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Earthquake Building Risk Assessment in Sana’a city, Yemen

Prepared by:
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Ministry of Oil & Minerals

(2) Main Research Objectives

- Building Damage Prediction at Sana’a city by Developing Historical Earthquake Scenarios and investigate the behavior of buildings during the strong earthquakes.

- Improvement our Disaster Management Planning through rising preparedness at city level.
Location:

Yemen is located in the southern west of the Arabian peninsula.

**AREA:**

528,000 km², 21 Governorate

**POPULATION:**

22 million.

- **Topography**
  
The country’s topography of Rugged Mountains, Volcanic Highlands, Deserts, and Coastal plains.

- **Geo-Tectonic setting**
  
(Arabian plate) is bordered by active seismic zone: the Red Sea from the west and Gulf of Aden from the south.

Geology and Tectonic
Earthquakes in Yemen and Sana’a region

Recent Earthquakes

Historical Earthquakes

Identified Yemenis Building Types
Example: Un-Reinforcement Masonry Building types (URM)

Burnt Brick

clay

Example: Reinforcement Masonry Building types (RM) filled by block stone and bricks

Concrete Filled by stones & brick

Concrete Filled by block
Example: Reinforcement Masonry Building types (RM) filled by stone

Concrete Filled by Heavy stones
Concrete Filled by Heavy stones
Concrete Filled by Heavy stones
Concrete Filled by light stones

Building inventory and Data Base Preparation.
Building Distribution in Sana’a City

Example for Classification of Building Types According to Existing Database

Construction Type (I)
1. Reinforced concrete building filled with Block
2. Reinforced concrete building filled with Stone
3. Masonry (Stone/concrete Block) buildings
4. Masonry (Bricks) buildings
5. Masonry (Clay) buildings

Number of stories (J)
1. Low-rise (1-3 stories)
2. Mid-rise (4-6 stories)
3. High-rise (more than 6 stories)

Construction date (K)
1. Construction year: Pre-1982
2. Construction year: Post-1982
## Seismic level Design in Buildings — HAZUS

### Example Results of Buildings classification

<table>
<thead>
<tr>
<th>Classification</th>
<th>Old sana’a</th>
<th>Shuaib</th>
<th>Azal</th>
<th>Al-Safiya</th>
<th>Al-Sabain</th>
<th>Al-Wahdah</th>
<th>Al-Tahrir</th>
<th>Ma’ain</th>
<th>Al-Thawra</th>
<th>Bani_Ahharth</th>
<th>Dhawahi_Hamdan</th>
<th>Sanhan_Bani_Bahlol</th>
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### Table

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<th>Material consisting of Rectangular Loops</th>
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<th>Ref. R1, R2</th>
<th>Ref. R3, R4</th>
<th>Ref. R5, R6</th>
<th>Ref. R7, R8</th>
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<td>R3, R4</td>
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<td>R3, R4</td>
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<td>Burnt clay brick/rectangular stone/concrete blocks in cement mortar</td>
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<td>1-2</td>
<td>R3, R4</td>
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<td>R5, R6</td>
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### Pre-code
- Low-rise Concrete Frame fill with Block, 1-3 story
- Mid-rise Concrete Frame fill with Block, 4-6 story
- High-rise Concrete Frame fill with Block, > 6 story
- Low-rise Masonry (Bricks), 1-3 story

### Low-code
- Low-rise Concrete Frame fill with Block, 1-3 story
- Mid-rise Concrete Frame fill with Block, 4-6 story
- High-rise Concrete Frame fill with Block, > 6 story
- Low-rise Masonry (Bricks), 1-3 story
Application Of HAZUS Methodology in Sana’a

**Earthquake Risk Assessment**

Diagram showing the methodology used for risk assessment analysis.
Simulation of Earthquake Scenarios.

Development of Earthquake Scenarios.

Figure  shows the location of earthquakes used for scenario damage assessment.
Site effects, Soil Conditions and Classification

Based on AVS30m and NEHRP guidelines

ground units divided to 3 Groups

Soil Conditions and Classification

Bendimerad_Soil_B
Bendimerad_Soil_D
Wald_Soil_B
Wald_Soil_C
Wald_Soil_D

Attenuation Model and soil condition

\[ \ln \left( S_A \right) = b_1 + b_2 (M - 6) + b_3 (M - 6)^2 + b_5 \ln (r) + b_6 \ln \left( \frac{V_s}{V_A} \right) \]

Where

\[ r = \sqrt{r^2 + h^2} \]

And

\[ b_1 = \begin{cases} b_1 & \text{for strike-slip earthquakes} \\ b_1 & \text{for reverse slip earthquakes} \\ b_1 \text{ else} & \text{if mechanism not specified} \end{cases} \]

\( S_A \) is spectral acceleration to be derived
\( b_1, b_2, b_3, b_5, b_6 \) are constants provided with the equation
\( M \) is the magnitude of the earthquake
\( r \) is the horizontal distance from epicenter
\( V_s \) is the shear wave velocity of the soil class provided by NEHRP classification

\[ Im = 1.6 * \ln \text{PGA} + 0.545 * M_w + 5.78 \]
Building Damage Analysis

1) Building Response Calculation

[Diagram showing spectral acceleration and spectral displacement with demand spectra for different building capacities and shaking intensities.]
2) Building Fragility Curves

Set up Input building data base and site condition as

HAZUS Method

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Calculation Fault, fragility and capacity parameters

Calculation Vulnerability curves for all URM(Block) buildings
Calculation Vulnerability curves for all RM(Rc+stone) buildings

Calculation Vulnerability curves for all URM(bricks) buildings
Calculation Vulnerability curves for all URM(clay) buildings

Expected Damage on buildings caused by Dhamar EQ .Scenario
Expected Damage on buildings caused by Hamdan EQ. Scenario

Risk Map in term of completely damage
(Damage Distribution map)
Discussion and Conclusions

- The initial results of expected damage on buildings show overestimation results acceptable at the broad level evaluation. However, the results seem not to be very accurate for fine level risk evaluation.

The graphs indicate that:

- High and Moderate rise buildings (URM or RM) is the most vulnerable to earthquake damage. Whereas low rise buildings is least vulnerable.

- Buildings located above soft sediments site have higher damage and more vulnerable to risk comparing to buildings located on hard rock.

- Buildings having structural properties similar to URML model type is damaged more than RML type.

- The highest Spectral ground acceleration was (0.05-0.07g) for long period and (0.1-0.15g) for short period and located at central part of Sana'a city. Whereas maximum estimated seismic intensity around VI.

Discussion and Conclusions

Expected damage on buildings

The structural properties of Yemini's buildings such as capacity, damage function, height of building, exact number of buildings per district, population and location must be provided completely with accurate level in future work to get the more realistic results of risk evaluation of buildings in study area.
(Thank you!)