Nonstructural Issues in Essential Facilities

California Hospitals
Sutter Health – CPMC Van Ness Geary
Case Study

R. Jay Love, SE
Sutter CPMC Van Ness Geary Campus Hospital

- 13 Story + 2 basement high-rise hospital in San Francisco, 11 km from the San Andreas Fault
- 1.15 Million Square Feet
- Essential Facility
- Steel Special Moment Resisting Frame superstructure designed for strength
- Supplemental Viscous Wall Dampers to control seismic drift
- Integrated Project Delivery Method

February 12, 2011
Integrated Project Delivery

• Integrate Project Delivery Team
  • 3-way contract between Owner, Architect, and Contractor
  • Risk/Reward Pool with 16 Trade Partners
    • 100% of profit at risk
    • 40% additional shared incentive available.
    • Three major trades account for over 2/3 of total cost
      • General Contractor
      • Electrical Subcontractor
      • Mechanical Plumbing Contractor
  • Design Team
    • Architect, Structural, MEP, Technology, Medical Planning
The Hospital Challenge

• Designing, revising, approving and constructing non-structural bracing for a California hospital under a full-speed ahead construction schedule.

• It’s a complicated process with many moving pieces
  • Technical approaches to simplify the process
  • Process approaches to simplify the process
The hospital is completely designed, coordinated, and agency-approved prior to start of construction.

California regulates the process through California Administrative Code, or C.A.C, Chapter 7 – Safety Standards for Health Facilities.
• Large hospitals can take 10 years to design and build
  • The design changes over such a long time.
  • Technologies change
  • Equipment changes

• Incremental design & approval
  • Site work and structural drawings prepared and permitted in advance of Interiors, Exteriors, Medical Equipment packages.
  • Design and coordination between Increments are essentially incomplete. This will haunt you during construction.
Coordination of Changes with Construction

• How does design/change management process fit in with actual construction?
  • Production Planning
  • Work Flow – TAKT timing
Integrated Project Delivery

• Allows for true production planning and supply chain optimization

• Greater opportunity to systematically control capacity and maximize flow

• Always think of the project as a production system

Courtesy of Klaus Berghede, Boldt Construction
Set project expectations

Integrate safety into Standard Work Processes

Deliver

Maintain rules, manage demands

Set project expectations

Establish Expectations

Safety Flow

Material Flow

Master Schedule

Production Planning

Phase Planning

Production Strategy

Sequence & Flow Analysis

Define Production Areas

Lookahead

Final scan for constraints, commit

Daily Production

Train & Execute

Review Actuals vs Planned

Action

10 – 0 Days

Make Ready

30 – 5 Days

Track Actual Hours per Production Areas Weekly

Action

10 – 0 Days

Allocate estimated labor hours to production areas

Establish Metrics with TP

Develop BIQ Process

Set Expectations for Production Tracking with TP

Tracking Flow

BIQ/Information Flow

Establish Expectations

Develop BIQ Process

Establish Metrics with TP

Develop Process ~ 120 Days

Review and Optimize 120 – 30 Days

Ensure durations are included in schedule

Engineering & Procurement

Make Ready 30 – 5 Days

Review and Optimize 120 – 30 Days

Make Ready 30 – 5 Days

Develop BIQ/Information Flow

Set Expectations

Set Expectations for Production Tracking with TP

Material Flow

Safety Flow

Set Expectations

Fabricate per production plan/areas

Onboard and train workforce

Pretask planning, be aware & safe

Train & Execute

Complete Installation Manuals/Visuals/Checklists/Videos

Complete Installation Manuals/Visuals/Checklists/Videos

Set Expectations

Set project expectations

Integrate safety into Standard Work Processes

Deliver

Maintain rules, manage demands

Set project expectations

Establish Expectations

Safety Flow

Material Flow

Master Schedule

Production Planning

Phase Planning

Production Strategy

Sequence & Flow Analysis

Define Production Areas

Lookahead

Final scan for constraints, commit

Daily Production

Train & Execute

Review Actuals vs Planned

Action

10 – 0 Days

Make Ready

30 – 5 Days

Track Actual Hours per Production Areas Weekly

Action

10 – 0 Days

Allocate estimated labor hours to production areas

Establish Metrics with TP

Develop BIQ Process

Establish Expectations for Production Tracking with TP

Tracking Flow

BIQ/Information Flow

Establish Expectations

Develop BIQ Process

Establish Metrics with TP

Develop Process ~ 120 Days

Review and Optimize 120 – 30 Days

Ensure durations are included in schedule

Engineering & Procurement
TAKT PLANNING: FLOW

- All cars physically fit on the road

- If we could all just set our cruise control to 30 Mph....
TAKT IN CONSTRUCTION

(1) Each floor is broken up into areas with similar amount of scope

(2) Each discipline has one week to complete each area

(3) Only one trade occupies an area at the same time

(4) All disciplines’ material is delivered to ‘their’ work area only

(5) All disciplines complete and move to the next area every Friday
A train that runs through the project:

- The railway track outlines the area sequence the team is set to follow.
- Each train car is one discipline.
- Speed of the train is set by the lead car.
- All cars are connected and move together in the required sequence.
- All cars moving through the areas at the same pace in a finish to start order.
# TAKT AT VNGC

<table>
<thead>
<tr>
<th>Floor</th>
<th>L4</th>
<th>L5</th>
<th>L6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Takt</td>
</tr>
<tr>
<td>Work</td>
<td>Takt</td>
<td>Takt</td>
<td>Taki</td>
</tr>
</tbody>
</table>
• How does Immediate Occupancy affect design assumptions?
  • Increased Seismic bracing forces
  • Equipment seismic certification to assure equipment required for continued operations will remain operational after the Design Earthquake.

• Construction Administration
  • Only Approved work can be installed.
• Preparation of Construction Documents
  • Structural Engineer of Record – required for all Acute Care Projects unless
    • Alterations or repairs that do not affect structure may be done by Mechanical, Electrical, or Civil where the work done is normally performed by other disciplines
  • SE shall sign and affix every sheet of drawings affecting structural work
    • Notation to indicate SEOR’s role in preparing or reviewing the document
  • All construction documents shall be signed and stamped **prior** to issuance of a building permit or approval of amended construction documents.
• “All architects and engineers to whom responsibility has been delegated … as listed on the application shall observe the work of construction for their portion of the project.” (CAC 7-141)
“Work shall be executed in substantial conformance with the construction documents approved by the Office.”

- Changes in the work shall be made by amended construction documents (ACDs) approved by the office.
- Only changes that materially alter the work shall be submitted to the Office for review.
- All amended construction documents shall be approved by the office prior to installation of the work.

- What does “materially alter” mean?
- Change process during construction critical to schedule.
Changes to the Approved Work

• “Shall be executed in substantial conformance with the construction documents approved by the Office.”
  • Correction of errors in design
  • Changes in scope

• Amended Construction Documents, or ACDs.
  • Submittal for review required for changes that materially alter the work
  • All ACD shall be approved by the Office prior to installation of work.
Changes to the Approved Work

• Non material changes
  • Clarification and interpretation of plans and specifications by responsible design professional.
    • If calculations by SEOR ... are necessary to determine structural or non-structural adequacy, an ACD submittal must be made.
  • Construction means and methods
    • Sequencing, coordination of work and methods of assembly/construction.
  • Substitution of equivalent equipment, products or materials
  • New details based on other approved details, in whole or in part. Reference to approved details must be shown.
OSHPD Preapproved systems/details

• Preapproval of Manufacturer’s Certification (OPM)

• Special Seismic Certification Preapproval (OSP)
  • “Active” equipment/components listed in CBC section 1705A.13.3 – Moving, rotating parts, electrical switches/relays or other internal components sensitive to earthquake forces and critical to function of equipment
  • Testing provided by independent approved laboratory

• OSHPD Preapproved Details (OPD)
  • Standard Partition Wall Details
  • Standard Suspended Ceiling Details.
ACD Review Process

• Weekly meetings with OSHPD District Structural Engineer
  • SEOR
  • Architectural
  • Contractor
  • Inspector of Record

• Review ACDs
  • Includes all revisions due to Material changes
  • OSHPD Sign off and logging changes into OSHPD database

• Review Non-material Change RFIs
• Component forces and interstory drifts
  • Based on primary structural analysis
    • Nonlinear Response History Analyses with seven ground motions
  • Acceleration and Interstory drift values shown and approved on the Increment 2 documents
  • Values available for use for Exterior, Interior, Medical equipment anchorage engineering and design
Non-structural Components

• Chapter 13 – ASCE 7
  • Importance Factor, \( I_p = 1.5 \) if;
    • Component required for life safety purposes after an earthquake, or
    • Conveys or supports toxic, explosive, or hazardous substances, or
    • Located in a Risk Category IV structure and needed to continue operation of the facility
  • Seismic Design Forces on components, \( F_p \)
  • Seismic Relative Displacements, \( D_{pl} = D_p I_e \)
    • Interstory drift, \( D_p = \Delta y - \Delta y_{-1} \)
Nonstructural Components

• ASCE 7 – Eqn. 13.3-1

\[ F_p = \left[ \frac{0.4a_pSD_{SWp}}{R_p^p I_p^p} \right] \left[ 1 + 2 \frac{z}{h} \right] \]

• ASCE 7 – Eqn. 13.3-4

\[ F_p = \frac{a_i a_p W_p}{R_p^p I_p^p} A_x \]
Floor Accelerations, $a_i \cdot A_x$

- Maxima of the NLRH average in both directions
- Measured at corners of building plate to capture torsion
- Includes Accidental Torsion loading
• Exemptions from Non-structural Seismic Bracing Requirements
  • Furniture
  • Temporary or Moveable equipment unless
    • permanently attached to building utility services such as electricity, gas or water.
    • Movable equipment stationed in one place more than 8 hours, greater than 400 lbs or CM > 48”.
  • Fixed equipment less than 400 lbs on the floor with CM less than 48” above floor, or less than 20 lbs located elsewhere
Design Earthquake Interstory Drift Ratios

North-South Drift Ratios

East-West Drift Ratios
### Increment 2 - General Notes

#### $a_i \cdot A_x$ Values for Equation 13.3-4

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>aiAx (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 (R0OF)</td>
<td>0.86</td>
</tr>
<tr>
<td>12</td>
<td>0.80</td>
</tr>
<tr>
<td>11</td>
<td>0.59</td>
</tr>
<tr>
<td>10</td>
<td>0.71</td>
</tr>
<tr>
<td>9</td>
<td>0.76</td>
</tr>
<tr>
<td>8</td>
<td>0.74</td>
</tr>
<tr>
<td>7</td>
<td>0.95</td>
</tr>
<tr>
<td>6</td>
<td>0.98</td>
</tr>
<tr>
<td>5</td>
<td>1.03</td>
</tr>
<tr>
<td>4</td>
<td>0.75</td>
</tr>
<tr>
<td>3</td>
<td>0.84</td>
</tr>
<tr>
<td>2</td>
<td>1.13</td>
</tr>
<tr>
<td>1</td>
<td>0.94</td>
</tr>
<tr>
<td>P2</td>
<td>0.76</td>
</tr>
<tr>
<td>P3</td>
<td>0.60</td>
</tr>
</tbody>
</table>

### Interstory Drift Values

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>INTERSTORY DRIFT (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L13-L12</td>
<td>2.15</td>
</tr>
<tr>
<td>L12-L11</td>
<td>1.75</td>
</tr>
<tr>
<td>L11-L10</td>
<td>1.75</td>
</tr>
<tr>
<td>L10-L9</td>
<td>1.75</td>
</tr>
<tr>
<td>L9-L8</td>
<td>1.75</td>
</tr>
<tr>
<td>L8-L7</td>
<td>1.75</td>
</tr>
<tr>
<td>L7-L6</td>
<td>2.25</td>
</tr>
<tr>
<td>L6-L5</td>
<td>2.25</td>
</tr>
<tr>
<td>L5-L4</td>
<td>2.40</td>
</tr>
<tr>
<td>L4-L3</td>
<td>1.75</td>
</tr>
<tr>
<td>L3-L2</td>
<td>0.55</td>
</tr>
<tr>
<td>L2-L1</td>
<td>0.65</td>
</tr>
<tr>
<td>L1-P2</td>
<td>0.25</td>
</tr>
<tr>
<td>P2-P3</td>
<td>0.25</td>
</tr>
</tbody>
</table>
Structural Design Issues

• Nonstructural Bracing & Anchorage depend on concrete anchors
  • Pre-installed embeds in floor decks
  • Post-installed anchors

• Anchor capacities depend on concrete thickness

• Add concrete thickness to improve anchor capacities and avoid through-bolting connections
  • Consider 4” Lightweight concrete instead of 3-1/4” concrete
  • Consider 5” Normal weight concrete
Heavy medical equipment on Diagnostic and Treatment, or D&T, floors

- Locations are uncertain during design phase and construction of floor deck

Consider

- substituting 2 inch metal deck for 3 inch deck in areas of heavy equipment,
- adding rebar in low flutes to increase floor slab strengths
  - Improves equipment anchorage options
  - Provides future flexibility for unknown equipment weights and locations
• Nonstructural bracing design frequently occurs after approval of the primary system.

• All changes occur within a regulatory oversight process to approve the design prior to construction.

• Everyone on the project must cooperate/collaborate to make this happen on schedule, to keep the train moving.