HCAI WHITE PAPER ON INSTRUMENTATION

Section III Draft

III. UTILITY OF HOSPITAL INSTRUMENTATION

Seismic instrumentation is vital to safety evaluation of hospitals and their contents following earthquakes. Fortunately, as described in previous sections, there are many hospitals which are currently instrumented in California. Adaptation of some rather simple hardware-software-Internet technologies can make the instrument data recorded during earthquakes almost immediately available for safety assessment of hospital buildings and their contents.

Over the period of past three decades, seismic instrumentation and evaluation of the responses of instrumented buildings has resulted in significant changes and updates in seismic design codes and practice. These include but are not limited to the following code changes and improvements:

- Design ground motions and lateral force procedures (Fenves 1990; Uang and Maarouf, 1992; Czarnecki et al 1994; De la LLera and Chopra 1995; Chopra et al 1998; Bozorgnia et al 1999; Goel 2003; Zimmerman, R. et al 2014; Hernandez-Bassal and Kunnath 2020, 2021).
- Site response provisions (Crouse and McGuire, 1994; Silva and Toro 1996; Stewart and Liu 2000).
- Seismic design and expected performance of reinforced concrete structures ((Moehle 1989; Filippou 1989; Bleiman et al 1994; Naeim 1996; Naeim et al 1998).
- Seismic design and expected performance of steel structures (Astaneh et al 1990; Malley 1995; Naeim 1996; Kariotis 1996; Naeim et al 1999).
- Soil-foundation-structure interaction effects (Fenves 1989; Poland et al 1993; Stewart 1999; Naeim et al 2008; Ghahari et al 2015).
- Accidental torsion provisions (De la LLera and Chopra 1991, 1992; Xiang et al 2017, 2018)
- Estimates of building natural periods and damping ratios (Harris et al 2015; Xiang et al 2016).
- Design and performance of nonstructural components and systems (Rihal 1991; Fathali and Lizundia 2012; Wang and Hutchinson 2019).

The utilization of seismic instrumentation for checking structural damage to hospital buildings after an earthquake or its aftershocks have been demonstrated now for a period of more than 20 years (Rojhan et al 2002, 2003; Naeim et al 2004, 2005; Bernal and Hernandez 2005; Miranda et al 2006; Dionisio and Nasseri 2009; Tokas and Lobo 2012; Muin and Mosalam 2018; Loh and Loh 2019; Martuscelli and Moehle 2019; Farrar 2020; Gao and Mosalam 2021).

The importance and value of instrumentation for identifying the nonstructural hazards from stationary and movable equipment inside and outside of the hospital buildings have been demonstrated among others by Naeim et al 2005; Wang and Hutchinson 2019; Martuscelli and Moehle 2019; Gao and Mosalam 2021.

The following simple example of such utility (Naeim et al 2021) illustrates the need for wide distribution and enhancement of seismic instrumentation of California hospital buildings and integrating instrumentation into seismic health monitoring systems for California hospitals. At the time of the 1994 Northridge earthquake, the Sylmar County Hospital (Figure 1) was one of the California hospitals instrumented by California Strong Motion Instrumentation Program (CSMIP) for HCAi. This building was specifically designed using a new structural system to resist major earthquakes without significant structural damage and this objective was achieved during the Northridge earthquake. The performance of nonstructural components and contents though was quite different during the Northridge and resulted in closure of this hospital for an extended period of time (Figure 2).

Figure 1. An outside view of Sylmar County Hospital Building the day after the 1994 Northridge earthquake

Figure 2. Examples of nonstructural damage at Sylmar County Hospital in the 1994 Northridge earthquake (Naeim 1997)

If the instrumentation of the building was connected to simple application on a computer, then, or to a cell phone or tablet app now that could process the sensor data and pass them through some very basic fragility functions such as those embedded in HAZUS-MH (FEMA 2020) or FEMA P-58 documents (FEMA 2018), then accurate image of the status of the building would have been immediately available as shown in Figures 3 to 6.

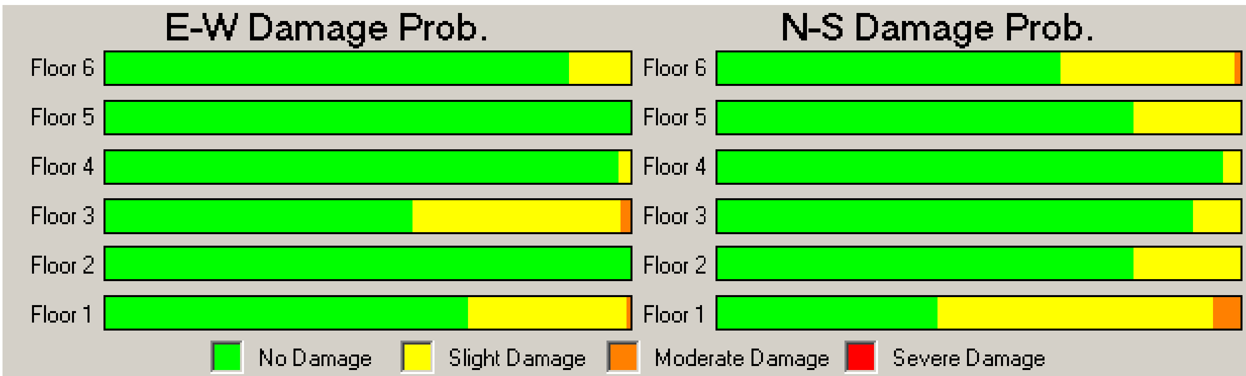

Figure 3. Instrumentation indicates no damage to slight damage status of the Sylmar County Hospital structural system following the 1994 Northridge earthquake using relevant HAZUS-MH fragility function.

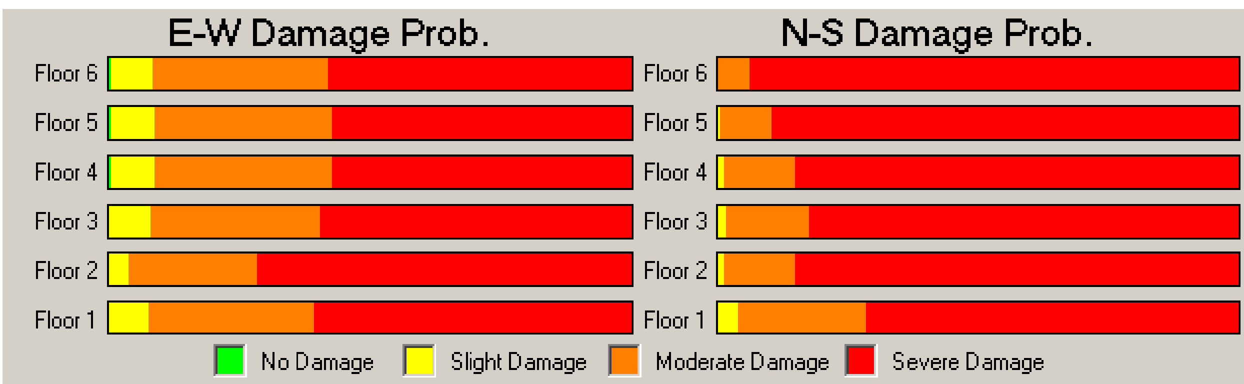

Figure 4. Instrumentation indicates moderate to severe damage status for the nonstructural systems of the Sylmar County Hospital following the 1994 Northridge earthquake using relevant HAZUS-MH fragility function.

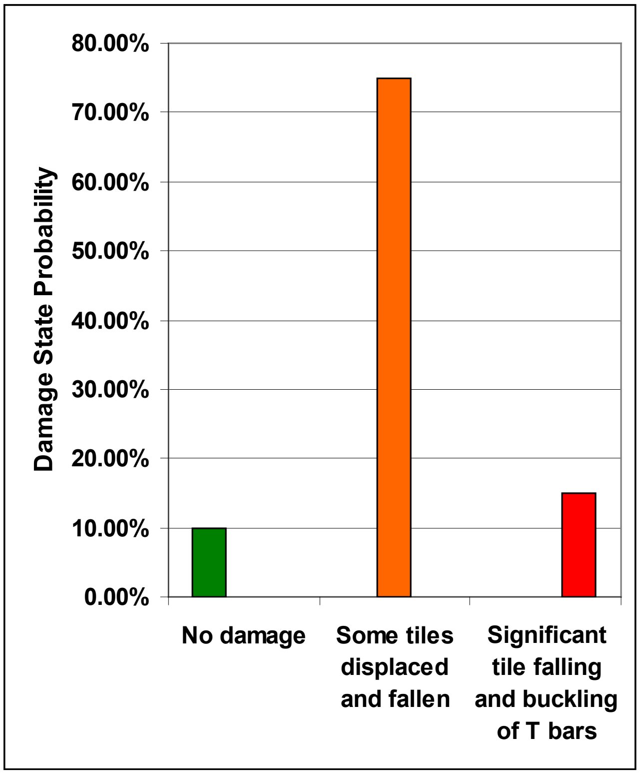

Photo from Naeim 1997

Figure 5. Instrumentation indicates displaced suspended ceiling tiles on the first floor of the Sylmar County Hospital following the 1994 Northridge earthquake using relevant FEMA-P58 fragility function.

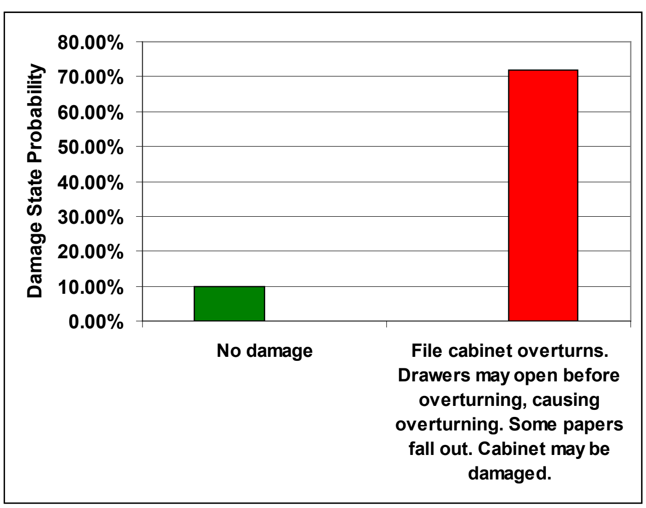

Photo from Naeim 1997

Figure 6. Instrumentation indicates overturning of file cabinets on the 6th floor of the Sylmar County Hospital following the 1994 Northridge earthquake using relevant FEMA-P58 fragility function.

Applications of newer approaches and technologies (Ebrahimian 2016; Fayaz and Galasso 2022) have the potential of providing even more accurate, timely and useful information regarding the status of the hospital buildings and their contents. In particular, for the hospital buildings that are base-isolated and/or supplemented with energy dissipation devices, the instrumentation would give direct measurement of the isolator deformation and provide information on the effectiveness of energy dissipation devices. The timely estimation of the structural and nonstructural performance from the instrumentation data would facilitate post-earthquake response in a hospital building.

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