# REHABILITATION OF A FIRE DAMAGED BUILDING

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**Synopsis:** Almost ten years ago today, a landmark Reinforced Concrete Building serving as General Headquarters for the Armed Forces of the Philippines was Burned for the Third Time. This paper discusses the Investigation, Design, Construction and Monitoring Procedures used in the Structural Rehabilitation. Extensive use of Computer Analyses and Design as well as Computer Aided Drafting (CAD) including computer generated 3D details of critical connections, other than speeding up the design process resulted in effective communication of Designer's intentions in a timely manner to all concerned. The cost of rehabilitation, not to mention the preservation of the Historical Value of the Building and reduced time to occupancy led to the owner's decision to rehabilitate rather than demolish and reconstruct this Building.

## 1. INTRODUCTION

The last fire at the AFP General Headquarters Building resulted in an Engineering assessment being commissioned by the client to determine the viability of further rehabilitation efforts and to determine the integrity of the various Structural Elements that were involved or exposed to the Fire. Our office was retained to undertake this study and was subsequently engaged by the owner to undertake the Detailed Engineering needed for the rehabilitation and structural upgrading of the whole Building.

This paper discusses the steps and procedures undertaken by this office from the start of the investigation, to the Detailed Analysis and Design Engineering and the inspection and monitoring during the construction.

## 2. ENGINEERING BACKGROUND

### 2.1 Investigation Phase

The Investigation Phase was done over a Three (3) month period in 1988 culminating in the submittal of a report which concluded that although major repairs would be needed, the Historically Valuable Building could be saved despite three fires and two rehabilitations, without demolishing the Historical Facade (Figure 2) which was the focal point of the whole General Headquarters Complex of Camp Emilio Aguinaldo, the Headquarters and Administrative complex of the Armed Forces of the Philippines.

### 2.2 Methodology

The investigation study required destructive and non-destructive tests. Numerous cores were extracted in suspect concrete after numerous Rebound Hammer Tests were performed to indicate

the location of relatively weaker concrete. In addition, steel reinforcement was extracted for tensile tests in some areas to serve as bases for our subsequent Structural Analyses and Investigation.
Reinforcing bars were exposed at critical structural sections such as at Beams, Girders, Column and Slabs to determine spacing and sizes of reinforcing bars for the existing structure. Fortunately, Plans of the First and Second Rehabilitation Programs were still available and were verified to be relatively accurate except in some instances, for which field changes were required during the ongoing rehabilitation. The rehab programs undertaken prior to this study involve buildup in concrete members one on top of the other for affected areas.

### 2.3 Results of the Investigation

From the results of the numerous rebound hammer readings undertaken, it was already evident that there were large disparities in the strengths of the two concrete layers. Figure 3 shows the existing configuration before rehabilitation.

The lower layer for Beams and Girders is composed of what we now term as the "original" concrete used in the original construction and the "rehab" concrete on top and integrated with the R.C. Slab used in the first and second structural rehabilitation. The original concrete on the underside showed very low concrete strengths, often preventing extraction of intact cores. Evidently, the original concrete in both Wings had been affected by exposure to Fire as borne out by the rebound hammer tests, the core extraction and subsequent tests on the intact cores.

Figure 4 is a chart of the results of Unconfined Compression Tests on intact cores. Of the more than 78 cores extracted, all of the low concrete strengths (below fc'=2500 psi) were obtained on the original concrete. Zero strengths represented concrete cores which disintegrated during extraction mainly from the original concrete.

All of the later rehab concrete showed consistently high concrete strengths averaging approximately 3500 psi. These results were predicted and anticipated by the numerous rebound hammer tests before the corings were performed.

From the foregoing, we were able to make the following conclusions:

1) The original concrete used in the original building construction was of relatively lower strength compared to more recent Rehab Concrete. This is probably due to the following:

   - The original concrete had been subjected to at least two previous fires, thus damage was progressive.

   - Poor quality concrete was used in the original construction.

   - The original concrete would pose a danger to building occupants if left in its existing condition.

2) Newer “Rehab” concrete although being subjected to the same fire exposure during the last fire has been relatively unaffected by it.

3) There was no need to totally demolish or condemn the Building and only structural strengthening of the historically important Building would be required to restore it to its former function.

4) The strengthening and rehab measures to be implemented, would also be directed towards upgrading the structural performance of the Building and bring it up to Present Day Seismic Code Design Standards.

   Other than the foregoing which were purely of technical nature, the decision to go ahead on the structural rehabilitation was also dictated by practical reasons which weighed heavily in favor of rehabilitation rather than outright total demolition and reconstruction.

   The practical considerations are as follows:

   - Cost - The cost of structural rehabilitation is approximately thirty four percent (34%) of the cost of a totally new Building with the same floor area.

     Based on the winning bid, the cost of the Civil/Structural Works for the rehab scheme amounted to only one third of the cost per square meter for the demolish/construct scheme.

   - Time - Time to occupancy would be greatly shortened from a minimum of eighteen (18) months for a demolish/construct scheme to about five (5) months for the rehabilitation scheme eventually adopted.

   - Historical Value -There was a need to preserve the historical value and architectural details of the Building.

## 3. ENGINEERING ANALYSES AND DETAILED DESIGN

Several findings and engineering decisions were made during the structural analyses and detailed design stages as follows:

- The Preliminary Structural Analyses showed that the existing structural system even without the effects of the fire would be **inadequate** to sustain Seismic Lateral Forces.

- The existing details, even for the rehabbed portion, will not comply with Seismic Detailing Standards for Zone 4 existing at the time as mandated by ACI 318-83 and the National Structural Code of the Philippines and therefore structural strengthening would be necessary.

- In the structural analyses, the contribution of the original column core concrete was entirely neglected and the new column was idealized as a Hollow or Box Column enclosing the original concrete core. A specific custom program was developed in-house to analyze the hollow column and generate column interaction diagrams for various cases of loading.

3-D Computerized Frame Analyses were conducted. The East Wing, West Wing and Central Core were idealized as independent structures because of the provision of a Seismic Joint in the original construction. The subsequent strengthening details also preserved this Seismic Joint.

The rear portion of the Central Core was totally demolished and replaced by a new structure integrated with the existing core. This was necessary as this part was still supported on Timber Flooring during the last fire and relatively was more severely damaged.

On the basis of the analyses results, a Reinforced Concrete Seismic joint detailed to existing Code was found adequate. The most important feature of this detail is the provision of additional Vertical Reinforcing bars through the joints to provide for continuity. Confining ties were placed in addition to the confinement by additional rehab concrete on the Beams and Girders meeting at the joint. *(See Figure 5)*

The horizontal beam and girder bars were in turn confined within the column vertical bars. The illustration of Figure 6 shows the Rehab Scheme adopted for the Beams, Columns and Slabs.

It is important to note here that although the East Wing Columns have been earlier rehabilitated after the previous fires, it was still necessary to provide for additional vertical reinforcing bars through the joints to be confined with closely spaced ties as the existing details were found to be inadequate. Again, in the Structural Analyses of this system, the existing core concrete and reinforcing bars were neglected thus imparting a far bigger "Factor of Safety" in reality.

Negative moments for the existing Beam and Girder needed additional reinforcement for continuity and also to increase lateral load resistance. Additional reinforcing bars were also needed to increase positive moment carrying capacity.

The negative Bars were placed and confined within the new column vertical bars and new ties were integrated to confine the reinforcing bars as well as the positive moment reinforcing bars which were threaded in to the existing Beam hoops.

### 3.1 Computer Analyses and Design

The computer analyses and design was carried out using M-STRUDL, an enhanced microcomputer implementation of the STRUDL Software written in C Language which was popular at the time. In-house developed software for the analysis of the Hollow or Box Column was used as earlier stated as well as spreadsheet programs for generating column interaction diagrams.

## 4. REHABILITATION PROCEDURES

### 4.1 General

Great emphasis was placed on the value of effective bonding between the old and new concrete requiring the use Structural Epoxy Bonding agents. In the process, stringent surface preparation procedures were required to ensure the effectiveness of the Bonding.

We assigned a Senior Structural Engineer on full time basis to monitor and ensure that surface preparation and epoxy application are carried in accordance with the specifications and to oversee rehabilitation in general.

In addition to this, detailed structural rehabilitation procedures were included as part of the plans and specifications to set the minimum basis for rehabilitation. This included outline or step by step procedures for chipping, demolition, surface preparation, epoxy application and reinforcing bars installation. In order to forestall any misinterpretation of Plans and Specifications, the Contractor was required to submit a detailed *construction methodology* for acceptance and approval by the owner through the consultant. This requirement identified a lot of areas that were overlooked during the bidding stage and was very invaluable in this regard as it enabled the owner and engineer to check the Contractor's intentions and directions for the rehab even before fieldwork started. Revisions and changes in the methodology were made in the course of construction, nevertheless, this requirement helped immensely in identifying possible problems during the implementation.

### 4.2 Computer Aided Drafting and Detailing

Three Dimensional (3D) drawings and reinforcing bar layouts as in Figure 6 & 7 were prepared to ensure that the intended reinforcing bars details were faithfully carried out in the field by the Contractor. Extensive use of CAD to generate 3D Plots were made. The extent of detailing required and implemented using CAD would defy manual efforts, given the time pressure. Thus, the decision to fully utilize our CAD Graphics facility which was still relatively crude at the time, to support the project and generate 95% of the drawings proved to be a wise one and was effective in ensuring a clearer understanding of the complicated reinforcing bars layouts. In addition, changes necessitated by unforeseen field conditions could be done easily by just revising the electronic files.

### 4.3 Detailed Rehabilitation Requirements and Procedures

Based on the findings during the investigation phase, it was decided that all original Beam and Girder concrete would have to be removed and replaced as this could fall off or spall off during an Earthquake. Because of the adequacy of the later rehab concrete for the Slabs and Top portions of Beams and Girders, it was decided to retain and integrate these with the new rehab concrete. This was a major cost saving. The existing columns' concrete cover would have to be removed to expose the old reinforcing bars and a new rehab concrete and reinforcing bar cage were installed to envelope this core concrete. Vertical column reinforcing bars as well as Beam/Girder negative bars and positive moment bars were made continuous through the joints and confined with Hoops and Ties in accordance with ACI 318 and 315. Extensive use of shoring was specified and required as early as the bid stage in all instances to prevent any movements in the Building Frame during rehabilitation when it was very vulnerable.

Due to the fragile and weakened nature of some elements, the use of heavy Pneumatic Jackhammers was prohibited and only small hand held rotary air hammers and bush hammers were allowed to be used to demolish the original concrete. Vibrations during construction operations was carefully avoided and extensive use of shoring was required.

The existing original reinforcing bars for Beams, Girders and Columns were retained and integrated with the new rehab reinforcing bars and concrete. This in a way compensated for the setting up of creep/shrinkage stresses affecting the structural elements due to the bonding of the old and new concrete.

### 4.4 Surface Preparation

The original concrete cover was chipped off (Figure 9) to expose the existing reinforcing bars. Cleaning of the reinforcing bars proceeded immediately using a wet type sand blasting equipment until all the reinforcing bars were to bare white metal finish.

High pressure water spraying (Figure 8) was used immediately before epoxy application in order to remove all loose and defective concrete and for final cleaning of reinforcing bars. This utilized a 6,000 psi (41.3 Mpa) High Pressure washer. The quality of bonding surface and rough texture was assured by this final surface preparation procedure.

The tight spaces and reinforcing bars cages required epoxy application by hand brushing. It was therefore necessary to require that the epoxy would have an adequately long "overlay time" of at least six (6) hours to allow application, erection of forms and pouring of concrete. This requirement meant that the forms would have to be collapsible and allow for easy installation. Prefabricated laminated plywood forms were specified to eliminate the need to refinish the stripped surfaces.

### 4.5 Concreting

It was necessary to pour the concrete columns in two lifts with the last lift being poured monolithically with the upper Beam Column joint (Figure 10). Maximum 3/8" (9.5mm) aggregate was specified to ensure that the congested areas are effectively filled by concrete. Breather holes were punched in the slabs to prevent entrapment of air that could block the flow of concrete. Very small diameter hand held electric Driven Pencil Poker Vibrators were utilized in most instances due to the tight spaces involved. The Concrete Mix required the use of a plasticizer because of the low water cement ratio (0.42) required on top of the minimum guide specification of fc'=4000 psi (27.6 Mpa) Concrete Cylinder Compressive Strength. The low water cement ratio was required to reduce shrinkage to a minimum. Wet curing of the poured concrete elements also helped to reduce shrinkage. The more than liberal distribution of new and old reinforcing bars in a way prevented shrinkage movements that would have otherwise caused concrete to crack.

## 4.6 Construction Methodology

Unlike conventional construction projects, this rehabilitation project is unique in that rehab work can be started in almost all areas. However, due to priorities dictated by owner requirements and in order to further speed up the project, the contractor was required to adhere to a priority schedule which among others required completion of the roof within 40 days from award of contract. Completion of the roof would have allowed an all weather construction although extensive shoring would have been required.

Additionally, the rehab procedures dictated that no two adjacent columns would be rehabbed simultaneously so as not to unduly weaken the Building. The soundness of this requirement was amply proven during the July 16, 1990 Luzon Earthquake which registered Intensity 7.7 in the Richter Scale.

## REFERENCES

ASEP (1992) **National Structural Code of the Philippines Volume 1**. Association of Structural Engineers of the Philippines (ASEP), Manila.

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