Guidelines and General Considerations for Strong-Motion Instrumentation of Tall Buildings

Strong-motion instrumentation should be located in a building in order to learn as much as possible about the response of the building during an earthquake and to confirm/verify design and analysis assumptions. Some jurisdictions are calling for extensive instrumentation of certain tall buildings. Although more limited instrumentation is also useful, this guideline is targeted at the extensive instrumentation requirement.

1. It is important to measure horizontal and torsional motion from the base to the roof. This requires (at least) three separated uniaxial horizontal accelerometers on each of a number of floors. Two should be located near the perimeter of the building along opposite walls (as distant as practical from the core) to get the best torsional measurement. They should be at the same relative position along the walls (e.g., at mid-length) and oriented with sensing direction parallel to the adjacent walls. The third should be placed near the center of the floor, oriented perpendicular to the other two, to measure horizontal motion in that direction. (The number of floors to be instrumented is discussed below.)

2. It is also important to measure rocking at the base of the building, especially for a stiff building founded on soft soils, to determine any rocking contribution to the drift. At least two vertical accelerometers are needed, placed near opposing walls. To measure rocking in both directions, a third is needed near one of the two remaining walls.

3. For optimal interpretation and analysis of the recorded data, accelerometers on different floors should be stacked vertically if possible; that is, the accelerometers should be placed at the same relative position on each floor, so the same location in the response is measured.

4. If there are features near the roof having unusual architectural configurations or heavy mechanical equipment, it may be important to place additional sensors there.

5. The total number of accelerometers depends on the number of stories:

Stories	Minimum. No.*	Recommended No.
6-10	12	15
11-20	15	19
21-30	21	26
31-50	24	30
>50	30	38

(*Los Angeles Dept. of Building and Safety, “Structural Monitoring Equipment in Buildings Designed with Nonlinear Response History Procedure”, P/BC 2014-117.)

As an example, a 34-story building would have a minimum of 24 accelerometers, with 30 recommended. Three horizontal accelerometers would be located at the base level, the roof level, and on each of five intermediate levels. Three vertical accelerometers would be located at the base. In general, the intermediate levels would be chosen where there are changes in stiffness or mass, or offsets in the structural system, or innovative structural systems; otherwise they would be evenly distributed over the height. On certain floors, accelerometers would be placed on adjacent floors to measure the interstory drift. Additional accelerometers could include a vertical accelerometer at mid-span and possibly one at a nearby column on instrumented floors where significant nonstructural components are present.

It is often most practical to install the accelerometers in the interstitial space above the false ceiling if present. This keeps the accelerometers out of the way of normal building activities and reduces the likelihood of damage. For example, the accelerometers planned to measure the motion of the 8th floor would actually be located on the underside, above the ceiling on the 7th floor.

6. Accelerometers are generally the most effective sensors in strong-motion monitoring, but other sensors (e.g., relative displacement sensors, strain gauges, etc.) may be also be useful in certain situations.

7. The central recorder should be located in a utility or electrical room with AC available on one of the lower floors of the building for convenience. Remote communication with the central recorder is essential to access data following a significant event. The communication link should be at least a phone line; a hardwired Ethernet port is the preferred form of communication.

8. Cabling from each accelerometer to the recorder should be dedicated continuous runs (i.e., no splices) to achieve robustness not possible via a building's internal network for example. A pathway will need to be established for the vertical run from the accelerometers on the upper floors to the recorder location. If there is more than one recorder, a dedicated cable is needed to interconnect them for common timing and triggering. Depending on local ordinances and fire codes, cabling may need to be plenum rated.

9. Maintenance and service of the instruments shall be provided by the owner of the building subject to the approval of the Building Official. Experienced private companies, or agencies like CSMIP (www.conservation.ca.gov/cgs/smip) or NSMP (www.earthquake.usgs.gov/monitoring/nsmp), should be contracted for monitoring and/or maintenance. Data produced by the instruments shall be made available to the Building Official upon request. A sign stating, "Maintain clear access to this instrument" shall be posted in a conspicuous location near each accelerometer and the recorder.

Documentation

Documentation of the accelerometer location and orientation is important since after an earthquake it may not be possible to access certain areas in a building until building officials have visited. With good documentation, analysis of the recorded data and assessment of the structural response can occur without accessing the building. The accelerometer locations should be clearly and accurately documented to facilitate interpretation of the data. A sensor layout diagram should be prepared similar to Figure 1, showing the accelerometer locations on plan and typical sections. Since strong shaking is infrequent, care must be taken that by the time an earthquake occurs, sensors have not been moved for construction and not returned to the original location and orientation. Digital photos should be taken to document the location and orientation of each accelerometer at installation and after any subsequent construction is completed. It is valuable to archive design plans, especially structural plans, to allow thorough analysis of the data and finite-element modeling of the building after earthquake motions have been recorded.

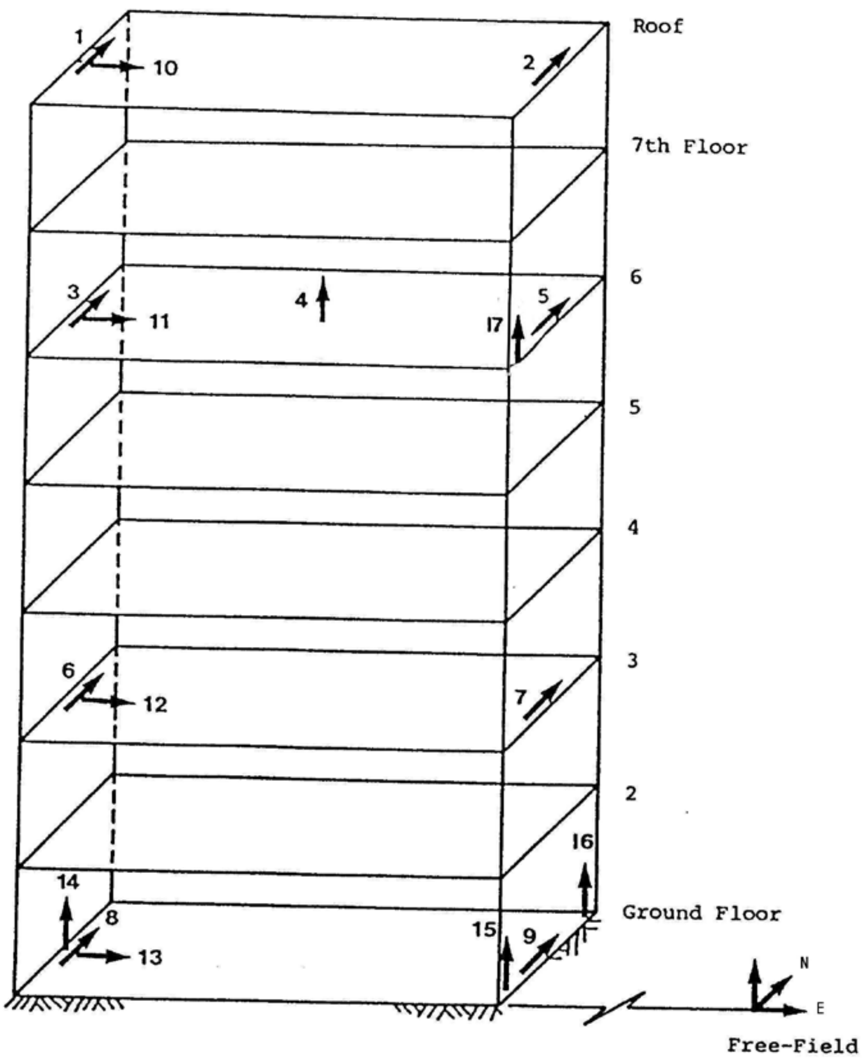

Figure 1. Example sensor layout. Torsional and NS translational motions are recorded by accelerometer pairs 1-2, 3-5, 6-7, and 8-9. EW translation motions are recorded by sensors 10-13. Base vertical input and rocking are recorded by accelerometers 14-16. For non-structural components on the 6th floor, vertical motion is recorded by sensor 4, with 17 near a column for reference.