Team

Piero CM Stanford University
Mek SE University of Wisconsin Madison
Mary CM Loughborough University
Adrian LCFM Bauhaus University Weimar
Dimitris SE Technical University of Denmark DTU
Łukasz MEP Silesian University of Technology
Ada A Warsaw University of Technology
Owners

- Renate
- Sebastian
- Konstantinos
- Eeshan
- Karolina
- Tobias
TEAM CONNECTION
Navigating the Real and Virtual World

Navigating the virtual world from homes
Navigating the Real and Virtual world

Navigating the virtual world from quarantine

VR headset
Team Process – Platforms

Comunication

Collaboration

Coordination

OneDrive

Documentation Files

AUTODESK®

BIM 360™

Model Files

Collaboration

Fast Clashes!

AUTODESK®

BIM 360™ GLUE

Ideas!
VR Team Journey and Impact

Winter statistics

Spring statistics

Architect is using VR everyday for the final design!
The Role of VR in our Design

- Troubleshooting
- Owners meeting walkthrough
- Explaining ideas
- Design check/solving problems
CONNECTION TO THE SITE
Site Context

San Francisco State University Engineering Department

Sports facilities
Shopping center
San Francisco University Campus
Lake Merced & Golf fields

A: Let’s emphasize the view to the Lake!
Site Context - Architecture

Possible view opening
Main crossroad
Missing connection
Pedestrian flow
Possible view opening
Site Context - Construction

- Road access
- Existing retaining wall
- Restricted site area
- Road access
- Road access
- Height difference
- Winston Dr
- N State Dr
- High construction and labor costs
- Site and noise restrictions

Library – student center
Site Context - Environment

- Most windy side: West and North-West
- Average velocity: 10.5 mph

- Balanced temperature
- Hottest month: September
- 3 HVAC seasons: cooling, heating, only ventilation

https://klimaat.ca/epw/

Cooling Time
Heating Time

https://www.weather-us.com
## Site Context - Environment

### Insolation Table

<table>
<thead>
<tr>
<th>District</th>
<th>Zip Code</th>
<th>Insolation (kWh/m²/yr)</th>
<th>Expected AC output (kWh/yr per kW system)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(a)</td>
<td>(a)(0.67)</td>
</tr>
<tr>
<td>1</td>
<td>94121</td>
<td>1.531</td>
<td>1.026</td>
</tr>
<tr>
<td>2</td>
<td>94123</td>
<td>1.664</td>
<td>1.115</td>
</tr>
<tr>
<td>3</td>
<td>94133</td>
<td>1.679</td>
<td>1.125</td>
</tr>
<tr>
<td>4</td>
<td>94116</td>
<td>1.492</td>
<td>1.000</td>
</tr>
<tr>
<td>5</td>
<td>94117</td>
<td>1.694</td>
<td>1.135</td>
</tr>
<tr>
<td>6</td>
<td>94102</td>
<td>1.669</td>
<td>1.118</td>
</tr>
<tr>
<td>7</td>
<td>94116</td>
<td>1.524</td>
<td>1.021</td>
</tr>
<tr>
<td>8</td>
<td>94114</td>
<td>1.631</td>
<td>1.093</td>
</tr>
<tr>
<td>9</td>
<td>94110</td>
<td>1.689</td>
<td>1.132</td>
</tr>
<tr>
<td>10</td>
<td>94124</td>
<td>1.657</td>
<td>1.110</td>
</tr>
<tr>
<td>11</td>
<td>94134</td>
<td>1.671</td>
<td>1.120</td>
</tr>
<tr>
<td>average</td>
<td></td>
<td>1.627</td>
<td>1.090</td>
</tr>
</tbody>
</table>

Source: [https://www.sfog.us](https://www.sfog.us)

### Map of District Seven

[Map of District Seven showing the location of District Seven within San Francisco.]
Site Context - Environment

- Highest rainfall: December to February
- Driest time: June to August
- High humidity all over the year
Site Context – Soil Profile

**Soil Conditions**

- Well sorted fine to medium sand
- Bearing Capacity: 3500 psf
- Not in Liquefaction Zone
- Water Table: 14' below grade

![Soil Profile Diagram]
Earthquake hazard

Risk Category: III

ASCE7-16: "Building and other structures, the failure of which could pose a substantial risk to human life."
CONNECTION BETWEEN WINTER AND SPRING
Concept Evolution

1. CONNECTING THE DOTS
   - Analysis of given dimensions

2. CONNECTING THE STREETS
   - Connecting the street levels
   - Adding floor height for better interior perception

Entrance from Winston Dr

Entrance from N State Dr

STANFORD

STANFORD
Concept Evolution

Kinetic facade

The Connection
- Lake view from atrium
- Resilience
- Water collection
- Using nature for sustainability
- Rocking walls vs earthquake

The Circulation
- Open workspaces for students
- Green walls
- Living walls

CRIT

WINTER PRESENTATION
Concept Evolution

CONNECTING THE AREAS
- Expanding the cantilevers
- Integrating the terraces

CONNECTING THE VIEWS
- Emphasizing the atrium
- Passage of view

Increasing sustainability
- PV panels farm instead of skylight on the roof
- UFAD System
- Efficient glazing
- Prefabrication

OWNERS MEETING
26th April

Integrated facade system
Connection to…

Community

LEARN

COLLABORATE

SERVE THE COMMUNITY
Connection to...

Community

Nature

LEARN

COLLABORATE

SERVE THE COMMUNITY

BE SUSTAINABLE

BE RESILIENT

BE INNOVATIVE
Connection to...

Community

Nature

Data

LEARN

COLLABORATE

SERVE THE COMMUNITY

BE SUSTAINABLE

BE RESILIENT

BE INNOVATIVE

DESIGN

CONSTRUCT

OPERATE
Connection to Community

LEARN

COLLABORATE

SERVE THE COMMUNITY
Goal 1: Connection to Community

Locally → Globally

UNIVERSITY COMMUNITY

Learn
Collaborate
Sustainable working conditions

NEIGHBORHOOD

Support
Offer
Coliving community
University Community

Faculty member

Learn
- Lectures
- VR classes

Collaborate
- Teamwork
- Digital education

Work
- Offices
Meeting Spot
Level 0 Floor Plan

Level 0

- Atrium
- Café with support area
- Auditorium
- Large classrooms
- Small classrooms
- Staircase
- Toilets
- Communication
Café

- Additional income
- Insurance during a lockdown
- 718 sqf with support area
- Nature atmosphere – living wall
Café

✓ Extension to the Plaza
✓ Inside – outside connection
Lecture in Auditorium

- Digital education
- Acoustic ceiling panels
Lecture in Auditorium

- Terraced floor
- Rentable area
Auditorium Floor Sandwich

- 9'
- 8'9"
- 22'
Outdoor Lecture Space

- Multifunctional space
- Outdoor lecture
- Part of the tours
- In the evening – outdoor cinema
Providing Shelter – Advantages & Measures

**Advantages**
- Facilities (kitchen, bathrooms) are available
- Fresh air through installed sensors
- Guaranteed supply of water and electricity

**Measures**
- Quick adjustment of air flow/quality through
- Separation of air flow from other parts of the building
- Automated disinfection through Ultra Violet Disinfection robot
- Insurance against loss of rent during lockdown

© http://www.uvd-robots.com/
Level –1 Floor Plan

- Large Classroom
- Storage
- Mechanical rooms
- Staircase
- Communication
Break in Atrium

- Main meeting space
- Collaboration space

Collaborate
Break in Atrium

✓ ‘Sit & walk & enjoy the view’ staircase
✓ Main meeting space
Break in Atrium

- Low e glazing = 0.2
- Low Visual Light Transmittance = 0.37
Level +1 Floor Plan

Level +1

- Open workspaces
- Seminar room
- Faculty offices
- Student offices
- Instructional labs
- Small classrooms
- Staircase
- Toilets
- Communication
Spaces for Collaboration

- Individual work spaces

Collaborate
Flexible spaces for collaboration

✓ Open workspace
✓ Individual desk/ combined desks / team rooms / conference rooms
Flexible spaces for collaboration

✓ Flexible seminar rooms
✓ Adjusted to needs and type of class
Passive Cooling

- Equal office dimensions
- Passive cooling for better air conditions
- UFAD system
MEP System

Primary system
- Reverse Air Heat Pumps

Secondary system
- Displacement ventilation
  - Fan coils – 4 pipe system
  - Heat/cooling recovery

✓ High effective system
✓ Flexibility
✓ Individual control
Reverse Air Heat Pump
✓ One devices to ensure correct temperature
✓ High effective device
✓ Environmentally friendly – no CO2 emission
✓ Taking less space than Ground Heat Pumps
✓ Low operating costs
✓ Powered by energy from PV panels
Secondary System

Displacement ventilation
✓ Highly effective
✓ Better thermal comfort
✓ Air distributed directly to occupancy zone
✓ Reducing volume of air to heat/cool

Fan coil system
✓ Individual temperature for each space
✓ High effective devices
✓ Located under raised floor - invisible

✓ Supply ducts
✓ Exhaust ducts
✓ Fan coils
## Shared Profit with Student Communities

<table>
<thead>
<tr>
<th></th>
<th>Best Case</th>
<th>Base Case</th>
<th>Worst Case</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Costs</strong></td>
<td>- 10%</td>
<td>Normal economic situation</td>
<td>+ 10%</td>
</tr>
<tr>
<td><strong>Rent</strong></td>
<td>+ 10%</td>
<td>- 10%</td>
<td></td>
</tr>
<tr>
<td><strong>Discount rate</strong></td>
<td>- 5%</td>
<td>+ 5%</td>
<td></td>
</tr>
</tbody>
</table>

**Rent:** $1 m per year

<table>
<thead>
<tr>
<th></th>
<th>Best Case</th>
<th>Base Case</th>
<th>Worst Case</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STV (Water + Energy cost)</strong></td>
<td>$ 250.000</td>
<td>$ 270.000</td>
<td>$ 300.000</td>
</tr>
<tr>
<td><strong>TVD (Target construction cost)</strong></td>
<td>$ 11.600.000</td>
<td>$ 12.200.000</td>
<td>$ 12.800.000</td>
</tr>
<tr>
<td><strong>LCC (25 years)</strong></td>
<td>$ 34.900.000</td>
<td>$ 36.200.000</td>
<td>$ 37.500.000</td>
</tr>
<tr>
<td><strong>NPV - After Financing and Tax</strong></td>
<td>$ 3.300.000</td>
<td>$ 1.700.000</td>
<td>$ 100.000</td>
</tr>
<tr>
<td><strong>Break Even in Year</strong></td>
<td>2030</td>
<td>2034</td>
<td>2043</td>
</tr>
</tbody>
</table>

10% of profit is donated to student communities
Connection to Nature

BE SUSTAINABLE

BE RESILIENT

BE INNOVATIVE
Connection to Nature

CHALLENGE: Earthquake

Sustainable

Resilient

Superstructure:
Gravity:
- Glulam columns & beams
- CLT Panels with 1 ½” Gypcrete topping

Lateral:
- CLT rocking walls
Rocking Wall System

Self-centering capability provided the PT tendon

Earthquake energy dissipated by replaceable Krawinkler fuses – wall remains undamaged

✓ Resilience
Rocking Wall System

Connection to the diaphragm -
Design depends on target displacement

PT tendon
Krawinkler fuses
Glulam column
Steel bracket

Level 1
Level 2
Level 3
Structural Health Monitoring

- Strain gauges on Krawinkler fuses
- Check for excessive deformations
- Load cells at PT tendons' anchors
- Can re-tension tendons from roof

Resilience
Rocking Walls - Landlord Insurance

✓ Biggest natural hazard: earthquake
✓ Rocking walls are necessary to get a landlord liability insurance
✓ Insurance covers costs for reconstruction up to $5 m.
✓ Insurance covers loss of rent during reconstruction

© Swiss RE, NatCat Risk Assessment Report
Criteria for Crane Selection

Capacity: 7,100 lb to 13,200 lb
Min. 100 ft tall

Capacity: 7,900 lb to 42,300 lb

150 ft
123 ft
76 ft
Structural Framing Plan - Substructure

Concrete column  ■  12"x12"
Concrete beam  ■  12"x20"
Concrete shear wall  ■  12” thick
Concrete retaining wall  ■  12” thick
Strip footing  ■  18” thick
Combined footing  ■  18” thick
Structural Framing Plan - Level 0

- **Glulam column**
  - 10”x10”
  - 12”x12”

- **Glulam girder**
  - 6 3/4" x 13.5”
  - 7” x 27”

- **Flitch girder**
  - 7” x 22.5”
  - 7" x 13.5"

- **CLT rocking walls**
  - 8" x 8’-8”
Auditorium Case – Flitch Beams

钢材

木材

A

Ada

Gyyyyy, we need to do something about these deep beams in the auditorium

SE

Dimitris & Mek

hmmmm, how about Flitch beams??!

$$E_{steel} \approx 16 \cdot E_{wood}$$
Site Layout – Construction Plan

- ZONE 1
- ZONE 2
- ZONE 3

Winston Dr
N State Dr

North

Legend
- Fence
- Footprint
- Flatbed Truck
- Waste area
- Stairs
- Material Laydown
- Parking area
- Site Office
- Toilet
- Crane position
- Crane Radius

3D View
Structural Framing Plan - Level 1 & 2

Glulam column
- 10"x10"
- 12"x12"

Glulam girder
- 6 3/4" x 13.5"

Glulam brace
- 6 3/4" x 13.5"

Flitch girder
- 7" x 27"
- 7" x 22.5"
- 7" x 13.5"

CLT rocking walls
- 8" x 8'-8"
Standardized Structural Members

<table>
<thead>
<tr>
<th>Element</th>
<th>Size</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glulam column</td>
<td>10&quot;x10&quot;</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>12&quot;x12&quot;</td>
<td>181</td>
</tr>
<tr>
<td>Glulam girder</td>
<td>6 3/4&quot; x 13.5&quot;</td>
<td>264</td>
</tr>
<tr>
<td></td>
<td>7&quot; x 27&quot;</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>7&quot; x 22.5&quot;</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>7&quot; x 13.5&quot;</td>
<td>12</td>
</tr>
<tr>
<td>Flitch girder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLT rocking walls</td>
<td>8&quot; x 8'-8&quot;</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Element</th>
<th>Size</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLT Panels</td>
<td>19' x 9.5'</td>
<td>108</td>
</tr>
<tr>
<td></td>
<td>28.5' x 9.5'</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>16' x 9.5'</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>9.5'x 4' 7&quot;</td>
<td>2</td>
</tr>
</tbody>
</table>
Typical Connection Details

Beam to beam & beam to column

Source: Rothoblaas Alumaxi

Column to column & column to concrete

Source: Rothoblaas Pillar
Typical Connection Details

Source: Simpson Strong-Tie CCCQ

Source: Structurlam

Source: Rothoblaas SHARP 501200H

Continuous beams

CLT Panel to Panel

CLT Panel to beam
Connection to Nature

CHALLENGE: Water scarcity

- innovative
- sustainable
- resilient

Integrated facade system for water collection
Facade

- Harvesting water from fog
- Modular click-in-place construction
- Openable windows for cleaning and maintenance
- Integrated water gutter connected with pipes along the columns
- Water flow to 2 water collectors on site

© https://aaqr.org/articles/aaqr-17-01-fog-0040.pdf
Fog Catcher

✓ Most windy side: West and North - West
✓ Average velocity: 4.7 m/s

✓ Harvesting fog mostly whole year
✓ Most efficient in morning and afternoon
✓ North + West – efficiency increased by wind flow
✓ East – morning fog
Water Collection

- Rainwater collection: 272,712 gal/year
- Fog catcher: 293,858 gal/year
- Greywater collection: 194,384 gal/year
- Reducing water consumption by 80%

- Drainage system
- Roof water
- Fog catcher
Facade

Fog catcher as shading system

**BEFORE**

Cumulative Insolation

410 000 kWh

170 kWh/m²

Study Settings:

2 404 m² selected

1-1 to 12-31 sunrise to sunset

**AFTER**

Cumulative Insolation

298 000 kWh

124 kWh/m²

Study Settings:

2 404 m² selected

1-1 to 12-31 sunrise to sunset
# Shading Analysis

<table>
<thead>
<tr>
<th>Time</th>
<th>20th of June</th>
<th>21st of December</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00 AM</td>
<td>Morning sun on NE</td>
<td>Morning sun on SE</td>
</tr>
<tr>
<td>3:00 PM</td>
<td>Highly lit Atrium</td>
<td>Highly lit Atrium</td>
</tr>
</tbody>
</table>

- **20th of June**: Morning sun on NE, Highly lit Atrium
- **21st of December**: Morning sun on SE, Highly lit Atrium
Facade

Structure integrated with the facade system

3/8" thick steel angle
Facade Module Assembly

A+SE+C Collaboration

STRUCTURE

CLAD ED PANELS
WOODEN FRAMES
WOODEN SOLID PANELS

FACADE ASSEMBLY
1st STAGE
PACIFIC 2020
Supplier Location and Logistics

- Construction Site
- Timber Suppliers
- Concrete Suppliers
- Connection Suppliers
- Rebar Suppliers
- Union Labor
- Equipment Suppliers
### Risks and Rewards

<table>
<thead>
<tr>
<th>WHAT?</th>
<th>RISKS</th>
<th>REWARDS</th>
<th>IMPACTS</th>
<th>WHOM?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facade with fog catcher</td>
<td>Water proofing, re-work, transportation, too many stakeholders' involvement</td>
<td>Robust quality testing, faster installation, fewer workmen</td>
<td>Construction process</td>
<td>Environment, Construction process, Clients and Users</td>
</tr>
<tr>
<td>Pre assembly of Glulam structure; CLT panels and interior walls</td>
<td>Fire rating, transportation, phyto contamination</td>
<td>Lesser emissions during production and transportation, faster installation, lesser O&amp;M costs</td>
<td>Environment, Construction process, Clients and Users</td>
<td>Clients and users</td>
</tr>
<tr>
<td>Bathroom pods</td>
<td>MEP Flooding and earthquake</td>
<td>Higher production precision and lesser waste and time</td>
<td>Environment, Construction process, Clients and Users</td>
<td>Clients and users</td>
</tr>
</tbody>
</table>
Shared Risks and Rewards

✓ IPD agreement

Risk for owners

Reward for owners

Reward for team

Risk for team
Supply Chain Management

- Elements tagged
- GPS tracking
- Quantity inspection
- Construction
- Billing
- Post construction

Kit of parts for assembly line

- Elements
- Connections
- Module
Connection to Nature

CHALLENGE: Traffic pollution

CHALLENGE: Electricity gain

Innovative
Resilient
Sustainable

Integrated green system

LIVING WALL

ROCKING WALL

GREEN WALL
Green Walls

✓ Absorbs CO₂ from the polluted air caused by traffic and fire.
✓ CO₂ consumption: 2,847,987.50 kg CO₂/year
✓ Watered by moisture and humidity from the air
✓ Area: 161 m²
Living Walls

✓ Produce electricity for plug load
✓ 4 W/m²

Per day it can fully charge:
✓ 500 smartphones
✓ 300 laptops

✓ Clean indoor air
✓ Natural indoor cooling
Connection to Nature

CHALLENGE: Electricity gain

Innovative
Resilient
For community

PV farm on the roof

Coliving community
Solar Analysis

View from South West

SOLAR ANALYSIS

View from South East

View from North West

View from North East
Number of PV panels: 376
Power: 169 kW
Produced electricity: 271,000 kWh/year
PV panel efficiency: 22%
Power of each panel: 450 W
Area of one panel: 22 ft²
Energy Consumption Optimization

- Using high insolated solid panels
- Fog catcher as a shading system
- Reducing glazed area
- Using low E glass
- Designing LED lights in every room
- Adding daylight control sensors
- Choosing high effective Air Heat Pump
Energy Consumption

✓ Energy consumption: 58 kWh/m²/year
✓ Area of the building: 3173 m²
✓ Annual energy consumption: 184 000 kWh/year

✓ Produced energy: 271 000 kWh/year
✓ Consumed energy: 184 000 kWh/year
✓ Remaining energy: 87 000 kWh/year
Energy Consumption

✓ Free charging of electric cars for university community

✓ Energy to the neighborhood in case of blackout

Produced energy:

271 000 kWh/year

✓ 68% is required to cover the energy demand of the building

✓ Consumed energy:

184 037 kWh/year
Energy Storage

- Energy storage per each battery: 13.5 kWh
- Number of batteries: 68
- Stored energy: 918 kWh
- Average energy consumption: 504 kWh/day
- How long can we power building from batteries: 2 days
STV Analysis

Life Cycle Assessment Results Overview

Performance Relative to Life Cycle Impact Targets

<table>
<thead>
<tr>
<th>Impact</th>
<th>Target</th>
<th>Project</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon (kgCO2e)</td>
<td>3 714 897</td>
<td>-1 137 712</td>
<td>-31%</td>
</tr>
<tr>
<td>Energy (MJ)</td>
<td>120 909 807</td>
<td>-4 061 723</td>
<td>-5%</td>
</tr>
<tr>
<td>Water (kgH2O)</td>
<td>73 347 945</td>
<td>66 889 066</td>
<td>91%</td>
</tr>
<tr>
<td>Ozone (kgCFC11c)</td>
<td>-</td>
<td>5.9E-02</td>
<td>-</td>
</tr>
</tbody>
</table>

- Carbon negative
- Energy negative

How we met the target?

- PV panels located on the roof
- High effective sanitary equipment
- Collecting water from rain, fog catcher and reuse the greywater
- Using timber as the main building material
- Green Walls with CO2 consumption
STV Analysis

STV Optimization

GWP reduced by green walls
Energy reduced by PV
Break-even Analysis

- Earlier break even without PV/Batteries and Fog catcher
- PV/Batteries and Fog catcher have high intangible value
### Value for Money

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>CONNECTION - without PV/batteries</th>
<th>CONNECTION - server instead cloud</th>
<th>CONNECTION - without fog catcher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside/Outside connection</td>
<td>★★★★★</td>
<td>★★★★★</td>
<td>★★★★★</td>
</tr>
<tr>
<td>Serve for community and users</td>
<td>★★★★★</td>
<td>★★★★★</td>
<td>★★★★★</td>
</tr>
<tr>
<td>Educational purpose</td>
<td>★★★★★</td>
<td>★★★★★</td>
<td>★★★★★</td>
</tr>
<tr>
<td>Natural hazards approach</td>
<td>★★★★★</td>
<td>★★★★★</td>
<td>★★★★★</td>
</tr>
<tr>
<td>STV (water + electricity)</td>
<td>$0.27 m ★★★★★</td>
<td>$1.9 m ★★★★★</td>
<td>$0.27 m ★★★★★</td>
</tr>
<tr>
<td>TVD (target construction cost)</td>
<td>$12.2 m ★★★★★</td>
<td>$11.2 m ★★★★★</td>
<td>$12.2 m ★★★★★</td>
</tr>
<tr>
<td>NPV</td>
<td>$1.7 m ★★★★★</td>
<td>$2.4 m ★★★★★</td>
<td>$1.4 m ★★★★★</td>
</tr>
<tr>
<td><strong>VALUE FOR MONEY</strong></td>
<td>★★★★★</td>
<td>★★★★★</td>
<td>★★★★★</td>
</tr>
</tbody>
</table>
Connection to Data

DESIGN

CONSTRUCT

OPERATE
Determination of Gravity Loads

- Superimposed deadload of **15 psf**
- **LRFD** with load combination **1.2D + 1.6L** governing strength design

Source: ASCE 7-16

### Typical Live Load (psf)

- **Classrooms**: 40 psf
- **Offices**: 50 psf
- **Auditorium & bathrooms**: 60 psf
- **Corridors above 1st floor**: 80 psf
- **Large Classroom**: 100 psf
- **1st floor corridors**: 100 psf
- **Staircase**: 100 psf
- **Mechanical & storage**: 125 psf
Gravity Load Path

Gravity load  Transfer load  Compression

123'6"

9'6"

PACIFIC 2020 100
Gravity Load Analysis

- Typical girder width increased from 5 1/8” to 6 3/4”
- Columns supporting auditorium beams side length increased from 10” to 12”
- Serviceability load combination D+L
- Deflection limit of L/240 (L/120 for cantilevers)
Modal Analysis

Mode 1:

Mode 2:

Mode 3:

<table>
<thead>
<tr>
<th>Mode</th>
<th>Effective Modal Mass Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ux</td>
</tr>
<tr>
<td>1</td>
<td>0.564</td>
</tr>
<tr>
<td>2</td>
<td>0.216</td>
</tr>
<tr>
<td>3</td>
<td>0.028</td>
</tr>
</tbody>
</table>
Lateral Load Path

Lateral load  Transfer load  Compression  Tension
CLT Panel: Equivalent braced frame (HSS 5x5x1/2)

Krawinkler fuse: MultiLinear Plastic Link with nonlinear properties in the vertical direction

PT Tendon: Modelled as a load with the tendon’s material properties

Uplift movement: Gap support – very stiff in compression, zero stiffness in tension
Nonlinear Time History Analysis

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>Site Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>III</td>
<td>C – Very dense soil and soft rock</td>
</tr>
</tbody>
</table>

Nonlinear time history analysis

Scaled response spectra

Selected ground motions

Mean maximum story drift & vertical displacement
Nonlinear Time History Analysis

<table>
<thead>
<tr>
<th>Ground motion</th>
<th>Max story drift (in)</th>
<th>Uz (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>El Centro</td>
<td>-1.43</td>
<td>0.83</td>
</tr>
<tr>
<td>San Fernando</td>
<td>-1.34</td>
<td>0.77</td>
</tr>
<tr>
<td>Corinth</td>
<td>1.53</td>
<td>0.88</td>
</tr>
<tr>
<td>Loma Prieta</td>
<td>1.48</td>
<td>0.81</td>
</tr>
<tr>
<td>Duzce</td>
<td>1.14</td>
<td>0.61</td>
</tr>
<tr>
<td>Northridge</td>
<td>1.19</td>
<td>0.69</td>
</tr>
<tr>
<td>Darfield</td>
<td>1.51</td>
<td>0.80</td>
</tr>
<tr>
<td><strong>Average value</strong></td>
<td><strong>1.37</strong></td>
<td><strong>0.77</strong></td>
</tr>
</tbody>
</table>

Story drift < 0.02 \cdot h_{story} = 3.36”

Mean maximum uplift of the rocking wall
Nonlinear Time History Analysis

Modification factor = 20

Joint with Maximum displacement

Loma Prieta, 1989

max $U_x = 3.75''$
Construction Schedule

Project Duration: 246 Calendar Days – 36 Weeks.

Project Start Date: 15th August 2024

Project Finish Date: 18th April 2025

Total Construction Cost: ~ $ 12.0 M
4D Simulation
Logistical Bottleneck

Installation of Façade and interior work
Construction Schedule

**Project Duration**: 300 Calendar Days – 43 Weeks.

**Project Start Date**: 15th August 2024

**Project Finish Date**: 11th June 2025

**Total Construction Cost**: ~ $12.2 M

Infinite Resources

---

*Image depicting a scatter plot with 'Time in Calendar Days' on the x-axis and 'Cost x $1000' on the y-axis, illustrating the project timeline and costs. The graph shows a trend with a focus on 'Infinite Resources'.
Model Based Cost Estimation

BIM MODEL

Quantity Take-Off

COST DATABASE

QTO ESTIMATING

RSMeans data from GORDIAN

PACIFIC 2020 113
Construction Cost Tracking

**TVD - TRACKING OVER TIME**

- **Target** = $11,900,000
- **Model at 80% cost estimation based on model and assumptions**
- **Wind turbine façade** -> Fog catcher façade
- **Model at 100%**
- **Increased area of fog catcher façade**
- **Inclusion of Tesla Batteries**
- **Conversion of rocking walls to green walls**
- **Fog catcher rates and area**

- **Fishbowl**
- **22 Apr**
- **Spring...**

- **$12,200,000**
- **$11,500,000**
- **$10,200,000**
- **$10,000,000**
- **$9,600,000**
- **$9,400,000**
- **$10,990,000**
- **$11,900,000**

**TARGET = $11,900,000**
Construction Cost Comparison

Spring Presentation
- $826,000

22-Apr
- $1,480,000

Fishbowl
+ $949,000

Winter Presentation
+ $788,000

TARGET = $11,900,000
LEED Certification

✓ Collected points: 81
✓ LEED PLATINUM CERTIFICATION

https://www.bdcnetwork.com
https://millennialmagazine.com
TVD – STV – LCC Connection with @Risk

- Monte Carlo simulation
- Tornado diagram shows effects of variables on NPV
- STV: Low impact of water & electricity cost
- TVD: biggest impact
✓ Risk map after risk management shows only risks for which we are responsible
✓ Main risk strategies:
  1. Avoid: use of software, fixed interest rates
  2. Transfer: construction companies or planners, insurances
  3. Mitigate: use of digital twin
Summary of Challenges
Expect the Unexpected

Be a shelter during earthquake
Reduce CO2
Collect water
Produce and store energy
Clean air
Give shelter!

Earthquake resilient
Water scarcity
Energy Plus Building
Cleaning air from pollution
Pandemic resilient

Carbon Neutralizing Materials - structure
Rocking walls
Collecting water from Fog Catcher, Water from roof, Water on side
PV farm
Energy storage
Living walls
Green walls
Contribution and support for community

Produce energy for neighbors
Financially Resilient - Covenants

- Loan Life Cover Ratio (LLCR) based on ratio of cash flow to outstanding loan
- Debt Service Cover Ratio (DSCR) based on ratio of cash flow to debt service
- No breach of covenants

- Enough buffer
- Less risk of increasing costs
DPR Challenge – To industrialize what?

- Facade module without fog catcher
- Pre-assembly of Glulam beams, columns; CLT Panels and Interior partition walls
- Reduced on-site incidents & fatalities
- Waste reduction
- 4 weeks reduction and schedule certainty
- Lower LCFM costs
- Reliable data source for digital twin
- 4 weeks reduction and schedule certainty
- Waste reduction
- Reduced on-site incidents & fatalities
- Lower LCFM costs
- Reliable data source for digital twin
- Pre-assembly of Glulam beams, columns; CLT Panels and Interior partition walls
Buro Happold Challenge – Digital Twin

**Digital Twin**
- Connects physical and virtual building
- More than a tool for data storage or BIM
- Addition of live data increases user experience
- Improves functionality

---

**Data Integration**

**Without Digital Twin**
- Design data

**With Digital Twin**
- Build data
- Finance data
- Maintenance data
- Operation data

- Life cycle data
VISION MOCK-UP SCENARIO IN CASE OF AN EARTHQUAKE

- CREATED FROM TEAM PACIFIC FOR AEC GLOBAL TEAMWORK 2020 -

http://pbl.stanford.edu/AEC%20projects/projpage.htm

✓ Use of Digital Twin during operation phase
✓ Combination of virtual and physical walkthrough
✓ Goal: reduce time to repair the building
Lessons Learned

“Brainstorming collaboratively is the best tool in order to achieve something great.”

“One little thing can change everything what you done before.”

“Listen with the intent to understand, then question!”

“It doesn’t matter, if you’re 3m or 30000km from each other. We are everywhere at the same time.”

“You can have a great design but you need an even better story.”

“Efficient technology can close the loop between all disciplines.”

“Sometimes you need to take a step back and rethink everything.”

“Sometimes you need to take a step back and rethink everything.”
THANK YOU

Renate Fruchter
Karolina Ostrowska
Sebastian Enevoldsen
Konstantinos Koutsoupakis
Eeshan Shah
Tobias Oberlein

Greg Luth
Prashant Sharma
Erik Kneer
Norayr Badasyan
Tim-Tarek Fergin
Plamen Ivanov
Forest Peterson
Forest Podva
Glenn Katz
John Nelson
Joseph Hewling
Ewa Kunkel
Justin Schwaiger
David Bendet
Daniel Cohen
Adrian’s wife

Peter Trautwein
Sylvia Marczyk
Kosuke Horigome
Varun Gupta
Sara Pearce-Probst
Adhamina Rodriguez
Mazen Faloughi
Humberto Cavallin
Brian Bessenaire
Sven Steiger
Nick Arenson
Tim Schrotenboer
Ana Kragelj
Adam Pekala
Rene Morkos
Robert Dallmann