Seismic Analysis of Special Moment-Resisting Frame

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1. Introduction

Abstract:

To ensure that the buildings are built to withstand the tests of time and nature, civil engineers perform a number of analysis techniques such as time history analysis, and ASCE 7-05's equivalent lateral force procedure. The latter is a procedure that is designed to mimic real loads caused by earthquakes, while the former is meant to test the building performance against an actual earthquake. The goal of this project is to apply both methods to design a three-story structure using special moment-resisting frames, and determine which method will produce the best results.

The project was intended to provide community college students research opportunities and make recommendations to improving curriculum at either San Francisco State University or Canada College.

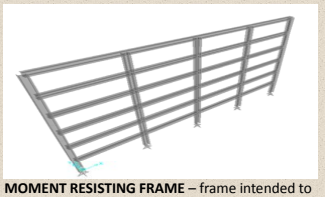
Goals:

I. Develop project management and teamwork skills.
II. Build upon our knowledge in the field of Civil Engineering.
III. Deliver a set of recommendations to be implemented into lower division engineering coursework.

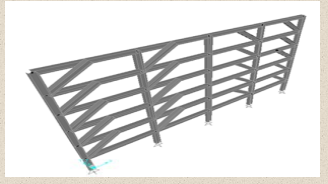
2. Approach

I. Review basic concepts behind static elements of steel design.
II. Familiarize with the AISC Steel Manual and ASCE 7-05 design procedures.
III. Design and test a Special Moment Resisting Framed structure.
IV. Perform a time history analysis and compare the performance results with results from the ASCE 7-05 12.8 Equivalent Lateral Force Procedure.
V. Repeat as necessary to ensure that the structure is built to the minimum design standards along with minimal overall weight.

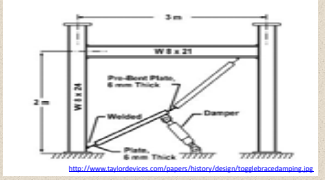
3. Design Selection Process



MOMENT RESISTING FRAME – frame intended to remain elastic and exhibit ductile behavior, meaning they stretch before breaking apart, during a major earthquake.

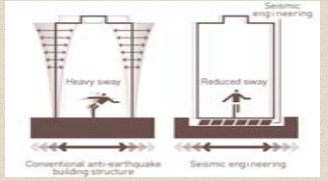


ECCENTRICALLY BRACED FRAME – frame that has high elastic stiffness and superior inelastic performance characteristics.



http://www.taylordevices.com/papers/history/design/toggle bracedamping.jpg

DAMPING SYSTEM – system has a chamber containing incompressible fluid that transfers between the chamber, thus converting kinetic energy of earthquake into heat energy.

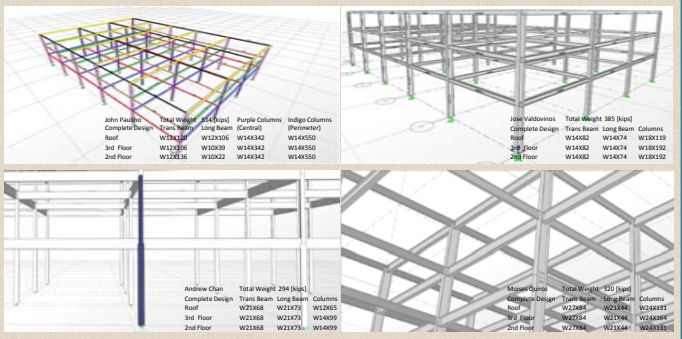


BASE ISOLATED STURCTURES – they absorb less shear forces across their isolation surface than structures that are not isolated from the base.

4. Design

- Special moment-resisting frames offered the best performance per cost.
- Something of note is that SMRFs inherently allow for an open air design; that is to say that SMRF's allow for big open spaces to be incorporated in to the design of the structure.
- Each member designed and tested their own 3-story SMRF structure.

Below: Special Moment Resisting Frame design's along with the total weight of the building.



John Paulino — Total Weight 314 [kips]

Complete Design	Trans Beam	Long Beam	Purple Columns (Central)	Indigo Columns (Perimeter)
Roof	W12X106	W12X106	W14X342	W14X550
3rd Floor	W12X106	W10X39	W14X342	W14X550
2nd Floor	W12X136	W10X22	W14X342	W14X550

Jose Valdovinos — Total Weight 385 [kips]

Complete Design	Trans Beam	Long Beam	Columns
Roof	W14X82	W14X74	W18X119
3rd Floor	W14X82	W14X74	W18X192
2nd Floor	W14X82	W14X74	W18X192

Andrew Chan — Total Weight 294 [kips]

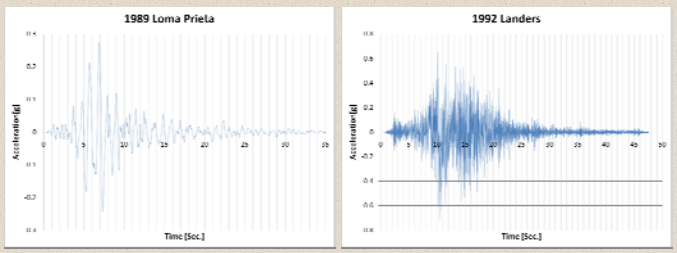
Complete Design	Trans Beam	Long Beam	Columns
Roof	W21X68	W21X73	W12X65
3rd Floor	W21X68	W21X73	W14X99
2nd Floor	W21X68	W21X73	W14X99

Moises Quiroz — Total Weight 320 [kips]

Complete Design	Trans Beam	Long Beam	Columns
Roof	W27X84	W21X44	W24X131
3rd Floor	W27X94	W21X44	W24X146
2nd Floor	W27X84	W21X44	W24X131

5. Earthquakes

- Earthquakes chosen based on their magnitudes and or their proximity to a large populous.
- Implemented into SAP2000 for both the X and Y directions and scaled up the magnitude to 85% of the demanded design base shear.
- The buildings must adhere to no less than 3.3 inches of drift at its minimal.

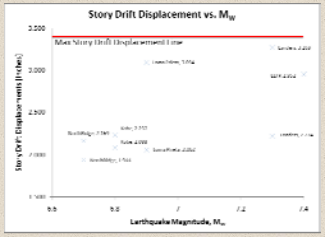


Earthquake	Magnitude (M_w)	Ground Acceleration (g)	Duration (sec)	Cost	Loss of Life
Loma Prieta 1989	6.9	0.274	15	$11 Billion	63 Killed, 3,757 Injured
Landers 1992	7.3	0.727	120-180	Minimal	3 Killed, 400+ Injured
Northridge 1994	6.7	0.511	10-20	$20 Billion	57 Killed, 8700+ Injured
Kobe 1995	6.8	0.693	20	$100 Billion	6,434 Killed

6. Analysis and Results

In our procedures we tested frame system after frame system, each time analyzing the drift between each floor levels, taking note of the changes each time. Our general findings indicated that the 3rd floor beams incurred the largest drifts. Further testing indicated that if we increased the beam size for the 3rd floor beams, we incurred less drift. The 3rd floor system was the determining factor in controlling the amount of drift for our building system. This was true for both lateral and longitudinal directional earthquake forces. If we were not to consider for the ease of construction, it would be possible to just beef up the 3rd floor beams in order to lighten up the columns for the rest of the building. As it were, the columns more than exceeded the required dead and live loads and so our design could benefit from a lighter design.

- Our designs were able to reach less than 1% of the allowable drift.
- Allowable limit of 3.3 Inch, our values performed to within 26.37% of the induced earthquakes.
- 3 out of 4 earthquakes occurred in California, so our designs would have saved lives in California and in the Kobe, Japan earthquake.
- Closest drift was within 6.95% of the max allowable drift.



Above: Picture of building undergoing a time history analysis
Left: Story Drift Displacement Graph

Conclusion

- ACSE 7-05 Equivalent Lateral Force Procedure performs within the acceptable limit in relation to seismic activity within California.
- Both Time History Analysis and ELFP have their advantages and disadvantages.
- It is necessary to perform both, as the performance based time history analysis induces stress close to the maximum allowable drift load on a structure.

7. Curriculum Improvement Deliverables

From certain keen aspects of our work, we developed tutorials along with a list of recommendations on how to implement SAP2000 into a typical statics course.

- Easy to use SAP2000 educational version tutorials.
- SAP2000 can implemented easily as either a honors course work or in a club.
- SAP2000 will aid today's future civil engineers in their lower division course work and provide them with the ability to check their work on an actual performance based simulator.
- Maximize the students time on homework, along with providing the tools so that students can rely on themselves to check their answers.

Acknowledgements

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