

Prepared for:
The Municipality of Anchorage Planning Department
and the Geotechnical Advisory Commission

Downtown Anchorage Seismic Risk Assessment & Land Use Regulations to Mitigate Seismic Risk

Prepared by:



MMI Engineering, Inc.

1915 63rd St. NE
Tacoma, Washington 98422

Project Number MMW550
Submitted to the Municipality on December 29, 2010

Finalized on March 25, 2013
by the Municipality of Anchorage
Community Development Department/Planning Division



Graben formation on 4th Avenue near C Street,
Anchorage, 1964 Alaska Earthquake



Pressure ridge at toe of L Street slide,
Anchorage, 1964 Alaska Earthquake

Prepared for:
The Municipality of Anchorage Planning Department
and the Geotechnical Advisory Commission

Downtown Anchorage Seismic Risk Assessment & Land Use Regulations to Mitigate Seismic Risk

Prepared by:



MMI Engineering, Inc.

1915 63rd St. NE
Tacoma, Washington 98422

Project Number MMW550
Submitted to the Municipality on December 29, 2010

Finalized on March 25, 2013
with copy edits
by the Municipality of Anchorage
Community Development Department/Planning Division

Donald Ballantyne, PE
Senior Consultant

TABLE OF CONTENTS

EXECUTIVE SUMMARY

| | | |
|-----|---|----|
| 1 | INTRODUCTION..... | 1 |
| 1.1 | Project Objective..... | 1 |
| 1.2 | 1964 Alaska Earthquake..... | 2 |
| 1.3 | Project Approach and Report Overview | 5 |
| 1.4 | Project Team | 6 |
| 2 | EARTHQUAKE SCENARIO..... | 7 |
| 3 | GEOLOGIC HAZARD | 9 |
| 3.1 | Geotechnical Setting | 9 |
| 3.2 | Definition and Delineation of Slopes | 9 |
| 3.3 | Anticipated Slope Displacements Due to Seismic Shaking | 11 |
| 4 | PROTOTYPICAL BUILDINGS | 15 |
| 5 | RISK ASSESSMENT APPROACH | 17 |
| 5.1 | Ground Shaking Damage..... | 17 |
| 5.2 | Ground Failure Fragilities..... | 18 |
| 5.3 | Ground Failure Damage | 21 |
| 5.4 | Combined Damage due to Ground Shaking and Ground Failure..... | 21 |
| 6 | RISK ASSESSMENT RESULTS, ANALYSIS, AND RECOMMENDATIONS..... | 23 |
| 6.1 | Contribution of Shaking and Ground Failure to Combined Risk | 23 |
| 6.2 | Sensitivity to Underlying Fragility Assumptions..... | 24 |
| 6.3 | Analysis | 24 |
| 6.4 | Recommendations | 26 |
| 7 | DRAFT ZONING ORDINANCE DEVELOPMENT | 43 |

| | | |
|-----|---|----|
| 7.1 | Very High Vulnerability | 43 |
| 7.2 | High Vulnerability..... | 43 |
| 7.3 | Moderate Vulnerability and Low Vulnerability..... | 43 |
| 8 | REFERENCES | 45 |

APPENDICES

| | |
|--|----|
| Appendix A – Ground Failure Susceptibility Hazard Overlay District | 47 |
| Appendix B – Task 1, Technical Memorandum Earthquake Scenario | 57 |
| Appendix C – Task 2, Technical Memorandum Prototypical Buildings..... | 61 |
| Appendix D – Task 5.1, Technical Memorandum Seismic Displacements..... | 67 |
| Appendix E – Tasks 5 and 6, Technical Memorandum Loss Modeling | 97 |

TABLES

| | |
|---|----|
| Table 4.1 Structural Classifications for the Ten Prototypical Buildings | 16 |
| Table 6.1 Impacts to Prototypical Buildings Due to Shaking & Ground Failure in an IBC Design Level Earthquake- Ground Failure Hazard Zone 5 Sorted on Maximum Total Deaths | 28 |
| Table 6.2 Impacts to Prototypical Buildings Due to Shaking & Ground Failure in an IBC Design Level Earthquake- Ground Failure Hazard Zone 4 Sorted on Maximum Total Deaths | 30 |
| Table 6.3 Impacts to Prototypical Buildings Due to Shaking & Ground Failure in an IBC Design Level Earthquake- Ground Failure Hazard Zone 3 Sorted on Maximum Total Deaths | 32 |
| Table 6.4 Impacts to Prototypical Buildings Due to Shaking & Ground Failure in an IBC Design Level Earthquake- Ground Failure Hazard Zone 5 Sorted on Loss Ratio..... | 35 |
| Table 6.5 Economic Impacts to Prototypical Buildings in an IBC Design Level Earthquake- Ground Failure Hazard Zone 5 (Note (a) – Includes Building Damage) | 38 |
| Table 6.6 Sensitivity Test Results: Economic Impacts to Prototypical Buildings (with Mat Foundations) Subject to Ground Shaking & Ground Failure in an IBC Design Level Earthquake- Ground Failure Hazard Zone 5 (Note (a) – Includes Building Damage)..... | 40 |

| | |
|---|----|
| Table 6.7 Sensitivity Test Results: Expected Deaths and Total Casualties in Prototypical Buildings (with Mat Foundations) Subject to Ground Shaking & Ground Failure in an IBC Design Level Earthquake-Ground Failure Hazard Zone 5 | 41 |
|---|----|

FIGURES

| | |
|---|----|
| Figure 1.1 Map of Downtown Anchorage Seismic Zones | 1 |
| Figure 1.2 Cross section of soil strata in L Street slide area in 1964 Earthquake. (Moriwaki et al, 1985).... | 3 |
| Figure 2.1 Scenario Shake Map (from the USGS)..... | 8 |
| Figure 3.1 Overlay of Downtown Anchorage with Seismic Zones and Cross-Sectional Lines. | 11 |
| Figure 3.2 Displacements by Percentage of Area within each Zone..... | 13 |
| Figure 6.1. Fatalities by Building Type for Seismic Hazard Zones 2/3, 4, and 5..... | 34 |
| Figure 6.2. Loss Ratio by Building Type for Seismic Hazard Zones 2/3, 4, and 5 | 37 |

PHOTOGRAPHS

| | |
|--|---|
| Photo 1.1 Collapse of Fourth Avenue near C Street, due to earthquake caused landslide. Before the earthquake, the sidewalk at left, which is in the graben, was at street level on the right. The graben subsided 11 feet in response to 14 feet of horizontal movement. Source USGS..... | 3 |
| Photo 1.2 The marquee of the Denali Theater, which was in the graben of the Fourth Avenue landslide in Anchorage, subsided until it came to rest on the sidewalk in front of the theater, which was on ground that was not involved in the landslide. Source USGS. | 4 |
| Photo 1.3 A graben formed at the head of the "L" Street landslide in Anchorage during the earthquake. The slide block, which is virtually unbroken ground to the left of the graben, moved to the left. The subsidence trough sank 7 to 10 feet in response to 11 feet of horizontal movement of the slide block. The volume of the trough is theoretically equal to the volume of the void created at the head of the slide by movement of the slide block. A number of houses seen in this photograph were undercut or tilted by subsidence of the graben..... | 4 |
| Photo 1.4 Photo 1.4 House displaced by compressional ridge formed at toe of L Street landslide. Source USGS..... | 5 |

DEFINITION OF TERMS

Bootlegger Cove Clay – clay deposit underlying downtown Anchorage that failed during the 1964 Alaska Earthquake.

Building Loss Ratio - dollar value of building damage (structural + non-structural) divided by building replacement value.

Casualty Severity Level – four point scale of the extent of injury, with 4 being the worst (death).

Design Ground Motion – shaking intensity for which a building is designed to perform at a prescribed level of performance such as life safety or continuous operation. The shaking intensity is provided at various shaking frequencies of vibration. The representative subsurface conditions for the ground motion must be specified such as whether it is on bedrock or at the surface where it has been amplified or deamplified.

Design Level Earthquake – earthquake ground motion selected for which the building structural design is prepared for a specified level of performance, i.e., collapse prevention.

Earthquake Scenario – a planning tool that defines the size, location, and intensity of an earthquake along with a description of the expected damage.

Fragility – relationship between shaking intensity and expected level of damage shown as a percentage.

Geologic Hazard – geologic structure that has the potential to fail resulting in loss of life or loss of property. Examples include landslides and liquefaction.

Graben – a block of ground forming behind or between larger blocks of ground that are moving apart. In some cases a graben can subside vertically such as occurred in the 1964 Great Alaska Earthquake in downtown Anchorage. (See Figure 1.2.)

Ground Failure – loss of soil bearing or structural capacity.

Hazard Risk – the probability of a hazard event occurring, coupled with the consequences of its occurrence.

HAZUS Model Building Type – system of building categories based on the type of structural system, e.g., braced steel frame, moment concrete frame, concrete shear wall, etc.

HAZUS Occupancy Class - buildings classified into three broad occupancy/use-related categories: residential, commercial/institutional, and industrial. These categories are used to determine the non-structural element make-up of the buildings and the nature and value of their contents.

Mat Foundation – large concrete foundation structure acting as a single element supporting a building. It could be thought of as a concrete barge supporting a building.

Maximum Total Deaths – the greater of day time and night time expected deaths.

North American Plate – tectonic plate covering the U.S. including Alaska, Canada, and the western side of the Atlantic Ocean.

Pacific Plate – tectonic plate covering much of the North Pacific, which moves northwest under the North American Plate in Alaska.

Pressure Ridge – soil plowed up in front of movement of large moving block of soil such as occurred in the 1964 Great Alaska Earthquake in downtown Anchorage. (See Figure 1.2.)

Probabilistic Ground Motion – the ground motion resulting from an earthquake with a given probability of occurrence in a defined time period (or recurrence interval), e.g., ground motion for an earthquake that has a 10% chance of exceedance in 50 years, or a 475-year return period.

Prototypical Building – a category of future typical buildings with specific use and parameters.

Seismic Hazard Zone (also Zone, Hazard Zone) – area with similar geotechnical parameters that would be expected to have similar response characteristics in an earthquake.

Sensitivity Analysis – the study of how the variation of one parameter in a model can affect the results.

Shake Map – A ground motion map produced by the USGS for earthquakes and earthquake scenarios.

Shallow Foundation – A foundation with structural members developing their capacity below frost level and/or just below the depth of the building basement. In the case of this study, a Shallow Foundation is intended to mean a series of small shallow foundations that perform independently with only limited structural interconnection with grade beams.

Subduction Fault – the interface of one tectonic plate sliding under another tectonic plate, e.g., the Pacific Plate subducting under the North American Plate.

ACRONYMS

ATC – Applied Technology Council

DHS – Department of Homeland Security

FEMA – Federal Emergency Management Agency

GIS – Geographical Information System

HAZUS – Hazards US

IBC – International Building Code

PGD – Permanent Ground Deformation

USGS – United States Geologic Survey