EMERGENCY POST-EARTHQUAKE INSPECTION & EVALUATION OF DAMAGE IN BUILDINGS

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ABSTRACT

Recommended procedures are presented for emergency inspection and evaluation of post-earthquake damage to assess the extent of damage and to evaluate the relative safety for occupancy of buildings. Guidelines for recruiting and training competent field personnel and procedures for carrying out field operations safely and effectively are developed.

INTRODUCTION

This paper describes a portion of recommended nationally applicable seismic design provisions. These provisions have been produced by the Applied Technology Council, associated with the Structural Engineers Association of California, under contract with the National Bureau of Standards (NBS) with funding by NBS and the National Science Foundation Research Applied to National Needs Program, as part of the Cooperative Federal Program in Building Practices for Disaster Mitigation initiated in 1972 under the leadership of NBS. The preparation of the procedures is being carried out by a committee composed of the authors plus Messrs. Thomas Atkinson and David Messinger.

The procedures described herein are intended to reduce the incidence of death and injury to occupants of buildings which have been weakened or placed in jeopardy by seismic activity or by aftershocks. A secondary purpose is to assess damage to service systems which would render buildings unusable and/or pose a health hazard to occupants and the community. Finally, statistical assessments of damage are necessary to estimate the magnitude of the disaster in terms of cost of damage, numbers and types of buildings affected, and to provide data for government planning for aid to communities.

Advance planning is essential for effective inspection and evaluation of post-earthquake damage in buildings. The most effective and efficient means of organizing inspections is generally through established agencies within the local jurisdiction. Accordingly, the agency regulating building inspection and safety within the cognizant jurisdiction would be responsible for conducting damage surveys. Recognizing that such an agency would probably not be adequately staffed for the task, mutual aid from neighboring communities would be required.

Even maximal aid from public and governmental agencies may not be adequate. Local jurisdictions should therefore develop plans to enlist the aid of private sector engineers and others to assist in assessing and evaluating damage to buildings. In an emergency these individuals must be contacted and transported to emergency operation centers, and there must be stockpiles of earthquake damage inspection forms and equipment and transport to the damage areas.

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The principal elements in planning for and carrying out effective emergency inspection and evaluation of earthquake damage are: (1) organization, training, and mobilization of inspection personnel, (2) inspection procedures, (3) evaluation of structural and nonstructural damage, (4) evaluation of auxiliary systems, and (5) emergency control actions based on the damage evaluation.

The experience of the Building and Safety Department of the City of Los Angeles, whose 250 building inspectors evaluated 27,160 structures in the month following the 1971 San Fernando Earthquake, helps to define emergency damage inspection procedures: (1) An operative communications system is essential; because telephones may not function after a major disaster, it is imperative that an emergency communications system--probably radio--be available. (2) The boundaries of heavily damaged areas must be quickly defined, and overall damage assessed, preferably by air reconnaissance. (3) Efficient forms for compiling and evaluating statistical data must be devised. (4) Plans for obtaining emergency aid from other jurisdictions must be developed, including orientation for inspectors unfamiliar with the area.

INSPECTION PERSONNEL AND ORGANIZATION

The type of personnel needed for inspection teams will vary depending on the classes of structures to be investigated. Structures in average neighborhood shopping centers and surrounding areas could, for instance, be examined by architects, building inspectors, and construction foremen, while larger and more complex structures should be examined by experienced structural engineers. Inspections teams should be aided by specialists such as photographers, amateur radio operators, and other communications specialists. Recruitment of personnel could be through engineering and architectural societies, technical associations, trade unions, and large engineering and construction firms.

Enrollment in manpower pools should be on a regional basis so as to include personnel from areas not affected by a disaster. Personnel lists should be compiled on both a statewide as well as local basis, and be maintained at local mobilization points and at State Department of Emergency Services headquarters. The lists should be updated at least every two years.

Enrollment forms should show special qualifications, age, physical endurance, commitment to participate in training programs, and commitment to serve on-call for not less than two years. The lists should be processed into a data bank, classifying personnel by geographical location and special skills. To avoid problems with legal liability for actions by personnel and with discipline and control, consideration should be given to mobilizing special inspection teams under government power of conscription with conditions of service and compensation rate as part of the enrollment procedure.

Mandatory training programs should be organized for inspection teams, encompassing the following: (1) disaster relief plan organization, (2) mobilization procedures, (3) team organization, (4) communications procedures, (5) identification of types of damage, (6) structural and nonstructural hazard identification, (7) recording procedures, (8) temporary hazard abatement, and (9) estimation of damage losses and possible repair costs. In addition, special training should be provided for: (1) evaluation of damage with respect to safety for continued occupancy, (2) evaluation of damage to utilities and services for health hazards, (3) evaluation and identification of on-site soil and foundation conditions, (4) identification of structural load-resisting systems without benefit of plans, and (5) identification of mechanical and electrical systems without benefit of plans. Classroom training, correspondence courses with assignments and periodic examinations, and workshops to discuss problems encountered in recent earthquakes should be used. Field exercises, including simulated disasters and involving all disaster relief agencies, should be held with participation in at least one such exercise mandatory for re-enrollment.

PROCEDURES FOR INSPECTION AND EVALUATION

Before effective identification and evaluation of damage can be undertaken, several operations must be completed, including: (1) identification of areas where damage must be assessed, (2) closing-off of damaged areas, and (3) activation of the central control group or groups.

To define the damage area, photo reconnaissance flights should be initiated as soon as possible with planning the joint responsibility of appropriate federal, state, and local governmental agencies. Damage evaluation by driving through the area on a block-by-block basis is less desirable than overflights because of access problems to heavily-damaged areas and less rapid accumulation of data. Closing-off of damaged areas should be the responsibility of the police. The central control group should be informed of the boundaries so as to plan the mobilization of inspection teams and to arrange for personnel access.

The central control group coordinating the inspection efforts and mutual aid between affected areas would: (1) establish communication with the central disaster relief organization, (2) mobilize headquarter office forces and inspection teams, (3) retrieve stored equipment and arrange for issuance of supplies to inspection teams, (4) arrange transportation and communications, (5) arrange for personnel feeding and housing, (6) process inspection reports, (7) respond to inspection requests, (8) issue preliminary damage assessment data to pertinent agencies and news media, and (9) conduct special inspection parties through damaged areas.

Inspection personnel should report automatically to their mobilization point if they have been unaffected by the earthquake and are located in or near the disaster area. Personnel from other areas should be notified by the appropriate agency. In case of loss of telephone service, notification could be by radio. In reporting personnel must use whatever means of transportation is in operation, including personal vehicles if necessary. Prearrangement for use of government vehicles and car pools should be part of the operations plan. A form of pass familiar to state and local police should be issued in advance to all enrolled persons with blank passes available at mobilization points for emergency use. The head of the Building Inspection Agency should have control of pass issue.

Mobilization points should be established considering that some may be rendered inoperable by the disaster. Preferably, the mobilization point would serve as the coordination center for damage evaluation. If the center also housed police, fire, and other vital functions, coordination of effort would be greatly enhanced.

Inspection teams would be formed as personnel report for duty. Engineers familiar with specific structures should be assigned to investigate same. Inspection priority should be established with essential community facilities heading the list. An emergency radio system with mobile two-way units for each team would be most helpful. If such is not available, the following might be considered: (1) taxicab two-way radios, (2) walkie-talkies, (3) amateur short-wave, (4) private cars with or without two-way receiver-transmission systems, (5) military vehicles, and (6) foot messengers.

After inspection teams are at a building, they must identify the lateral force resisting system, and evaluate damage to this system and to other building elements to ascertain whether the building should be posted as unsafe for occupancy. To expedite inspection and recording of observations, forms have been developed for recording data on damage to structural and nonstructural elements, mechanical, electrical, and plumbing systems, and on soil and site conditions. These forms were designed so the data can be punched directly on IBM cards for processing. Generally, it is desirable to (1) identify the building, (2) identify the inspection team by code number, (3) record the time and date of inspection, (4) detail the building location, (5) describe the occupancy (use, special contents, and number of occupants, (6) describe number of stories above and below grade, shape and dimensions (plan and elevation) and foundation/soil conditions, (7) describe the structural system (roof, floors, walls, frame, connections), (8) identify all materials of construction, and (9) describe special features and construction details (finishes, lighting, mechanical and electrical systems and special equipment, stairs, parapets, etc.). Information should also be provided on (10) damage in structural and nonstructural elements and distortion or malfunctions of nonstructural elements, (11) the degree of hazard from sources within the building and adjacent buildings, and (12) cost estimates of loss and cost of repair or demolition. Finally, inspection team recommendations and any action taken should be noted.

Several classes of structures should receive special attention. Hospitals: Because of the complexity and interdependence of the service systems, qualified engineers with experience in hospital design should assess their condition. Hospital operating personnel should accompany the team, and consideration should be given to the state of the buildings and the potential hazards of dangerous gases, liquids, or solids, and radiation emission. Utilities: Most utilities have emergency plans for investigating and repairing damage to their facilities, and therefore communication between their staff and the central control group should have top priority. Schools: The service systems of many school buildings can be expected to be severely damaged; however, these systems are usually relatively simple and their potential for creating hazardous conditions is negligible. Cognizant technical and custodial school personnel should be listed at emergency operating centers. Office Buildings: The services provided in most office buildings are relatively simple; however, complex electrical equipment is often present, posing a serious fire hazard if wiring is disrupted; structural complexities may create difficulties for inspectors. In most low-rise office buildings, the mechanical equipment and power supply systems are relatively simple to inspect. The stability of heavy equipment and its supports, and the potential for fire hazard, should be evaluated. In high-rise office buildings, mechanical equipment is often concentrated at mid-height and service distribution systems may be extensive, complex, and difficult to observe. The weight of equipment, and the potential instability of mechanical components, is of concern. The cognizant operating technical personnel should have emergency plans coordinated with the local emergency control group, and should if possible accompany the inspection team. The inspection team for any complex office bulding should be composed of specially qualified personnel. Manufacturing Plants: Although the size and complexity of service systems in manufacturing plants vary widely, the standard investigative team should be capable of inspecting and evaluating hazards associated with common industrial plants. Where dangerous materials are present and/or there is risk of fire or explosion current information on such conditions should be on file in the emergency operating centers, and investigative teams provided with a checklist of special hazards. Local fire departments often maintain current files on such potential hazards and inspection teams should have access to this information. Elevators: Because of the complexity of controls and potential operating hazards, an initial cursory inspection should be made and followed by a more detailed inspection by specialists. Elevators should be posted as nonoperable unless their continued operation is essential under emergency conditions.

HAZARD POSTING AND REINSPECTION

After an inspection team has concluded its evaluation, all buildings will be posted with one of the following: (1) inspection notice posted: minor damage, no hazard to occupants, (2) posted green: badly damaged, possible hazard to occupants, limited entry only, (3) posted blue: major damage, safety of building questionable, entry prohibited, (4) posted red: major damage representing a severe hazard, in a state of incipient collapse, entry prohibited. Local governmental bodies should enact enabling ordinances prohibiting entry into buildings so posted.

A determination that a building must not be occupied can have severe impact on the owner or tenant. Because relatively large aftershocks often occur, weakened buildings possibly may be further damaged. A reinspection of all structures classified as unsafe to occupy or marginal in their first inspection must be required within one week. Reinspections should be more meticulous and complete. The reinspection team should be highly qualified and preferably be licensed structural engineers. A record of the reinspection must be filed with the agency in charge. Copies of these forms should be sent to police and fire departments and to participating state and federal disaster agencies.

REFERENCES:

Recommended Seismic Design Provisions for Buildings, Appendix "Emergency Post-Earthquake Inspection and Evaluation of Damage in Buildings," ATC-3, Applied Technology Council, Palo Alto, California (to be published).