Seismic Analysis of Special Steel Moment-Resisting Frames

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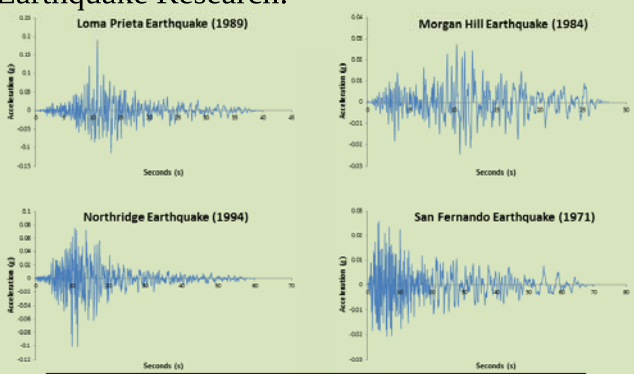
Abstract:

This project focuses on designing a five-story steel moment-resisting frame in the earthquake-prone San Francisco Bay Area, California near the Hayward fault. The structural engineer's main priority is safety; buildings have to be designed with a strong infrastructure such that they will withstand severe earthquakes. The objective of this research is to understand how to implement today's seismic technologies into designing a cost-efficient and environmentally friendly building. Computer-aided programs SAP2000 (Structural Analysis Program) and MS Excel are used to design, simulate and analyze the structure. This research internship program allows for the development of project management, time management and teamwork skills, all of which help strengthen students' knowledge of seismic design in Civil Engineering and enhance preparation for academic and professional careers. The project intends to provide community college students research opportunities and make recommendations on improving engineering curriculum at San Francisco State University and Cañada College.

Introduction:

Earthquake civil engineering is concerned with the design and analysis of structures to withstand hazardous earthquake at specific locations and steel seismic design is one of approaches. Starting in the late 1800's, steel began to replace cast iron and became readily available for applications in large scale engineering structures. This triggered a tide of tall buildings, including the Home Insurance Building in Chicago (1884), and the Manhattan Building in New York (1889). Steel frame buildings began to rise all across the nation without any major changes in their connections or design for nearly a century after the 1880's. But after structural failures during the 1994 Northridge Earthquake, there was a fundamental rethinking in the design of seismic resistant steel moment connections. This led to the FEMA researching on the SAC Steel Project, which redesigned seismic-resistant steel moment connections. This project instituted strict building codes for all steel structures, such as the American Institute of Steel Construction (AISC), and the Los Angeles Region Uniform Code Program (LARUCP). These building codes and design specifications were strictly followed during the entire design process of our building during this internship.

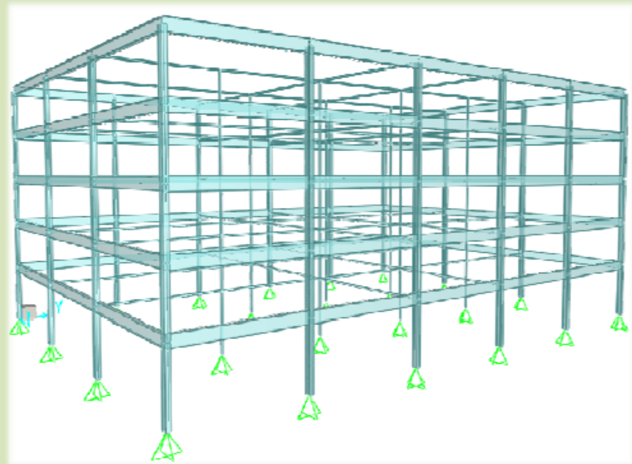
Earthquake Research:



Earthquake	Magnitude	Ground Acceleration (g)	Duration(s)	Cost	Loss of Life
Loma Prieta, 1989	6.93	[illegible]	40	$6 Billion	63 killed, 3,757 injured
Morgan Hill 1984	6.19	[illegible]	27	$7 Million	27 injured
Northridge 1994	6.70	[illegible]	60	$20 Billion	57 killed, 8,700+ injured
San Fernando 1971	6.61	[illegible]	79	$505 Million	65 killed, 2,000+ injured

Four historic earthquake grounds were selected from the Pacific Earthquake Engineering Research Center (PEER) Ground Motion Database based on the location, intensity, and the duration. Seismic activity data including duration and peak ground acceleration (g) from PEER were imported to SAP2000 to simulate the response of our designed frame to different earthquakes.

Our Building Design:



Design Specifications:

I. Design a 5-story Special Moment Resistant Frame Structure located at 3939 Bidwell Drive, Fremont, CA 94538.

Design Process:

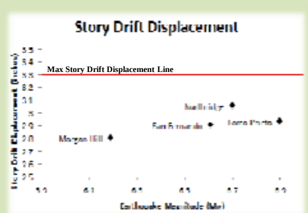
I. Research the soil type and seismic response coefficient based on our building's location using the U.S. Geological Survey (USGS) database.

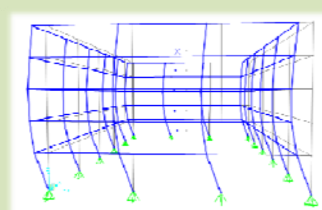
II. Apply the ASCE 7-05 Equivalent Lateral Force Procedure to determine the base shear, the dead load and the period of the structure.

III. Utilize SAP2000 for a step-by-step Time History Analysis of the building response when subjected to selected ground motions.

IV. Research on how our design can become eco-friendly and investigate how Moment-Resisting Frames can resist seismic activity on the moon.

Analysis and Results:





During our structural design, we simulated the earthquake ground movements on our building to investigate how it would behave. The building responded differently to selected earthquakes. We observed that the beams on the second floor showed the largest deformation, thus we decided to increase their size in comparison to the beams of all the other floors. Also, we found the drift could be minimized by making the columns heavier than all the beams. Once we designed a structure that would withstand all the forces, we redesigned the frame to decrease the weight of the beams while still satisfying the maximum allowable story drift to be cost effective.

Environmentally Friendly Research:

Since the turn of the 21st century, there has been a growing emphasis on green building or being environmentally friendly. Our research on how to reduce the environmental impact of our building design began by looking at the NASA Sustainability Base located at Moffett Field in Mountain View, California. This building was chosen because it is one of the most revolutionary green buildings in the world and has won the Leadership in Energy and Environmental Design (LEED) Platinum Plaque. We noticed many ecologically friendly methods used in the green building design such as properly disposing of all waste created during construction, designing the structure to allow more natural light and better ventilation, planting gardens and trees around the building to reduce carbon dioxide and produce clean air, installing solar panels to replenish energy consumed and eliminate harmful pollutants, and sourcing materials from local vendors. These innovations are vastly advancing the idea of eco-friendly engineering and will be implemented into our design.



Buildings on the Moon:

To help propel NASA's goal of human settlement in outer space, we expanded our seismic analysis on special moment-resisting frames to the surface of the moon. We researched the landscape and studied the environment to gain a better understanding of the lunar conditions and determine if our structure would endure ground shaking. Moonquakes, the technical term for seismic activity on the moon, are less intense (magnitude of 4 on the Richer scale) but last for a longer duration (up to 10 minutes) in comparison to earthquakes. Due to the terrain of the moon being a large dry-rigid chunk of stone, seismic activity of the same magnitude/intensity on the moon would cause more damage than that on Earth where the water and soil dampen seismic vibrations. Low magnitude moonquakes will not cause serious damage to our structure but their extended duration may cause issues such as low-cycle fatigue.

Summary and Conclusions:

Through this research, we expanded our knowledge in the field of civil engineering in protecting society from earthquakes. We understood what a professional civil engineer does to design and construct a building. We learned the basic principles in seismic design of steel frames, the building codes from the ASCE 7-05 Lateral Equivalent Force Procedure, and how to implement these codes into the design of our structures. We were exposed to SAP2000 which is utilized by civil engineering firms in over 160 countries for the design of major projects. This internship opportunity has given us an insight to graduate level course work and strengthened our understanding of fundamental engineering principles. We gained a better understanding of what a certified engineer faces in the field of civil engineering, but most importantly is how vital their work is towards the community.

Acknowledgements:

This program is sponsored by the NASA Office of Education through the Curriculum Improvement Partnership Award for the Integration of Research (CIPAIR), Grant Number NNX10AU75G.