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CONFERENCE REPORT



# Seismic resilience of Arctic infrastructure and social systems: 1st international workshop

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Environmental, ecological, and social changes interactively influence the seismic response of built infrastructure, the natural environment, and social systems in the Arctic. This includes direct and indirect climate impacts on earthquake-induced damages and post-earthquake recovery. Challenges with currently available knowledge are that 1) scientific knowledge is discipline-focused, 2) local community and Indigenous knowledge is not always equally respected and incorporated, and 3) even in some sectors, the fundamental technical understanding is [2]lacking.[3] In order to design new sustainable and resilient systems that will minimise the damage of earthquakes to Arctic infrastructure and environmental systems, scientists and engineers need to better understand the threats facing communities and their infrastructure, including the local and global consequences of a changing climate. Knowing that some Arctic and sub-Arctic regions are seismically active, such a holistic approach becomes even more pressing. For example, the state of Alaska in the U.S. is one of the most seismically active regions in the world. About 10% of the world's instrumented seismic events occur in Alaska, including some of the largest historic earthquakes.[4] Seismically induced hazards can impact both natural environments (such as ground deformations, landslides, rock falls, tsunamis, liquefaction) and built infrastructure (such as collapse of buildings and bridges and disruptions in lifeline systems including transportation networks, power transmission, water supply and sewage systems, and communication networks). All of these damages and disruptions directly impact social systems and communities. Thus, any resilience metrics, recovery decision, or mitigation strategy require inputs from a range of stakeholders with different perspectives.

A workshop was hosted by the University of New Hampshire to facilitate convergent discussions and to assess and prioritise the research needs and future directions of seismic resilience in the Arctic. The overarching goal of this workshop was to build capacity for investigating the resilience of Arctic infrastructure and social systems in response to seismic events in light of a changing climate. The core

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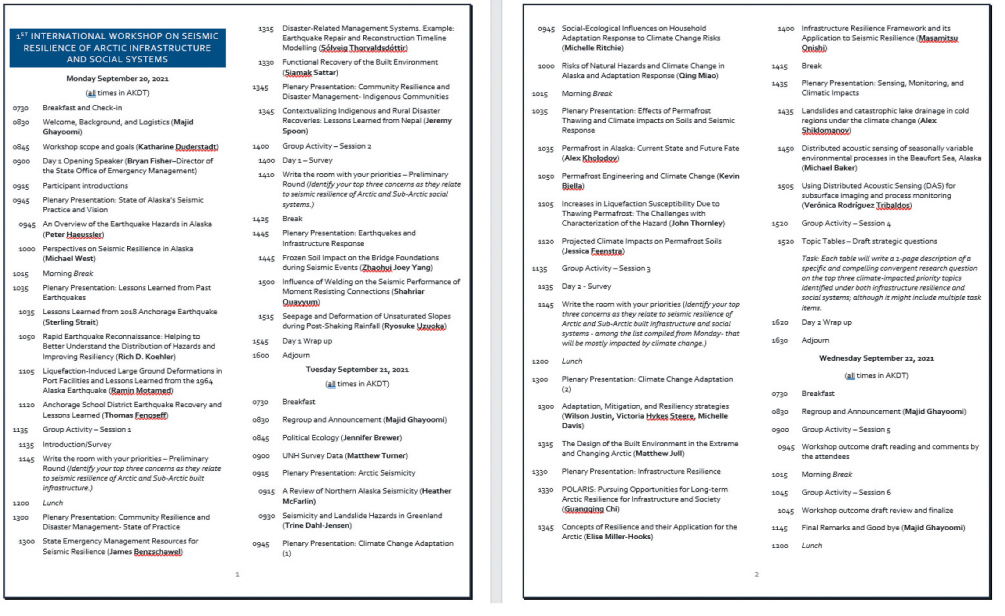
[1][20–22 September 2021; Hotel Captain Cook, Anchorage, Alaska, USA; Hybrid Format.]
[2]More facts about the workshop can be found on https://sites.google.com/view/1st-arctic-seismic-resiliency/home
[3]Rockstrom and Clement, "Arctic Resilience Report."
[4]Scher, "Influence of the 1964 Great Alaska Earthquake."

objectives were to (1) foster collaboration among the diverse group of participants; (2) identify, define, and prioritise research needs and ideas; and (3) propose strategies for outreach to Indigenous communities and best practices for co-production of knowledge. The workshop identified priority concerns in the seismic resilience of built infrastructure and social systems and how climate change will affect these concerns. Participants drafted six convergent research ideas to address the highest priority concerns and motivate future research initiatives.

This workshop brought together about 50 participants from different sectors, including researchers, policy makers, first responders and disaster recovery planners, industry partners, local and Indigenous community representatives, and other related stakeholders. The participants' expertise covered a wide range of disciplines ranging from earthquake engineers, seismologists, permafrost experts, geo-hydrologists, climate scientists, disaster managers and urban developers, social scientists, risk and uncertainty experts, and economists. Although most of the attendees were from the United States, researchers from Greenland (Denmark), Iceland, and Japan also participated.

Figure 1 presents a snapshot of the workshop agenda, while Figure 2 presents a set of selected photos reflecting some of the workshop activities. The workshop started with a keynote presentation by Bryan Fisher, the Director of the State of Alaska Office of Emergency Management, and ended with drafting workshop outcomes and identifying research and action priorities. Overall, 31 speakers presented their research and/or perspectives, including 29 technical presentations, a visionary presentation by three members of Indigenous communities, and a summary of UNH expert interview data conducted prior to the event. The presentations were organised under the following plenary themes



1ST INTERNATIONAL WORKSHOP ON SEISMIC RESILIENCE OF ARCTIC INFRASTRUCTURE AND SOCIAL SYSTEMS

**Monday September 20, 2021**

(all times in AKDT)

0730 Breakfast and Check-in
0830 Welcome, Background, and Logistics (**Majid Ghayoomi**)
0845 Workshop scope and goals (**Katharine Duderstadt**)
0900 Day 1 Opening Speaker (**Bryan Fisher**–Director of the State Office of Emergency Management)
0915 Participant introductions
0945 Plenary Presentation: State of Alaska's Seismic Practice and Vision
0945 An Overview of the Earthquake Hazards in Alaska (**Peter Haeussler**)
1000 Perspectives on Seismic Resilience in Alaska (**Michael West**)
1015 Morning *Break*
1035 Plenary Presentation: Lessons Learned from Past Earthquakes
1035 Lessons Learned from 2018 Anchorage Earthquake (**Sterling Strait**)
1050 Rapid Earthquake Reconnaissance: Helping to Better Understand the Distribution of Hazards and Improving Resiliency (**Rich D. Koehler**)
1105 Liquefaction-Induced Large Ground Deformations in Port Facilities and Lessons Learned from the 1964 Alaska Earthquake (**Ramin Motamed**)
1120 Anchorage School District Earthquake Recovery and Lessons Learned (**Thomas Fenoseff**)
1135 Group Activity – Session 1
1135 Introduction/Survey
1145 Write the room with your priorities – Preliminary Round *(Identify your top three concerns as they relate to seismic resilience of Arctic and Sub-Arctic built infrastructure.)*
1200 *Lunch*
1300 Plenary Presentation: Community Resilience and Disaster Management- State of Practice
1300 State Emergency Management Resources for Seismic Resilience (**James Benzschawel**)
1325 Disaster-Related Management Systems. Example: Earthquake Repair and Reconstruction Timeline Modelling (**Sólveig Thorvaldsdóttir**)
1330 Functional Recovery of the Built Environment (**Siamak Sattar**)
1345 Plenary Presentation: Community Resilience and Disaster Management- Indigenous Communities
1345 Contextualizing Indigenous and Rural Disaster Recoveries: Lessons Learned from Nepal (**Jeremy Spoon**)
1400 Group Activity – Session 2
1400 Day 1 – Survey
1410 Write the room with your priorities – Preliminary Round *(Identify your top three concerns as they relate to seismic resilience of Arctic and Sub-Arctic social systems.)*
1425 Break
1445 Plenary Presentation: Earthquakes and Infrastructure Response
1445 Frozen Soil Impact on the Bridge Foundations during Seismic Events (**Zhaohui Joey Yang**)
1500 Influence of Welding on the Seismic Performance of Moment Resisting Connections (**Shahriar Quayoum**)
1515 Seepage and Deformation of Unsaturated Slopes during Post-Shaking Rainfall (**Ryosuke Uzuoka**)
1545 Day 1 Wrap up
1600 Adjourn

**Tuesday September 21, 2021**

(all times in AKDT)

0730 Breakfast
0830 Regroup and Announcement (**Majid Ghayoomi**)
0845 Political Ecology (**Jennifer Brewer**)
0900 UNH Survey Data (**Matthew Turner**)
0915 Plenary Presentation: Arctic Seismicity
0915 A Review of Northern Alaska Seismicity (**Heather McFarlin**)
0930 Seismicity and Landslide Hazards in Greenland (**Trine Dahl-Jensen**)
0945 Plenary Presentation: Climate Change Adaptation (1)
0945 Social-Ecological Influences on Household Adaptation Response to Climate Change Risks (**Michelle Ritchie**)
1000 Risks of Natural Hazards and Climate Change in Alaska and Adaptation Response (**Qing Miao**)
1015 Morning *Break*
1035 Plenary Presentation: Effects of Permafrost Thawing and Climate Impacts on Soils and Seismic Response
1035 Permafrost in Alaska: Current State and Future Fate (**Alex Kholodov**)
1050 Permafrost Engineering and Climate Change (**Kevin Biella**)
1105 Increases in Liquefaction Susceptibility Due to Thawing Permafrost: The Challenges with Characterization of the Hazard (**John Thornley**)
1120 Projected Climate Impacts on Permafrost Soils (**Jessica Faenstra**)
1135 Group Activity – Session 3
1135 Day 2 - Survey
1145 Write the room with your priorities (*Identify your top three concerns as they relate to seismic resilience of Arctic and Sub-Arctic built infrastructure and social systems - among the list compiled from Monday- that will be mostly impacted by climate change.)*
1200 *Lunch*
1300 Plenary Presentation: Climate Change Adaptation (2)
1300 Adaptation, Mitigation, and Resiliency strategies (**Wilson Justin, Victoria Hykes Steere, Michelle Davis**)
1325 The Design of the Built Environment in the Extreme and Changing Arctic (**Matthew Jull**)
1330 Plenary Presentation: Infrastructure Resilience
1330 POLARIS: Pursuing Opportunities for Long-term Arctic Resilience for Infrastructure and Society (**Guangqing Chi**)
1345 Concepts of Resilience and their Application for the Arctic (**Elisa Miller-Hooks**)
1400 Infrastructure Resilience Framework and its Application to Seismic Resilience (**Masanobu Oshiki**)
1415 Break
1435 Plenary Presentation: Sensing, Monitoring, and Climatic Impacts
1435 Landslides and catastrophic lake drainage in cold regions under the climate change (**Alex Shiklomanov**)
1450 Distributed acoustic sensing of seasonally variable environmental processes in the Beaufort Sea, Alaska (**Michael Baker**)
1505 Using Distributed Acoustic Sensing (DAS) for subsurface imaging and process monitoring (**Verónica Rodríguez Tribaldos**)
1520 Group Activity – Session 4
1520 Topic Tables – Draft strategic questions

*Task: Each table will write a 1-page description of a specific and compelling convergent research question on the top three climate-impacted priority topics identified under both infrastructure resilience and social systems; although it might include multiple task items.*

1620 Day 2 Wrap up
1630 Adjourn

**Wednesday September 22, 2021**

(all times in AKDT)

0730 Breakfast
0830 Regroup and Announcement (**Majid Ghayoomi**)
0900 Group Activity – Session 5
0945 Workshop outcome draft reading and comments by the attendees
1015 Morning *Break*
1045 Group Activity – Session 6
1045 Workshop outcome draft review and finalize
1145 Final Remarks and Good bye (**Majid Ghayoomi**)
1200 *Lunch*

**Figure 1.** A catalogue of workshop agenda.

**Figure 2.** A hybrid workshop with different presentation topics and activity sessions.

- State of Alaska's seismic practice and vision
- Lessons learned from past earthquakes
- Community resilience and disaster management- state of practice
- Community resilience and disaster management- Indigenous communities
- Earthquakes and infrastructure response
- Arctic seismicity
- Climate change adaptation
- Effects of permafrost thawing and climate impacts on soils and seismic response
- Infrastructure resilience
- Sensing, monitoring, and climatic impacts

Live survey questions throughout the workshop helped to understand attendees' big picture perspectives and prepare participants for insightful discussions and follow-on group activities. During the initial group activity sessions, participants were asked to share their three main concerns or priority topics for (a) seismic resilience of Arctic and sub-Arctic built infrastructure and (b) seismic resilience of the Arctic and sub-Arctic social systems. The top 20 priority topics (10 for each category) were compiled and shared with the participants. They were then asked to choose their top two priority topics under each category that would most likely be impacted by climate change. The organising team determined the top three climate-impacted seismic resilience concerns for both built infrastructure and social systems. Interestingly, these highly ranked priority topics were also the most commonly identified ones during the top 10 assessments on the first day, demonstrating the importance of climate change on people's seismic hazard perception.

The participants were later divided into small interdisciplinary teams to draft strategic science questions, research approach, and outreach and engagement plans using the top priorities in infrastructure and social systems. A mix of discipline experts sat around each table to encourage cross-disciplinary talks. A short summary of each priority topic is listed below:

- *Effect of permafrost degradation and soil liquefaction (soil properties) on seismic resilience of built infrastructure and social systems*: The discontinuous permafrost zones typically have a lower level of seismic resilience due to a warming climate and changes in hydromechanical properties of soils. This would increase the earthquake-induced damage through different mechanisms, such as soil liquefaction.
- *Cascading effects of earthquakes on built infrastructure and natural systems*: Two specific effects were emphasised; i.e. earthquake-induced tsunamis (high waves) and landslides, which have been occurring in higher frequency under changing climate.
- *The significance of redundancy in lifeline infrastructure (power, communication, etc.) under the conditions of climate change*: The infrastructure across the Arctic maintains different levels of redundancies, resulting in inconsistent recovery processes. Infrastructure resilience investments are not always focused on the risk and consequences of failure but rather on economic value.
- *The effects of small, local, and Indigenous community capacity on seismic resilience of Arctic systems*: These communities have strong social networks and relationships that enhance resilience to environmental shocks. Many traditional response and recovery programmes have not been designed for small communities and their seismic vulnerabilities, with fewer resources allocated to these groups. Climate change also makes traditional ways of living difficult and may challenge existing community capacity to manage seismic direct and cascading effects.
- *Effects of resources distribution on seismic resilience of Arctic systems*: Three major issues were identified, including inhibition of resources, public health resources, and access hurdles. Climate change effects can vary among resources; thus, adaptation strategies, community input, and feasibility of engineering problems must be considered accordingly.
- *Effect of inequality in access to information and resources on seismic resilience of Arctic systems*: Low population density and unevenness of urbanisation in addition to limited transportation infrastructure in the Arctic creates problems with access to crucial information, public safety, education, and resources related to seismic events. Climatic impacts might aggravate these issues and increase inequalities. There are great opportunities in citizen science activities by directly integrating residents in knowledge transfer and data collection.

The last group activity sessions were devoted to drafting and finalising the workshop report, especially the six priority research topics. The participants collectively reviewed and commented on each section. The detailed results of the live workshop surveys, pre-workshop expert interviews, and full workshop outcome are either published or will be presented in future publications[5] and are also available on the workshop website along with all the presentation slides.[6] Based on the insights and discussions during this event, several research and practice ideas were initiated in order to (1) model and evaluate the infrastructure system response to earthquakes in the Arctic, (2) understand the interdependencies among infrastructure systems and the extent of the required system redundancy to ensure network

[5]Turner et al., "Connecting Climate Change and Seismic Resilience"; and Ghayoomi et al., "Workshop Outcome Report."
[6]Website link: https://sites.google.com/view/1st-arctic-seismic-resiliency/home

functionality in case of infrastructure failure, (3) integrate the substantive understanding of social decision processes and institutional context into seismic resilience models to enable safer, more sustainable, and adaptive infrastructure, (4) accommodate discrepancies between physical and social science understandings of the functionality, resilience, and adaptiveness with respect to Arctic infrastructure systems.

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