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SUMMARY OF EXISTING RAPID SCREENING PROCEDURES

A large number of methods for rapid analysis of seismically hazardous buildings can be found in the literature; however, these are generally abbreviated engineering analyses, requiring a trained engineer and access to the structural drawings. Only a few rapid visual screening methods have been found to exist, and none has had widespread practical application. Some of the available methods have been tested in limited areas for the purpose of refining the survey techniques but never have been applied to an entire community. In many cases the survey method that was chosen depended upon the ultimate use of the data that were gathered—for example, property loss estimation or life-safety estimation versus hazardous building identification. Thus, the different survey formats are in many cases a result of different goals, budgets, and personnel requirements.

This section presents citations and a summary of each RSP identified during the review of the literature, present practice, and community surveys. Each RSP has a brief acronym or other identifier (e.g., NBS 61 refers to the methodology developed at the National Bureau of Standards by Culver et al., 1975; OAKLAND study refers to a survey of buildings in the City of Oakland published in 1984), a bibliographic citation, and typically a one-paragraph summary overview of the methodology or study. The rapid screening procedures have been divided into two groups, surveys and methods, and are presented in reverse chronological order within each of these groups. Surveys are defined as those RSPs that have actually been applied to a real community. Methods are defined as those RSPs that are found in the literature, but as far as could be ascertained have not been applied to any community. Comparisons of certain aspects of the methods are presented in tables in Chapter 4.

SURVEYS

City of Redlands Study. Seismic Strengthening, Final Report and Handbook (1987). Report published by the Department of Economic and Community Development, County of San Bernardino, California. Also M. Green, personal communication.

> This handbook develops an RSP and presents a case study in the City of Redlands, California. The study was sponsored by the County of San Bernardino and the Southern California Earthquake Preparedness Project to identify potentially hazardous unreinforced masonry bearing wall buildings and to encourage voluntary seismic strengthening. The visual survey is designed to be conducted by inspector level personnel, with data being entered on forms (provided herein in Appendix A). Initial survey target areas were chosen based on the density of suspect unreinforced masonry buildings. Design level, building configuration, non-structural hazards, and adjacencies were used to identify the hazardous buildings. The survey resulted in maps showing the distribution and location of hazardous buildings in the city. Buildings were then ranked using a chart of tolerability of failure versus probability of failure for each building. The ranking included occupancy information. In its present

form, the method is limited to URM bearing wall structures and is therefore too limited for an ideal RSP.

San Francisco Study. A Survey of Unreinforced Masonry Buildings in San Francisco (1987). Report by Seismic Investigation & Hazards Survey Advisory Committee, and Department of Public Works. F. Lew, personal communication.

This survey was conducted by the San Francisco Building Department (1985-1986) to identify all unreinforced masonry buildings in the city. An office phase employed Assessor's files, Sanborn maps and Parapet Safety Program files to identify pre-1950 non-wood construction (approx. 6000). Every street in the city was then visually screened by building inspectors to determine and confirm which buildings were unreinforced masonry. The result of the survey is a list of approximately 2100 unreinforced masonry buildings that will be used with a future ordinance specifying mitigation procedures and timetables. Factors such as building configuration, occupancy, age and size were noted, but this information was not used. Costs and level of effort are as follows: two inspectors full time for one year surveyed this city of 700,000 population for a total reported cost of $120,000 (including clerical support).

ABAG. Perkins et al. (1986). Building Stock and Earthquake Losses - The San Francisco Bay Area Example Report by the Association of Bay Area Governments (ABAG), Oakland, California.

This is a survey conducted to estimate the building inventory for nine San Francisco Bay Area counties for estimation of earthquake losses. Specific hazardous buildings were not identified; only estimates of the number and geographic distribution of buildings of each type were provided. Hence, there is no well-defined methodology for identifying specific seismically hazardous buildings. Many of the data were collected from land use maps, interviews with local building officials, Sanborn maps, and previous studies. "Windshield" surveys were conducted by ABAG project staff and a graduate student in architecture to supplement data on building types and to identify seismically suspicious unreinforced masonry buildings in older downtown, commercial, and industrial areas.

Stanford Project. Thurston, H. M., Dong, W., Boissonnade, A. C., Neghabat, F., Gere, J. M., and H. C. Shah (1986). Risk Analysis and Seismic Safety of Existing Buildings. John A. Blume Earthquake Engineering Center, TR-81, Stanford University, Stanford, CA.

This expert-system based method has two steps: (1) Using a computer program, Insight 2 (termed an expert shell), a pre-field screening is performed on the basis of geology, ground motion (MMI), building importance, and vulnerability (furnished from building department and other sources). (2) If the pre-field screening warrants it, an inspection of the building including drawings and building access is performed. A numerical value for risk is assigned using an expert system built from the Deciding Factor shell. (Loosely defined, an expert-system is a computerized data base or "knowledge base" containing logic and rules that process input information to arrive at some conclusion. Ideally its logic is similar to the thought process of a human expert.) Palo Alto was used as a case study to validate the expert system by comparing its risk evaluations with those of experts. Sample data sheets are included herein in Appendix A. The use

of an expert system to supplement visually obtained survey data should make this method suitable for a larger target audience; however, in its present form the field survey is too detailed for a rapid visual procedure. In addition, the weighting scheme used to rank building hazard is subjective and not based specifically on damage-related data. This is an extension of earlier work by Miyasato et al. (1986).

Low-Rise Study. Wiggins, J. H., and C. Taylor (1986). Damageability of Low-Rise Construction, Vol. II & IV. Report by NTS Engineering for National Science Foundation, Long Beach, California.

This is an NSF-supported project to develop a methodology to estimate earthquake losses in low-rise buildings. A rating scheme based on a maximum value of 180 points is used. This study is an extension of the method developed for the 1971 Long Beach study. The insurance industry is the primary user of this method. Data gathering, however, is not done by field inspectors. Instead a short questionnaire about relevant aspects of the structure is completed by the building owner and decisions are made from the responses. As such, this is not an RSP.

U.S.-Italy Workshop. Angeletti, P., and V. Petrini (1985). Vulnerability Assessment, Case Studies. US-Italy Workshop on Seismic Hazard and Risk Analysis (Damage Assessment Methodologies), Varenna, Italy, 73-100.

Two methods are presented. The first, a subjective side walk survey, can be performed quickly (12–16 buildings/day per team), and the second is a more in-depth survey with quantitative vulnerability assessments (4–8 buildings/day per team). Both methods were tested on 490 buildings (379 masonry, 111 reinforced concrete) in Forli, Italy, in 1984, using 100 public technicians and 15 earthquake engineering experts and on 293 buildings (279 masonry, 14 reinforced concrete) in Campi Bisenzio. The results are in the form of histograms and maps of vulnerability classes.

Charleston Survey. Survey of Critical Facilities for the City of Charleston, South Carolina (1984-1985). M. Harlan, personal communication.

This study, funded by FEMA, was conducted for the purpose of estimating structural vulnerability and loss of function for the Charleston area in the event of a large earthquake. The study was not used to identify buildings for seismic rehabilitation. Probable Maximum Loss (PML), was used as the measure of damage. (PML was defined by Steinbrugge (1982) as the "expected maximum percentage monetary loss that will not be exceeded for 9 out of 10 buildings.") All critical facilities were evaluated, totaling about 350 buildings. No non-critical facilities were reviewed. Copies of the survey forms and rating forms are included in Appendix A. The advantage of these forms is that they are in a check-off format, thus minimizing omissions. The disadvantage is that they are too long for a rapid visual procedure. This survey was much more detailed than an RSP. Building entrance and plan review were often necessary to determine the PML modifiers needed for Steinbrugge's method. The vulnerability report has not yet been published. Third or fourth year university engineering students performed the survey. Students were given one to two weeks of training before going into the field. Each student reviewed an average of 3 buildings per day. Cost data were not available.

Palo Alto Survey. Survey of Buildings for the City of Palo Alto (1984-85), F. Herman, personal communication.

In 1984-1985, a local jurisdiction (Palo Alto, California) developed an ordinance and a survey method to identify and cite seismically hazardous unreinforced masonry and other specified buildings. The survey focused on three types of structures: (1) unreinforced masonry, (2) pre-1935 construction with more than 100 occupants, and (3) pre-1976 construction with more than 300 occupants. Seismically hazardous buildings were identified, primarily based on age and type of construction, number of occupants, and present condition. A sidewalk survey conducted by civil engineering graduate students under the supervision of a building department official was supplemented with Sanborn maps, building department files, and information from a previous survey conducted in 1936. Hazardous buildings were cited and owners were given one to two years to submit a detailed structural analysis of the building for city review. Examination of the several sample data sheets (included in Appendix A) shows that very little site or structure-specific information was requested in the sidewalk survey. All information about configuration problems, nonstructural hazards, and building dimensions would be included in the remarks area at the discretion of the inspector. This is because the method was essentially pass/fail based on whether a building could be classified into one of the three categories described above.

Oakland Study. Arnold, C. A. and R.K. Eisner (1984). Planning Information for Earthquake Hazard Response and Reduction. Building Systems Development Inc., San Mateo, California.

This is an NSF-sponsored investigation by Building Systems Development and the University of California, Berkeley, of urban planning for seismic risk mitigation, using Oakland as a case study. The procedure was mainly a sidewalk survey of building exteriors following an initial screening using information from Sanborn maps, assessor's files, and building permits. The survey was conducted by graduate students in architecture with guidance from a registered architect. The final product was the identification of "seismically suspicious" buildings, determined mostly on the basis of structural system and configuration factors and, to some extent, occupancy. Some factors, such as non-structural hazards, were noted, but it is not clear that they were used in identifying the seismically suspicious buildings. The report does not specify how the collected data were combined to determine the hazard of a building and thus the method requires a great deal of technical judgment. An example of the data collection sheet used in the sidewalk survey is included in Appendix A. Although building types and occupancy classes are well defined, other information is loosely defined, possibly leading to a lack of consistency among different data collectors. The level of effort expended involved 2 graduate students in architecture, a total of approximately 350 hours for 2500 buildings, and an approximate cost of $20,000.

Multihazard Survey. Reitherman, R., Cuzner, G., and R. W. Hubenette (1984). Multihazard Survey Procedures. Report by Scientific Service, Inc., Redwood City, California, for FEMA. (R. Hubenette, personal communication).

This method, developed for FEMA and

adopted in FEMA technical report TR-84, is designed to apply to essential facilities necessary for disaster operations. The method identifies and quantifies, on a scale of 1 to 5, a building's vulnerabiliy to radiation, fire, earthquake, high wind, tornado, hurricane, and flood hazards. The vulnerability is determined from a combination of the resistance of the construction and the exposure of the building to the particular hazard, but this calculation is not done by the surveyor. All data are processed by computer at the national level (FEMA). The method has been adopted and implemented since 1985 in many states, including California, Florida, North Carolina and Arizona. However, the priority for the multi-hazard surveys is civil defense related, and in many cases the earthquake portion of the survey is not performed. All survey data are collected on a standardized form (included in Appendix A) and are entered in a national database. The data collection form is organized to facilitate the computerized data processing, but it is difficult to follow. Rather than a checkoff format, the form requires the use of numerical codes that are not easily memorized. One of the promising and unique features of this method is that inference rules are provided for cases when visual inspections, drawings, and other supplemental information are not adequate to positively answer survey questions. The method is more detailed than an RSP, as building entrance is necessary and sometimes plans are reviewed. The survey can take from one hour to three days per building. Survey personnel need a minimum of two years undergraduate technical background. Cost information was not available.

New Madrid Study. An Assessment of Damage and Casualties for Six Cities in the Central United States Resulting from Two Earthquakes, M=7.6 and M=8.6, in the New Madrid Seismic Zone (1983). Report by Allen & Hoshall, Inc., Memphis, Tennessee, for FEMA.

This study, also known as the Six Cities Study, assesses damage due to earthquakes on the New Madrid fault zone. An extensive inventory of buildings was supplied by FEMA for the six project cities. These data were checked and in some cases supplemented by visits to the sites by a structural engineer and an engineering technician. In other cases, the data were verified by telephone contact with facility managers. The inventory was limited to a few representative structures of well-defined classes such as hospitals, critical structures, transportation systems, public utilities, and schools, and was primarily to assess the type of construction for each of the classes. Three different survey forms were available depending on the class of the structure and information required (see Appendix A). This is not a rapid visual screening procedure, but a sampling procedure to infer the properties of the larger building inventory for use with fragility curves to estimate damage. Cost information was not available.

OSA Hospital Survey. Earthquake Survivability Potential for General Acute Care Hospitals in the Southern California Uplift Area (1982). Report by Office of the State Architect for Office of Statewide Health Planning and Development, California. J. Meehan, personal communication.

This inventory and evaluation of hospitals in the Palmdale Bulge area were done by structural engineers from the Office of the State Architect. Hospitals were classified into six

"survivability index" categories from A (low risk) to F (high risk) based on the date of construction and structural information. The criteria used in this survey require extensive engineering judgment and are specific to hospitals as they are based on adherence to Titles 17 and 24 of the California Administrative Code. Data were gathered by extensive interior and exterior visual inspections along with an in-depth review of construction drawings when possible. Level of effort was probably one to two engineer-days per hospital, depending on the complexity. This was not a rapid procedure, but rather a detailed inventory of hospital resources, such as beds and rooms, as well as anchorage of equipment and availability of emergency services.

Los Angeles Study. Survey of Unreinforced Masonry Bearing Wall Buildings (1978-1979) for the City of Los Angeles. E. Schwartz, personal communication.

This study in the City of Los Angeles was performed by city building inspectors during 1978-1979 for the purpose of identifying bearing wall unreinforced masonry buildings, but not infill or other types of URM. Preliminary identification of pre-1934 URM was performed using assessor's files, Sanborn maps, and records from a previous parapet stabilization program, resulting in identifying about 20,000 potentially hazardous buildings. A block-by-block visual survey of building exteriors (and interiors when possible) reduced this to a final count of about 8,000 hazardous buildings. Although configuration and state of repair were noted, the primary criterion used to identify the hazardous buildings was the existence of unreinforced masonry bearing walls. An average of 40 minutes was spent at each building. After the data were collected, hazardous buildings were placed in one of four classes: (1) essential buildings, which were mostly state- or city-owned; (2) high-risk buildings, with more than 100 occupants and/or few interior walls; (3) medium-risk buildings, defined as having 20 to 100 occupants and/or many interior partitions; and (4) low-risk buildings, those buildings with less than 20 occupants. These categories were used to prioritize the mitigation procedures. The level of effort expended involved 6 inspectors, 1 senior inspector, 1 structural engineer, 2 clericals, all for 2 years, at a cost of approximately $400,000.

University of California Study. McClure, F. E. (1984). "Development and Implementation of the University of California Seismic Safety Policy." Proceedings, Eighth World Conference on Earthquake Engineering, San Francisco, 859-865. F. McClure and L. Wyllie, personal communication.

In response to the 1975 seismic safety policy implemented by the University of California, a survey of buildings with area greater than 4,000 sq ft and with human occupancy was conducted by experienced structural engineers (Degenkolb Associates were consultants on this project). Based on structural, non-structural and life-safety judgments, a seismic rating of good, fair, poor, or very poor was assigned by observations of building exteriors and a review of design drawings and previous engineering reports. Two to four days were spent on each of 9 campuses, for a total review of 44 million sq ft, of which 21% rated poor or very poor. The effort was split between reviewing drawings and on-site inspection. There were no formal criteria in this study, as decisions were made on a building by building basis. A considerable amount of

judgment and engineering experience was required to perform this survey.

Santa Rosa Study. Identification of Seismically Hazardous Buildings in Santa Rosa, 1971-present. W. E. Myers. personal communication. Also, Myers, W. E. (1981). "Identification and Abatement of Earthquake Hazards in Existing Buildings in the City of Santa Rosa." Proceedings, 50th Annual SEAOC Convention, Coronado, CA, 55-66.

This study arose from an ordinance adopted by the Santa Rosa City Council in 1971 to review all buildings constructed before December 31, 1957 (one and two-story wood frame, single family dwellings were exempt from the review process). A preliminary review is performed by a city official (experienced structural engineer) to determine if further review is necessary, based on whether the building complies with the 1955 UBC. Any further review is the responsibility of the building owner and must be prepared by a structural or civil engineer. The initial screening consists of a half day (on average) detailed site inspection involving entry into the building, including the basement, attic, and other portions of the building, noting such features as wall ties, openings, and diaphragms. Fire as well as earthquake-related hazards are usually identified. Data are collected using a handheld tape recorder, and later transcribed. Where possible, plans are examined, although in many cases they are unavailable. In a few cases rough calculations are performed. Subsequently a report is written (2 to 20 pages depending on the complexity of the structure) and submitted to the owner with a timeline for mitigation. The established priority of review was based on the number of occupants, buildings with the most occupants being reviewed first. Reviews began in 1972 on churches and other buildings with assembly occupancy greater than 100 persons, and in 1987 the city was reviewing buildings with smaller occupancy such as office buildings and retail stores. Between 1972 and 1987, approximately 400 buildings were initially reviewed (out of approximately 600 in the city) with about 90 percent requiring further review. Due to the detailed nature of the visual inspection and the level of engineering expertise required, this does not fulfill the definition of an RSP. The level of effort expended was: 1 full-time engineer employed by the city for 15 years, and a cost of approximately $500 per building.

Long Beach Study. Wiggins, J. H., and D. F. Moran (1971). Earthquake Safety in the City of Long Beach Based on the Concept of Balanced Risk. Report by J. H. Wiggins Co., Redondo Beach, California. Also E. O'Connor, personal communication.

This study was developed as part of a model ordinance (Subdivision 80) for the City of Long Beach. It was a significant advancement in the techniques of rapid identification of seismically hazardous buildings. In the original methodology, five factors were scored and combined to form a hazard index: (a) framing system/walls, (b) diaphragm/bracing, (c) partitions, (d) special hazards, and (e) physical condition. A score of 0–50 indicated rehabilitation was not required; 51–100 indicated some strengthening was required; and 101–180 indicated a serious life hazard existed. This widely known method was not directly employed by Long Beach but was modified in the ordinance to score the following five structural resistance factors for unreinforced masonry: (a) wall stability, (b) wall anchorage, (c) diaphragm capacity, (d) shear connection capacity, and (e) shear or moment resisting element capacity. Occupancy,

importance and occupancy potential factors were also included. A survey of 928 pre-1934, type 1, 2 or 3 buildings was conducted by city building inspectors over several years. Deadlines for hazard mitigation depend on the ranking provided by the hazard index.

METHODS

Seismic Design Guidelines for Upgrading Existing Buildings (A Supplement to "Seismic Design Guidelines for Buildings") (1986). Dept. of the Army.

This is a methodology developed for the Army that contains both a rapid visual component and a detailed structural analysis. The result of the visual survey is a list of buildings that should be further reviewed. The first step is to eliminate buildings from the survey inventory using eight prescribed criteria. The remaining buildings are then classified as (1) essential, (2) high risk or (3) all others. All available design criteria such as drawings, calculations, and specifications are compiled and pertinent information is transferred to the screening form (Appendix A). A field survey is then performed, allocating 10 to 30 minutes per building. Buildings are eliminated from the list if it would not be feasible or cost effective to upgrade them, or if they are identical to other structures that will be reviewed.

ATC-14, (ATC, 1987). Evaluating the Seismic Resistance of Existing Buildings. Applied Technology Council, Redwood City, California.

Although this extensive methodology contains no rapid visual screening aspect, it is included in this review because Section 4.2.2 and Appendix C of ATC-14 contain checklists of features that, if elaborated, could form the basis for an RSP. Moreover, buildings identified by the ATC-21 methodology as seismically hazardous should be reviewed in detail with the methodology presented in the ATC-22 Handbook (in preparation), which is based on the ATC-14 methodology.

A Methodology for Seismic Evaluation of Existing Multistory Residential Buildings. U.S. Department of Housing & Urban Development, 3 volumes. Pinkham, C. W., and G. C. Hart (1977).

This method is based on NBS 61 (described below); however in this case only Masonry B (UBC 73, sections 2414, 2415 and 2418) and Masonry A (all other concrete or brick masonry) are targeted. This is essentially a rapid analysis procedure with a preliminary visual screening component. The data collection forms are the same as those for NBS 61. However, the criteria for preliminary screening are not well defined and therefore require a good deal of judgment.

NBS 61. Culver, C. G, Lew, H. S., Hart, G. C., and C. W. Pinkham (1975). Natural Hazards Evaluation of Existing Buildings, BSS 61, National Bureau of Standards, Washington, D.C.

This is an extensively developed methodology, designed for building officials and engineers, to evaluate existing buildings for major natural hazards: earthquake, high wind, tornado, and hurricane. Evaluation of existing buildings is performed in three levels, the first of which is a simple visual procedure, providing input to several simple equations that result in a Capacity Rating (CR). This method has been widely referenced but not directly or explicitly applied to any region, as far as could be determined. Data collection forms and field evaluation forms are

included in Appendix A. It can be seen that the data collection forms are quite extensive and assume that the inspector will have access to the interior of the building and to soils and geologic reports; thus, this is not a true sidewalk survey. Bresler et al. (1975) point out that the weights employed and the algorithms or equations for determining the capacity ratio (see field evaluation forms) are arbitrary and gave misleading results for a trial building they examined.

Not included in this list are earthquake loss estimation studies such as those prepared by the federal government for the Los Angeles area (NOAA, 1973), Salt Lake City area (USGS, 1976), San Francisco Bay area (NOAA, 1972), and Puget Sound, Washington, area (USGS, 1975).