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BUILDING OCCUPANCY RESUMPTION PROGRAM FOR POST-EARTHQUAKE DAMAGE ASSESSMENT AND RECOVERY

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ABSTRACT

In the chaotic aftermath following a major earthquake, building owners often need rapid, accurate, and reliable damage information to resume occupancy or take appropriate measures for building recovery. Within 3-10 days of the event, municipal-deputized safety evaluators typically provide a rapid safety assessment. However, to completely assess the building's condition, a more detailed structural assessment is often necessary. Without prior arrangements, owners may have to wait weeks to coordinate with a qualified structural engineering professional. To avoid this delay, some jurisdictions have adopted programs based on the Building Occupancy Resumption Program (BORP) developed by the City and County of San Francisco that allows owners to pre-certify qualified structural engineers for post-earthquake inspection of their buildings. In non-participating jurisdictions, a similar "unofficial" approach can facilitate the post-earthquake assessment efforts. This paper outlines the basic BORP phases and provides recommendations for alternate programs based on building owners needs.

Introduction

Following a major earthquake, building owners often need rapid, accurate and reliable damage information to resume occupancy or take appropriate measures for building recovery. However, the number of safety evaluators available to perform a rapid evaluation will be limited as building departments prioritize inspections to buildings with important post-earthquake functions and to areas of greatest public hazard rather than expeditious business resumption.

Within 3-10 days of a disaster, municipal inspectors supplemented by deputized volunteers can typically provide a rapid safety evaluation (ATC 1989a). However, to completely assess a building's condition, a more detailed engineering evaluation is often recommended. In this scenario, owners may have to wait weeks to coordinate with a qualified structural

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engineering professional. In the interim, lack of building access can prevent the execution of critical operations and increase recovery time.

To avoid this delay and to reduce their post-earthquake workload, some jurisdictions have adopted programs similar to the Building Occupancy Resumption Program (BORP) developed by the City & County of San Francisco that allows owners to pre-certify private post-earthquake inspection of their buildings by qualified structural engineers (Turner 2006). The program is based on a pre-disaster evaluation of the building and is triggered by the declaration of a local emergency. The result of the post-earthquake inspection is reported both to the building owner and the building department. BORP or a similar program can dramatically decrease recovery time for owners or facility managers who rely upon uninterrupted building occupancy.

This paper outlines the basic phases of the BORP and provides recommendations for alternate programs in other jurisdictions. The alternate programs can be tailored to suit the needs of specific building owners or tenants.

Background

Following the California San Fernando Earthquake in 1971, the Structural Engineers Association of California (SEAOC) began collaborating with the State Office of Emergency Services (OES) to develop a plan whereby government could utilize private engineering resources during an emergency. The first draft of the plan was completed in 1978, and was entitled the Safety Assessment Plan (SAP) for Volunteer Engineers. Subsequently, the American Society of Civil Engineers (ASCE) joined SEAOC in the program, providing State OES with access to additional engineers for the safety assessment of buildings and infrastructure. Other professional organizations also joined the program, providing not only engineers, but also architects and building inspectors to conduct safety assessments after a disaster.

Under the plan's guidelines, the SAP evaluators assess if buildings are safe for either continued use and occupancy, or restricted use. Inspectors are required to hold some type of professional license as civil/structural engineer or architect, have relevant design or evaluation experience with similar buildings, and be certified proficient with ATC-20, *Procedures for Post-Earthquake Safety Evaluation of Buildings* (ATC 1989a) hereafter referred to as ATC-20.

Approximately 95% of the buildings receive the rapid evaluation. If the evaluation determines the building is unsafe for occupancy or limits occupancy to restricted, either a further detailed evaluation by SAP evaluators or an engineering evaluation by the owner's engineer is then required.

In 1989, the Applied Technology Council (ATC) published ATC-20 and ATC 20-1 – *Field Manual: Post-Earthquake Safety Evaluations of Buildings* (ATC 1989b). This effort was funded by State OES, the Office of Statewide Health Planning and Development (OSHPD), and the Federal Emergency Management Agency (FEMA). These documents were made available in 1989, just one month before the Loma Prieta Earthquake. This large magnitude earthquake provided an opportunity to test the program in an emergency that impacted multiple jurisdictions. In the resulting aftermath, the City of San Francisco had over 125,000 buildings to inspect (Turner 2006). Volunteers where provided, but many had not received the required training outlined in ATC-20. Safety assessments were performed, but in many cases occupancy was either restricted or prohibited. Due to the demand for qualified structural engineers, most building owners had to wait three weeks or more for engineering evaluations.

In 1996, to reduce critical building recovery time BORP was developed by a public/private partnership between the City & County of San Francisco Department of Building Inspection (DBI) and local chapters of the Building Owners and Managers Association (BOMA), Structural Engineers Association of Northern California (SEAONC), and the American Institute of Architects (AIA).

Under the program, the Department of Building Inspection (DBI) staff and SEAONC volunteers review the designated structural inspectors' qualifications and the inspection program plans (manuals). Upon approval, the building department gives the building owner or structural inspectors official placards with which to post the building following an earthquake and authorizes automatic deputizing of the structural inspectors upon declaration of a local emergency. Within eight daylight hours of an earthquake, the inspectors are to respond and the inspection program is to be implemented, reporting results to DBI within 72 hours.

Since the inception of the program in San Francisco, over 100 buildings have approved BORP plans. In addition, a number of states and other building jurisdictions have established similar programs. In jurisdictions without a specific program, building owners can contract with engineering firms to provide a private post-disaster inspection plan similar to BORP.

Program Components

As shown in Figure 1, the BORP process consists of three basic phases. The first is the assessment of the building and preparation of a documented plan, including a building-specific post-earthquake inspection manual. The second or maintenance phase of the program includes required annual updates and renewal activities. The third phase is the post-disaster implementation of the program.

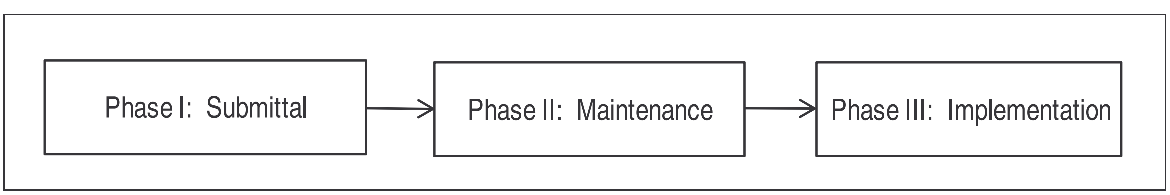

Figure 1. The BORP Process.

Phase 1 Submittal

The submittal process begins with a building owner employing a qualified consultant to assemble an emergency evaluation team. The extent of responsibility and liability is governed by the contractual agreement between the owner and the consultant. The consultant is responsible for developing a building-specific post-earthquake inspection plan. This is achieved through walkthroughs, drawing reviews and analyses as appropriate to understand the expected building performance in an earthquake. The intent of the program is that the consultant who develops the plan becomes part of the emergency evaluation team following the disaster. A minimum of one primary and one alternate inspector is designated by the consultant for each of the applicable inspection disciplines.

Structural inspection disciplines are included for all structures while elevator and life safety systems disciplines are required for high-rise buildings. The elevator and the life-safety system inspectors might be employees of the company that performs the building's routine maintenance. After an earthquake, these disciplines report their findings to the structural inspector.

Few architects consider structural inspections within their purview; however, architects can add expertise to the team to address nonstructural hazards such as blockage of exits, facade and ceiling assembly hazards and life safety system performance. For older buildings, architects/engineers experienced with historic structures might be considered.

For BORP, the requirements for an acceptable submittal are listed in a defined checklist. Copies of the manuals and drawings should be stored at a location that is accessible at both the building to be evaluated and the structural inspector's office. If structural drawings do not exist or are unclear, as-built drawings with clear descriptions of the structural systems are acceptable. Essential data includes the building's structural aspects along with information on elevators, egress paths, use or occupancy, emergency power provisions, and fire detection and suppression systems. Specific instructions are provided as to the location and handling of any hazardous materials stored on the property. Emergency access information and procedures for maintaining safe exit paths are designated. Documentation is provided verifying that personal safety gear, flashlights, walkie-talkies, caution tape, ladders and barricades are stored on site and readily available for emergency situations. The corresponding jurisdiction provides placards to store at the building.

The emergency plan allows a quick and thorough evaluation of potential damage to a building by the qualified inspectors. The procedures must as a minimum meet the requirements of a detailed evaluation as specified in ATC-20, and the inspector must complete and submit a detailed evaluation form to the building department. Figure 2 outlines the procedure for the plan. The plan is automatically initiated within eight daylight hours of a disaster declaration without the need of contact with the building or the building department. This is important as communications are typically disrupted after an earthquake. Building engineers or other designated staff members receive simple training to recognize hazardous structural damage even before the inspectors arrive and make decisions about building evacuations. They can also document any observed damage prior to the arrival of the inspectors.

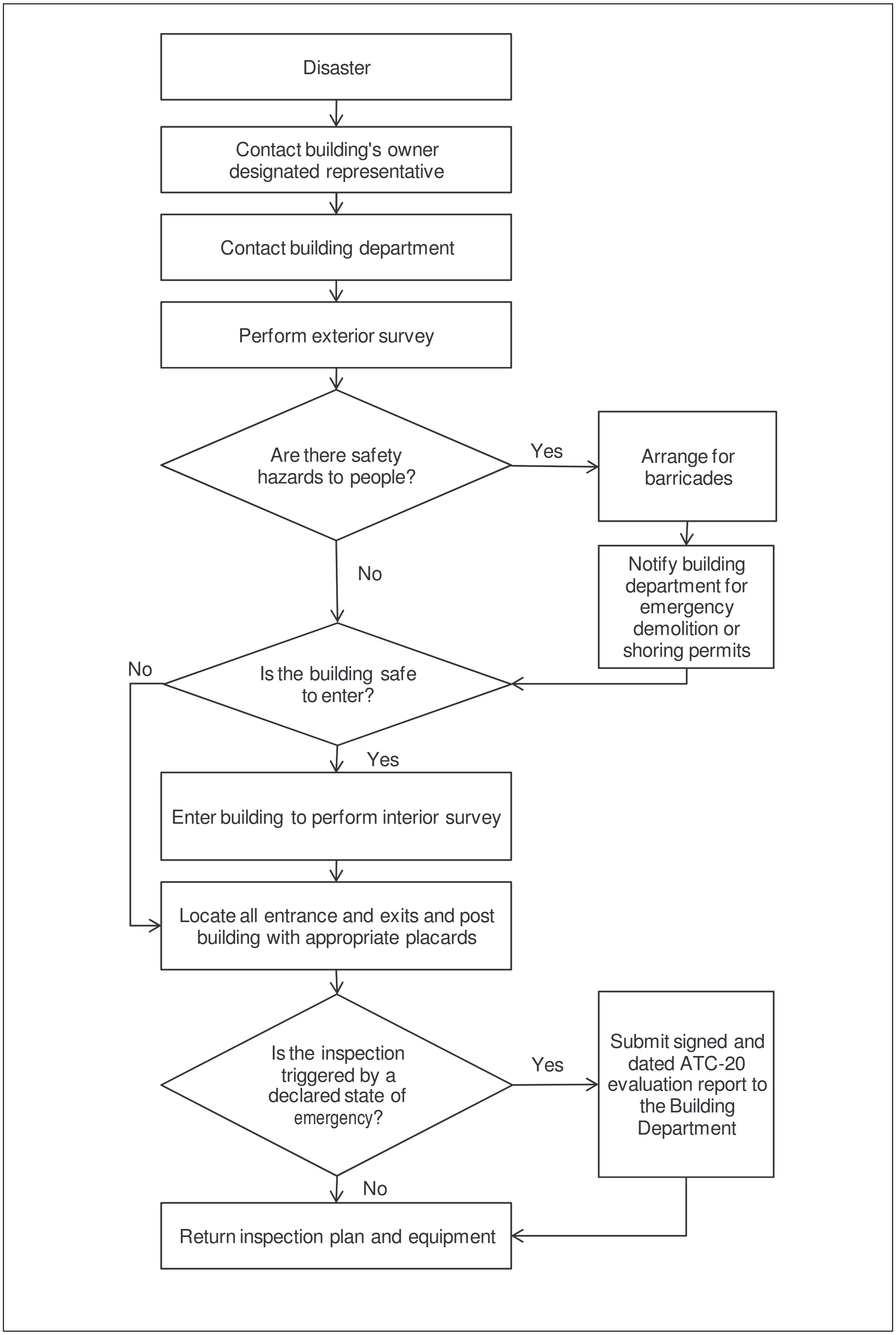

Figure 2. Emergency inspection plan flow chart.

Phase II Maintenance

BORP is developed such that it may be maintained over the life of the building. With the passage of time, changes may occur to the building, with inspection personnel, and with client relationships. The program is renewed on an annual basis either through confirmation to the City that no significant changes have been made or through documentation of any changes including key contact information. At this time, it is also recommended that the designated building inspectors and owner representatives meet to review the program and thus remain familiar with it. Consequently, an annual retainer fee for the structural inspector may be appropriate.

Phase III Implementation

Following a disaster, the program's approved emergency evaluation team becomes deputized by the jurisdiction to give them authorization to perform inspections and post buildings which are on the pre-certified list. As is the case for all SAP evaluations, the structural inspection begins on the exterior and only proceeds inside if the building appears safe. Unlike the SAP evaluators, the designated structural inspector is armed with an extensive knowledge of the building and with a manual indicating where damage is most likely to have occurred. The structural inspector is also authorized by the owner to remove finishes as necessary to observe the building's structural elements. By so doing, inadequate information or uncertainty is less likely to lead to an inaccurate placard posting.

If a public safety hazards exists, the plan would require contacting the corresponding building department for any required emergency demolition or shoring permits. Once the inspection is complete the structural inspector posts the appropriate placard on the building. If the owner and structural engineer have a pre-earthquake agreement or can quickly develop an agreement, the structural inspector can proceed directly with developing any mitigations and repair schemes needed to reoccupy the building before the inspector is engaged to do other work.

The inspector must complete official colored safety placards and mount them in a clearly visible place near all usual points of entry to the building. The placard includes the date of inspection and inspector's identification number. A detailed evaluation form is prepared and given to the building official. Aftershocks after the inspection could require additional inspections and a change of the placard. The placards describe the general post-earthquake state of the building as follows:

Green—The building has been inspected and no restrictions on use or occupancy have been found.

Yellow—The building has been inspected and found to be damaged as described on the placard. This placard can be used as a catchall to cover a wide range of hazards that may limit use of the building or portions of the building but not make it completely unsafe. Examples of such hazards include a cracked parapet above an exit or a portion of the building has collapsed but other portions do not appear to have been damaged. A yellow card may allow for limited use of the building for removal of property, but restrict continuous occupancy or habitation in the building.

Red—The building has been inspected and determined damaged and unsafe. No entry is allowed, except as specifically authorized in writing by the jurisdiction. Repairs can be made to mitigate the hazard.

Program Adaptation Outside San Francisco

Many cities and entities are either considering or participating in programs similar to that established in San Francisco. In these locations, if the jurisdiction does not have a formal program, coordination among an owner, inspector, and building department can lead to the formation of an informal arrangement as follows:

- Perform an initial inspection of the building, gather drawings and other documents, assemble equipment and safety apparatus, and formulate a post-earthquake inspection plan.

- Coordinate with the building department in the local jurisdiction to formally or informally establish a program. It is possible the corresponding jurisdiction will not deputize the inspectors and thus an official posting of the building will not be possible. It is also possible that the jurisdiction will not officially acknowledge any program, and the owner and engineer will have to present findings of the inspection to SAP evaluators as they arrive at the building following a disaster.

- Where applicable, establish instrumentation systems for the building (see below). Determine the building assessment and/or evacuation threshold levels.

- Maintain the program, as required by the corresponding building department.

- Implement the post-earthquake inspection within the predefined time specified following the disaster.

- In the event of a disaster, coordinate and manage any required mitigation and repair work to facilitate the resumption of building occupancy.

Program Instrumentation Options

The use of instrumentation (strong motion sensors or accelerographs) can greatly enhance the post-earthquake evaluation of buildings. The location and extent of instrumentation will depend on the owner requirements and the critical nature of the facility.

For a campus of buildings on different terrain and or soil types, a few well-distributed strong motion sensors in combination with pre-earthquake evaluations can help prioritize inspections following a disaster.

Steel moment frame buildings were identified as vulnerable in the 1994 Northridge, California earthquake. For a steel moment frame building, a sensor placed at ground level can determine whether or not a building has experienced shaking in excess of the threshold of 0.25g set by FEMA 352 (FEMA 2000). Following a disaster, if the building department implements the FEMA requirements, having the acceleration data can assist in determining the need for costly and time-consuming moment frame connection inspections. Without the data, the building department may have to estimate the building's ground motions and conservatively estimate higher ground motions to have occurred.

Detailed post-earthquake inspections of high-rise buildings can be an extremely time-consuming process. A distribution of strategically placed accelerographs within the building can streamline the damage assessment process. By analyzing a detailed computer model of the building prior to the earthquake, the structural inspector can predetermine the threshold levels likely to cause damage. A post-earthquake comparison of measured accelerations and displacements to threshold values could trigger an assessment or evacuation. After a disaster, the model could be analyzed using the actual input ground motions recorded during the earthquake. If damage is likely, the analysis could point to specific locations for visual assessment. The analysis could minimize disruptive inspections and accelerate mitigation if building occupancy has been restricted. Finally, the recorded data could be evaluated for changes in the building's response. A significant change is indicative of damage. Lack of such change could confirm an "inspected (green)" placard posting.

Although the manual retrieval of acceleration data can be cost effective, by implementing an instrument network in the building(s), the structural inspector and others can monitor conditions instantaneously (Figure 3). Following a disaster, the information can assist in the determination of whether evacuation of the building is necessary.

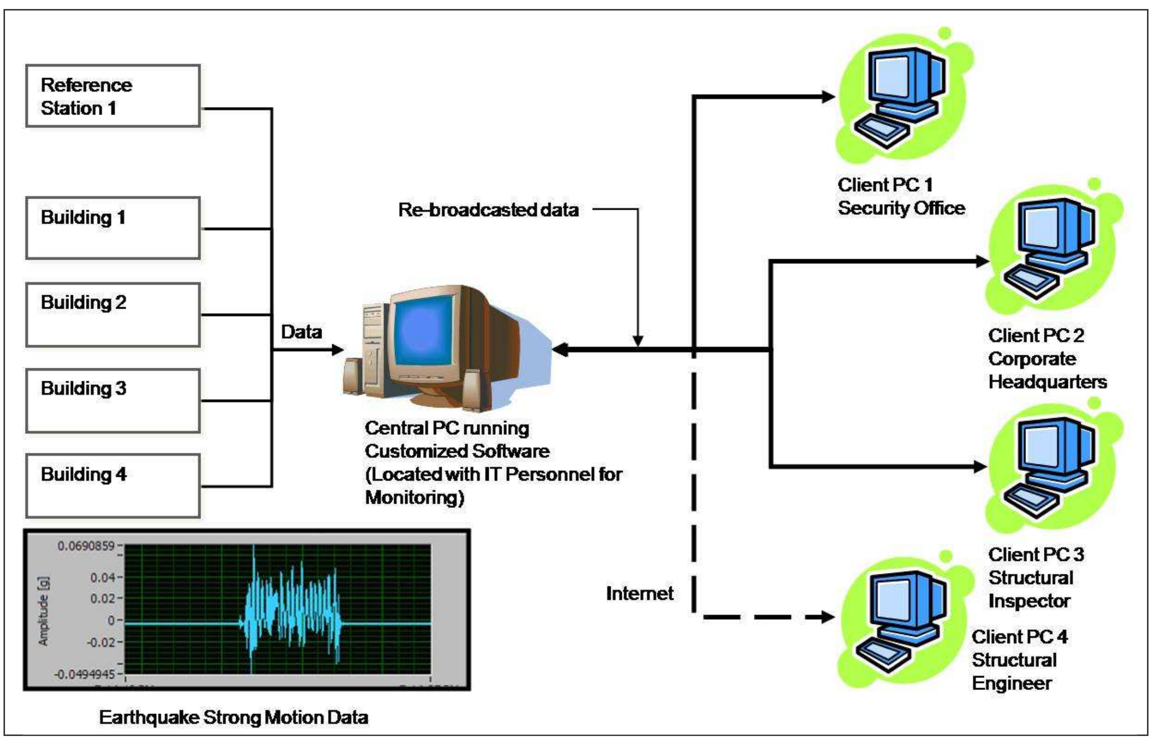

Figure 3. Earthquake instrumentation network.

Occupancy Resumption Program Cost Considerations

Initial development costs for some type of resumption program will vary significantly based on the size and complexity of the building or facility, familiarity of the selected inspectors with the structural systems, availability of construction drawings, the extent of preparation required to complete the written inspection program and the scope of any instrumentation and monitoring systems. There are typically no building department fees associated with establishing a program.

Maintenance costs will typically be minimal if there are no major changes to the building. Monitoring of any instrumentation will vary with the scope and complexity of the system. The monitoring service is typically a monthly service charge. The program implementation cost following a disaster is difficult to estimate. The cost can vary significantly based on the size and state of the structure, the degree of analysis to be carried out, and on the magnitude of the disaster. However, it could be argued that these costs will be lower than if no program is implemented because the structural inspector will be better prepared for the inspection. More importantly, the building will be reoccupied sooner.

Conclusions

The building occupancy resumption program (BORP) provides a template for building owners to develop post-earthquake inspection plans prior to the occurrence of a disaster. By coordinating with corresponding building departments, formal or informal programs can be developed in buildings and facilities susceptible to disaster. The focus of this paper has been earthquakes, but such programs could apply to hurricanes, floods or other disasters.

The program can be developed in conjunction with an instrumentation system to provide instantaneous monitoring of the building. The acceleration data can provide the engineer with input for a time history analysis of structural response, thereby facilitating a precise post-earthquake damage analysis. The result can allow a focused assessment on structural systems most likely to have experienced damaged. The program provides building owners the means to optimize occupancy recovery with a prepared response. The prearrangement establishes a commitment on behalf of the inspectors who might otherwise have no obligation to provide recovery services following a disaster.

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