13th National Conference on
EARTHQUAKE ENGINEERING
PORTLAND, OREGON | JULY 13-17, 2026

Resilience Through Community Engagement and Technology

Application of 360 Degree Imaging and Construction Progress Documentation Platforms in Large-scale Experiments: a CFS10 Case Study

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ABSTRACT

Large-scale experiments require documentation of construction processes and damage throughout test protocols. Traditional photographic records, while useful, face challenges of organization and accessibility, and ease of use. To address these issues, the landmark testing of a 10-story cold-formed steel building, coined CFS10, conducted at the NHERI@UC San Diego shake table explored an integrated solution using 360° imaging and a construction progress documentation platform. Low-cost 360° cameras were used to scan the building at key construction and testing stages. Captured images were automatically mapped to building floor plans and made accessible through a web-based platform. This approach enabled comprehensive visual coverage with minimal time investment: ~10,000 ft^2 (930 m^2) scanned in 3 hours. A Google Street View-like interface provided intuitive navigation and retrieval of time-stamped, spatially mapped photographs. The method supported coordination with remote partners, and accurate visual damage documentation. However, issues such as photo resolution and stitching quality as well as barrier to entry stemming from a lack of opensource tools pose challenges for long-term dissemination through public repositories and for enabling broad data reusability. Lessons from this study highlight the benefits of such solutions to preserve perishable information. Broader adoption could significantly improve documentation standards for large-scale test programs.

Introduction

Imaging using 360° cameras has seen broad adoption across disciplines as the technology becomes more affordable and immersive. Photogrammetric applications include post-hazard reconnaissance data collection [1-2], cultural heritage preservation [3], crime scene documentation [4], real-estate marketing and others. The construction domain also presents rich opportunities for specialized applications [5-6]. Various commercial platforms enable construction progress monitoring with the intent of improving accuracy, reducing site visits and saving resources. Comparable continuous visual documentation is essential in experimental programs to track construction, assess damage, and support post-test analyses. 360° cameras have, e.g., previously been innovatively applied in fire testing [7]. This case study explores an integrated solution employing 360° imaging

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Singh A, Speicher MS, Cyizere Rukundo F, Hutchinson TC and Schafer BW. Application of 360 Degree Imaging and Construction Progress Documentation Platforms in Large-scale Experiments: a CFS10 Case Study. *Proceedings of the 13th National Conference in Earthquake Engineering*, Earthquake Engineering Research Institute, Portland, OR. 2026.

with a construction progress documentation platform within the CFS10 experimental program, which involved testing a full-scale, 10-story cold-formed steel building [8-10] at the Natural Hazards Engineering Research Infrastructure shake table at University of California San Diego (NHERI@UC San Diego) [11].

Application to CFS10 Experimental Program

Traditional photographic records, while immensely useful and readily available, often suffer from challenges of organization and accessibility, which limits their usefulness for collaborative analyses, especially for remote collaborators. Within the CFS10 project, alongside digital cameras, low-cost commercially available 360° cameras (4K resolution per lens) were used, capturing 2 panospheric photos/sec. The CFS10 program involved specimen construction, instrumentation, and a multi-hazard testing phase of both earthquake and live fire experiments, with a total duration of approximately 11 months. The project employed shared Google Drive folders for file management and a dedicated Slack workspace *cfsnheri* for team communication. Fig. 1 shows both the digital photographs and 360° imaging schemes used for documentation. Once this workflow was established, scans were performed at key construction milestones and various damage states during the seismic and fire test protocols. Software platforms for construction progress documentation offer the ability to capture the state of a jobsite using 360° imagery and automatically mapping to the building floor plans, such as shown in Fig. 1b. The 360° cameras enabled comprehensive visual coverage with minimal time investment: scanning ~10,000 ft^2 (930 m^2) across all levels of the building in approximately 3 hours. The walk path of the user is tracked through the platform's phone application. The user interface enables an interactive virtual walkthrough after background processing, which was typically completed within an hour for the CFS10 building floor area.

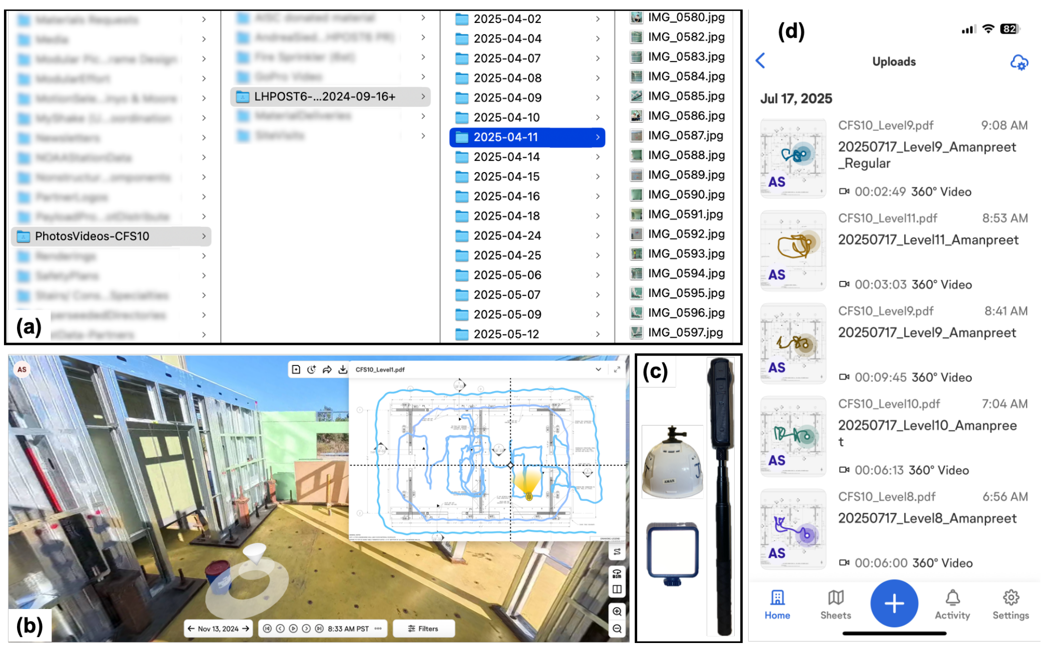

Figure 1. (a) Digital photograph organization on cloud storage and populated by collaborators, (b) reality capture accessible via a web-based platform, (c) camera and accessories used for 360° imaging, and (d) phone application interface for connecting to camera and uploading scans for processing.

Fig. 2 shows features in the web-based platforms for navigating across virtual walkthroughs. A split view allows users to view photographs from the same (approximate) physical spot captured at different times of the project. BIM (building information model) views can also be displayed side-by-side, providing a comparison of the as-built versus the building design model. Further, annotated photographs taken by other users/cameras can be added to augment the virtual walkthrough. Features such as these allow researchers and collaborators to remotely inspect construction details, coordinate with trade-partners, and validate and document visual damage. Fig. 3a shows how the 360° images and BIM viewer was used, e.g., to determine appropriate size and location of interior finish cut-outs for installation of a cable tray. Fig. 3b exemplifies an instance of researchers determining if observed damage was seismic test induced or pre-test fabrication or construction defects.

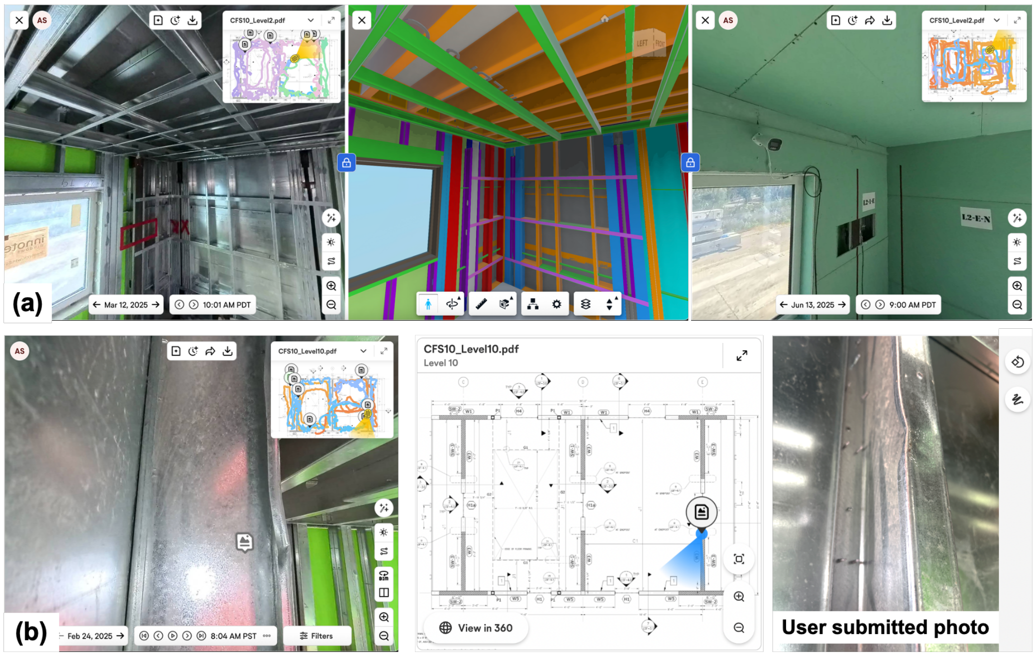

Figure 2. Examples of (a) BIM viewer and split view, and (b) augmented field notes features of progress documentation platform. Note date/time stamps and spatial mapping to floor plan for each image.

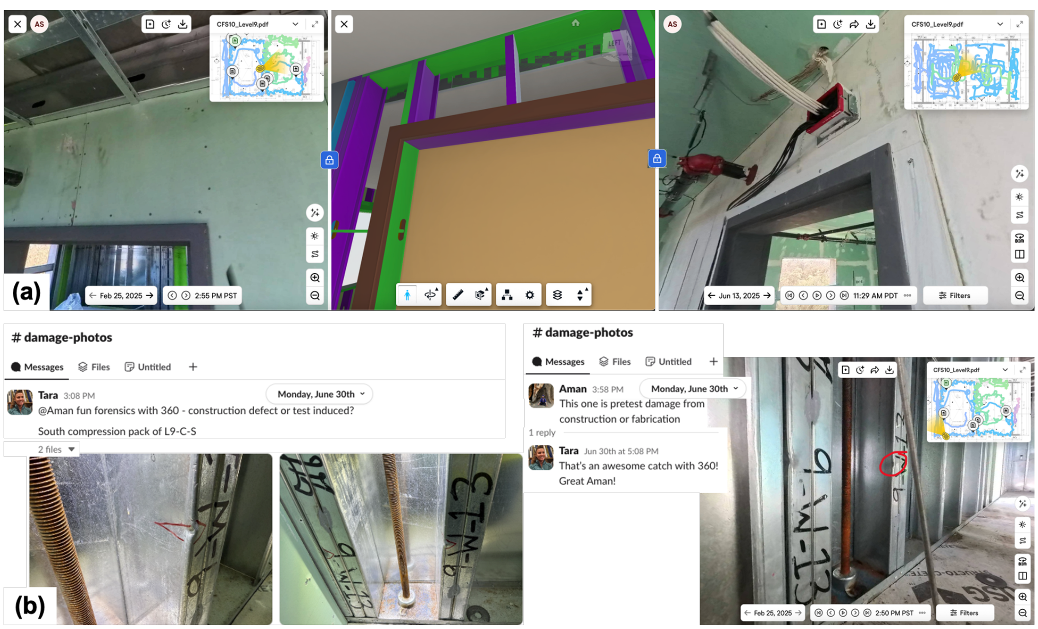

Figure 3. (a) Coordination with remote trade partners for cable tray installation, and (b) validation and documentation of damage (snippets from *cfsnheri* workspace *#damage-photos* channel on *Slack*).

Benefits and Data Reuse

The automated workflow from a 360° scan to a virtual walkthrough on a web-based platform provides several benefits. The speed of scanning enables collecting a large amount of information in a relatively short amount of time. The comprehensive nature of scans captures information which may be missed due to time constraints and identified at a later stage. Information can also be shared with various stakeholders, either in real-time or in the future. The resulting large dataset also creates new possibilities for understanding the performance of the tested building. The structural and nonstructural aspects of the building can be visually tracked over the entire construction and testing series. Potential applications may include virtual insurance loss adjustment, see Fig. 4, or machine learning model-based damage detection. Surveys related to building function could also be pursued, testing out hypothetical building tagging and occupancy decisions that play out during the aftermath of real earthquake events. Such walkthroughs can also serve as immersive educational tools in architecture, engineering, and construction training. Advances in camera technology and artificial intelligence-based image enhancement should address current limitations of inadequate photo resolution and stitching quality for tasks which require greater detail. The use of enterprise-level products and a lack of opensource tools also raises challenges for long-term storage and dissemination such that basic interactive functionality can be maintained.

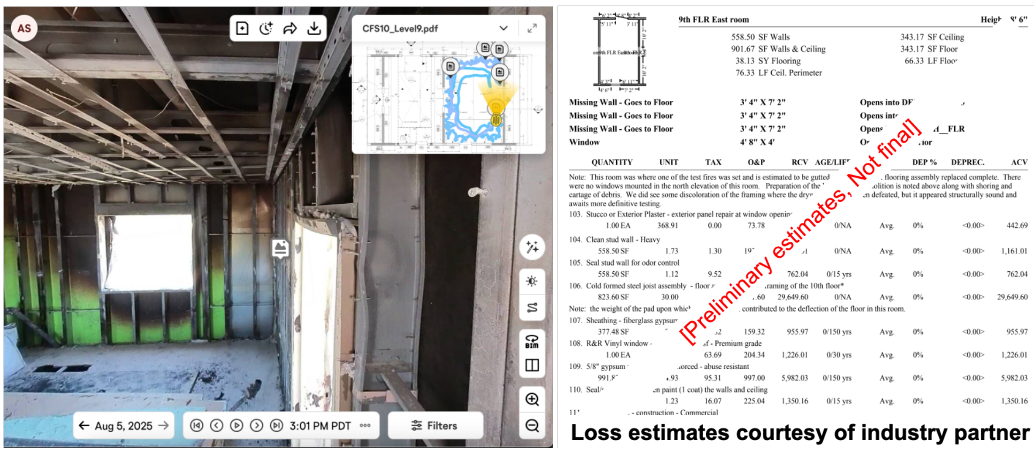

Figure 4. Potential data reuse example of virtual insurance loss adjustment.

Conclusions

This case study summarizes an application of 360° imaging and a construction documentation platform, which enabled a comprehensive, collaborative and streamlined method for visual documentation in large-scale testing. The details provided by the 360° imaging enabled understanding the damage progression over a series of seismic and fires tests, promoting better understanding of structural and nonstructural building performance. Lessons learned from this case study underscored the benefits of these novel technology and software solutions. While the cameras itself are low cost, procuring a license of a documentation platform might be cost-prohibitive or nonessential for smaller-scale or shorter test programs conducted over a few weeks span. Opportunities for future use will further promote the benefits of collecting such data during large scale experiments. Broader adoption of such methods may stimulate development of opensource solutions for storing and sharing images which are typically generated in proprietary file formats.

Acknowledgments and Disclaimer

The CFS10 project is a collaborative research project, with support through the National Science Foundation (NSF) grants CMMI 1663569 and CMMI 1663348, project entitled: Collaborative Research: Seismic Resiliency of Repetitively Framed Mid-Rise Cold-Formed Steel Buildings and numerous other federal/state and industry partners. A complete list of all sponsors/partners to the CFS10 program may be found at: cfs10.ucsd.edu/sponsors-partners. The efforts of all undergraduate and graduate students, visiting scholars (cfs10.ucsd.edu/people) and LHPOST6 staff (nheri.ucsd.edu/about/personnel) are greatly appreciated. The authors gratefully acknowledge OpenSpace for providing access to their platform, which enhanced this work. Certain commercial or proprietary products may have been used in this study and discussed in the paper. This is not intended to imply recommendation or endorsement by National Institute of Standards and Technology, nor is it intended to imply that such product is necessarily the best available for the purpose. Findings, opinions, and conclusions are those of the authors and do not necessarily reflect those of the sponsoring organizations.

References

1. Martell M, Terry N, Sengupta R, Salazar C, Errett NA, Miles SB, Wartman J, Choe Y. Open-source data pipeline for street-view images: A case study on community mobility during COVID-19 pandemic. *PLoS ONE* 2024; 19(5): e0303180. DOI: 10.1371/journal.pone.0303180.
2. Roueche DB, Nakayama JO, Cetiner BM, Sabarethinam K, Kijewski-Correa T. Hybrid framework for post-hazard building performance assessments with application to hurricanes. In *Proceedings of the 14th Americas Conference on Wind Engineering* 2022.
3. Mah OB, Yan Y, Tan JS, Tan YX, Tay GQ, Chiam DJ, Wang YC, Dean K, Feng CC. Generating a virtual tour for the preservation of the (in)tangible cultural heritage of Tampines Chinese Temple in Singapore. *Journal of Cultural Heritage* 2019; 39:202-11. DOI: 10.1016/j.culher.2019.04.004.
4. Abate D, Toschi I, Sturdy-Colls C, Remondino F. A low-cost panoramic camera for the 3D documentation of contaminated crime scenes. In *International Society for Photogrammetry and Remote Sensing* 2017; 42: 1-8.
5. Shinde Y, Lee K, Kiper B, Simpson M, Hasanzadeh S. A systematic literature review on 360° panoramic applications in architecture, engineering, and construction (AEC) industry. *Journal of Information Technology in Construction* 2023; 28: 405-437.
6. Sacks R, Girolami M, Brilakis I. Building information modelling, artificial intelligence and construction tech. *Developments in the Built Environment* 2020; 4:100011. DOI: 10.1016/j.dibe.2020.100011.
7. Hoehler MS. On the development of a transparent enclosure for 360° video cameras to observe severe fires in situ. *Fire Safety Journal* 2021; 120:103024. DOI: 10.1016/j.firesaf.2020.103024.
8. Singh A, Hutchinson TC, Torabian S, Schafer BW, Peterman KD, Padgett L, Jones H. Structural design narrative of the CFS-NHERI 10-story test building for multi-dimensional shake table testing. *Cold-Formed Steel Research Consortium (CFSRC) Colloquium* 2022.
9. Singh A, Zhang J, Rivera D, Eladly M, Jones H, Kovac A, Padgett L, Rivera D, Smith K, Torabian S, Peterman KD, Schafer BW, Hutchinson TC. CFS-NHERI 10-story building shake table test specimen: design updates. In *Proceedings of the 18th World Conference on Earthquake Engineering* (WCEE2024) 2024.
10. Hutchinson TC, Eladly M, Ji R, Rivera D, Cyizere Rukundo F, Singh A, Sorosh S, Zhang J, Zhang X, Padgett L, Jones H, Karns J, Schafer BW. Advancing use of cold-formed steel framing systems for mid-rise residential construction in seismic zones via full-scale shake table testing. To appear in *Proceedings of the 8th Residential Building Design & Construction Conference* 2026.
11. McCartney JS, Van Den Einde L, Morrison M, Palermo A, Lotfizadeh K, Lai C-T, Conte JP. Multi-degree of freedom shake table testing of large-scale structural and geotechnical systems with NHERI-UCSD LHPOST6. *Frontiers in Built Environment* 2025; 11: 1573390. DOI: 10.3389/fbuil.2025.1573390.