specific chapter in their building code, Chapter 31 - "Rehabilitation of Older Buildings," which provides provisions applicable to existing buildings that are different than those for new buildings. These approaches are discussed in further detail in the HUD Guidelines for Setting and Adopting Standards for Building Rehabilitation.

CONDITION EVALUATION METHODS

All of the innovative regulatory strategies discussed above call for levels of performance that may be less than those for new construction as long as essential life-safety and health levels are maintained. It is recognized that many technical judgments will be required to implement these new concepts. These decisions are primarily related to application of performance-based code provisions and condition assessment of the existing buildings, impact of proposed changes on the building's performance, and the determination of acceptable compliance alternatives.

In order to begin to provide a basis for such decisions, CBT developed a report containing state-of-the-art listings of data for evaluating building components and systems.(5) This report lists evaluation methods for the structural materials of concrete, steel, masonry, and wood, as well as for HVAC, plumbing, and electrical systems. The principal audiences for the manual are those involved with making technical decisions concerning rehabilitation of an existing building including contractors, building officials, architects, and engineers.

The format for presentation of information on evaluation methods includes a short discussion of the methods and identifies parameters which may be evaluated (internal voids, compressive strength, reinforcing bar locations, etc.); advantages and limitations of the methods are presented; and references where more detailed information can be found are listed.

DEVELOPMENT OF BUILDING REHABILITATION STANDARDS

The innovative regulatory concepts discussed above all rely upon a better technical understanding of the performance of existing buildings and on the development of methods of evaluation both before and after rehabilitation. The need for consensus on these issues is important in order to gain regulatory acceptance. The American Society of Civil Engineers (ASCE) and the American Society for Testing and Materials (ASTM) have recently embarked upon standards-making activities to meet these needs.

The American Society of Civil Engineers has undertaken the development of recommended practice standards for condition assessment of existing buildings. Assessment techniques will be identified and guidance provided on their use relative to frequency, location, and interpretation of results.

The American Society for Testing and Materials Committee E06, Performance of Building Constructions, has recently formed a new Subcommittee, E06.24, on Building Preservation and Rehabilitation Technology. The scope of this new committee is:

> "the development of standards in the technology of conservation, preservation, and rehabilitation of buildings and structures."

Task groups have been formed and are at work in the following areas:

Building materials, structural
Building materials, nonstructural
Building mechanical systems
Building furnishings and fixtures
Special structures, monuments, and sites
Total structure

The development of standards by ASTM is expected to relate to materials, test methods, and recommended practices.

RESEARCH NEEDS FOR BUILDING REHABILITATION

Work to date on building rehabilitation indicates that many technical issues remain unresolved. Major research categories identified to date include: 1) test methods (e.g., condition assessment of plumbing and electrical systems); 2) analytical procedures (e.g., method for estimating hydraulic and pneumatic loads on existing plumbing systems); 3) field inspection guidelines (e.g., interpretation of foundation distress); 4) data on archaic systems (e.g., load capacity of existing structural elements); 5) technical basis of regulations (e.g., rationale for ventilation and illumination requirements); 6) application of innovative materials and systems (e.g., reduced size venting technology for existing plumbing systems); 7) prediction of properties of materials in existing buildings (e.g., permeability of exterior cladding); and 8) economic considerations (e.g., difficulties in estimating rehabilitation costs). Research needs to be conducted to address these issues in order to more fully use our existing building resource.

The American Concrete Institute has a new Subcommittee, ACI 364 on Rehabilitation of Structures, which is undertaking the development of design requirements for rehabilitation of concrete structures. Also, ACI 437 on Strength of Structures is developing a document on "Strength Evaluation of Existing Concrete Buildings."

SUMMARY

It was widely recognized that existing buildings present technical problems that are often different from those encountered in new construction. This difference results not only from the nature of the construction process but also from the application of current building regulations for new buildings and their processes of enforcement. Progress has been made and continues toward removal of regulatory constraints. Model codes have been changed and innovative requirements and approaches to enforcement are being tried. An anlaysis of numerous studies has indicated the strong need for technical evaluation techniques to facilitate decision making in building rehabilitation. Many technical problems remain to be solved through research which needs support from both the public and private sectors. These activities will encourage the economic re-use of existing buildings which responds to the need for more affordable buildings in the United States.

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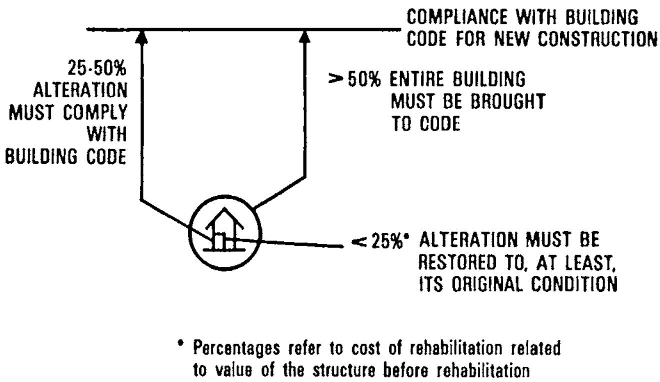

Fig. 1--Application of 25-50 percent rule

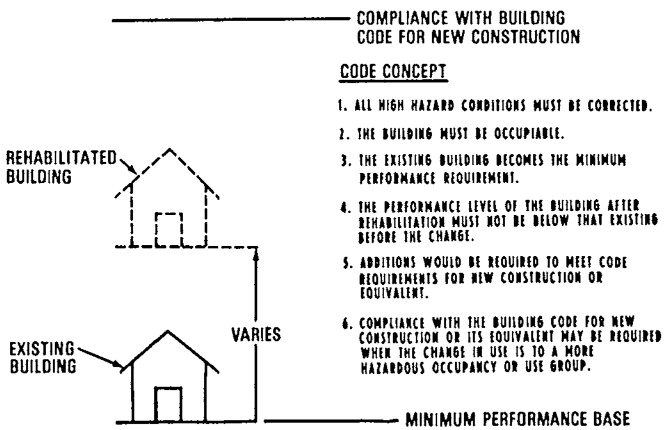

Fig. 2--New code concept for repairs, alterations, additions to and changes in use of existing buildings

SP-85-6

Verification of Structural Adequacy

By Dov Kaminetzky

Synopsis: The various steps that must be taken in order to determine the adequacy of a structure which is to be rehabilitated or restored are described. After the history of the structure has been researched, a condition survey of the structure and its foundations should be performed and supplemented with a geometry check. Laboratory testing of material samples then follow with structural analysis carried out to determine final structural adequacy and economical feasibility. A case history is described. The paper is concluded with recommendations for the establishment of an ACI guideline and additional research.

Keywords: building; economics; evaluation; loads (forces); reinforced concrete; renovating; repairs.

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INTRODUCTION

There is one component of any rehabilitation or restoration that must be satisfied as a precondition to any other consideration. This one essential element is the establishment of the existence of the structural integrity of the frame, its components and its foundations. Where this integrity is non-existent or questionable, consideration must be given to its upgrading to an acceptable level and the cost connected with this undertaking. This is the crossroads where many projects face the "live or die" dilemma. Without a solid integral structure, it is very likely that a decision to demolish and reconstruct will ensue.

The Process of Degradation and Deterioration

Degradation and deterioration of the structural elements of a building produce distress of varying magnitudes.

The deterioration, corrosion, and decay of materials such as concrete, steel and wood occur if they are exposed to moisture and the atmosphere. Roofs and structural elements at the envelope of the building, therefore, are most susceptible.

The degradation and deterioration of the materials, such as concrete and masonry, reduces the strength of the structural members. The Winter of 1978 issue of "Technology and Conservation" Magazine of Art, Architecture and Antiquities included the following on page 22: "A building, over time, is subjected to deterioration induced by pollution, wind, temperature variations, rains and other natural forces, but it also can be greatly affected by changes in the constructed environment surrounding it and by additions to its own structure."

Simply put, the process of degradation and deterioration proceeds in the following steps leading to a failure mechanism:

(i) Foundation settlement of semi-rigid structures. This settlement results in movement of the structures in all three planes. Excessive vertical settlements induce stresses in the frame and the walls which will crack wherever those stresses exceed the resistance (strength) of the building members and components.

(ii) Lateral movements result in separations of walls and floors with the increase of buckling probabilities due to greater unbraced length of the supporting members.

(iii) The decrease of material resistance and strength in time without corresponding maintenance program reduces the expected load-carrying capacities of components such as concrete, steel, brick, mortar, and timber. The influence of water penetration through walls or roofs on the reduction of strength is always a predominant factor.

Future Life of Structure

One of the preconditions for evaluation of structural adequacy is the knowledge of the requirement for the extent of life of the structure. It would have been ideal, if the conclusion of the study of the structural adequacy of building could be stated as:

1. Presently the structure has an estimated life of ten years based on present maintenance program.

2. With specified repair "A" (cost of "A" dollars), the structure will have an estimated life of 25 years.

3. With specified repair "B" (cost of "B" dollars), the structure will have an estimated life of 40 years.

Latent Defects

The problem of latent defects can be most serious and must be answered. Normally, a structural defect will manifest itself in the form of excessive deflection, excessive bowing or structural damage in the form of spalling or cracking. When these diagnostic signs are not present, it is reasonable to assume that these defects are non-existent. However, wherever a rehabilitation of a structure is coupled with a change of use, it is prudent to perform additional in-situ testing.

Discussion

The steps to be followed in the process of evaluation of the existing strength of the structure are:

A. Study the history of the structure.

B. Perform a condition survey which will identify defects such as excessive deflections, cracking, fracture, spalls, or corrosion of metals.

C. Establish or verify basic geometry. Survey and measure in the field or obtain from existing plans (when available) supplemented with careful field verification.

D. Establish or verify shape, locations, size and cross section of embedded elements such as rebars or structural steel sections.

E. Establish strength of materials such as concrete, steel or masonry by review of existing construction records supplemented by a combination of non-destructive (Fig. 1) and destructive tests (Fig. 2).

F. Compute the present structural capacity of the structural frame, its components and its foundation.

G. Perform a full-scale load test of elements or an entire structural section, in the event questions and doubts still persist regarding the true and actual strength and the load-carrying capacity.

H. Study and design the repair of all existing defects and/or the upgrading to higher live loads where required.

A. History of the Structure

Design and construction records should be obtained from the present owner, previous owners, architects, engineers or contractors.

Design drawings and specifications supplemented by shop drawings and "as-built" drawings are most important for strength verification.

Local Departments of Buildings are a good source for plans and also for history data such as alterations, violations and miscellaneous complaints. Any time spent in this search is a worthwhile investment, as the recreating of new drawings by field surveys and measurements is a highly costly endeavor and the final resulting product could never be a comparable substitute to an original set of drawings.

Design parameters, most importantly the live loads, concentrated loads, wind loads and any other special loading for which the structure may have been designed are important to obtain.

The design method used, such as working stress, ultimate load methods or special additional "built-in" safety load factor should be researched. The date of construction may provide a lead as to the codes used.

The history record of the actual occupancy type and loadings should be studied.

Construction records should include concrete test cylinders, mill reports of reinforcing bars, construction progress photos, and records of difficulties during construction.

It is essential that a review of the structural elements of a building should include the foundations of the building. The type of foundation, elevation of bottom of foundation and a knowledge of soil stratification should be known and evaluated. Building Department records may include this information. However, experience has shown that the records of older buildings are generally incomplete. There may be little or no records of foundations and soil stratification for these buildings.

B. Condition Survey

Visual inspection of the structure with all defects and damage photographed and recorded in full detail with carefully annotated sketches the presence of the following:

1) Cracks identified as to width, depth, length and location, and crack pattern plotted.

2) Spalls, shalings and other surface defects.

3) Corrosion of rebars, extent of corrosion and amount of lost cross section.

4) Loose, corroded or otherwise defective connectors for precast concrete or steel elements.

5) Deformations, whether permanent or deformations (movements) under loads. Out of verticality of columns and other misalignments.

Criteria which may be used in considering building deformations or movements are: visual appearance, serviceability or function, and stability.

(a) Visual Appearance

Visible deviations of members from the vertical or horizontal will often cause subjective feelings that are unpleasant and possibly alarming. Persons vary in their appraisal of relative movement and are often guided by comparisons with neighboring or adjacent buildings or members. There seems to be wide acceptance that general deviations from the vertical or horizontal in excess of about 1/250 are likely to be noticed. For horizontal members it is suggested that a local slope exceeding 1/100 (1/8" per foot) would be clearly visible as would a deflection to length ratio or more than about 1/240. The actual critical ratios depend on the function of the building.

Visible deviations which have no structural impact may be corrected by the application of the architectural finishes on floors, columns and walls.

Visible damage is difficult to quantify as it depends on subjective criteria. Moreover, damage which is acceptable in one region or one type of building might be quite unacceptable in another (residential vs.

industrial). In our practical experience in the observation of building performance and failure investigations, a five-point classification has been used: very light, light, moderate, extensive and very extensive. Emphasis is on ease of repair. Approximate crack widths are listed and are intended merely as an additional indicator rather than a direct measure of the degree of damage.

The classification in Table A relates only to visible or aesthetic damage. In situations where cracking may allow corrosion or allow penetration or leakage of liquids or gases, the criteria will be much more stringent.