IV. IMPROVING THE USEFULNESS OF OUR CURRENT STRONG MOTION DATA AND NETWORK

Submitted by Marshall Lew and Tony Shakal

Weak or missing areas in the available Strong Motion data we collect

Strong motion instrumentation has been installed in less than 20 percent of hospital facilities in California. The actual percentage of hospital buildings with strong motion instrumentation is probably less than 5 percent because most hospital campuses have multiple buildings. Building code requires that certain types of hospital buildings be instrumented because of the use of certain new structural technologies or unusual building irregularities or geometries. The accelerations of the earthquake motions at the sensor are recorded.

As mentioned previously, strong motion instrumentation in buildings has been used historically as a forensic tool in trying to understand the behavior of buildings which have been subjected to strong earthquake motions. Strong motion instrumentation can provide a quantitative understanding, in addition to qualitative understanding, of what happened to a building from a damaging earthquake. Strong motion instrumentation has helped to calibrate our building codes and can aid in identifying structural behaviors and the dynamic capacities of building materials. However, the strong motion data is not readily available until sometime after the earthquake event has occurred.

Advances in technology and communication now may enable strong motion instrumentation data to be available in real or near-real time which will provide more timely feedback on the performance of buildings and systems and potentially identify key indicators of distress or concern regarding the structural integrity of a building or facility.

Accessibility of data after the earthquake

Collection and curation of the data from strong motion instrumentation mandated by HCAI is managed by the California Strong Motion Instrumentation Program (CSMIP), a part of the California Geological Survey. The strong motion data is recorded digitally and transmitted electronically to CSMIP servers.

Timeliness of data retrieval and analysis after the earthquake

The speed of transmission of the strong motion data from the various instruments will depend on the availability and capacity of the telecommunication channels which may be affected by earthquake and post-earthquake events.

The data transmitted to CSMIP is raw data that must be processed to be in a uniform standard format that can be readily used by researchers and other analysis platforms. CSMIP has a network of thousands of strong motion instruments in California and the availability of the processed data may be delayed because of the sheer amount of data to be processed. Also review of the processed data by CSMIP may be needed for quality control and assurance purposes.

If the recorded data can become more readily accessible in real or near-real time, the strong motion data can be used to assess damage and provide a more scientific basis for decision making regarding continuing occupancy and services in buildings more quickly. More rapidly available data can also be used to prioritize resources for recovery and restoration of services.

Potential Departure - "White Box" The desired rapid data recovery and processing mentioned in sections of this report could potentially be accomplished by augmenting the existing instrumentation at a hospital with a partner-box near the recorder. At this time hospital instrumentation is typically comprised of motion sensors at certain locations in the building which are all cabled back to a recorder. At the time of an earthquake, the data from these sensors are written to the memory of the recorder. After the event, the data is transmitted to the data center in Sacramento where it is received and processed and then posted to the data center at www.strongmotioncenter.org, followed by notification of the facility contact for some facilities. With the introduction of a partner 'white box' next to the recorder, all the functions of data retrieval, data processing, and notification could be done on-site, very rapidly, with immediate notification of key people. The box would retain all the data from the sensors and the calculated motions and responses.

The box would just be a hardened PC in a box, and it would receive the data from the adjoining recorder, immediately process it with onboard software, and then push the results to facility managers and/or HCAI. The data would also be available for study at a local web site in the box. The data would still subsequently be transmitted to the strong motion data center for final filtering and curation, and would be uploaded to the Internet data center site. But the rapid data release and notification for one hospital would not wait upon communication delays or performance of functions that need to be done for the many other stations.

This approach would remove the vulnerability to loss or low speed of the communication channel between the hospital and the data center in Sacramento, since the information would be available onsite in the 'white-box', at its URL on the web. This approach is developed around the 'white box'. It is likely that this could be purchased from the instrumentation manufacturer, and it would interface directly with the manufacturer's recorder. The software loaded in the box could be as specified by SMIP and HCAI, and the software could also be modified by SMIP as needed for specific situations. For example, the data from certain sensors could be defined as key, and the box would process these and report them out immediately.

Additional content that could be of value from improving the existing building instrumentation or the network itself

The current strong motion instruments record the earthquake motions in particular directions. Displacement is a vector that indicates how much a point moves relative to an initial position. Velocity is a vector which shows the direction and rate of motion of that point. Acceleration is a vector which shows the direction and magnitude of changes in velocity. Strong motion instruments used in California record the accelerations of the motions at the recording device as well as relative displacements at certain locations.

The complete motion of a point can be described by recording the motions in three orthogonal directions (i.e., two horizontal directions that are at right angles to each other, and the third direction being vertical). From the recorded accelerations, the velocities and displacement of a point can be calculated. However, this requires the recorded accelerations to be processed after the event and may not be readily available.

Knowing the accelerations experienced during an earthquake is helpful in estimating the forces induced in buildings, especially for short or low-rise buildings. However, the velocities are more useful for the evaluation of mid-rise buildings and displacements may be more useful for the evaluation of tall buildings. Relative displacements can also be useful in evaluating the behavior of portions of buildings; an example would be the evaluation of the relative displacement between two floor levels which can be used to estimate the drift of the structure and determine whether damage may have occurred. In addition, relative displacements can be used to evaluating the motion across a plane of isolation in a base-isolated building.

What we would like from the existing network as it grows in the future

There is no doubt that the existing network will record strong motion data from the inevitable future earthquakes. With advances in technology and communications, this data can be used extensively and effectively to provide very useful information to owners and operators of hospital facilities regarding the structural health of their facilities and help them to make informed decisions regarding operations, occupancy and allocation of resources after significant earthquake events.

Some facilities may need additional instrumentation to provide the necessary resolution of data to identify some key indicators of damage. However, there may also be more low-cost instrumentation that may be able to provide this data that may be commercially available that may not necessarily be part of HCAI's instrumentation program. Individual or corporate hospital operators may find that investment in private seismic health monitoring systems may be beneficial and financially sound provided that the recorded data will be available for curation, and for subsequent analysis by HCAI and engineering researchers.

Background and Objectives of Hospital Instrumentation

Structural Instrumentation

It can be argued there are two principal reasons for the strong motion instrumentation of hospitals.

1) First, the recorded data from instrumentation in a structure should help the building managers to rapidly know the state of the structure after a strong shaking event. This is quantitative information, not just qualitative, during a time when the facility managers need to be making decisions about continuing use of the facility and taking certain response actions.

The data measurements are needed very soon after the shaking stops, and certain rapid, limited, data-processing may need to be done for most effective use of the measurements. Note that the benefit in this situation is to the facility managers of the specific facility where the measurements are made.

2) The second principal reason for strong motion instrumentation is to provide information for a set of structures, not individual structures. In many ways, new design provisions occur in hospital construction before usage in regular structures. So hospital designs and construction, are, in a way, a 'beta' implementation of new design principals. Generic knowledge can be obtained and evaluated from a given structure, and then used to provide verification of the design assumptions and decisions for a class of hospitals. So in this second category, all hospitals of that type potentially benefit from the extensive data recorded in a few structures of that type. Design rules can be updated for future structures, and existing hospitals can be retrofit/strengthened in some aspects, based on the general knowledge. In this case, extensive analysis and possibly numerical modeling will often be used to extract the most knowledge from the data.

Non-structural Instrumentation

Under the first category considered above, decisions can be made based on the qualitative measurements obtained from the sensors in a building. There may be 15 or 20 sensors at various locations in the structure. However, this number of sensors is not needed to arrive at the conclusions about the hospital condition. In most cases decisions could be made nearly as well using the recording of a ground station on the hospital campus. That 3-channel station in the parking lot could be used to make decision about the building almost as well, in a rapid response time, as the fully instrumented structures.

In terms of the overall HCAI network, it would seem this is the greatest need. Many hospitals in California do not have any strong motion measurements nearby, even those in high seismic likelihood areas. A goal of having a ground station outside each facility could go a long way toward helping facility managers and/or HCAI make decisions about facility usage and response after strong shaking.

Potential Costs

A hospital ground station costs a fraction of what a fully instrumented hospital costs, and its installation and maintenance can be done without interfering with staff or patients. The instrumentation to measure the motions of a structure must continue to be high-resolution, high accuracy, since their data will be compared with computer models of the motion, including displacements that entail careful double integration. In contrast, since a ground response station operates in a stand-alone mode, the instrument can be lower precision and thus significantly less costly.