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Guidelines for Identification and Mitigation of Seismically Hazardous Existing Federal Buildings

Prepared for use by:

Interagency Committee on Seismic Safety in Construction

U.S. DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
(Formerly National Bureau of Standards)
National Engineering Laboratory
Center for Building Technology
Gaithersburg, MD 20899

March 1989

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ABSTRACT

This report, **Guidelines for Identification and Mitigation of Seismically Hazardous Existing Federal Buildings**, was prepared by the Interagency Committee on Seismic Safety in Construction in support of the National Earthquake Hazards Reduction Program, the President's plan to implement the Earthquake Hazards Reduction Act of 1977 (Public Law 95-124). The **Guidelines** are intended for consideration and use, as appropriate, by Federal agencies in their plans for mitigation of seismic hazards in existing buildings. Some Federal agencies have their mitigation plan in operation. It is not the intent of these **Guidelines** to supercede the existing plans.

Comments on this report are welcome. They should be forwarded to:

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Keywords: buildings; earthquakes; earthquake hazard; evaluation; existing buildings; federal agencies; guidelines; mitigation; seismic safety; strengthening

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1. INTRODUCTION

1.1 Background

Existing buildings that were not designed to be earthquake-resistant constitute one of the major potential hazards to life and property. A building may be vulnerable due to ground shaking caused by the earthquake, soil liquefaction, landslides, surface rupture, and also by tsunami. The huge inventory of existing buildings makes the reduction of the earthquake hazard a complicated and costly issue that must be worked out carefully with full consideration of the economic impact.

There are several factors which make it technically and economically difficult to identify and upgrade many buildings which could be hazardous in terms of life safety or post-earthquake operational capability:

- (a) while most areas of the United States are susceptible to some level of seismic hazard, many areas have not required buildings to be designed to resist seismic forces;
- (b) seismic design criteria have been upgraded over the years and it may not be feasible to bring all existing buildings, including those which were designed according to old codes but may not meet current codes, into conformance with the provisions of current codes; and
- (c) historically, some buildings not designed to current codes have performed adequately during earthquakes, while other buildings designed to specific codes have not performed satisfactorily.

This report provides guidelines to Federal agencies for use in their programs to identify, evaluate, and strengthen existing buildings to reduce the threat to life safety and to reduce major damage to critical and essential buildings.

1.2 Scope

The basic goal for strengthening of existing buildings is to provide life safety and, where necessary, post-earthquake operational capability. Buildings vulnerable to structural damage pose the most serious hazard to life safety. First priority must be given to identifying structures that might be susceptible to structural damage and/or collapse. Nonstructural components that could be a threat to life safety should be identified next.

Buildings exempted from investigation under these guidelines (Sect. 3.2.1) should be investigated for nonstructural hazards, but these investigations could be incorporated into regular maintenance inspections or even be a special investigation for buildings housing toxic and explosive substances.

This report presents a systematic methodology for identifying hazardous conditions and supplying decision makers with information on the extent of the hazard and the feasibility of mitigation. A viable strategy for mitigation of hazards can be developed and targets for implementation established.

Section 2 provides recommendations pertinent to implementing a mitigation program for hazardous buildings. Guidelines for prioritizing buildings and scheduling the seismic evaluation are presented. The final decision is left to the responsible agency based on budget constraints and overall agency programs.

Section 3 describes a procedure for identification of hazardous buildings and Section 4 describes qualitative evaluation procedures. Section 5 makes recommendations for requirements for levels of acceptable performance for existing buildings. Section 6 suggests mitigation techniques.

It is recognized that Federal agencies must have flexibility in dealing with hazardous buildings which can have significantly different characteristics. Additional constraints are imposed when a building is leased or built under a grant program instead of being owned by the agency.

1.3 Definitions

Critical Building - a building which, in case of "failure" may cause secondary effects such as release of toxic substances, fire or explosion.

Essential Building - a building which must be safe and useable for essential or emergency functions during and after a major earthquake.

Federal Building - a building owned, leased, assisted, or regulated by Federal agencies.

2. PROGRAM FOR SEISMIC EVALUATION OF EXISTING BUILDINGS

Implementing a program for seismic evaluation of existing buildings will depend upon availability of funds and the priority of mitigation action relative to other requirements. It would be generally infeasible, in terms of time and funding, for an agency to carry out detailed engineering analyses on every building in its inventory. Therefore, simplified methods will be required for identifying vulnerable buildings and needed retrofit measures. Priorities can be set only when there is knowledge of the degree of hazard, potential effect on current occupants or agency's mission, and the feasibility of mitigation.

Following is a recommended schedule which is reasonable and feasible:

- a. All buildings located in NEHRP* seismic map areas 6 and 7 or UBC* seismic zones 3 and 4 and with occupancy of 100 or more people should be evaluated within five years.
- b. All critical and essential buildings located in NEHRP seismic map areas 6 and 7 or in UBC seismic zones 3 and 4 should be evaluated within five years.
- c. All other buildings in NEHRP seismic map areas 6 and 7 or in UBC seismic zones 3 and 4 should be evaluated within eight years.
- d. All critical and essential buildings located in NEHRP seismic map areas 3, 4 and 5 or in UBC seismic zones 1, 2A and 2B should be evaluated within eight years.
- e. Buildings in NEHRP seismic map areas 3, 4 and 5, or in UBC seismic zones 1, 2A and 2B should be evaluated, on a case-by-case basis, within twelve years.
- f. All nonstructural components, which may be a threat to life safety, of buildings in NEHRP seismic map areas 3 through 7 or UBC seismic zones 1 through 4 should be evaluated within five years.

* See references

3. IDENTIFICATION OF HAZARDOUS BUILDINGS

3.1 General

The potentially large cost of an engineering investigation of all existing buildings in areas of seismic risk makes it necessary to approach the identification of hazardous buildings in a carefully planned manner. No single approach would meet the need of all agencies, because:

- a. The number of buildings in agency inventories varies greatly.
- b. The diversity of buildings; i.e., use, occupancy, size, location, type and age, complicates establishing a single approach.
- c. Availability, completeness, and accuracy of information on each building vary widely.
- d. The best strategy for prioritizing the investigation and mitigation efforts of each agency would not be uniform.

In general, buildings located in high seismic hazard areas should be evaluated first. The following screening factors may be considered in establishing an effective evaluation program.

3.2 Screening Factors

The first step in dealing with a large inventory of existing buildings is to apply a screening process that eliminates unnecessary evaluation and identifies buildings requiring further evaluation.

3.2.1 Primary Screening Factors

Buildings, except critical and essential buildings, which fall in any of the following categories need not be evaluated for earthquake vulnerability:

- a. Those designs that meet or exceed the provisions of: the NEHRP Recommended Provisions, or the 1976 edition (or later) of the Uniform Building Code.
- b. Those located in NEHRP map areas 1 and 2 or in UBC seismic zone 0.
- c. One story wood-frame and one story pre-engineered metal buildings.
- d. Buildings, except essential buildings, occupied by fewer than 6 people.
- e. One- and two-family houses which are two stories or less.

3.2.2 Secondary Screening Factors

After the primary screening, agencies should set priorities for qualitative evaluation and retrofiting. As a minimum, the priorities should consider:

- Seismicity
- Site conditions
- Structural types
- Occupancy
- Building use

Some methods for prioritizing structures are suggested in Appendix A.

3.2.3 Critical Buildings

- a. All critical buildings located in NEHRP map areas 3 through 7 or in UBC seismic zones 1 through 4 should be evaluated. The type of evaluation will depend upon the nature of the hazardous substance, such as toxic chemicals and explosives, contained in the buildings.
- b. Critical buildings located in NEHRP map areas 1 and 2 and in UBC seismic zone 0 need not be evaluated.

3.2.4 Essential Buildings

- a. All essential buildings located in NEHRP map areas 6 and 7 or in UBC seismic zones 3 and 4 should be evaluated in the initial phase of program.
- b. Essential buildings located in NEHRP map areas 3, 4, and 5 and in UBC seismic zones 1, 2A and 2B may be deferred from the initial phase of program.

In some instances, it may be more economical and reasonable to evaluate, at the same time, a complete complex consisting of a number of buildings in lieu of individual priorities.

4. EVALUATION OF EXISTING BUILDINGS

Qualitative Evaluation based on examination of available design documentation and field inspection shall be carried out for the structural system and for each exterior or interior nonstructural system or component which may pose a seismic hazard. It should be a two step approach: preliminary evaluation and detailed evaluation.

4.1 Preliminary Evaluation

The preliminary evaluation is intended primarily to reduce further the large inventories and avoid unnecessary investigation costs. It should

determine, at the least practical cost, whether the structure provides an acceptable degree of safety or a more extensive evaluation is required.

For preliminary evaluation, as well as determining the acceptable degree of safety, ATC-21 (FEMA-154) Handbook on "Rapid Visual Screening of Buildings for Potential Seismic Hazard" (ATC-1988)* may be used. The Handbook provides a procedure for determining if a building needs further analysis without performing a detailed structural analysis.

4.2 Detailed Evaluation

A detailed evaluation of buildings not eliminated in the preliminary evaluation will be required to determine the earthquake resistant capacities of critical elements of the building and the extent of any deficiencies. ATC-14 "Evaluating the Seismic Resistance of Existing Buildings" (ATC-1987)* or ATC-22 "Seismic Evaluation of Existing Buildings" (ATC-1989)* may be used.

The ATC-14 methodology includes a state-of-the-art review of existing documents and has incorporated information from earlier methodologies. It is based on assumptions that one or more of the following events pose danger to human lives:

- o the entire building collapses
- o portions of the building collapse
- o components of the building fail and fall
- o exit and entry routes are blocked, preventing the evacuation and rescue of the occupants

The fundamental approach in ATC-14 is to ascertain whether there is a complete lateral resisting system with a coherent load path and whether appendages and veneer are properly attached. The adequacy of seismic performance of the structural system and components and exterior and interior nonstructural systems is expressed in terms of the Earthquake Capacity Ratio. The methodology is applicable to all parts of the U.S.

ATC-22, which is based on ATC-14, provides a step-by-step procedure for evaluating existing buildings. The methodology is to identify structural weaknesses that have been observed in past earthquakes to lead to failure and falling of components or to partial or total collapse, with an attendant loss of life.

4.3 Earthquake Capacity Ratio

The earthquake capacity ratio can be expressed in terms of the ratio of seismic capacity to seismic demand of critical structural members. The capacity to demand ratios can be computed using the procedure described in ATC-14, ATC-22 or other appropriate procedures.

* See references

The earthquake capacity ratios for the critical elements of the lateral force resisting system are indices of the structural resistance of the existing building. The lower the values the higher the potential risks. If the lowest value of the earthquake capacity ratio is less than unity, the building should be considered a life safety hazard and so reported to the building owner.

5. REQUIREMENTS FOR MITIGATION OF HAZARDOUS BUILDINGS

Determine the level of acceptable performance for an existing building exposed to earthquake forces based on the predominant performance requirement imposed on the building, i.e., basic life safety of the occupants or post-earthquake operational capability.

5.1 Basic Life Safety Requirements

The basic life safety requirements for an existing building are that during a major earthquake it: 1) does not collapse, partially or totally and 2) performs adequately to provide unobstructed ingress and egress. This level is the minimum performance requirement for an existing building normally occupied by personnel and located in NEHRP map areas 3 through 7 or in UBC seismic zones 2A, 2B, 3, and 4. This level should provide life safety for the occupants, containment of hazardous or lethal contents, and a safe means of egress after a major earthquake. However, the damage incurred by the building may not be repairable. Recommended actions for the abatement of the structural deficiencies in buildings with basic life safety performance requirements are:

- a. Where the building's earthquake capacity ratio as defined in Section 4.3, is 0.80 or greater, no action is required.
- b. Where the building's earthquake capacity ratio is less than 0.80 but greater than 0.50, mitigation is recommended within 10 years.
- c. Where the building's earthquake capacity ratio is 0.50 or less, mitigation is recommended within 5 years.

5.2. Post-Earthquake Operational Capability Requirements

Post-earthquake operational capability requirements are intended to provide continued operation or function of the building during and immediately after a major earthquake. This level is the maximum performance requirement for an existing building. Recommended actions for the abatement of the structural deficiencies in buildings with post-earthquake operational requirements are:

- a. Where the building's earthquake capacity ratio is 0.90 or greater, no action is required.

- b. Where the building's earthquake capacity ratio is less than 0.90 but greater than 0.50, mitigation is recommended within 10 years.
- c. Where the building's earthquake capacity ratio is 0.50 or less, mitigation is recommended within 5 years.

5.3 Cost Impact Study

Perform a cost impact study to determine a reasonably accurate estimate of the total costs to strengthen the building. If the total cost exceeds projected budgetary constraints, the continued use of the building should be limited to storage; the building should be phased out; or other strategies, such as lowering seismic hazard exposure by changing occupancy requirement should be assessed carefully.

6. MITIGATION TECHNIQUES

6.1 Strengthening Methods

Strengthening the structural and nonstructural systems of an existing building may be a viable strategy for mitigating earthquake hazards. Various strengthening methods may be applied. The basic principles of earthquake-resistant design should be followed. It is recommended that the guidelines given in the Technical Manual of the Army, Navy, and Air Force "Seismic Design Guidelines for Upgrading Existing Building" or "Techniques for Seismically Rehabilitating Existing Buildings" by URS/John A. Blume & Associates* be used. These documents provide guidelines for upgrading both structural and nonstructural members. They provide the conceptual development for seismic upgrading and detailed techniques for strengthening structural and nonstructural elements with illustrated examples. They further provide guidelines for the cost effectiveness of upgrading existing buildings based on data obtained from the preliminary evaluation and the detailed structural analysis.

6.2 Quality Assurance Requirements

Whenever repair and strengthening procedures are implemented, quality assurance should be as rigorous as that required for new construction.

The requirements for inspection and material testing for new work also apply to modification of existing structural components or systems. However, special procedures are necessary to assure the quality of alterations involving those techniques which are no longer used in new construction. Therefore, the overall adequacy of a repair or strengthening program cannot be guaranteed by conformance of work to code and testing requirements for new construction alone.

* See references

APPENDIX A

METHODS FOR PRIORITIZING INVESTIGATIONS OF EXISTING STRUCTURES

A number of methods for establishing priorities have been developed. Each agency should determine the factors suitable to its purposes. The following brief descriptions of some methods are offered for information only.

- a. The Naval Facilities Engineering Command has developed a computer program to search automated data files on structures and prioritize them by applying factors selected according to size, age, replacement cost and usage. This program can be easily expanded to include other factors if desired.
- b. "Handbook on Establishing Priorities for Seismic Retrofitting of Buildings" currently being developed by FEMA. Expected to be completed in Spring, 1989.

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