30 Nov 2018 Alaska M7.0 Earthquake:

Anchorage Bowl
Mobile Homes & Chimneys

Quick Report

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Preliminary Findings

• Mobile homes
  – No reported collapses (toppling off piers)
  – Apparently only slight damage
  – Performed better than expected
    • Compared to California

• Chimneys
  – Survey teams report few damaged
  – Still better than expected performance
    • Compared to California

• Why the difference…?
Mobile Homes
Anchorage Mobile Homes

Mobile homes in Anchorage

Source: U.S. Census

5,200 installed in 1970s
1970s Enabling Legislation

• 1971 Alaska law AS 45.30
  – Deals with mobile homes
  – Based on NFPA 501B (aka ANSI 119.1)
  – Rules for tie-downs

• 1976 Dept of Housing & Urban Dev. (HUD)
  – Set nation-wide “HUD-code” certification
  – Requires tie-downs on all mobile homes
2018 Alaska Earthquake (M7.0)

- 17 recording stations in Anchorage Bowl
- PGA < 0.4g and PGV < 12 in/sec

![Graph showing relationship between Peak Ground Accel. PGA (g) and Peak Grd. Vel. PGV (in/s). Mean PGV + SD = 12 in/s, Mean PGA + SD = 0.38g]
Mobile Home Damage Function

- For *Unanchored* mobile homes

**Damage function**

Mobile homes *likely* to topple

(> 50% chance)

Mobile homes *unlikely* to topple

(< 50% chance)

Mean PGV + SD in Anchorage

PGVs were low so even *unanchored* homes unlikely to topple

- For Unanchored mobile homes

<table>
<thead>
<tr>
<th>Peak Grd. Vel., PGV (in/s)</th>
<th>0.30</th>
<th>0.35</th>
<th>0.40</th>
<th>0.45</th>
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<td>(Slender Piers)</td>
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<td>(Squat Piers)</td>
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Tipping Coefficient ($\alpha$)

0
10
20
30
40

Peak Grd. Vel., PGV (in/s)

(Slender Piers)

(Tipping Coefficient ($\alpha$))

(Squat Piers)
Why Good Performance...?

- 1970s mobile homes were tied-down
  - Anchorage historic high wind area
  - Recent memory of Great 1964 quake

- Low PGV in Anchorage Bowl
  - Even *unanchored* homes unlikely to collapse

- Contrast with California
  - Many older mobile homes *lack* tie-downs
  - Suffer collapses during earthquakes
Anchorage Chimneys

• Two types:
  – Masonry (on older homes)
  – Metal flue in wood chase (newer homes)
Masonry Chimneys

- Plain masonry (vulnerable)
- Reinforced masonry (rugged)
Metal Chimneys

- Light-weight and very rugged
- No damage expected

Diagram:
- Spark arrestor
- Chimney chase
- Metal flue
- Plywood sheathing
- Stud framing
- Air gap
Chimney Vulnerability

• Plain masonry: *can be highly vulnerable*
  – Depends on many factors:
    • Height, tensile strength, shaking intensity, etc

• Reinforced masonry: *low vulnerability*
  – If properly meeting code

• Metal type: *very low vulnerability*
  – No reported failures in any quakes
Anchorage Chimney Damage

- Plain masonry chimneys
Masonry Chimney Codes

• Anchorage used UBC prior to IBC

• 1946 UBC required chimneys to be reinforced and anchored to house
  – CA experience: many chimneys were not meeting code even after that date

• Prescriptive requirements later set
  – Four #4 bars in 1967 UBC
  – Metal strapping in 1970 UBC

• Pre-1995 construction *might* not meet code
  – 1994 Northridge CA quake was wake-up call
  – 30,000 chimneys damaged in Los Angeles
Anchorage Housing Inventory

Two-thirds built after 1970
(> 75,000 units)

Total homes in Anchorage
(single-, multi-family & mobile homes)

Source: U.S. Census
Anchorage Chimney Inventory

- Metal chimneys popular in Anchorage starting in the early 1980s
  - Low cost a key factor

- Two-thirds of Anchorage homes built after 1970…thus:
  - Many metal chimneys
  - Fewer masonry chimneys
    - Reinforced if meeting code

- Vulnerable plain masonry chimneys are in the minority
Plain Masonry Chimneys

- Anchorage PGA < 0.4g
  - 2-foot chimneys not vulnerable
  - 5-foot vulnerable if weak masonry
  - 8-foot could have problems

Shaded areas indicate 50% chance of extensive damage
Fragility Curves

• Probability of extensive damage vs PGA

Mean PGA + SD in Anchorage

Weak Masonry (10 psi)

Expected Strength (60 psi tensile strength)

15% to 40% chance of extensive damage

\[ \beta = 0.6 \]

Peak Ground Acceleration (g)

Probability of Extensive Damage

Flue

21 in

5 feet

Mean PGA + SD in Anchorage

Weak Masonry (10 psi)

Expected Strength (60 psi tensile strength)

15% to 40% chance of extensive damage

\[ \beta = 0.6 \]

Peak Ground Acceleration (g)
Why Good Performance...?

• Small numbers of *plain* masonry chimneys
  – Versus metal and reinforced masonry

• Anchorage PGA < 0.4g
  – *Tall* plain masonry chimneys vulnerable
  – *Weak* masonry vulnerable
  – *Short* well-built masonry *not* vulnerable
  – Appears consistent with damage surveys

• Contrast with California
  – Many older homes w/ plain masonry chims.
  – Hence, more chimneys damaged in quakes
Next Steps

• Quantify damage statistics better
  – Review Anchorage building inspection reports
  – Review Anchorage building permit records

• Anchorage site visit
  – March 2019

• Create report on findings
  – Complete by 4Q this year
Special Thanks

• Jessica Freenstra (Golder Assoc, AK)
  – Photos

• Janise Rogers (GeoHazards, CA)
  – Photos

• EERI Learning From Earthquakes team
  – Discussions on observed damage