthquake. Several of the rehabilitation projects used techniques without the appropriate theoretical and experimental support. The next major earthquake will test the reliability of all these works.