Structural Collapses During Construction: Lessons Learned 1990-2008

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Work Related Fatalities

Source: BLS CFOI Data
Fatality Rates
(Fatalities per 100,000 workers)

Source: BLS Injury/Illness Data
STRUCTURAL COLLAPSES DURING CONSTRUCTION
1990-2008 (TOTAL 96)

- 77 STRUCTURES (80%)
- 19 STRUCTURES (20%)

CONSTRUCTION ERRORS
DESIGN ERRORS
NUMBER OF MAJOR STRUCTURAL COLLAPSES
(TOTAL 96)

- STEEL STRUCTURES: 60
- CONCRETE & MASONRY STRUCTURES: 29
- WOOD STRUCTURES: 7
GROUP OF STEEL STRUCTURAL COLLAPSES (TOTAL 60)

- SPECIAL STEEL STRUCTURES AND CRANES: 18
- STEEL FRAME STRUCTURES: 14
- SCAFFOLDS: 6
- STEEL ROOF TRUSSES AND JOISTS: 14
- TELEVISION ANTENNA TOWERS: 5
- COFFERDAMS: 3
GROUP OF CONCRETE AND MASONRY STRUCTURAL COLLAPSES (TOTAL 29)

- 12 SHORINGS SUPPORTING FRESHLY PLACED CONCRETE
- 5 PRECAST CONCRETE STRUCTURES
- 4 CONCRETE FRAMES
- 3 DEMOLITIONS INVOLVING CONCRETE STRUCTURES
- 5 MASONRY WALLS
STRUCTURAL COLLAPSES DUE TO DESIGN ERRORS (TOTAL 19 STRUCTURES)

- Steel Structures: 13
- Concrete Structures: 5
- Masonry Structures: 1
At design stage:

• For concrete structures, do not use exterior slender columns against wider perimeter beams.

• Show rebar details at typical beam column joints.
PARTIAL P6 TO P9 FRAMING PLAN (CONTRACT DRAWING S-1.36, REV. 50)

(NTS)
SECTION THRU EXTERIOR BEAM
(LOOKING NORTH)
At design stage:

• Show rebar details for
  • Development length
  • Splice length
ORIGINAL POSITION OF BEAM RB-35

COLUMN C.3.5

BEAM RB35
COLUMN C.3.4A

CROSS SECTION AT COLUMN LINE B20 AFTER THE COLLAPSE
LOOKING SOUTH

* RB35
* SAME BEAM MARK AS PER SHOP DWG
EXTERIOR END OF THE BEAM RB-35 AFTER THE COLLAPSE

- #901 Rebar
- #702 Rebar (North Face)
- Stirrups
- Rebar fractured at the bent corner.
- 7" APP.
- N. Face
- 3'-0"
- 2'-0"
- 6'-0"
- 8"
- N. Face
At design stage:

• Consider construction loads during design of parking garage floor slabs and columns

• As actual loads during construction could be higher than design live load (see below).
• Code permits design live load of 40 psf and permitted to be reduced to 30 psf for slab and 15 psf for columns.
• At design stage:
  • For post tensioning beams, avoid fixed end anchorage at both ends of the interior column.
  • Avoid wider and shallower beams framing with slender columns.
  • Show rebar details at some beam column joints to avoid congestion of rebars and to prevent honeycombing (voids) into concrete.
• At design stage:

• While performing formwork design, engineer should consider
  » Properties of actual concrete mix used
  » Rate of pour
  » Use of retarder in concrete mix
At design stage:

- For composite steel beam design engineer should consider
  - Non composite beam design during construction for construction live loads
  - Composite beam design for final condition
Typical Composite Construction
• At design Stage:

  • Engineer should consider stability check against lateral-torsional buckling during construction phase for
    » Bridge girders.
    » Primary exterior steel truss supporting secondary steel trusses.
• At design Stage:

• Truss manufacturer to design temporary braces for spans greater than 60’-0”.

» Show locations and sizes of all braces (top chord, diagonal, lateral, and bottom chord)
• At design Stage:

• Provide anchor points for fall protection use during construction work

» For future maintenance work and to avoid extra cost of engineering and labor.

» Design anchors for 5,000 pounds or a factor of safety 2.0 for maximum fall arrest force.
• At design Stage:
  
  • Provide tanks or major equipment at ground level to avoid high climbing for future maintenance work.
• At design Stage:

• Position splices for steel columns so the splices can be done from floors.
At design stage:

- Engineer must consider OSHA’s requirements for factor of safety (see below) which is different from consensus standards such as ACI, AISC, AITC, IBC, etc.

  - Scaffold design
  - Fall protection anchorage design
  - Cable size for lifting beams, equipments etc.
  - Four anchor bolts for all steel columns, excluding posts.
Questions?