PALU EARTHQUAKE AND TSUNAMI

September 28, 2018

Released: April 10, 2020
NHERI DesignSafe Project ID: PRJ-2129

DATA REPORT

Team Members: Back row (Left to Right): Jacob Stolle, Tomoyuki Takabatake, Takahito Mikami, Ryota Nakamura, Yuta Nishida. Front Row (Left to Right): Muhammad Fadel Hidayat Marzuki, Abdul Gafur Marzuki, Hendra Achiari, Tomoya Shibayama, Ian Robertson, Clemens Krautwald, Miguel Esteban.

Field Assessment Structural Team (FAST): Ian Robertson, University of Hawaii at Manoa

FAST Collaborators (self-funded, in alphabetical order)

Hendra Achiari, Bandung Institute of Technology (Indonesia)
Miguel Esteban, Waseda University (Japan)
Clemens Krautwald, Tech. Univ. of Braunschweig (Germany)
Takahito Mikami, Tokyo City University (Japan)
Ryota Nakamura, Toyohashi University of Technology (Japan)
Tomoya Shibayama, Waseda University (Japan)
Jacob Stolle, University of Ottawa (Canada)
Tomoyuki Takabatake, Waseda University (Japan)

Data Report Coordinator: Tracy Kijewski-Correa, University of Notre Dame

PREFACE

The National Science Foundation (NSF) awarded a 2-year EAGER grant (CMMI 1841667) to a consortium of universities to form the Structural Extreme Events Reconnaissance (StEER) Network (see https://www.steer.network for more details). *StEER builds societal resilience by generating new knowledge on the performance of the built environment through impactful post-disaster reconnaissance disseminated to affected communities.* StEER achieves this vision by: (1) deepening structural engineers' **capacity** for post-event reconnaissance by promoting community-driven standards, best practices, and training, as well as their understanding of the effect of natural hazards on society; (2) **coordination** leveraging its distributed network of members and partners for early, efficient and impactful responses to disasters; and (3) **collaboration** that broadly engages communities of research, practice and policy to accelerate learning from disasters. StEER works closely with other extreme event reconnaissance organizations and the Natural Hazards Engineering Research Infrastructure (NHERI) to foster greater potentials for truly impactful interdisciplinary reconnaissance after disasters.

Under the banner of NHERI's CONVERGE node, StEER works closely with the wider Extreme Events Reconnaissance consortium including the Geotechnical Extreme Events Reconnaissance (GEER) Association and the networks for Nearshore Extreme Event Reconnaissance (NEER), Interdisciplinary Science and Engineering Extreme Events Research (ISEEER) and Social Science Extreme Events Research (SSEER), as well as the NHERI RAPID equipment facility and NHERI DesignSafe CI, long-term home to all StEER data and reports. While the StEER network currently consists of the three primary nodes located at the University of Notre Dame (Coordinating Node), University of Florida (Atlantic/Gulf Regional Node), and University of California, Berkeley (Pacific Regional Node), StEER aspires to build a network of regional nodes worldwide to enable swift and high quality responses to major disasters globally.

StEER's founding organizational structure includes a governance layer comprised of core leadership with Associate Directors for each of the primary hazards as well as cross-cutting areas of Assessment Technologies and Data Standards, led by the following individuals:

- **Tracy Kijewski-Correa (PI),** University of Notre Dame, serves as StEER Director responsible for overseeing the design and operationalization of the network and representing StEER in the NHERI Converge Leadership Corps.
- **Khalid Mosalam (co-PI),** University of California, Berkeley, serves as StEER Associate Director for Seismic Hazards, leading StEER's Pacific Regional node and serving as primary liaison to the Earthquake Engineering community.
- **David O. Prevatt (co-PI),** University of Florida, serves as StEER Associate Director for Wind Hazards, leading StEER's Atlantic/Gulf Regional node and serving as primary liaison to the Wind Engineering community.
- **Ian Robertson (co-PI),** University of Hawai'i at Manoa, serves as StEER Associate Director for Coastal Hazards, serving as a primary liaison to the coastal engineering community and ensuring a robust capacity for multi-hazard assessments.
- **David Roueche (co-PI),** Auburn University, serves as StEER Associate Director for Data Standards, ensuring StEER processes deliver reliable and standardized reconnaissance data suitable for re-use by the community.

ACKNOWLEDGMENTS

This material is based upon work supported by the National Science Foundation under Grant No. CMMI 1841667. Any opinions, findings, and conclusions or recommendations expressed in this material are those of StEER and do not necessarily reflect the views of the National Science Foundation. All authors and editors listed on the cover page participate as volunteer professionals. Thus, any opinions, findings, conclusions or recommendations expressed herein are those of the individual contributors and do not necessarily reflect the views of their employer or other institutions and organizations with which they affiliate.

Special thanks also go to the organizers of this international reconnaissance effort: Professors Shibayama and Esteban of Waseda University, for extending the invitation for StEER participation. This effort would have not been possible without the leadership and careful planning demonstrated by these colleagues. The team is further grateful for the significant logistical and planning assistance from Hendra Achiari of Bandung Institute of Technology in Bandung, West Java, Indonesia and his student (Muhammad Marzuki) and brother (Abdul Marzuki, State Institute for Islamic Studies in Palu). Their familiarity with Palu and willingness to support the team's efforts at such a difficult time for their community was vital to the success of the effort.

StEER also appreciates the assistance of the Earthquake Engineering Research Institute (EERI) and its Virtual Earthquake Reconnaissance Team (VERT), facilitated by the early outreach of VERT subcommittee co-chair Erica Fischer, University of Washington, in assembling an event summary in advance of FAT-1's departure.

The sharing of videos, damage reports and briefings via Slack by the entire NHERI community was tremendously helpful and much appreciated. StEER further recognizes the efforts of the DesignSafe CI team who continuously supported and responded to StEER's emerging needs, particularly Tim Cockerill who helped team members get activated on Slack swiftly.

For a full listing of all StEER products (briefings, reports and datasets) please visit the StEER website: https://www.steer.network/products

ATTRIBUTION GUIDANCE

Citing Images, Data or Data Derivatives from this Dataset

The use of images from this published data set, and the use of these or any other data to conduct additional analyses or prepare various visualizations or data derivatives should use the full citation information and DOI from DesignSafe (these are available at https://www.steer.network/products).

TABLE OF CONTENTS

1.0 Event Summary and Team Configuration

A 7.5 magnitude earthquake and subsequent tsunami hit Palu and Donggala in Central Sulawesi, Indonesia on Friday, September 28, 2018, killing at least 2,245 people. A large number of persons were injured and missing following this event, with displaced populations in the tens of thousands in the three most affected areas: Donggala, Palu City, and Sigi. StEER's previously published reports offer additional information on the hazard characteristics and extent of impact respectively based on third-party reports and direct field observations:

Preliminary Virtual Reconnaissance Report (PVRR)	PRJ-2104	https://doi.org/10.17603/DS2XD5S
Early Access Reconnaissance Report (EARR)	PRJ-2128	https://doi.org/10.17603/DS2JD7T

Following a request from Indonesia, UNESCO's Intergovernmental Oceanographic Commission coordinated post-tsunami surveys by International Tsunami Survey Teams (ITSTs), in collaboration with Indonesian authorities led by the National Commission of Indonesia for IOC-UNESCO and The Coordinating Ministry for Maritime Affairs. All ITSTs were required to work closely with an Indonesian collaborator for the field survey and also to obtain appropriate research/survey permits and visas. This Field Assessment Structural Team (FAST), operating under this protocol, represented the first and only StEER team responding to this event. The FAST included one StEER member (Ian Robertson, StEER's Associate Director for Coastal Hazards) embedded within a larger self-supported ITST of international researchers, primarily from Japan, but also inclusive of Indonesian researchers.

This ITST collected data from October 27 to 31, 2018 along the entire coastline of Palu Bay. The primary objectives of the FAST in this mission were to:

1. Deepen the understanding around tsunamis generated by slip-strike faults (a particular concern for the west coast of the US);
2. Document the performance of structures during both the earthquake and tsunami, and particularly the sequential effects of both events;
3. Field validate some of the tsunami loading expressions in ASCE 7-16 based on forensic analysis of damaged and near-collapse structures;
4. Identify areas should be investigated by other teams or followed up by NSF RAPIDs/StEER FASTs.

The international research team was organized by Professors Tomoya Shibayama and Miguel Esteban of Waseda University, Tokyo, Japan with the broader mission of measuring tsunami inundation, ascertaining the source of the tsunami, and observing the impact of the earthquake and tsunami on infrastructure and local populations. The ITST received significant logistical and planning assistance from Hendra Achiari, a lecturer at Bandung Institute of Technology in Bandung, West Java, Indonesia. He was assisted in the field by one of his students,

Muhammad Marzuki, and his brother, Abdul Marzuki, a lecturer at the State Institute for Islamic Studies (IAIN) in Palu, both of whom grew up in Palu and knew the area well.

The ITST team was organized under several sub-teams:

- Structural Assessment Team which included StEER representative Ian Robertson
- Tsunami Survey Team
- Drone Survey Team
- Household Survey Team

whose names, affiliations and team assignments are summarized in Table 1.1.

Table 1.1. Team Members and Affiliations

Team Member	**Affiliation**	**Team Assignment**
Tomoya Shibayama (Lead)	Waseda University, Japan	Tsunami Survey Team
Miguel Esteban	Waseda University, Japan	Bathymetry Survey Team Household Interview Team
Ian Robertson	University of Hawaii, USA	Structural Assessment Team
Mikami Takahito	Tokyo City University, Japan	Tsunami Survey Team
Tomoyuki Takabatake	Waseda University, Japan	Tsunami Survey Team
Hendra Achiari	Bandung Institute of Technology, Indonesia	Tsunami Survey Team
Ryota Nakamura	Toyohashi University of Technology, Japan	Drone Survey Team
Jacob Stolle*	University of Ottawa, Canada	Structural Assessment Team
Clemens Krautwald*	Technical University of Braunschweig, Germany	Structural Assessment Team
Yuta Nishida*	Waseda University	Drone Survey Team
Muhammad Fadel*	Bandung Institute of Technology, Indonesia	Household Interview Team
**Graduate student*		

Note that this Data Report focuses on data documenting the structural performance during this earthquake and tsunami as collected by StEER Associate Director Ian Robertson (the only data included in this DesignSafe project). Other aspects of the investigation are referenced herein for completeness, but additional details and the data itself should be acquired from the corresponding international team members.

2.0 Data Collection Methodology

The primary emphasis of this dataset/data report are the observations generated by Ian Robertson as part of the Structural Assessment Team to document damage to structures, as well as other evidence of the hazard intensity generating these impacts. The work of this team was informed by and in coordination with other teams referenced in Section 1.0, e.g., the Drone Survey Team worked to capture point cloud data to reconstruct 3-D models of specific buildings in Palu.

The primary methodology engaged by the Structural Assessment Team was ground-level observations documented via photographic evidence. Given the limited amount of time in a highly impacted area, these were not detailed forensic investigations, but instead focused on broadly assessing the built environment's performance over a large expanse of the impacted area and over a wide range of building and infrastructure classes. Assessments focused on areas of highest impact, as documented by scout teams in the area and the preliminary virtual reconnaissance report (Robertson et al., 2018).

Assessments documented primary structural typologies and construction details (when evident), damage levels and likely failure mechanisms. These were established using direct observations, dimensional measurements, in-situ material strength testing (Schmidt Hammer), and material sampling for subsequent laboratory testing, accompanied by geotagged photos. When possible, the role of earthquake vs. tsunami in instigating observed damages/failures was determined based on evidence of inundation depths as inferred from debris lines, waterlines, and displaced objects. Eye witnesses were engaged when possible to confirm construction details and sequencing of earthquake/tsunami damage.

Working in tandem with the Structural Assessment Team, Indonesian researcher Muhammad Marzuki led a small local team in interviews of affected populations. Similar interviews were performed by members of Prof. Shibayama's Japanese delegation. The survey instrument was previously published as an Appendix in the EARR for this event (Robertson et al., 2019). In all, 200 individual interviews were performed during the mission. These data were compiled and analyzed at Waseda University under the direction of Prof. Miguel Esteban, but are not included in this dataset. They have been published by Harnantyari, et al. (2020).

Videos were captured during the inbound flight to Palu on October 27, 2018 and are also included in the dataset.

3.0 Chronology and Geospatial Distribution of Data Collection

27 October 2018
(abbreviated fieldwork - travel day)

1. All teams investigated shoreline at south end of Palu Bay
2. All teams investigated liquefaction site at west side of Palu

DAY 2: 28 October 2018

1. Bathymetry Survey along western coastline of Palu Bay from Donggala to just north of Palu
2. Structural Assessments along west side of Palu Bay, working from Donggala toward Palu
3. Drone Survey Team collected 3-D drone imagery of the South East coast of Palu Bay
4. Tsunami Survey Team surveyed the South and East coasts of Palu Bay

DAY 3: 29 October 2018

1. Structural Assessment Team started survey at the East abutment of Palu Bridge IV, the yellow double arch bridge crossing the mouth of the Palu river, and proceeded up the East side of Palu bay.
2. Tsunami Survey Team surveyed the West coast of Palu Bay, collecting runup elevations and inundation depths at a number of locations.
3. Drone Survey Team collected 3-D drone imagery of the Southwest coast of Palu Bay

DAY 4: 30 October 2018

1. Tsunami Survey Team traveled up to the earthquake epicentral region to record run-up and inundation elevations, collecting more eye-witness reports and survivor surveys.
2. Bathymetry Surveys conducted along south shore and west coast of Paul Bay
3. Drone Survey Team joined with the Structural Assessment Team to fly over selected building sites in Palu and the large liquefaction site at the south end of the airport runway

DAY 5: 31 October 2018
(abbreviated fieldwork - travel day)

1. Entire team visited the south coastline of Palu Bay. Drone Survey Team flew over the central portion of the South coastline of Palu Bay to complete 3-D scans of the entire South Coast.
2. Structural Assessment Team measured dimensions relating to the velocity calculation from video of incoming bore, taken from the spiral ramp of the shopping center parking garage. Video previously curated as part of EARR (Robertson et al., 2019)
3. Structural Assessment Team also visited the Roa Roa Hotel site to collect samples of reinforcing bars for further testing.

4.0 Archived Data Products

This section details the directory structure created in DesignSafe-CI and the contents therein.

□ Directory D1. Field survey photos and videos

FORMATS = JPG, MOV, XLSX

This directory contains additional folders with photographs collected on the ground, organized by mission day, e.g., **Palu Day 1 Photos** or **Palu Day 1 Videos**. Within each mission day folder, additional subfolders further organize photographs by specific site, adopting the following naming convention:

□ #### Description Lat Long

where #### is a four-digit site identifier, Description defines the location or site class, and Lat Long are a pair of numerical values defining the approximate coordinates of the site.

Photographs within these sub-folders are named by the following convention

PT-MMDDYY-P####-IR.JPG

where PT is the event code (Palu Tsunami), MMDDYY is the month, day and year the image was acquired in two digit format, P#### is a sequentially numbered photo identifier, and IR is the initials of the investigator (Ian Robertson).

Videos within these sub-folders are named by the following convention

PT-MMDDYY-V####-IR.MOV

where PT is the event code (Palu Tsunami), MMDDYY is the month, day and year the video was acquired in two digit format, V#### is a sequentially numbered video identifier, and IR is the initials of the investigator (Ian Robertson).

A summary of the contents of these mission day folders is provided below:

Mission Day Folder	Date	Coverage
Palu Day 1 Photos	October 27, 2018	7 sites/subdirectories
Palu Day 1 Videos	October 27, 2018	2 aerial videos
Palu Day 2 Photos	October 28, 2018	25 sites/subdirectories
Palu Day 3 Photos	October 29, 2018	23 sites/subdirectories
Palu Day 4 Photos	October 30, 2018	5 sites/subdirectories

A corresponding Photo-Video Log (excel file) has tabs for each of the folders described in the above table. Under each tab, the following information is provided for each file in that directory:

Col. A	Col. B	Col. C	Col. D	Col. E	Col. F	Col. G
File Name	Date Taken	Time Taken	Latitude	Longitude	Location/ Community	Description

□ Directory D2. 3D Renderings

FORMAT = FBX

This directory contains approximate Filmbox renderings of three notable sites documented by the Drone Survey Team:

File Name	**Coordinates**
Dunia Baru Restaurant	(-0.909517, 119.875655)
Petobo Sub-District	(-0.94, 119.912)
Tatura Mall	(-0.908287, 119.87627)

Note these renderings were previously published as part of the EARR (Robertson et al., 2019) and are included in this dataset for completeness.

□ Directory D3. Daily Summaries

FORMAT = PDF

This directory contains daily summaries (5 in total) capturing key observations and illustrative examples of the damage documented by the Structural Assessment Team, using a StEER standard template.

□ Directory D4. Dissemination Products

FORMAT = PPTX

This directory contains a 70-minute narrated presentation prepared by Ian Robertson. It provides a comprehensive overview of both the earthquake and tsunami and the resulting damage to structures and other components of the Palu infrastructure. It was prepared shortly after the field survey so is based only on observations made during the survey without the benefit of later field survey reports or detailed data analysis. To activate the presentation please open the file in Powerpoint, select “Slide Show” and “From Beginning”. If any of the narrations or animations do not activate automatically use the “page up” and “page down” keyboard buttons to replay a particular slide. If the videos do not play correctly, they can also be accessed in the

Videos directory of the published EARR: https://doi.org/10.17603/DS2JD7T (Robertson et al., 2019).

5.0 Contacts

For inquiries on this project, please contact:

StEER Representative	Overall Mission Leader
Ian Robertson ianrob@hawaii.edu	Tomoya Shibayama shibayama@waseda.jp

6.0 References

Harnantyari, A.S., Takabatake, T., Esteban, M., Valenzuela, P., Nishida, Y., Shibayama, T., Achiari, H., Rusli, Marzuki, A.G., Marzuki, M.F.H., Aranguiz, R., and Kyaw, T.O., (2020). "Tsunami awareness and evacuation behaviour during the 2018 Sulawesi Earthquake tsunami." International Journal of Disaster Risk Reduction, 43. (DOI: https://doi.org/10.1016/j.ijdrr.2019.101389)

Robertson, Ian; Kijewski-Correa, Tracy; Roueche, David; Prevatt, David, (2018-10-04), "PALU EARTHQUAKE AND TSUNAMI, SULAWESI, INDONESIA PRELIMINARY VIRTUAL ASSESSMENT TEAM (PVAT) REPORT", DesignSafe-CI [publisher], Dataset, doi:10.17603/DS2XD5S (DOI: https://doi.org/10.17603/DS2XD5S)

Robertson, Ian; Esteban, Miguel; Stolle, Jacob; Takabatake, Tomoyuki; mulchandani, Harish; Kijewski-Correa, Tracy; Prevatt, David; Roueche, David; Mosalam, Khalid, (2019-01-15), "StEER - PALU EARTHQUAKE AND TSUNAMI, SULAWESI, INDONESIA: FIELD ASSESSMENT TEAM 1 (FAT-1) EARLY ACCESS RECONNAISSANCE REPORT (EARR)" , DesignSafe-CI [publisher], Dataset, doi:10.17603/DS2JD7T (DOI: https://doi.org/10.17603/DS2JD7T)