3D LASER SCANNING TECHNOLOGY

Key in Preserving Historic Structures After South Napa Earthquake

Figure 1: 3D point cloud overlaying the 3D BIM model.

Objectives

- Present alternative preservation strategies for post-disaster public safety recovery and reconstruction methods.
- Educate city officials and disaster service workers with the Office of Emergency Services about the value of using 3D laser scanning technology to set priorities for shoring up and stabilizing buildings that present "imminent hazards."
- Serve as a model for other communities in demonstrating the effectiveness of immediate response to a seismic disaster using 3D laser scanning technology.

BY SHARI KAMIMORI

Background

Many San Francisco Bay Area residents were rudely awakened at 3.20 a.m. on August 24, 2014, by an earthquake in south Napa, Calif.—one with a magnitude of 6.0, according to the U.S. Geological Survey. It was the largest earthquake to strike the Bay Area since 1989, when the region was shaken by the unforgettable and destructive 6.9 Loma Prieta earthquake.

The epicenter was located about five miles southwest of Napa (a city of about 77,000 people) reported the Pacific Earthquake Engineering Research Center,[1] University of California at Berkeley. Although Napa received the brunt of the tremor, other nearby cities including American Canyon, Vallejo and Sonoma felt the impact. Located on the northern shores of San Francisco Bay, the Napa region is internationally known for its burgeoning wine and tourist industries.

The south Napa earthquake caused significant ground-shaking damage in the epicentral region, initially yellow tagging (restricted use) approximately 1,700 buildings in the City of Napa alone, while 200 received red tags (unsafe to enter or occupy). Of these

1,900 tagged buildings, around 700 of these are "historic," according to Sally Evans, cultural resource consultant for Napa County Landmarks.

In Wayne Donaldson's published document, *The First Ten Days: Emergency Response and Protection Strategies for the Preservation of Historic Structures*,[2] he states, "The majority of all decisions for the disposition of earthquake-damaged, historic structures are made within the first 10 days of a declared national emergency."

The typical process for evaluating buildings after an earthquake is highly subjective. In California, building safety inspectors rely on industry standard protocols for determining if a building is safe, unsafe or may have limited use after a seismic event. Human error and time are the two factors that could result in inaccurate field evaluations. For instance, after the Napa earthquake, many green-tagged buildings—presumed to be safe and fully operational—were reclassified as red-tagged 48 hours later.

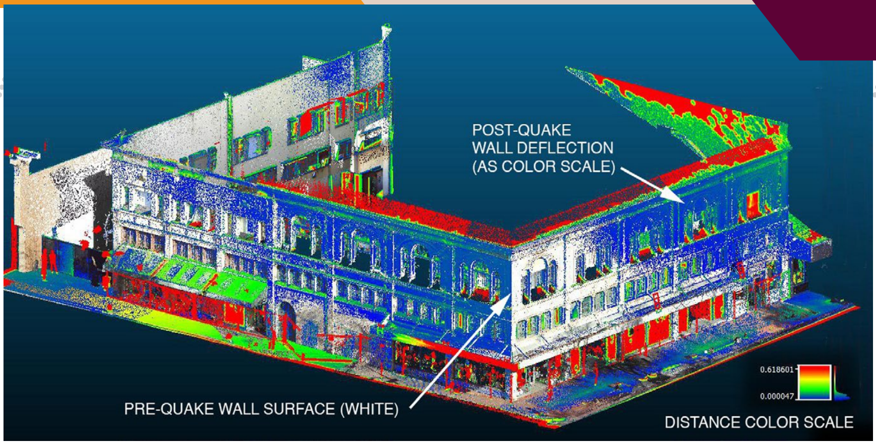

Figure 2: Post-quake south and west wall surfaces.

Program Description:

The Gordon Building, which is on the National Register as an historic site, is located in Napa's downtown historic district. On January 15, 2014, the 20,000 square-foot building interior and exterior were surveyed using a high-definition, 3D laser scanner. The deliverables included a building information model (BIM) and 2D CAD as-built documentation created from the scan data (see **Figure 1**) for the rehabilitation and restoration project.

After the earthquake, our team returned to the site to re-scan the Gordon Building on September 3, 2014, with the intention of comparing and analyzing the scan data pre- and post-quake. The resulting evaluation would be used to assess failure of the structure and to what extent the damage posed a safety hazard.

Using 3D laser scanning technology, our team was able to safely survey three sides of the red-tagged building in a half-day and evaluate the scan data 24 hours later. Since the scanning process is unobtrusive, we did not disturb the fragility of the historic structure nor compromise the safety of the assessment team

Figure 3: Post-quake west wall showing pre- (yellow) and post-quake (orange) cracking.

members while inspecting the potentially dangerous and faulty structure. Within 48 hours, we could compare the pre-quake and post-quake point clouds and identify which areas of the building and to what extent they had suffered new damage or had further deteriorated.

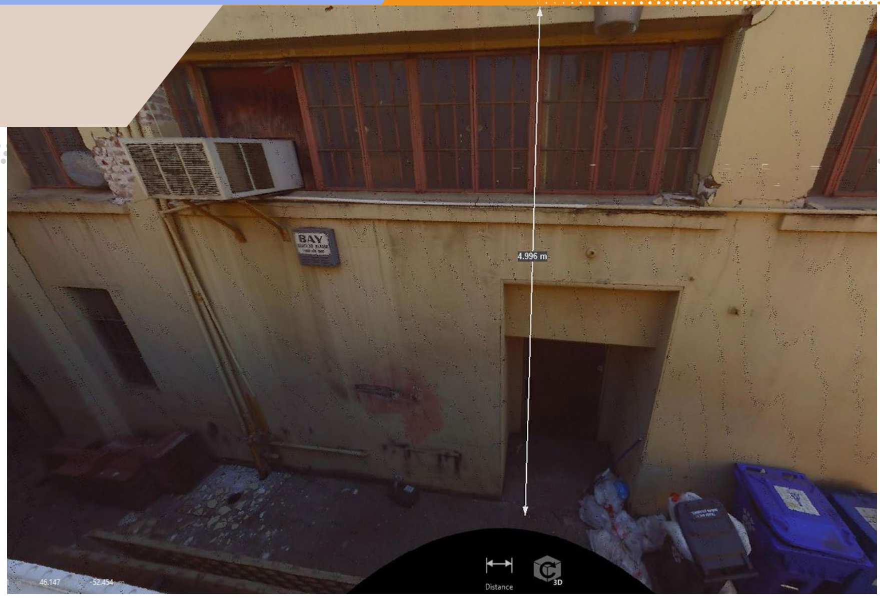

Figure 4: North wall ground to underside Level 2 = 4.99m.

3D Laser Scanning Results:

The pre- and post-quake 3D building scans were aligned with the point cloud analysis software *Cloud Compare.* A nine-level, octree algorithm assessed the distance between the pre- and post-quake scans and revealed the following:

- The distances are color-coded from blue to green to red to show the increasing distance between the two point clouds, also known as a scalar field analysis.
- The scalar field image shows how the walls are aligned at the lower corners, but then move gradually out of alignment from the lower street level to the diagonal upper cornice corner, as observed at the south and west wall surfaces. This indicated the building's torsional rotation clockwise around the Z-axis (see **Figure 2**). Note: The red areas are where the pre-quake scan, point cloud data were not captured when compared to the post-quake scan, and is not indicative of displacement between the two point clouds.
- Building cracks pre- and post-quake are observed and can be measured (see **Figure 3**).
- The long horizontal cracks are measured and compared to the 3D model/2D drawings. The observation concludes that the cracking occurred below the floor/roof levels, which the dimensioning confirms (see **Figures 4** & **5**).

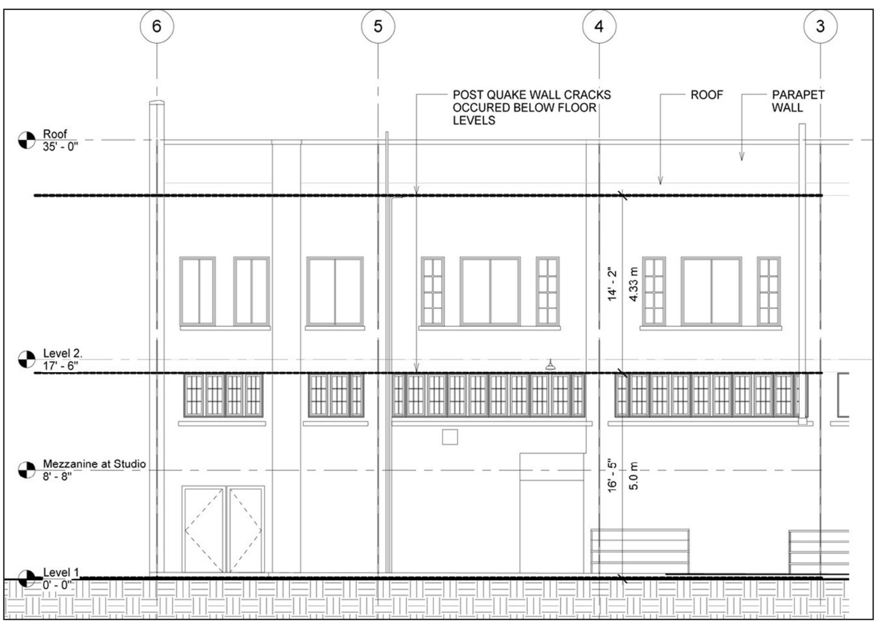

Figure 5: North wall 2D drawing with dimensions showing below floor/roof cracking.

Observations:

- The pre-quake scans were not taken initially with the intention of being used for comparison purposes and therefore, some false information is detected.
- The scan shadowing, noise and stray points show up as a deviation between the two scans (yellow and red). These are not indicative of deviations, but highlight where the post-quake point cloud has data points that are missing from the pre-quake point cloud.
- A suggestion for future cloud-to-cloud comparisons would be to use the same (or as close as possible) scanner locations for pre- and post-scanning.
- Some of the major cracks on the north wall (rear) existed prior to

the earthquake. It appears that the earthquake expanded some previously known weak areas and created new ones.

Lessons Learned:

- Using 3D laser scanners as a tool for building evaluation after an earthquake can optimize the ability to measure (e.g. out of planar walls, cracking, etc.) and provide a detailed assessment of the damaged building structures quickly, safely and with precise accuracy.
- Improved emergency response and protection strategies for the preservation of historic buildings continue to be imperative.
- A team of qualified assessment professionals, consisting of a preservationist, structural engineer, preservation architect and 3D laser scanning specialist with knowledge of historic preservation, should be readily available for emergency response following a seismic event. The team should collaborate with city and county officials, historic resource teams and registered disaster service workers.

References

[1] Grace S. Kang, Stephen A. Mahin. "PEER Preliminary Notes and Observations on the August 24, 2014, South Napa Earthquake." Introduction pp. 4 (September 17, 2014).

[2] Milford Wayne Donaldson, FAIA, Architect, Milford Wayne Donaldson and Associates. "The First Ten Days: Emergency Response and Protection Strategies for the Preservation of Historic Structures." Management of Natural Disaster Mitigation and Response Programs for Historic Sites: A Dialogue (Symposium June 27–29, 1995).

Acknowledgement

Thank you to the team who helped with the collection of data: Scott Page Design and Locus Construction Services

Shari Kamimori is President of 3D Virtual Design Technology, Inc. (www.3dvdt.com), located in the San Francisco Bay Area, servicing the AEC industries with as-built surveys using Scan to BIM technology. Shari is also an active committee member of Napa County Landmarks, Napa Calif.