# CHINESE HOSPITAL

NEW ACUTE CARE AND
SKILLED NURSING FACILITY

TIM ARIOSTO
STRUCTURAL OPTION
AE 482 – SENIOR THESIS

DR. RICHARD BEHR – FACULTY ADVISOR

# BUILDING STATISTICS



**Introduction**
Existing Structural System
Problem Statement
Proposed Solution
Lateral System Design
Architectural Impact
Damper Implementation
Cost and Schedule Impact
Conclusion

Courtesy of Jacobs-Carter Burgess

Courtesy of Google Maps

Location: 845 Jackson Street
San Francisco, CA

Size: 92000 SF

Height: 96.5' to Top of Roof

Dates of Construction: 2010-2013

Project Delivery Method: Integrated Project Delivery (IPD)

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## 1925 CHINESE HOSPITAL

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Courtesy of Google Maps

Addition to The Chinese Hospital

Replaces the Original Structure, Built in 1925

Designed to Maintain Floor-to-Floor Relationships

Design Highlights:

- 76 Additional Beds
- Additional Surgical Space
- A Cardiopulmonary Unit

# INTRODUCTION

# PROJECT TEAM

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Courtesy of Google Maps

Owner: Chinese Hospital

Architects: Jacobs Carter Burgess

Structural Engineer: ARUP North America

Mechanical Engineer: Mazzetti & Associates

Electrical Engineer: FW Associates, Inc.

Construction : DPR Construction, Inc.

# FOUNDATION LAYOUT

# EXISTING STRUCTURAL SYSTEM

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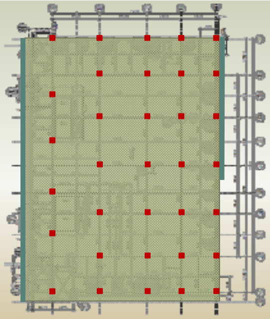

Foundation

- 36” Mat Slab
- 3’-0” x 3’-0” Concrete Pedestals
- Underpinning to maintain existing foundations

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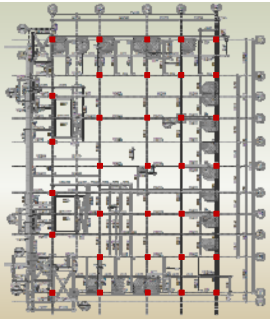
## COLUMN LAYOUT



## EXISTING STRUCTURAL SYSTEM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Gravity System

Varying Bay Sizes from 18'-0"x17'-0" to 23'-10"x24'-0"

Composite Beam Used

Floor System

3" Verco W3 Formlock Deck

Additional 3 ¼" of Concrete

# MOMENT FRAMES

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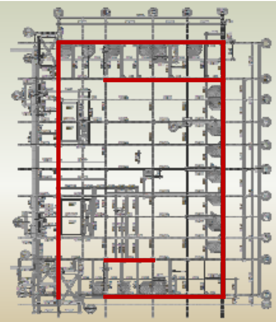

Special Steel Moment Frames
- 4 Perimeter Frames
- 2 Interior

Column Sizes
- W14x455 to W14x283

Beam Sizes
- W24x192 to W30x99

# PROBLEM STATEMENT

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San Francisco in Area of High Seismicity

Structural Deformation Occurs During Major Seismic Events

"Essential" Facilities are Required to Meet Strict Standards

"Hospital buildings that house patients who have less than the capacity of normally healthy persons to protect themselves…must be reasonably capable of providing services to the public after a disaster."

Seismic Safety Act of 1983

## FLUID VISCOUS DAMPERS

## PROPOSED SOLUTION


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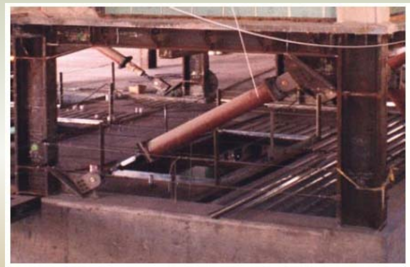

Courtesy of Taylor Devices Inc.
Photo Courtesy of Taylor et al.

- Performance Based Engineering Alternative Solution
- Incorporate Fluid Viscous Dampers into Structure
- Design Goals
  - Prevent Yielding in MCE event
  - Minimal Impact to Architecture
  - Low Cost of Implementation

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DESIGN STRATEGY

PROPOSED SOLUTION

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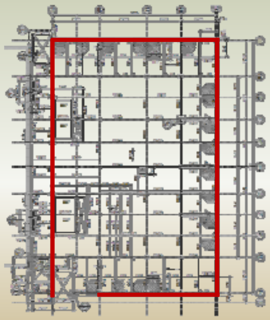

- Distribute Lateral Loads to Frames Proportionately
- Redesign Lateral System
  - For Strength Using R=8
  - To Meet .01Hx Drift Ratio
- Convert Frame Properties to a SDOF System
- Perform Nonlinear Analysis to Determine Required Damping
- Distribute Required Damping Throughout Frame

## DESIGN FORCES



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1. $1.4(D + F)$
2. $1.2(D + F + T) + 1.6(L + H) + 0.5(L_r \text{ or } S \text{ or } R)$
3. $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (L \text{ or } 0.8W)$
4. $1.2D + 1.6W + L + 0.5(L_r \text{ or } S \text{ or } R)$
5. $1.2D + 1.0E + L + 0.2S$
6. $0.9D + 1.6W + 1.6H$
7. $0.9D + 1.0E + 1.6H$

| Lateral Forces Summary | | |
|---|---|---|
| | Base Shear (kips) | Overturning Moment (ft-kips) |
| Seismic NS / Seismic EW | 772 | 64,854 |
| Wind NS | 152 | 26,828 |
| Wind EW | 106 | 18, 632 |

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## DESIGN FORCES

## LATERAL SYSTEM DESIGN


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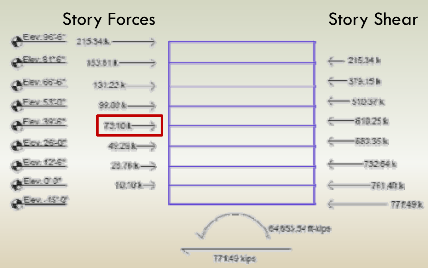


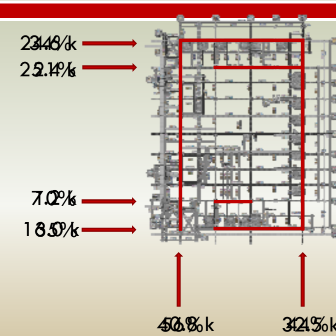

# DEMAND-TO-CAPACITY RATIO




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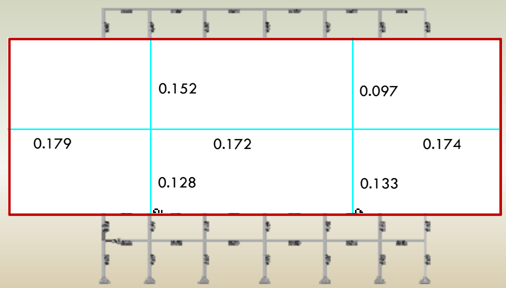


$$DC = \frac{Maximum\ Moment}{S_{Girder} F_y}$$

$$DC = \frac{Maximum\ Moment}{S_{Column}\left(F_y - \frac{P_u}{A_{Column}}\right)}$$

# PUSHOVER ANALYSIS

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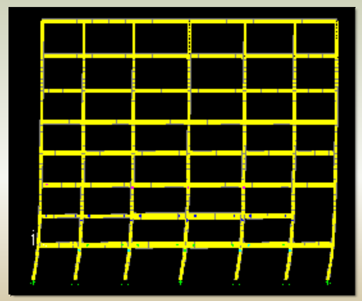

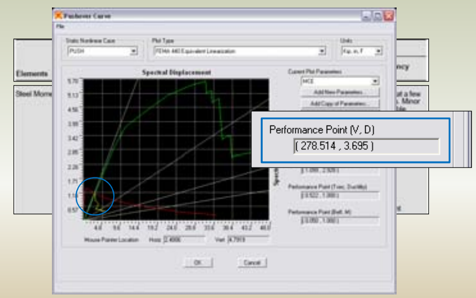

# CONVERSION TO SDOF SYSTEM

# LATERAL SYSTEM DESIGN


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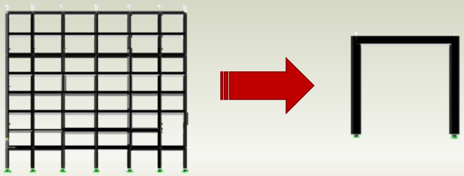

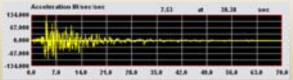

- Properties from Actual Frame Converted into SDOF System
  - Strength, Stiffness Taken from Pushover Analysis
  - Weight from Frame Tributary Area
  - Inherent Damping Assumed at 5% Critical
- Earthquake Time-History Data Taken from 1994 Northridge Earthquake

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# NONLIN ANALYSIS

## LATERAL SYSTEM DESIGN


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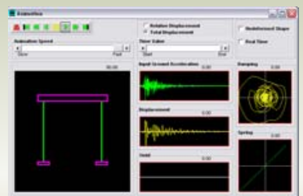

Frame E NONLIN Damper Analysis - Maximum Considered Earthquake

| Iteration | Performance Point Info | | Equivalent Frame Properties | | | Yield Events Based on Percent Damping | | | | | | | Optimal Damping Force (k) | Optimal Percent Damping |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | V (k) | D (in) | Stiffness 1 (k/in) | Stiffness 2 (k/in) | Strength (k) | 5% | 10% | 15% | 20% | 25% | 30% | 35% | | |
| Original Design | 433.049 | 3.417 | 126.734 | 25.347 | 433.049 | 4 | 2 | 1 | 1 | 0 | 0 | 0 | 252.32 | 24 |
| Smaller 1 | 412.267 | 3.366 | 122.480 | 24.496 | 412.267 | 4 | 2 | 1 | 1 | 0 | 0 | 0 | 255.57 | 25 |
| Smaller 2 | 404.425 | 3.436 | 117.702 | 23.540 | 404.425 | 4 | 2 | 1 | 1 | 0 | 0 | 0 | 246.00 | 24 |
| Smaller 3 | 390.408 | 3.508 | 111.291 | 22.258 | 390.408 | 5 | 3 | 1 | 1 | 0 | 0 | 0 | 234.29 | 23 |
| Smaller 4 | 383.584 | 3.499 | 109.627 | 21.925 | 383.584 | 5 | 3 | 1 | 1 | 0 | 0 | 0 | 232.80 | 23 |
| Smaller 5 | 373.895 | 3.506 | 106.302 | 21.260 | 373.895 | 6 | 2 | 1 | 1 | 0 | 0 | 0 | 223.05 | 22 |
| Smaller 6 | 364.527 | 3.483 | 104.399 | 20.920 | 364.527 | 4 | 2 | 1 | 1 | 0 | 0 | 0 | 228.06 | 23 |

- SDOF Frame Subjected to Time-History Data for Northridge Earthquake
  - Number of Yielding Events Recorded
  - Additional Damping Added to Achieve 0 Yielding Events
- Further Iterations to Reduce Strength and Stiffness of Structure

# DAMPING TRENDS

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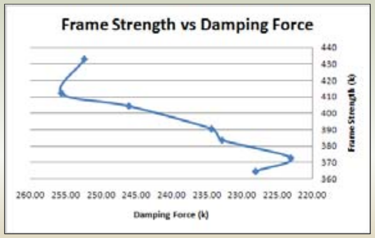


The Required Percent Critical Damping Always Falls at the Same Point Regardless of Strength

Continued Decreases in Frame Strength Eventually Result in an Increase in Required Damping

## PRELIMINARY CONCLUSIONS




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- Additional Damping is an Effective Means of Preventing Yielding During Earthquakes
  - Relatively Small Amount of Damping Required

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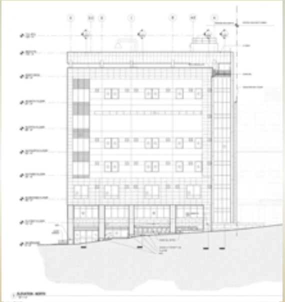
## DAMPER LAYOUT



## ARCHITECTURAL IMPACT

Dampers Cannot be placed in Loggia on Ground and 1st Floor

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## DAMPER LAYOUT

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Dampers Cannot be placed in Loggia on Ground and 1st Floor

Dynamic Soft Story Effect Requires Architectural Modification

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# DAMPER LAYOUT

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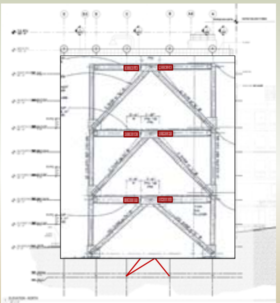

Courtesy of Haskell et al.

- Dampers Cannot be placed in Loggia on Ground and 1st Floor
- Dynamic Soft Story Effect Requires Architectural Modification
- Window Disruption Unavoidable Due to Constrained Interior Layout
- Possible Solutions
  - Use Different Brace Configurations
  - **Incorporate FVD's into Early Stage of Design**

## DISTRIBUTION OF DAMPING

## DAMPER IMPLEMENTATION

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| Damping Coefficent | | | |
|---|---|---|---|
| | Frame Damping Force (kips) | Number Required | Indiviual Damper Force (kips) |
| Frame A | 172.40 | 16 | 21.55 |
| Frame E | 223.05 | 16 | 27.88 |
| Frame 1 | 133.00 | 16 | 22.17 |
| Frame 7 | 120.73 | 16 | 20.12 |

Damping Force Distributed Through Structure in Parallel

NEHRP Requirements

- 2 Dampers per Floor, Configured to Resist Torsion

# DAMPING PROPERTIES

# DAMPER IMPLEMENTATION

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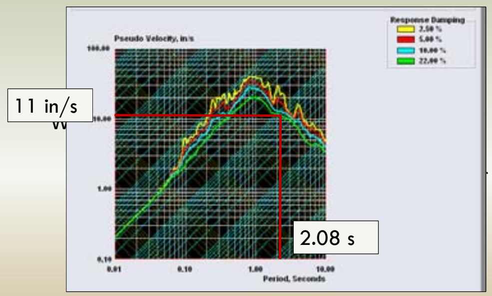


F - Based on Previous Requirements

C, α - Material Constants for Fluid

V - Max Velocity Found Using Response Spectrum

## DEVICE SELECTION

## DAMPER IMPLEMENTATION

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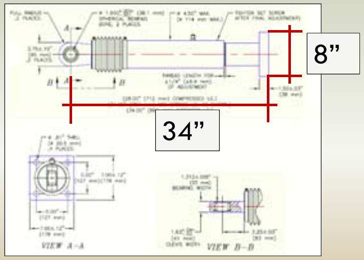


Taylor Devices, Inc. 55kip Capacity Fluid Viscous Damper

## COST IMPACT

## COST AND SCHEDULE IMPACT

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**Member Reductions**

| Frame | Columns (kips) | Cost ($) | Beams (kips) | Cost ($) | Savings ($) |
|---|---|---|---|---|---|
| Fra[illegible] | [illegible] | | [illegible] | | |
| Fra[illegible] | [illegible] | | [illegible] | | |
| Fra[illegible] | [illegible] | | [illegible] | | |
| Frame E | 18.71 | | 28.36 | | |
| Totals | 43.93 | 7939.89 | 41.99 | 11875.16 | 19815.05 |

| Dam[illegible] | [illegible] | C=F/V^α (k- | [illegible] | [illegible] | [illegible] |
|---|---|---|---|---|---|
| Frame A | 0.5 | 6.22 | 16 | 3600 | 57600 |
| Frame E | 0.5 | 8.05 | 16 | 3600 | 57600 |
| Frame 1 | 0.5 | 6.68 | 16 | 3600 | 57600 |
| Frame 7 | 0.5 | 6.07 | 16 | 3600 | 57600 |
| Total | | | 64 | | 230400 |

Total Cost = $210,585

Factors Affecting Cost
- Reduction in Lateral System
- Cost of Damper Devices
- Long Term Repair Costs

Schedule Impact
- Dampers Can Be Quickly Installed with Other Building Systems

# CONCLUSIONS

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Fluid Viscous Dampers Found to be an Effective Solution

Design Goals

- Prevent Yielding in MCE Event ✓
- Minimal Impact to Architecture ✗
- Low Cost of Implementation ✓

# ACKNOWLEDGEMENTS

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Craig Winters at Taylor Devices Inc.

My Family and Friends

# CONCLUSIONS

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## Questions and Comments