ASHSC Alaska Seismic Hazards Safety Commission

POLICY RECOMMENDATION 2013-1

VALUE OF SEISMIC INSTRUMENTATION FOR CRITICAL FACILITIES
(ADOPTED 7 OCTOBER 2013: UNANIMOUS)

Government, public and private owners of important facilities should incorporate and maintain seismic instrumentation as part of their routine operating systems, especially in the moderate to high seismic and more densely populated areas of Alaska. The Commission believes there is near-term economic value and life-safety benefit to state and local governments, facility owners, and the public from maintaining on-site or in-structure seismic instrumentation.

BACKGROUND

Based on a recent study by the Federal Emergency Management Agency[1] (FEMA) Alaska was ranked second only to California in terms of the estimated annualized earthquake loss (AEL), or damage, versus the replacement value of the total infrastructure. Additionally, the risk along the rail belt, from Anchorage to Fairbanks, compares with the greater Los Angeles and San Francisco metropolitan areas in terms of AEL per capita.

Seismic instruments are sensitive devices that detect and record vibrations caused by passing energy waves traveling through the earth, in particular those generated by an earthquake. Of particular interest to engineers, building officials and the public are ground motions strong enough to potentially cause ground failure or structural damage. The Alaska Earthquake Information Center (AEIC)[2] collects and analyzes strong motions measured at over 80 instrumented sites spread across the state; including denser instrument networks in the Anchorage and Fairbanks areas. While most of these instruments are situated on the ground away from the influence of a building (aka free-field), a number are also located within structures (from the basement to rooftop), and buried in 'down-hole' arrays.

Earthquake scientists and civil engineers have long recognized the importance of ground motion data for monitoring seismic activity, evaluating seismic hazards, damage estimate studies (e.g. FEMA *HAZUS*) and certainly structural design. However, less well known are studies over the past few decades which have demonstrated that strong motion records measured using on-site or in-structure instrumentation can be a simple and cost effective means to:

- Improve the validity, quality, and detail of information available to emergency responders and the public pertaining to the possible extent, types, and severity of damage within the subject area immediately following a damaging earthquake;
- Enhance the means available for engineers involved with assessing the potential damage to a building or facility immediately after an earthquake, thereby possibly optimizing the need, scope, and cost for more intrusive structural inspections, and/or possibly limiting the time before which the facility can be put back into operation; and,

[1] FEMA. 2008. HAZUS MH Estimated Annualized Earthquake Losses for the United States. FEMA 366.

[2] http://www.aeic.alaska.edu/

- Improve the cost and efficiency of structures to resist earthquake forces, new as well as upgrades to existing, and thereby reducing risk to the public through continued improvements to the building codes, and design and construction standards, on both a national and local level.

In conclusion, the Commission believes these applications demonstrate there is economic value and life-safety benefit to state and local governments, facility owners, and the public from maintaining on-site or in-structure seismic instrumentation.

IMPLEMENTATION & ASSESSMENT

The Commission will prepare a report providing more complete background and discussion to support the policy recommendation. This report will be completed within three months of the policy's approval date. The report will then be forward to the Alaska departments responsible for major structures (e.g. DEED and DOT&PF), and city building departments and major facility operators (e.g. power and communication utilities, pipelines, petroleum and chemical manufacturing, etc.) located in moderate to high seismic areas of the state (e.g. Anchorage, Fairbanks, Juneau, Kodiak, Wasilla, etc.).

Measure of the acceptance of this policy recommendation will be tracked by the number of entities that respond to and act upon the report.

The Commission's Education, Outreach and Partnering committee will be responsible for the implementation and assessment of this policy recommendation.

POSITION PAPER (*APPROVED 21 APRIL 2014*)

VALUE OF SEISMIC INSTRUMENTATION IN CRITICAL FACILITIES

The Alaska Seismic Hazards Safety Commission (ASHSC)[1] is charged by statute AS 44.37.067 with recommending means to mitigate the state's vulnerability to earthquakes. In this capacity, the ASHSC unanimously approved Policy Recommendation 2013-1[2] which states:

> *GOVERNMENT, PUBLIC AND PRIVATE OWNERS OF IMPORTANT FACILITIES SHOULD INCORPORATE AND MAINTAIN SEISMIC INSTRUMENTATION AS PART OF THEIR ROUTINE OPERATING SYSTEMS, ESPECIALLY IN THE MODERATE TO HIGH SEISMIC AND MORE DENSELY POPULATED AREAS OF ALASKA.*

This *Position Paper* summarizes the immediate and near-term value of seismic instrumentation to entities responsible for the operation, maintenance and safety of important public facilities (e.g. schools, emergency response and evacuation buildings, critical bridges, airports, dams, ports, principal utilities, etc.), as well as critical private industries (e.g. pipelines, petroleum production and storage plants, etc.), as an effective means to increase safety and reduce the magnitude of physical damage and economic effects from a future strong earthquake in Alaska.

INTRODUCTION

A recent study by the Federal Emergency Management Agency [11] ranked Alaska second in the United States only to California in terms of the estimated damage versus the replacement value of the total infrastructure per year (AEL - annualized earthquake loss). Further, the risk along the rail belt, between Anchorage and Fairbanks, compared with that in the greater Los Angeles and San Francisco metropolitan areas in terms of AEL per capita. Utilization of seismic instrumentation can be a simple and cost effective means to mitigate the consequences from a damaging earthquake [4, 7, 9].

The U.S. Geologic Survey[3] (USGS) and Alaska Earthquake Center[4] monitor earthquakes in Alaska utilizing over 80 sites equipped with strong motion accelerometers spread across the state, including closely-spaced networks in the Anchorage and Fairbanks areas. Most of these instruments are situated on the ground away from the influence of a building (aka free-field); however in Anchorage, the USGS also monitors four major structural[5] and one subsurface instrument arrays (Figure 1).

Earthquake scientists, structural engineers and emergency response managers have long recognized the importance of free-field ground motion data to locate earthquakes, quantify seismic activity, and for evaluating seismic hazards and damage estimate studies [e.g. 11, 18]; and the structural motion records for improving the economics, efficiency and safety of

[1] http//:www.seismic.alaska.gov

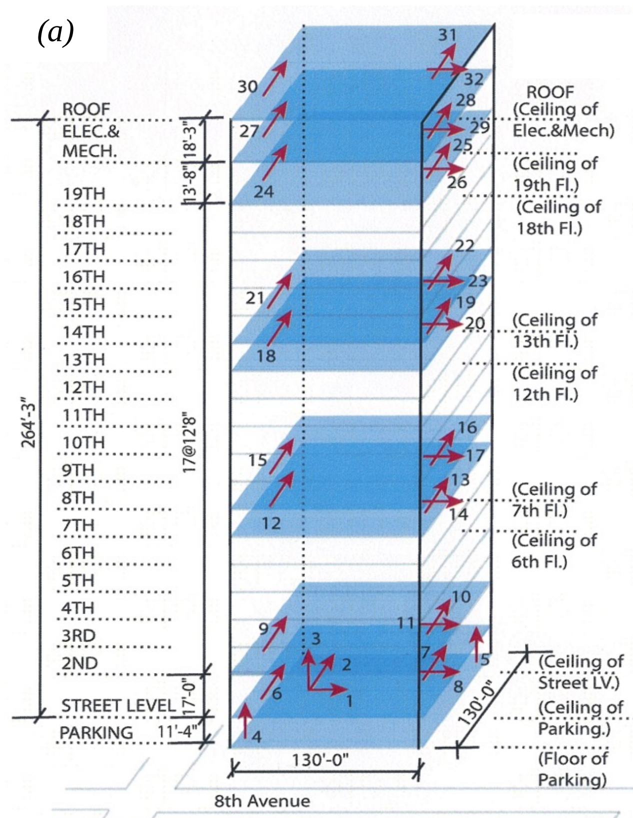
[2] Adopted 7 October 2013

[3] http://earthquake.usgs.gov/monitoring/anss/

[4] http://www.aeic.alaska.edu/

[5] Atwood Building, BP Building, Frontier Building, Port Access (*'C' Street*) Bridge

structures to resist earthquake forces through improvements of building materials, analysis procedures, and design codes on both a national and local level [e.g. 4, 9, 15].



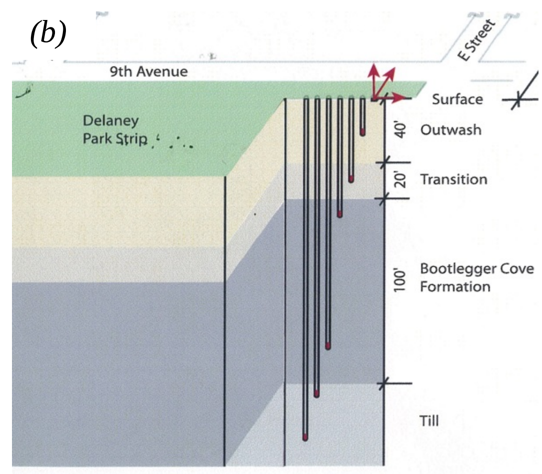


***FIGURE 1**: Schematic of (a) the Atwood Building structural array, and (b) the adjacent Delaney Park downhole array in Anchorage, Alaska [7].*

However, the value of seismic instrumentation to the owners and operators of important public buildings and critical infrastructure is less understood. This *Position Paper* summarizes the immediate and near-term value of structural seismic instrumentation[6] to entities responsible for the operation, maintenance and safety of important public facilities (e.g. schools, emergency response and evacuation buildings, critical bridges, airports, ports, key utilities, etc.) as well as critical industries (e.g. pipelines, petroleum production and storage plants, etc.) by:

- Improving the validity of engineering models to monitor the health of an existing structure, and too predict the response of that structure during a design-level earthquake, thereby optimizing the scope, schedule and economics of retrofits to increase its resiliency; and,

- Enhancing the means available for engineers to assess the potential damage to a building or facility immediately after a strong earthquake, thereby optimizing the need, scope, and cost for more intrusive structural inspections, and/or possibly limiting the time before which the facility can be returned to use.

[6] Information on planning, installation and maintenance of structural seismic instrument arrays can be found for buildings in [4, 7, 9], bridges in [3, 4, 15] and dams in [4, 10].

EVALUATION, MONITORING & RETROFITTING EXISTING STRUCTURES

The confidence in engineered evaluations of existing structures to resist design earthquake loading, and/or the design of economic modifications to existing structures to mitigate potential damage during a strong earthquake can both be improved when the structure is instrumented.

The seismic provisions in the national design codes have changed significantly over the past few decades, and will continue to change into the future, specifically to improve the safety, resilience, and economics of structures to resist forces induced during an earthquake. Many of these changes were based in large part on the actual response and performance of instrumented structures that had been subjected to significant earthquakes [4, 7, 9].

Prudent owners of public and critical facilities understand the cost and safety benefits of considering how changes made in the design building codes and standards may affect their existing structures. Present standards and engineering methods for evaluating and retrofitting existing structures to enhance structural resiliency and mitigate damage during a strong earthquake [e.g. 2] require several key physical properties of the structure, such as the periods of its fundamental modes of vibration, its displacement behavior under lateral loading (P-Δ effects), and the interaction between the structure foundation and the underlying load-resisting soils.

Numerous references have documented how actual accelerometer records measured in a structure during minor earthquakes can be used to determine the above key physical properties for buildings [e.g. 6, 8, 9] and bridges [e.g. 3, 15, 19]. Therefore, the validity of and confidence in the evaluations and/or retrofit design of an existing building or bridge to resist earthquake damage would be increased where these important physical properties can be defined or better qualified based on actual accelerometer data recorded in that structure, as opposed to estimating those properties using empirical or theoretical means.

Additionally, automated systems are being developed for important buildings using seismic instrumentation to facilitate real-time assessment of the health of the structure, and to qualify damage immediately following a strong earthquake [e.g. 7, 8, 16, 17].

POST-EARTHQUAKE ENGINEERING EVALUATIONS

Following a significant earthquake, the occupancy or operation of local structures could be interrupted until such time as the structure is screened to assess apparent or potential damage [e.g. 5]. Such rapid screening procedures are generally limited to visual observations, with obvious limitations [8]. Subject to the size and proximity of the earthquake, buildings may remain unoccupied for some time, further delaying important businesses and facilities from resuming operations; especially if there are signs of damage which require more detailed and intrusive investigations [8, 17]. However, since the late 1990s, numerous engineering methods have been devised to utilize actual accelerometer records as part of post-earthquake inspections to better assess and qualify the potential level of damage sustained in a structure (including buildings, bridges, docks, dams, etc.), explicitly to support and enhance confidence in decisions regarding either the safety and functionality of a structure for resumed use, or if that structure should receive more in-depth investigation [4, 8, 17].

While the methods to utilize strong motion records are not simple or absolute, they can (i) often be completed within days or weeks of the earthquake by engineers well experienced with geotechnical and structural seismic analysis; and (ii) improve the ability of engineers to more rapidly qualify the likelihood that the earthquake over-loaded or otherwise damaged the structure [4]. These attributes could in turn be used to optimize the scope and cost of more invasive and in-depth inspections, and thereby possibly reduce the time before the facility is put back into operation [e.g. 8, 17]. The following summarizes the general categories of methods to utilize ground motion records as part of post-earthquake damage inspections.

Geotechnical Stability Assessments - Visual inspection of ground motion records can qualify the peak acceleration and duration of strong shaking actually experienced at the site during an earthquake [e.g. 14]. These two parameters are very important to geotechnical engineers for estimating the potential magnitude of dynamic earth pressure and inertia loads on retaining walls (including basement walls), waterfront bulkheads, and in slopes during a post-earthquake damage assessment [e.g. 14]. Additionally, visual inspection of a strong motion record can also sometimes provide a quick indication of liquefaction (Figure 2) or significant softening in deeper soils, even when there may not otherwise be obvious evidence of such phenomena visible at the ground surface [e.g. 12, 13]. This is particularly important considering the effects of liquefaction on amplifying lower frequency (longer period) ground motions [1, 20]. The confidence in conclusions drawn from these uses would be directly related to the number and proximity of seismic instrumentation to the subject location.

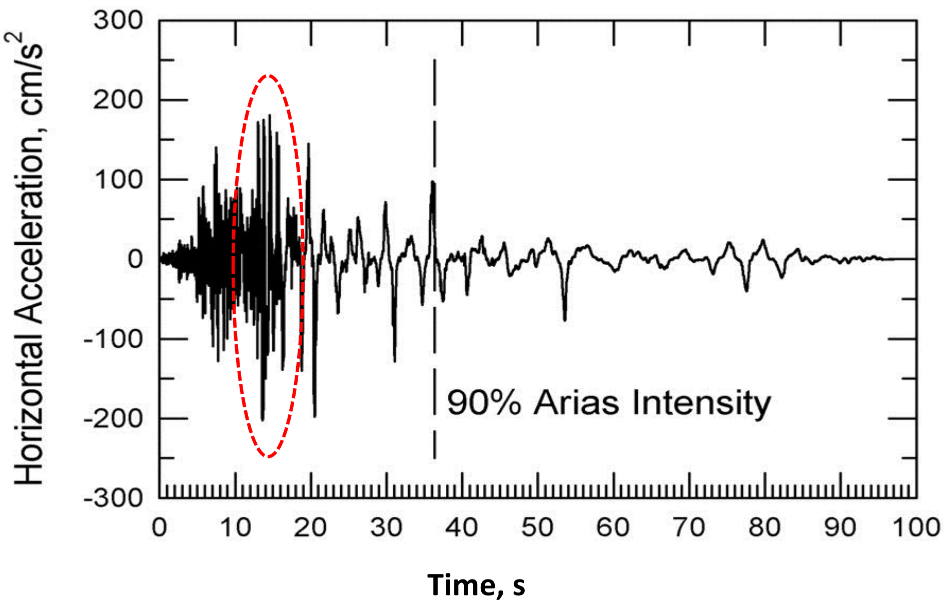


FIGURE 2*: N-S component of the surface instrument time history recorded at the Wildlife Liquefaction Array site, Imperial Valley, California, where liquefaction was documented, during the 1987 Superstition Hills M_W6.6 earthquake [12]. The change in wave amplitude and frequency after about 13-14 seconds of shaking was interpreted to represent the onset of liquefaction effects in the underlying soils [20].*

Structural Damage Assessments – There are numerous methods which utilize the acceleration response spectrum (ARS) developed from an actual wave-form record to estimate the lateral earthquake load (e.g. equivalent total base shear) on the structure, and then compare that with the lateral earthquake load assumed during design (or inferred using the building code effective at the time of construction when the design values are unknown) [4]. The complexity and accuracy of these methods range from using an ARS determined from the spectral coefficients predicted on the *ShakeMap*[7] or from a nearby free-field instrument (limited analysis time but high uncertainty), to using ARS generated from motions recorded on multiple floors of the subject building (longer analysis time with moderate uncertainty) [4].

Another category of methods utilize computer analysis of the actual ARS to identify shifts in the period of the structure's fundamental modes of vibration, or changes in the displacement time-history (e.g. drift between floors and at the roof), either of which could be indicative of non-linear or plastic deformation in the structural frame.

CONCLUSIONS

The above discussions demonstrate the potential immediate and near-term benefits of seismic instrumentation to state and local government jurisdictions, facility owners, and the public by:

- Improving understanding of the health of an existing structure, and the efficiency, scheduling and cost of retrofitting existing structures to better resist earthquake forces, thereby reducing risk to the public; and,
- Enhancing the means available for engineers assessing the potential damage to a building or facility immediately after a strong earthquake, thereby possibly optimizing the need, scope, and cost for more intrusive structural inspections, and/or possibly limiting the time before which the facility can be put back into operation.

Further, the cost of constructing earthquake-resistant structures (new as well as upgrades to existing), and the risk to the populace will continue to decrease through further improvements to the national building codes, design methods and construction standards based on the collective information documented from continued and expanded use of seismic instruments.

In conclusion, the ASHSC believes (i) the economic and safety risks from a strong earthquake to important public buildings and critical facilities in Alaska can be mitigated by incorporating seismic instruments into those structures; and (ii) these net benefits would likely far exceed the cost to installing and maintaining those instruments. Therefore, the ASHSC recommends that Government, public and private owners of important facilities, new and existing, consider incorporating and maintaining seismic instrumentation as part of their routine operating systems, especially in the moderate to high seismic and more densely populated areas of Alaska.

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[2] American Society of Civil Engineers (ASCE). 2014. Seismic Evaluation and Retrofit of Existing Buildings. *ASCE/SEI 41-13[updated and replaced ASCE/SEI 41-06 and ASCE/SEI 31-03]*.

[7] A computer generated map illustrating the potential intensity of shaking and damage experienced during an earthquake; based on actual strong motion records from regional free-field instruments, along with information on the local geologic conditions [19]. *ShakeMaps* are often available to emergency responders and the public within minutes of a significant earthquake. In Alaska *ShakeMaps* are generated by the Alaska Earthquake Center.

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