DEVELOPMENT OF THE FEMA-273 DOCUMENT – GUIDELINES FOR THE SEISMIC REHABILITATION OF BUILDINGS

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INTRODUCTION

The nation's inventory of existing buildings continues to grow. In those areas where codes, up until a so-called "benchmark" year, did not contain significant seismic considerations, many of these buildings run a risk of life-threatening damage should an earthquake provide potentially damaging ground motion. The downtown, older sections of every city and town in the nation contain buildings which fit this category. Every earthquake reinforces society's conviction that something must be done to reduce the hazard posed by these unsafe buildings. Even in areas deemed at present to have low seismicity, there exists a sampling of possible earthquakes, maybe rare, that can cause, in decreasing order of severity: collapse, or loss of life without collapse, or damage warranting building entry to be unsafe, or damage that halts a building's functioning. The earthquake hazard is real even if it is unclear.

The National Earthquake Hazard Reduction Program (NEHRP) was funded by the U.S. Congress to take the required steps towards a national reduction of the earthquake hazard. This paper describes some of the steps taken towards the reduction of the earthquake hazard posed by existing buildings, rather than the implementation of codes governing the design of new buildings. It is clear that the nation's concern should be focused on rehabilitating existing buildings to whatever extent is practical, because more lives are at risk and more interruption to society and its economy can be expected.

The Federal Emergency Management Agency (FEMA), the lead agency for the NEHRP program, embarked on a comprehensive project in coordination with the other NEHRP agencies (at the time, the U.S. Geological Survey (USGS), the National Institute of Standards and Technology (NIST) and the National Science Foundation (NSF)). The agencies did what each does best: the USGS with information on strong ground motion, NIST with technical oversight, and NSF with funded engineering research. The Applied Technology Council (ATC) was the program manager for a number of the projects that produced reports listed and described briefly in the following section.

Borrowing from the FEMA Foreword to FEMA-273: Since 1984, when FEMA first began the program to address the risk posed by seismically unsafe buildings, FEMA-273 has been the sought target. Preparatory steps were needed, and by 1990 the technical platform had been completed. FEMA-273 required the varied talents of over 100 consultants: engineers, researchers and writers, orchestrated by BSSC, ATC, and ASCE. Hundreds more donated knowledge and time on review, and with comments, criticisms and suggestions. The balloting process of BSSC over the last year of the effort added further improvement. No-one who worked on this project, whether volunteer, consultant, or staff, received monetary compensation commensurate with effort.

PREPARATORY STEPS TOWARDS FEMA-273, GUIDELINES FOR REHABILITATION

The concepts at work in the planning for the NEHRP program can be seen in the titles of the following reports. The reports in this list are technical reports leading towards rehabilitation. All are accompanied by supporting documentation whose reporting is not listed.

Rapid visual screening for potential seismic hazards. (FEMA-154 report, developed by ATC in the ATC-21 project, 1988.) A method for the rapid identification of buildings that would probably be to realize smart structural systems. See Figs. 6-8.

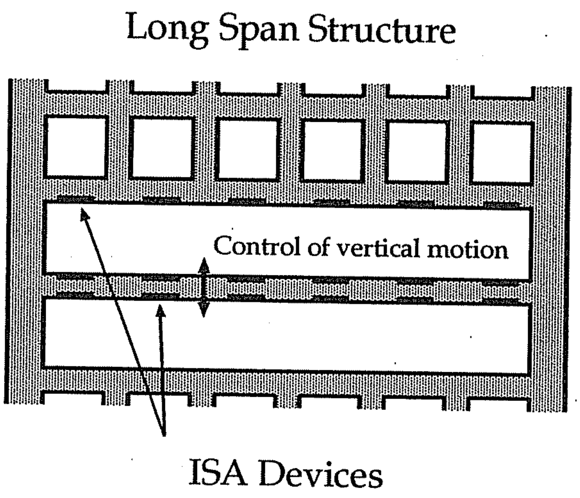


Fig. 6 Long Span Structure

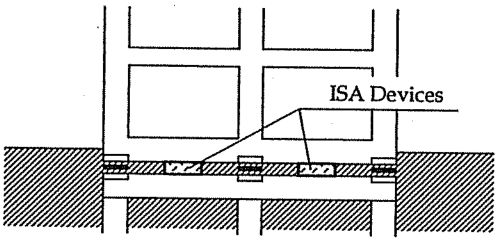


Fig. 7 Axial Force and Friction Control (for Base Isolator. Including trigger application)

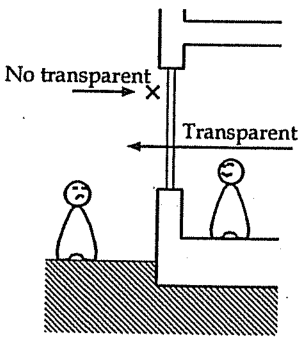


Fig. 8 Active Sound Transparency

(b) Sensing members
ISA materials can act as sensors because they cause change of electric or magnetic fields under deformation. Wireless application is also discussed.

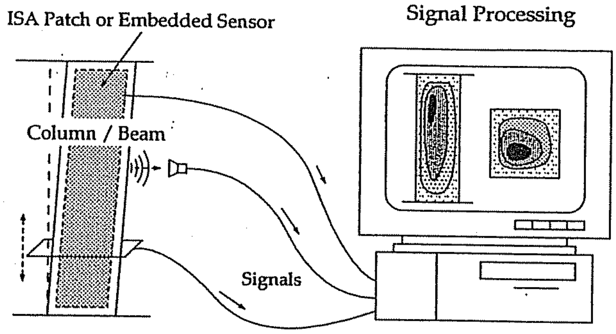


Fig. 9 Sensing with or without Cabling

4.CONCLUSIONS

This development research aims to apply the new technology like new materials and new structural systems, to develop smart structure systems which makes the performance of buildings advanced, to reduce the expense of construction and maintenance and eventually to ensure the future sustainability without trouble. Building Research Institute, Ministry of Construction (BRI) and National Science Foundation, U.S.A. has started the research and development of " Smart Structure Systems " in 1998. Feasibility study of smart structure system be developed are introduced.

hazardous in the event of an earthquake. This screening is conducted without gaining access. A city-wide application allows a local building department to determine the risk to its inventory.

NEHRP handbook for the seismic evaluation of existing buildings. (FEMA-178 report developed by ATC in the ATC-14 project (for NSF) and ATC-22 project (for FEMA); 1989, 1992.) A method for detailed evaluation of buildings, identifying structural flaws causing damage and collapse in the past and possibly again. FEMA-178 has been revised by ASCE to be an ASCE prestandard FEMA-310, 1998. FEMA-178 evaluates a building for a design earthquake comparable to one recurring in 500 years. FEMA-310 evaluates, in addition, for a bigger earthquake recurring in 2500 years.

NEHRP handbook of techniques for seismic rehabilitation of existing buildings. (FEMA-172 report, 1989, 1992.) These are useful techniques, although some are now dated due to the effectiveness of recent research results.

Seismic rehabilitation of buildings, Phase 1: issues identification and resolution. (FEMA-237 report, developed by ATC in the ATC-28 project, including a workshop for the resolution of the issues, 1992.) The guidance in this report shaped the development of the Guidelines.

NEHRP guidelines for the seismic rehabilitation of buildings. (FEMA-273 report, developed by ATC in the ATC-33 project, 1997.)

DEVELOPMENT OF FEMA-273

In 1991, the National Institute of Building Sciences (NIBS) entered a cooperative agreement with FEMA for a comprehensive seven-year program leading to the development of technically sound, nationally applicable guidelines for the seismic rehabilitation of buildings. Under the agreement, the Building Seismic Safety Council (BSSC) was program manager, and both the American Society of Civil Engineers (ASCE) and ATC were subcontractors. The program was to include the development of a consensus, that is, a unanimous consensus, among all the consultants working on the technical content, and to develop acceptance among all the potential users in the design engineering profession. The Guidelines were expected to be used as the primary resource in rehabilitation by engineers, academicians, code organizations, and building officials.

BSSC, as the program manager for FEMA, appointed the advisory panel, conducted the consensus review of the final draft from ATC, and developed an implementation plan that would ensure universal acceptance.

ASCE captured the research results to date (the project was not going to fund research to fill gaps in existing research results), and conducted the user workshops at the quarter points of the project.

ATC had responsibility for managing the technical content of the Guidelines, produced draft Guidelines at the quarter points of the work, responded to the consensus review comments, and developed examples of the Guidelines use. Sixty consultants were involved in the technical production.

THE APPLIED TECHNOLOGY COUNCIL – A SIDEBAR

The Applied Technology Council is a nonprofit, tax-exempt corporation established in 1971 through the efforts of the Structural Engineers Association of California. ATC's mission is to assist structural design engineers (in specialty fields such as earthquake, flood, soils, and wind) to keep abreast of technical developments and to use them effectively. To this end, ATC also identifies and encourages needed research and develops consensus opinions on natural hazard structural engineering issues in a non-proprietary format. ATC thereby fulfills a unique role in funded information transfer.

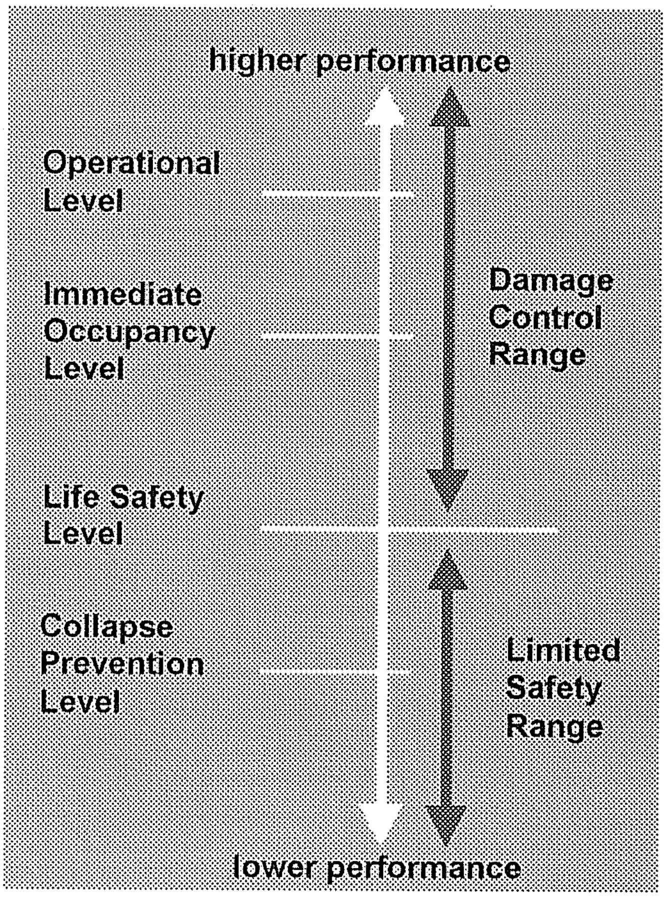
ATC is guided by a Board of fourteen directors. The Board consists of representatives appointed by structural engineers associations in the western United States and by ASCE, and four at-large representatives concerned with the practice of structural and multi-hazard engineering. Projects and administration are managed by a full-time Executive Director and support staff. ATC calls upon a wide range of highly qualified professionals as consultants on specific projects, thus incorporating the experience of many individuals from academia, research and professional practice, not available from any single organization.

ATC manages projects which benefit, and thereby fosters the advancement of, the structural engineering profession in all hazard reduction efforts, and which need a consensus of engineering opinion presented by a neutral source. Funding for projects is obtained primarily from government agencies.

IDENTIFICATION OF THE ISSUES

Issues were identified in FEMA-237 which reported on the first phase. Recommendations from FEMA-237 with a recognizable influence on FEMA-273, included:

- Provide a performance-based design approach;
- Address buildings and nonstructural components elements, but not other structures;
- Be nationally applicable (i.e., address an engineered building anywhere in the nation);
- Be written for design professionals (engineers, architects, and building regulatory personnel);
- Provide requirements that reflect the existence of different seismic zones;
- Include different performance goals, but specify minimum requirements for life safety;
- Include simple measures for simple, regular buildings not exceeding a specified size.



FEMA-273 SIGNIFICANT CONTENT

The use of three phrases needs some oversimplified clarification. The performance level of a building is directly related to how far along the yield plateau each seismic element, component, and joint of the building reaches; if it is not far, Operational Level may be attained; if it almost reaches rapid strength loss, Collapse Prevention Level may be attained. Earthquake ground shaking is greatly simplified to mean the design ground acceleration peak level, or the spectral acceleration response, and not a time-history (except in special applications). The recurrence interval for a specific earthquake ground motion (as clarified above) is statistically recoverable from the probability that this level can be exceeded in the next 50 years; a low probability, 2%, implies a rare, large earthquake with a recurrence interval of (approximately) 2500 years. With these clarifications at hand, the document contains several new features that depart significantly from previous seismic codes:.

- Criteria and methods for achieving various performance levels at various expected earthquake ground shaking levels, defined regionally in terms of recurrence intervals. The combination of these parameters (performance level and expected level of ground shaking) enable the user to seek one of the following rehabilitation objectives:

a) Basic Safety Objective: Life Safety for ground shaking recurring in 500 years and Collapse Prevention for ground shaking generally recurring in 2500 years.

b) Limited Objectives: Rehabilitation objectives less stringent than the Basic Safety Objective, such as performance levels less than Life Safety (for example, Limited Safety) for ground shaking recurring in 500 years, or Life Safety for less ground shaking, recurring, for example, in 100 years.

c) Enhanced Objectives: Rehabilitation objectives that call for a higher level of performance than the Basic Safety Objective, such as Immediate Occupancy, or Damage Control, for ground shaking recurring in 500 years, or Life Safety for higher ground shaking, recurring, for example, in 1000 years and Collapse Prevention for higher ground shaking, recurring, for example, in 5000 years.

- A Simplified Rehabilitation Method, applicable primarily to small regular buildings in areas of low and moderate seismicity. This method is appropriate only for Limited Safety objectives.
- A Systematic Rehabilitation Method — complete procedures for considering all components and seismic elements necessary to reach a specified performance level for any building. These procedures address rehabilitation strategies, analysis procedures and their selection, and material acceptance criteria.
- New methods of analysis, including (a) a new Linear Static Procedure based on estimating maximum structural displacements, and (b) a new Nonlinear Static Procedure — a Pushover Analysis — that will better account for structural behavior caused by progressive yielding of structural components.
- Detailed procedures for determining acceptability of existing components as well as designing new ones in the four major material groups: wood, concrete, steel, and masonry. These depart from current standard design procedures for new buildings, which generally, and correctly, consider all parts of the structure to have similar characteristics.
- Procedures for incorporating emerging technologies in the rehabilitation design, including seismic isolation and supplemental damping.
- Criteria for seismic rehabilitation of nonstructural components, coupled with various performance objectives and emphasizing those components important for the Basic Safety Objective. Both prescriptive and analysis procedures are included.

TRAINING SEMINAR SERIES

Currently ATC and BSSC are sponsoring training seminars on FEMA-273 in cities throughout the nation. To date, seminars have been held in Los Angeles, New York, Portland, Salt Lake City, San Diego, and Seattle. Up to 13 additional cities will be added over the next several months.

The seminar program has been developed for practicing structural and civil engineers, architects, seismic engineering educators and students, building regulatory personnel, and other technical design professionals. The two-day seminars include 12 hours of presentations on the following topics: Issues, Overview, Simplified Rehabilitation, Systematic Rehabilitation, Structural Dynamics, Computer Modeling and Analysis, Foundations, Nonstructural Components, Steel, Masonry, Concrete, Wood.

Each seminar includes presentations by individuals specially selected because of their technical expertise and their ability to convey technical information effectively to large audiences. The seminars are being co-sponsored by local structural engineers associations and local chapters of ASCE.