PRELIMINARY OBSERVATIONS IN THE AFTERMATH OF THE NOVEMBER 30, 2018 ANCHORAGE, ALASKA EARTHQUAKE

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Abstract
In the days following the November 30, 7.0M Anchorage earthquake, SOM engineering team Samantha Walker and Patrick Murren deployed to Alaska on a reconnaissance effort to chronicle building performance, view damaged buildings, and collaborate with the structural and earthquake engineering communities at large. The team spent several days in Anchorage and south-central Alaska documenting the visible damage via exterior building assessments, walkthroughs with building owners and tenants, and onsite observations where ground failures occurred. This paper documents the team’s observations, describes the seismology of south-central Alaska, and provides context for the team’s findings in relation to the Good Friday Earthquake of 1964. In collaboration with local structural and geotechnical engineers, the information gathered is being shared with the Earthquake Engineering Research Institute (EERI) reconnaissance teams in support of the organization’s mission to mitigate earthquake risk around the world.

The authors previously collaborated on reconnaissance efforts (Diaz, et al.) in the wake of the 2017 Central Mexico earthquakes. SOM has organized reconnaissance teams in the aftermath of several other major earthquakes, including the 1985 Mexico City earthquake, the 1989 Loma Prieta earthquake, the 1994 Northridge earthquake, the 1995 Kobe earthquake, and the 2008 Sichuan earthquake. The objectives of these trips are: to observe damage and apparent building behavior; to try to understand and explain the reasons for observed damage; and to share the information gathered with other building professionals, researchers, and organizations in order to improve the state of knowledge on building performance in earthquakes so that cities can be made more resilient in the face of these natural disasters.

1.0 Introduction
In order to evaluate the performance of structures during the Anchorage earthquake of November, 2018, it is instructive to compare it against observations from the Good Friday Earthquake of 1964. A brief description of the geography, building stock, and soil characteristics of Anchorage is also instructive in providing context for the team’s observations.

1.1 Context From 1964 Alaska Earthquake
To understand the performance of structures in the November 2018 Anchorage earthquake, it is instructive to revisit observations from the 1964 Good Friday Earthquake, a 9.2M event that still registers as the second largest recorded ground motion (trailing only the 9.5M Chile earthquake of 1960). The southern coast of Alaska roughly parallels the tectonic boundary between the Pacific and North American Plates. The Pacific Plate moves northward and, for most of this boundary, is subducted by the North American Plate on which Alaska sits. The tectonic stress build-up in Alaska is compounded by a form of torsional shear along the southeast coast of the state where the tectonic boundary is oriented as a strike-slip, rather than
subduction interface (Alaska Earthquake Center). While Alaska is subjected to frequent earthquakes along both boundaries, the 1964 earthquake was a subduction event that occurred at a depth of 15 miles with an epicenter in the Prince William Sound, approximately 75 miles east of Anchorage (Brocher, USGSa).

One of the defining characteristics of the 1964 earthquake was the substantial uplift experienced along stretches of the Alaska coast and subsequent subsidence experienced inland over a range of hundreds of miles. Land between the epicenter and the plate boundary offshore was uplifted on the order of several feet, including several areas where previously submerged portions of the seafloor were left exposed. This uplift also caused a large tsunami that resulted in heavy damage to coastal communities and deaths along the Alaska shoreline and as far away as northern California (Brocher, USGSa). It is noteworthy, however, that a tsunami did not occur in Anchorage either in 1964 or in 2018, as the city is sheltered in a low-tsunami risk area of the southern coast (Municipality of Anchorage).

There were very few ground motion recording stations in Alaska in 1964, but it is generally established that shaking in Anchorage lasted for a duration of over four minutes. Substantial structural damage occurred in Anchorage, including the notable collapses of the control tower at the Anchorage airport, a department store, and mid-rise apartment buildings in the downtown area. However, the effects of the earthquake in Anchorage were perhaps most notably manifested in myriad dramatic ground failures, including landslides, settlement and resulting grabens, and lateral spreading. Ground failures along 4th Street and L Street in the heart of downtown resulted in approximately 10 feet of settlement and heavily damaged all structures in the immediate vicinity. Most dramatically, the entire Turnagain Heights neighborhood, situated on coastal bluffs in the western portion of the city, was destroyed by a cascading series of landslides (USGSa). Today, this area is home to a coastal trail and greenspace fittingly named Earthquake Park.
1.2 Geography, Building Stock, & Soil Characteristics of Anchorage

A brief description of the geography, building stock, and soil characteristics of Anchorage is also instructive in providing context for the team’s observations. Anchorage is Alaska’s largest city with over 400,000 residents in the metropolitan area. The city is located on the southeast shore of the end of the Knik Arm, part of the Cook Inlet of the Gulf of Alaska. The city is bounded by the Cook Inlet (west) and its Knik (north) and Turnagain Arms (south), with the Chugach Mountains nearby to the east. The downtown area is situated in the northern part of the city along the Knik Arm and a smaller body of water, Ship Creek. The downtown area has a variegated building stock ranging from 1-2 story wood frame, masonry, and concrete structures to steel and concrete mid-rise buildings and several high-rises over 200 feet tall. The city is generally oriented in a north-south direction, with construction becoming more low-rise residential and commercial moving south toward Turnagain Arm, though there are high-rise and mid-rise structures located in midtown Anchorage. From observations on the ground, examination of building plans, and discussions with local engineers, it was evident that a variety of structural systems are implemented in mid-rise and high-rise construction, including steel moment frames, steel concentric braced frames, and reinforced concrete shear walls.

The typical soil profile in downtown Anchorage comprises two primary layers: a layer of gravel approximately 50 feet thick underlain by a thicker clay layer known as the Bootlegger Cove clay that is particularly...
susceptible to failure during seismic shaking. The USGS investigation of the 1964 earthquake (Grantz, et al.) and geotechnical investigations undertaken by the Municipality of Anchorage (GIS Services) have diagrammed two typical manners in which soil failures can occur in the city (Figures 5 and 6). In one scenario, failures occur vertically through the soil column and earthquake motion forces the column monolithically toward the coast. When this rigid body motion occurs, a relatively small portion of the column breaks off and settles into the void left by the ground movement, resulting in grabens (similar to the failures seen at 4th and L Streets in 1964). In a second scenario, multiple planes of slope failure develop in the weaker Bootlegger Cove layer, resulting in landslides toward the coast.

These hazards (Figure 7) have been mapped and made publicly available by the Municipality of Anchorage authorities. In the map, it can be seen that some of the most notable ground failures in the 1964 earthquake occurred near the shoreline in areas assessed with either “High” or “Very High” susceptibility to ground failure, including the large stretch of vulnerable land underlying the Turnagain Heights (now Earthquake Park) area.
2.0 Seismology of the 2018 Earthquake

The 7.0M November 30, 2018, Anchorage earthquake occurred at 8:29 AM local AKST at a depth of 29 miles. The epicenter of the earthquake was less than 10 miles from downtown Anchorage in a sparsely populated region on the western shore of the Knik Arm, at approximately the same latitude as the suburban community of Eagle River. Strong shaking typically lasted between 30 and 60 seconds across the Anchorage metropolitan area. Several aftershocks occurred in the days following the main earthquake, the largest being a 5.7M event in the evening of November 30 (USGSb).

Due to the dearth of ground motion recording stations in Alaska in 1964, it is difficult to draw comparisons with the ground accelerations experienced in the Good Friday Earthquake. One result of the 1964 earthquake was the introduction of a broad array of recording stations across Alaska and even—as described below—the instrumentation of a handful of buildings in Anchorage. The image below maps the recorded peak ground accelerations (PGAs) at stations throughout Anchorage with values ranging from 0.27g downtown to a maximum of 0.47g recorded at a midtown Anchorage station. A contour map of the PGAs provided below (Dutta, et al.) similarly indicates PGAs in the 0.2g - 0.5g range typically.
For reference, the ASCE 7-16 design response spectrum for a hypothetical soil site class D structure in downtown Anchorage—which per earlier studies (Martirosyan, et al.) appears to conform to typical subgrade conditions across the downtown area—is provided below and compared against contour maps of the 0.2-second period and 1.0-second period spectral accelerations. Noting the design-based earthquake spectral acceleration values of 1.00g (0.2-s period) and 0.77g (1.0-s period), it can be seen that for the most part, recorded ground motions did not exceed the DBE spectral accelerations for those particular periods. On the 0.2-second short period response map, two spikes in excess of the DBE values were noted—one near Lake Spenard at the airport and one near Rabbit Creek in the southern part of the city. From these maps, the majority of structures at the 0.2-s and 1.0-s fundamental periods were not subjected to design-level accelerations. The contour maps and relative differences between the DBE and recorded spectral accelerations also indicate a greater concentration of the earthquake’s energy at lower periods. The spectral accelerations recorded at instrumented high-rise buildings, shown in subsequent sections, and lack of observable cosmetic damage in those buildings further indicate that longer period structures were typically not subjected to design accelerations.
Fig. 11: 0.2-second period spectral acceleration contour map of Anchorage (Dutta, et al.)

Fig. 12: 1-second period spectral acceleration contour map of Anchorage (Dutta, et al.)
3.0 Reconnaissance Observations

Beginning approximately 24 hours after the earthquake, the authors performed a four-day reconnaissance of the area to document earthquake-related building and infrastructure damage and, where possible, to assist local authorities in their efforts to evaluate damaged buildings.

The reconnaissance focused on the most affected areas near the epicenter, including Anchorage and Eagle River. The locations visited by the SOM team are indicated in the map shown in Figure 13 below.

SOM shared its findings and coordinated its efforts with EERI, local reconnaissance teams on the ground in Alaska, and other researchers and professionals by participating in the nightly Clearinghouse Briefings organized by EERI. SOM also shared its findings by uploading photos and observations to the EERI Data Map, which is publicly available online.

The reconnaissance observations are summarized in the following sections. This article reflects a selection of representative cases from the SOM reconnaissance and does not purport to draw overall conclusions beyond the noted observations.

3.1 Anchorage

Throughout Anchorage, good structural performance was generally observed, with limited instances of nonstructural damage. Across building heights, building materials, and building usage, observed damage was generally limited to some cracked facades and windows, spalled stucco, fallen ceiling tiles, and toppled unbraced items or shelf contents. Figure 14 below shows cracked windows in some of the buildings in downtown Anchorage, which had already been boarded up the day after the earthquake.
There are a number of high-rise structures in Anchorage in the 15- to 25-story range. Most appeared to have withstood the earthquake with little to no evident damage. In addition to the broad array of ground motion recording stations in the area, there are also several instrumented buildings in Anchorage, including the Robert B. Atwood Building, the Frontier Building, the Hilton Anchorage East Tower, the BP Exploration Building, and the Alaska VA Healthcare System. These instrumented structures were an area of focus for the reconnaissance team.

The authors observed the exterior of the 20-story Atwood Building and noted little to no damage apparent from the exterior. Per reports from EERI peers, nonstructural damage was observed in some of the upper floors, mostly fallen acoustic ceiling tiles and rails as well as limited flooding from water pipe failure (Archbold, et al.). The authors also learned that the building’s structure is composed of a steel moment frame and shear wall plate lateral system. The records for the Atwood Building were obtained from the Center for Engineering Strong Motion Data (CESMD) website. The recorded site response spectra at the ground level of the Atwood Building are shown in Figure 15 below, compared to the ASCE 7-16 Design and MCE response spectra for site class D. The recorded spectra fall below the ASCE 7-16 Design response spectra. The recorded horizontal acceleration histories for two sensors at the ground and roof levels are shown in Figure 16 below. The peak acceleration was approximately 0.24g at ground level and increased to 0.44g at the roof level, with some of the middle stories exhibiting higher accelerations than some of the upper stories. The vertical acceleration history recorded by sensor 6 at basement level is shown in Figure 17 below. The peak vertical acceleration recorded at that location was 0.18g. A maximum displacement of 12.1 inches was recorded at the roof level. The maximum recorded story drift ratio at the roof was 0.004, which is significantly less than the allowable story drift ratio of 0.02 for buildings of this type per ASCE 7-16 and the operational performance drift ratio limit of 0.01 for light partitions per ASCE 41-13. The maximum recorded story drift ratio at the roof corresponds to a drift of 0.8 in, which is greater than the minimum drift limit of 0.5 in for glass fallout per ASCE 41-13.
Fig. 15: Recorded site response spectra (5% damping) at the Atwood Building ground level compared to the ASCE 7-16 Design and MCE response spectra (site class D).

Fig. 16: Recorded horizontal acceleration history at ground level, sensor 07, (top left) and roof level, sensor 32, (bottom left) of the Atwood Building.
The authors observed the 14-story Frontier Building from both the exterior and several interior floors. During the visit, the authors learned that the building’s structural system is composed of reinforced concrete core walls and post-tensioned flat floor slabs. Minor non-structural damage was observed, including cosmetic cracks between the partitions and columns as well as fallen sprinkler head covers. Figure 18 shows an example of typical cosmetic damage that was observed inside the Frontier Building. The records for the Frontier Building were obtained from the CESMD website. The recorded site response spectra at the ground level of the Frontier Building are shown in Figure 19 below, compared to the ASCE 7-16 Design and MCE response spectra for site class D. The recorded spectra fall below the ASCE 7-16 Design response spectra. The recorded horizontal acceleration histories for two sensors at the ground and roof levels are shown in Figure 20 below. The peak acceleration was approximately 0.20g at ground level and increased to 0.22g at the roof level. The vertical acceleration history recorded by sensor 6 at basement level is shown in Figure 21 below. The peak vertical acceleration recorded at that location was 0.11g. A maximum displacement of 9.4 inches was recorded at the roof level. The maximum recorded story drift ratio at the roof was 0.003, which is significantly less than the allowable story drift ratio of 0.02 for buildings of this type per ASCE 7-16 and the operational performance drift ratio limit of 0.01 for light partitions per ASCE 41-13. The maximum recorded story drift ratio at the roof corresponds to a drift of under 0.5 in, which is the minimum drift limit for glass fallout per ASCE 41-13.
Fig. 18: Cosmetic cracks between columns and partitions observed at the Frontier Building.

Fig. 19: Recorded site response spectra (5% damping) at the Frontier Building ground level compared to the ASCE 7-16 Design and MCE response spectra (site class D).
Fig. 20: Recorded horizontal acceleration history at ground level, sensor 05, (top) and roof level, sensor 33, (bottom) of the Frontier Building
The authors observed the exterior and interior of two other mid-rise buildings in downtown Anchorage. Through examination of the structural drawings, one of the buildings appears to be composed of a composite steel moment frame and reinforced concrete core lateral system, and the other a steel moment frame lateral system. From the exterior, potential flexural cracks were observed at the perimeter encased columns (see Figure 22). From the street level, the cracks did not appear to extend into the concrete encasement. On the interior, nonstructural damage in the form of dislodged ceiling panels was observed (see Figure 23). Per ASCE 41-13, to achieve position retention or operational performance levels in a seismic event, such integrated ceilings systems shall be retrofitted to meet the requirements of ASCE 7-16. One of the buildings also exhibited a vertical crack in the sheet rock over the height of the building at the joint where the core wall return stopped and transitioned to partition framing (see Figure 24).
Fig. 23: Typical nonstructural damage in a mid-rise building in downtown Anchorage (left: upper story, right: above ground parking garage)

Fig. 24: Vertical crack between core wall and partition inside building in downtown Anchorage
3.2 Eagle River

The authors visited Eagle River, which had suffered more building damage than Anchorage per reports from EERI peers. Multiple shear cracks in the brittle exterior finish of a commercial building were observed, but did not appear to extend into the structure beneath (see Figure 25).

The authors observed multiple types of nonstructural damage at the Eagle River Public Library, including brick veneer failure, shattered windows, and collapse of ceiling panels and rails (see Figures 26 and 27). The brick veneer failure was more significant on one side of the building, potentially indicative of a torsional issue. Many of the books had also fallen off the library shelves and workers wearing hard hats were partaking in the laborious task of replacing them (see Figure 28). Speaking with local tenants, the authors learned that the building adjacent to the library suffered major water damage from burst pipes, which flooded the building in the time it took to turn off the building’s water supply.
Fig. 26: Brick veneer failure at multiple locations at the Eagle River Public Library

Fig. 27: Shattered glass (left) and collapsed ceiling panels and rails (right) at the Eagle River Public Library
The authors observed significant fissures in the driveway and backyard of a private residence by Eagle River (see Figures 29 and 30). The fissure in the backyard continued across the house, cracking the slab-on-grade. At the largest opening, the fissure measured approximately one foot wide with a depth of several feet (see Figure 31). According to the homeowners, the house was constructed on fill. The earthquake caused the fill to settle towards the river, resulting in an elevation drop of several inches at some locations and foundation breakout from the porch posts (see Figures 32 and 33). At one corner of the porch, a steel pipe supporting a wood post buckled, which led to failure of the joist-to-post connection on one side and weak axis bending failure of the joist on the other side (see Figure 34). A shear crack in the front entrance slab-on-grade caused the entryway to drop several inches (see Figure 35). During the earthquake, the residents recounted that they felt their entire house undergo a vertical drop.
Fig. 31: Largest opening of fissure (bigger gauge required)

Fig. 32: Elevation change at fissure

Fig. 33: Fill settlement toward the river, resulting in foundation breakout from the porch posts
Fig. 34: Failure of the joist-to-post connection on one side (left) and weak axis bending failure of the joist on the other side (right) due to fill settlement.

Fig. 35: Shear crack in entrance slab on grade (left).
3.3 Infrastructure

The repair of major roadways that were damaged by the earthquake occurred rapidly in the days following the event. The damaged off-ramp of Minnesota Drive, an important link to the Ted Stevens Anchorage International Airport, was already under repair when the SOM team began its reconnaissance mission the day after the event.

Vine Road, a main artery outside the northern suburb of Wasilla, was heavily damaged due to lateral spreading of the soil where the road crosses over a bog (see Figure 36). Similar damage occurred in roads constructed over bogs during the 1964 earthquake (see Figure 37). Repairs commenced on Vine Road on December 4, four days after the event (see Figure 38) and the road reopened five days later. Nearby Pittman Road was similarly damaged from the earthquake. Although repair work was already underway on both roads, the significant dips over the damaged areas were still noticeable (see Figure 39).

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Fig. 36: Drone photo of Vine Road failure outside Wasilla, Alaska (Photo credit: Anchorage Daily News)

Fig. 37: Roadway constructed along a bog area, damaged in the 1964 earthquake (Photo credit: USGSa)

Fig. 38: Vine Road repairs underway

Fig. 39: Dip in Vine Road at damaged area
4.0 Conclusions and Next Steps

Overall, the damage caused by the 2018 Alaska earthquake appeared to have been mainly caused by ground failures and failure of non-structural components. The following types of damage were generally observed by the SOM reconnaissance team:

- Facade damage (cracked facades and windows, spalled stucco, and brick veneer);
- Interior nonstructural component failure (fallen ceiling panels and sprinkler head covers, and toppled unbraced items or shelf contents);
- Structural damage to a private residence caused by ground failure;
- Damage to roads caused by ground failure, particularly adjacent to bodies of water;
- Little observable damage in mid-rise and high-rise structures, likely owing to a concentration of earthquake spectral energy at lower periods.

As relatively little direct structural damage was observed in the wake of the 2018 Alaska earthquake, the information that the SOM team gathered from this reconnaissance mission will primarily provide insight on nonstructural component failures and the effect of ground failures on buildings and infrastructure. This information has been shared with the engineering community through organizations such as EERI. The team is also documenting its findings to be presented to educators, students, architects, and practicing structural engineers, both in the United States and internationally.

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1. Alaska Earthquake Center. https://earthquake.alaska.edu/event/20419010
11. GIS Services Data, Projects & Procurement Division - Information Technology Department, Municipality of Anchorage (December 2006). “Anchorage Bowl - Seismic Map.”