Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.VII)

12-4-1

SEISMIC DESIGN GUIDELINES FOR UPGRADING EXISTING BUILDINGS

George MATSUMURA[1], Joseph NICOLETTI[2], and Sigmund FREEMAN[3]

[1]Headquarters, U.S. Army Corps of Engineers, Washington D.C., USA
[2]URS/John A. Blume & Associates, San Francisco, California, USA
[3]Wiss, Janney, Elstner Associates, Inc., Emeryville, California, USA

SUMMARY

Guidelines were developed to (1) provide a strategy and method to identify potential seismically hazardous buildings on a priority basis and (2) establish criteria and methodology for strengthening those buildings identified as being hazardous. The guidelines were developed for military installations with a large inventory of buildings; but they are also adaptable for sites where only a few buildings or a single building require seismic evaluation. The step-by-step procedure includes building inventory reduction, preliminary screening, preliminary evaluation, detailed structural analyses, design concepts for seismic upgrading/strengthening, cost benefit analysis, final contract documents. Guidelines are also included for nonstructural elements, and material evaluation.

INTRODUCTION

The Tri-Services Committee of the Departments of the Army, the Navy and the Air Force incorporated the "Recommended Lateral Force Requirements and Commentary" of the Seismology Committee of the Structural Engineers Association of California (Ref. 1) into the 1982 edition of "Seismic Design for Buildings" (Ref. 2). In 1986 a second manual was published, "Seismic Design Guidelines for Essential Buildings" (Refs. 3 and 4), that presented a dynamic analysis approach that could be used in lieu of the lateral static force procedure of the basic manual. Both manuals were developed for use in the design of new construction. The military has a large inventory of buildings and the major changes that have been occurring in structural criteria for new construction naturally raise the question of the adequacy of the existing buildings.

The existing building should be evaluated on the basis of its actual performance characteristics, as best as can be determined, when subjected to a realistic postulated earthquake. The design of modifications for existing buildings should take into account the performance characteristics of the existing materials and how they interact with the new materials used to upgrade the structure.

The development of the new manual "Seismic Design Guidelines for Existing Buildings" (Ref. 5) uses the previous manuals (Refs. 2 and 3) as a basis for seismic evaluation and upgrading criteria. Adjustments were made for application to existing construction materials and to lateral force resisting systems of existing buildings. A review was made of procedures used for screening large inventories of buildings and techniques for rapid seismic evaluation of individual buildings (Ref. 6).

GENERAL

The manual prescribes criteria and furnishes design guidelines, procedures, and strategy to screen, prioritize, evaluate, upgrade, and strengthen existing facilities for seismic resistance. The criteria applies to all existing facilities in Seismic Zones 3 and 4, to only existing essential facilities in Seismic Zones 2, and to any other facilities designated by the approving agency. The manual is a supplement to TM 5-809-10/NAVFAC P-355/AFM 88-3, Chapter 13, (Ref. 2), referred to herein as the Basic Design Manual (BDM) and TM 5-809-10-1/NAVFAC P-355.1/AFM 88-3, Chapter 13, Section A (Ref 3), referred to herein as the Seismic Design Guidelines (SDG).

Seismic Hazard Risk Levels The evaluation and upgrading of existing buildings is based on seismic ground motions of the selected risk levels of two design earthquakes, EQ-I (50 percent probability of being exceeded in 50 years) and EQ-II (10 percent probability of being exceeded in 100 years).

Identification of Seismically Hazardous Buildings The military has a large inventory of buildings, and an effective strategy method is required to identify potentially hazardous buildings on a priority basis. The objective of this strategy/method is to minimize unnecessary investigations by (1) deleting buildings of minor importance and low hazard exposure from the large inventory, (2) identifying groups of similar buildings, and (3) prioritizing seismic safety evaluation and hazard mitigation (strengthening) efforts. Since the basic goals of seismic hazard mitigation for existing buildings are to enhance life safety (i.e., protection against collapse) and post-earthquake operational capability, it is essential to identify buildings with post-earthquake operational requirements or high risk (high-loss potential) functions.

Methodology for Seismic Evaluation and Upgrading Buildings The various steps in the methodology are illustrated by the flow chart in Fig. 1. Each step is covered by a chapter in the manual. Summaries of each chapter are given below.

INVENTORY REDUCTION

Prior to beginning the phased seismic evaluation procedure, the overall inventory of the installation is reviewed to select buildings that will be included in the evaluation program. The purpose of reducing the total inventory to a select group is to eliminate unnecessary investigations and to keep the scope of work within reasonable limits. Buildings that are excluded include nonessential buildings designed in accordance with the 1982 BDM, buildings located in Seismic Zone 0, one-story wood frame and preengineered metal buildings that are not essential or high risk, buildings occupied by no more than 5 persons that are not essential or high risk buildings, one and two family housing that is two stories or less, buildings of no more than 500 square feet or $50,000 replacement costs that are not essential or high risk, and structures scheduled to be replaced within 5 years.

PRELIMINARY SCREENING

Preliminary screening will be used after inventory reduction only if there is a need to further reduce the number of structures to be evaluated. The buildings remaining after the inventory reduction will be classified as essential, high-risk, or all others. The engineer will obtain available design data (e.g., drawings, design criteria, calculations, and specifications). Data pertaining to the "as-built" condition of a building are essential when available. Data and information will be reviewed by the engineer and the pertinent information will be transferred to the screening form used in the review process. It is expedient to transfer as much data as possible to the forms. When the design data are minimal or if none is available, such as may be for the older buildings, it will be noted on the screening form so that sketches with pertinent dimensions, sizes, and other notes regarding the structural systems can be made during the preliminary screening inspection. The screening forms are used to establish a check list for the visual observations to aid field note taking. The inspection survey need not be detailed. The time allotted for each building will vary, depending on the size and complexity of the structure, but should be between 10 and 30 minutes. A more detailed examination will be made during the preliminary evaluation. The field notes will be systematically reviewed to determine the number of buildings that will remain on the list for the preliminary evaluation process. Guidelines for removing buildings from the list are given in the manual.

PRELIMINARY EVALUATION

The preliminary evaluation provides the initial analytical data for estimating the vulnerability of the selected buildings to seismic damage. This is an important consideration in determining priorities for upgrading within each building classification (i.e., essential, high-risk, all others). When a preliminary evaluation is prescribed, the following basic steps are performed: (a) document review, (b) site inspection, (c) approximation of the capacity of the structure to resist seismic forces, (d) approximation of damage by reconciliation of the structural capacity with the earthquake ground motion demands, (e) recommendations. The document review and site inspection may not be required if all pertinent data and conditions have been obtained in the preliminary screening process. Generally, it will be done concurrently if the number of buildings is not large.

The value for capacity is a simplified representation of the capacity of the overall building for a specified level of stress or distortion such as when yielding of major structural members occur or when lateral displacements reach a prescribed limit. On the basis of the available documents and the visual observations, the capacity of the structure to resist lateral forces will be estimated by means of rapid evaluation technique. For the rapid evaluaiton technique, the capacity is represented by a curve similar to the capacity curve required for method 2, capacity spectrum method, in the SDG (Refs. 3 and 4). General guidelines for determining the capacity curve are given in the manual. A graphical reconciliation between the earthquake demand (site response spectrum) and the building capacity is used to estimate the amount of damage that will occur during a postulated earthquake. The procedure is essentially the same as the Capacity Spectrum Method prescribed in the SDG.

DETAILED STRUCTURAL ANALYSIS

The purposes of the detailed structural analysis are (1) to determine if the building satisfies the acceptance criteria or if it requires seismic upgrading, and (2) if it requires seismic upgrading to identify the deficiencies and to recommend alternatives for the upgrading. The acceptance criteria for the seismic resistance of existing buildings will be essentially as prescribed for the post-yield analysis for EQ-II in the SDG. If an existing building does not conform to the above criteria some latitude is provided in recognition that seismic upgrading is an expensive and disruptive process and it may be more cost-effective to accept an existing building that is marginally deficient rather than to enforce strict adherence to the criteria. The detailed structural analysis follows a procedure similar to that used for the preliminary evaluation for determining the capacity of the structure to resist seismic loads, except that the analysis is done in greater detail and with more accuracy in order to increase the reliability of recommendations for acceptability or upgrading. The procedure extends beyond the scope of the preliminary evaluation by identifying deficiencies and evaluating the effects of correcting deficiencies to improve the overall performance capabilities of the building.

DEVELOPMENT OF DESIGN CONCEPTS

Guidelines are provided for the upgrading of the structural systems, the determination of the capacities of new structural elements, and development of strengthening techniques. The design criteria for the development of concepts for seismic upgrading of existing buildings will be in accordance with the applicable provisions as required for new construction. In most cases the costs associated with full compliance, as opposed to a reduced force level, will be negligible. However, an allowable reduction will be permitted for acceptance in those cases where strict adherence to the unreduced criteria would result in much more expensive or disruptive procedures (e.g., a 15 percent reduction in the EQ-II response spectra may make is possible to accept an existing building without strengthening the existing foundations or the construction of an additional shear wall; however, if even with the reduced criteria foundation strengthening or a new wall is required, the upgrading design must be in compliance with the unreduced criteria). The development of the structural upgrading concept requires a complete understanding of the existing vertical and lateral load resisting systems of the existing building. The designer must be able to determine the consequences that the removal, addition, or modification of any structural or nonstructural element will have on the performance of the strengthened building.

COST BENEFIT ANALYSIS

Guidelines are provided to evaluate the cost effectiveness of upgrading seismically deficient existing buildings on the basis of data obtained from the preliminary evaluation, the detailed structural analyses, and the development of design concepts. Criteria are provided to determine the cost effectiveness of taking no action (i.e., leave "as is"), upgrading, or replacement of existing deficient buildings. A procedure to estimate the annualized repair costs and determine their present value is outlined in the manual. In addition to the economic analysis, social, political, and administrative considerations will be addressed. These may include the impact of the potential seismic hazards on life safety of the occupants or to the public (e.g., collapse of a facility containing hazardous materials); current and future use of the building and its importance to the mission of the activity; costs associated with temporary interruptions of use during the upgrading and/or repair work; functional characteristics of the

existing building (e.g., are there functional problems that could be corrected during the upgrading work?); and the historic significance of the building.

CONCLUSIONS

The manual presents a comprehensive methodology that can be applied to a large inventory of buildings as well as to individual buildings. It provides guidelines for identifying potentially hazardous buildings and for strengthening existing buildings to resist earthquake induced forces. The guidelines adapt the criteria used for new construction for application to existing buildings.

REFERENCES

1. "Recommended Lateral Force Requirements and Commentary", Fourth Edition, Seismology Committee, Structural Engineers Association of California, San Francisco (1980).

2. "Seismic Design for Buildings" (Tri-Services Manual), Departments of the Army (TM 5-809-10), Navy (NAVFAC P-355), and Air Force (AFM 88-3, Chapter 13), Washington, D.C. (1982).

3. "Seismic Design Guidelines for Essential Buildings", Departments of the Army (TM 5-809-10-1), the Navy (NAVFAC P-355.1), and the Air Force (AFM 88-3, Chapter 13, Section A), Washington, D.C. (1986).

4. Freeman, S. A., Nicoletti, J. P., and Matsumura, G., "Seismic Design Guidelines for Essential Buildings", Proceedings of the 8WCEE, Vol. I, pp. 715-722, Prentice-Hall, Englewood Cliffs, New Jersey (1984).

5. "Seismic Design Guidelines for Upgrading Existing Buildings", Departments of the Army (TM 5-809-10-2), the Navy (NAVFAC P-355.2), and the Air Force (AFM 88-3, Chapter 13, Section B), Final Manuscript, December 5, 1986 (expected publication late 1988, U.S. Government Printing Office, Washington, D.C.

6. Freeman, S. A., Nicoletti, J. P., and Tyrell, J. V., "Evaluation of Existing Buildings for Seismic Risk - A Case Study of Puget Sound Naval Shipyard, Bremerton, Washington", Proceeding of the U. S. National Conference on Earthquake Engineering - 1975, Earthquake Engineering Research Institute, El Cerrito, California, pp. 113-122, (1975).

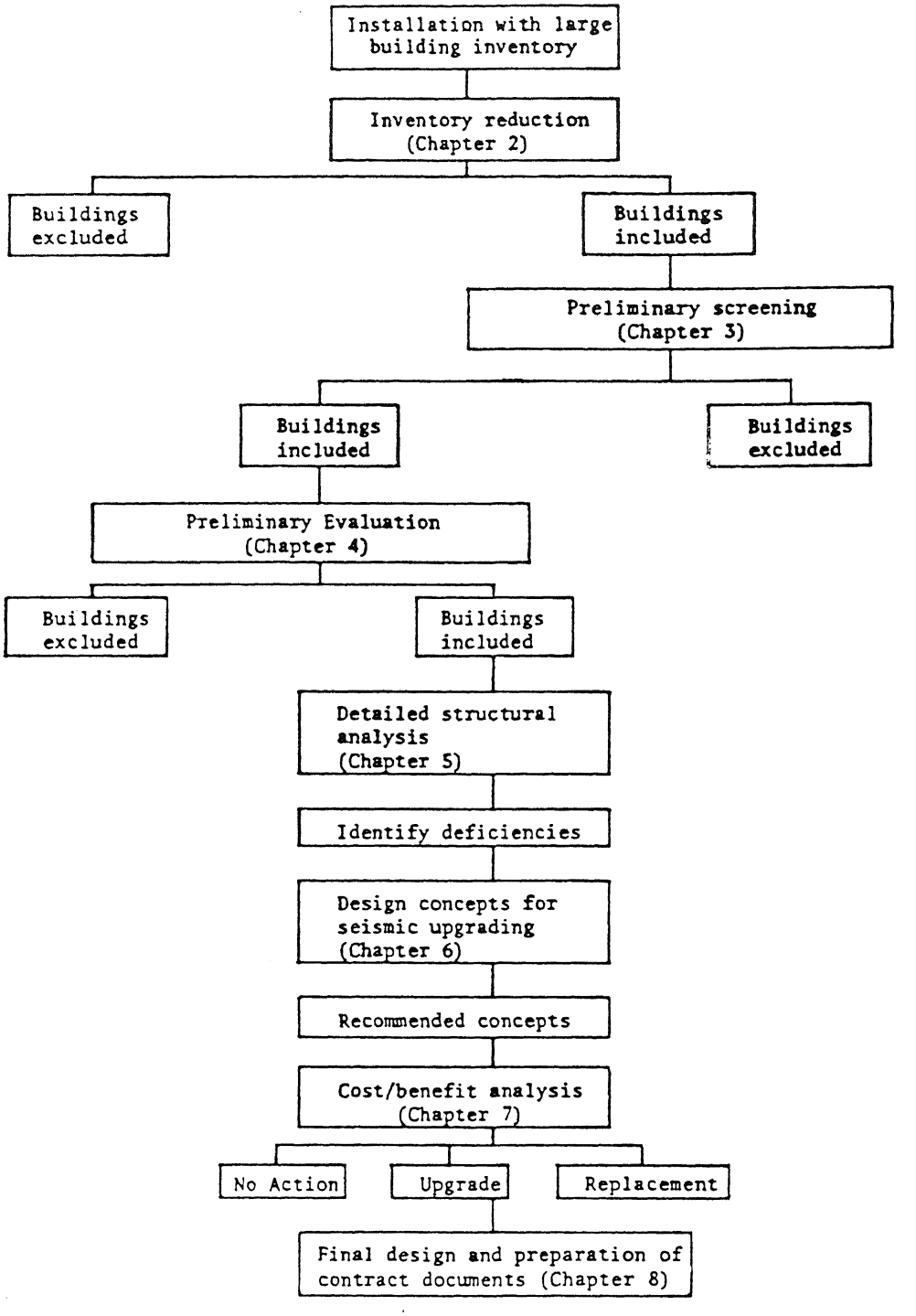

Fig. 1 Methodology for Seismic Evaluation and Upgrading