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Essential Steps in Adaptation of Old Buildings

By Boris Bresler

Synopsis: Essential steps in modifying structures for the purpose of adapting old buildings to new use are discussed in this paper. Eight basic steps are described: (1) preliminary site visit, (2) documentation of original design and construction, (3) identification of desired changes in the building, (4) identification of code requirements applicable to building alterations, (5) development of structural modification schemes and preliminary cost estimates, (6) verification of "as is" condition, review of adequacy of proposed modification scheme and estimated cost, (7) completion of design and construction documents, including drawings and specifications, and (8) coordination of engineering design with construction quality control and accommodation of possible need for design changes during construction.

Keywords: buildings; evaluation; renovating; repairs; strengthening; structural design.

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1. INTRODUCTION

In recent years, rehabilitation and renovation of existing buildings have grown to occupy a significant share of the concrete and masonry construction market. This growth has drawn an everwidening circle of developers, architects, engineers and contractors into this recycling process. The spirit of this recycling process is intended to meet the immediate need for additional space and to enhance security, stability, and beauty of the urban environment, while, at the same time, conserving basic materials and energy resources.

Three other factors contribute to the wide spread of recycling of old buildings:

(1) need for space at reasonable cost

(2) availability of sound old buildings, and

(3) tax incentives through depreciation and rehabilitation cost write-offs.

In an urban environment already densely built up, rehabilitation of existing space becomes an alternative to new construction, as it frequently meets the need for additional space at a reasonable cost. The old buildings have been conservatively designed and soundly constructed; only the fittest survived, the lesser contemporaries have already been torn down.

The <u>need</u> and the <u>availability</u> are necessary conditions for recycling, but they alone are not sufficient to generate the economic forces for implementation of recycling. Implementation is largely the consequence of economic incentives generated by depreciation write-off tax advantages. In the 1976 and 1978 tax reforms, Congress extended tax incentives to the preservation of historic buildings and renovation of old buildings generally. Under these tax regulations, "old" buildings which have not been rehabilitated for at least twenty years, qualify for write-off rehabilitation expense.

The scope of the renovation project may range from relatively minor remodeling to the complete reconstruction of a building. In almost all cases, however, public safety demands a reassessment of reliable performance, both structural and non-structural performance, of the modified building.

The most challenging problems of successful renovation are:

1. Choice of the new use for the old space.

2. Adaptation of the old space for the new use at a reasonable cost.

3. Accommodation of spatial modifications with full structural safety.

4. Accommodation of building code requirements with respect to mechanical, electrical, plumbing, and fire safety requirements.

Although there are many similarities between rehabilitation and new construction, there are a number of significant differences. The essential steps in the adaptation of old buildings to new use are outlined in Table 1. Starting with a site visit and a review of proposed new use and ending with construction, the process of adaptation, from the view of structural engineering, is divided into eight steps. When rehabilitation requires only minor or cosmetic alteration, some of these steps may be omitted. In any case, the architect, the structural engineer and the contractor have to work as a team to achieve safe and economically viable schemes for the desired space modification. In this paper, however, emphasis is placed on the contributions of the structural engineer.

2. SITE VISIT

The purpose of the initial site visit is to identify the type and age of construction, overall spatial configuration, gravity and lateral load resisting systems, and to make a preliminary assessment of the present condition of the building with respect to prior damage and repair as a result of degradation due to various causes such as foundation movement, normal deterioration, corrosion, thermal and humidity variations, fire or earthquakes. At the time of the initial visit, it may not be possible to make definitive determinations of construction details and the condition of structural materials because they are often enclosed by interior or exterior finishes. In such cases, the engineer's preliminary appraisal must often rely on indirect evidence such as conventional practice and code requirements at the time the building was constructed. Nevertheless, every effort must be made to collect as much evidence as possible from visual observations and measurement of accessible structural components. Special potential problems associated with cracking, excessive deflections, inadequate fire protection, deterioration of cladding, weather tightness, and wind, snow or earthquake resistance (where applicable) should be noted. Photographic records, notes or tape recordings of observations provide an indispensable source of data for evaluation of field observations.

Subsequent to the site visit, the proposed new use of the building should be reviewed with special reference to problems related to changes in the occupancy and functional and spatial uses of the building.

3. DOCUMENTATION OF ORIGINAL DESIGN AND CONSTRUCTION

A large number of buildings considered for recycling or adaptation were used originally as industrial or commercial buildings. The "fitness" and survival of these buildings can be attributed to good design and construction workmanship. In assessing the adaptability of these buildings to new uses, it is important to identify both the original design criteria and the construction details of old buildings.

The engineer's task in evaluating an existing building is greatly simplified when drawings and specifications for original construction are available.

The important elements of the documentation which relate to original design, construction, and subsequent modifications and service life are as follows:

1. A set of drawings describing original architectural, structural, mechanical, and electrical systems. As-built and shop drawings are preferable, as these will include all the changes made during initial construction. Building permits for subsequent modifications provide valuable information on the current "as-is" conditions.

2. A set of specifications which usually form a part of the construction contract and contain information on materials, workmanship, and quality control requirements.

3. Design calculations, including specified design loads, as well as structural and foundation design.

4. Reports of foundation studies - site borings, and soil test data.

5. Inspection records reflecting construction records and notes on any deviations from the original design and/or specifications, as approved by architects or engineers, during construction.

6. Material test records which often form a part of the inspection records. These records should include data on field control tests of concrete, mill or laboratory tests of steel reinforcement and other laboratory tests.

When these are not available (as in the case of many old buildings), sketches of plans, elevations, and sections of existing buildings must be prepared by measurements obtained in the field, and material characteristics must be established by removing and testing representative samples. Special care must be exercised in locating areas where representative samples can be safely removed from the structure. The nature of the foundation for the structure must also be identified, and the general condition of the structure with reference to needed maintenance and repair should be noted.

Because drawings and specifications for the original construction greatly simplify the engineer's problem of evaluating an existing building, it is often worthwhile to expend some effort in locating such documentation. In some cases, old architectural and engineering firms have passed on their archival materials to their associates or successors or to libraries, museums, and educational institutions. A thorough search of the various organizations' files and archival sources is often highly cost effective.

4. HISTORICAL BUILDINGS

Historical buildings deemed to be of importance to the history, architecture, or culture of an area or community, and so designated by appropriate public agency, require special consideration.

Evaluation of residual structural reliability requires special skills, and, in some cases, the standards of structural modification may be relaxed in order to preserve the original character of the building at an acceptable cost.

5. IDENTIFICATION OF DESIRED CHANGES IN THE BUILDING

The space modifications may be relatively minor, with addition or removal of only a few partitions, or it may be major with total "gutting" of the interior and "re-stuffing" it with new floors, partitions, stairwells, elevator shafts, etc. In some cases, the exterior walls will undergo only minor modifications, perhaps cosmetic only; in other cases, strengthening of exterior walls may be necessary. Floors and roofs can often be saved, but in some masonry buildings with wood floors, the latter may have to be removed and replaced by metal or concrete floor systems.

Assessment of fire safety may lead to a variety of required modifications: installation of fire detection and/or suppression system, addition of fire proofing, fire separation walls, fire doors and other exits, and, in some cases, addition of stairs or elevators. Trade-offs between alternative solutions would determine the final architectural space modifications.

Assessment of the need for structural modification is based primarily on evaluation of the performance of the building exposed to a variety of possible loading and environment conditions such as excessive live load, snow, wind, earthquake, fire, etc. Given a specific building, proposed occupancy and space changes, and given loading and environment requirements, the force and deformation response of structural elements can be calculated and compared to the estimated capacity. For satisfactory performance, the resistance capacity should exceed the response demand of an acceptable margin. This margin is a measure of the level of performance. The process is illustrated schematically in Figure 1.

Modeling the structural system and the various loading conditions, as well as calculating the response demand and capacity, follow the generally accepted procedures of structural analysis and design. As a minimum requirement, this process requires a review of the mandated level of structural adequacy established by a governmental agency having jurisdiction; the review must be based on present state-of-the-art and existing conditions in the structure. Thus, given the proposed occupancy and architectural space modification, structural sufficiency (for superstructure as well as the foundation) must be verified for gravity loads, combined gravity and lateral loads, as well as concentrated loads, impact, construction loads during modification, and special service conditions which may be appropriate for the case under consideration.

It is interesting to compare design live loads for different types of buildings recommended by different cities in 1900 with typical live loads specified in contemporary codes (see Table 2). In most cases, contemporary new buildings are designed for smaller live load requirements compared to those used in the design of old buildings. Also of interest are allowable stresses for concrete and masonry, as shown in Table 3.

Allowable stresses for concrete varied during different periods of time. Particularly significant were the variations in allowable stresses for shear in reinforced concrete. The progressive changes in these values for concretes of different strength are shown in Table 4. Except for a brief period of time, 1940-1956, when higher values of shear stresses were permitted, the general trend for allowable stresses in concrete is consistent. It should be noted, however, that prior to 1940, concretes having design compressive strengths in excess of 3000 psi were rarely used.

The strength of an unreinforced brick wall in compression and shear depends primarily on mortar. In the old codes, no values of shear allowable were given, but distinction was made between brick walls made with portland cement mortar and those made with lime mortar. It is interesting to note that there is relatively little change in allowable values over the years, although newer types of masonry - both concrete block and reinforced brick - have been developed for which increases in allowable stress are significant. This suggests that, provided there is no aging degradation in the construction materials, no reduction in allowable stresses for the type of construction considered, no requirements for the building under the new occupancy to withstand higher loads than those originally designed for, and no removal of gravity bearing structural elements in the spatial remodeling of the building, the structural modification for support of gravity loads may be minor.

6. REVIEW OF CODE REQUIREMENTS

Codes are continually revised to keep pace with changes in construction technology reflecting innovation in materials, structural systems and quality control methods, as well as new knowledge of structural behavior acquired through analysis, testing, and experience. Code revisions also include deletion of sections dealing with materials and methods of construction no longer in use.

While the code revisions play an important role in the advance of technology of new construction, the current codes often complicate the process of rehabilitating old buildings. The new codes are poor instruments for evaluating adequacy of existing buildings: non-compliance with current code does not mean poor performance of an old building. In many cases, old types of construction are just not covered in a current code. Upgrading an old building to comply with current standards for new construction is generally extremely difficult and costly as full upgrading often requires extensive demolition and reconstruction, and its economic impact can result in the abandonment of a rehabilitation project.

It is generally advisable during the preliminary stages of design to consult with local building officials to provide them with a chance for early input into rehabilitation process. At this time, the building official will have an opportunity to discuss with the designers what level of structural rehabilitation would be acceptable for the particular building. The official might also review preliminary schemes for reinforcement of different elements and may indicate a tentative approval of these methods.

Current code provisions on rehabilitation are based on a "passive" approach; i.e., assuming that old buildings are essentially tolerated until the owner chooses to remodel or change the use of the building. If the extent of proposed changes exceeds certain threshold levels, then the portion of the building affected, if not the entire building, is required to be upgraded.

Typical code requirements for alterations, additions, and repairs of existing buildings based on extent and nature of alterations are summarized in Table 5.

These requirements are based on the following criteria:

1. Extent of Alteration: This is defined either in terms of the value of alterations expressed as % of the value of the existing building, or in terms of space involved in alteration exprssed as % of the total space in the existing building.

2. Nature of Alteration: Generally, the alternations are subdivided into structural and non-structural alteration, the latter including all architectural, mechanical and electrical systems.

3. Increment of Alteration: Generally, any single or multiple alterations within a 12-month period are considered as the increment of alteration defining the extent of alteration. In some cases, all alterations cumulative since the building was built are included in defining the extent of alteration.

4. Change of Occupancy: Categories of buildings which fall in specific occupancy groups are defined in the code. Typical occupancy categories include: public assembly, schools, hospitals, commerical, industrial, hotels, and apartment houses and dwellings. Change in use or occupancy is accompanied by change in the number of occupants, change in the floor loading, change in the building contents, and, generally, changes related to life, fire, and seismic hazard risk.

   The code requirement related to change in use usually states that when a more hazardous use for a given building is proposed, the building should comply with all the requirements of the current code - particularly with respect to life, fire, and seismic hazards. When the new use is less hazardous, the entire building, subject to approval by the building official, need not comply with all the code requirements for the particular occupancy group. Some codes provide that when the change in occupancy increasing the hazard involves less than 30% of building space, only that space, not the entire building, need conform to the occupancy requirement.

7. ARCHITECTURAL AND STRUCTURAL MODIFICATION

Design professionals view rehabilitation projects differently according to the responsibility that each must assume. Architectural modifications focus on the reallocation of space for different needs, on the traffic flow within the building, on services, communications, and general environment in the building. Thus, the architect will be concerned with relocating walls and partitions, entrances and exits, stairs and elevators, toilets and other plumbing, lighting, exterior cladding and interior finishes, telephones and electric wiring, heating and air conditioning, fire detection, alarms, and suppression systems, and, in general, creating a pleasant environment in the space for the new use of space.

The structural engineer is concerned with the adequacy of the structure to carry gravity loads, lateral loads (wind, seismic), and the response of the structural system to such environmental conditions as changes in temperature and humidity. In rehabilitation of existing buildings, the structural engineer will focus on condition and strength of structural materials in the buildings, adequacy of structural floor and roof framing, vertical framing and walls, and adequacy of foundation system. Strengthening may be required as a result of removal of some walls or portions of floors necessitated by architectural space modifications, as a result of material deterioration, or as a result of an increase in loading due to a change in the use of the building.

One of the deficiencies in the design of old buildings is lack of provisions for lateral loadings - wind or seismic. The problem of seismic rehabilitation is a special problem and will be briefly addressed in a subsequent section. As for effects of wind on old buildings, it is important to ensure that the modifications in the old structure do not reduce its capability to resist wind. Anchoring the roof to the remaining structure, bracing of the roof, and the effectivenss of the remaining (or new) floors to act as horizontal diaphragms in distributing the lateral load to the walls or frames must be ensured.

The type of structural modification in a given building depends on the deficiencies discovered in the existing system. Generally, the modifications can be subdivided into two categories:

a. maintaining the original structural system and strengthening critical members or connections, and,

b. modifying the original structure by replacement of floor systems, vertical framing, and/or addition of structural elements to the vertical load carrying system or lateral bracing system.

Prior to the development of a structural modification scheme, an evaluation of the condition of existing structures and structural materials must be carried out. This requires testing in situ, or removal of specimens for testing in the laboratory. Assuming excessive degradation of the structure or of the materials may lead to costly and unnecessary modifications, and, in some cases, to unconservative modification schemes.

8. STRENGTHENING OF OLD BUILDINGS FOR EARTHQUAKE RESISTANCE

Many old buildings were designed prior to the introduction of adequate earthquake regulations and used types of construction which subsequently proved vulnerable to earthquake damage. Other old buildings may be vulnerable to damage because they deteriorated due to a variety of conditions, such as previous earthquake damage, fire damage, foundation settlement, or alterations. Most of these are old low-rise buildings, including apartment buildings, commercial, industrial, or public buildings constructed without adequate provision for ductile response or without adequate horizontal bracing or membrane systems tying together the vertical elements of the building.

Where seismic exposure risk is significant, alteration of existing buildings to conform to current code standards of earthquake resistant design is often not feasible. There is a rapidly growing concern, especially in California, for the seismic safety of existing buildings. This concern has sparked the trend towards a more "active" approach to rehabilitation of older buildings. For example, in 1971, the Santa Rosa City Council adopted Resolution 9820 which provides procedures for the systematic survey and reconstruction of existing buildings. The resolution establishes a priority system for building review based on occupancy (theaters and hotels before markets, and offices before apartments and warehouses). The city is required to perform a preliminary review of the buildings in their order of priority, to identify any existing fire or existing seismic hazards, to determine whether corrective work is needed and to furnish the property owner with a report identifying any deficiencies found. If any rehabilitation is necessary, the resolution requires the owner to submit detailed plans, prepared by a licensed engineer, to the city to obtain a building permit for the required work. The work must be completed within one year after receipt of the report from the city. To enforce the resolution, the city is empowered to order vacation and demolition of the building if the owner failes to perform the necessary rehabilitative work. Recognizing the impact such a program would have on their community and attempting to make the reconstruction economically feasible, the review is limited only to those buildings constructed prior to 1958, and requires compliance with the provisions of the 1955 Uniform Building Code.

Other California cities have also undertaken similar rehabilitation programs designed to abate safety hazards in