# Design Loads on Structures During Construction

# ASCE 37-14

# Design Loads During Construction

- Purpose of this presentation is to become familiar with ASCE 37-14, including:
  - Types of Loads to consider during design
  - Terminology used in the Standard
  - Consideration of wind loads and how reduced wind loads may be used for selected project parameters
  - Specific example of wind load in a "hurricane prone area"
  - 2 examples along the Gulf Coast where a structural collapse occurred during construction

# Design Loads During Construction

## SAFETY CONSEQUENCES

OSHA investigated 96 structural collapses during construction involving fatalities and injuries over the period from 1990 to 2008

- 80% were caused by construction errors (ex. not following installation procedures, did not provide temporary bracing, etc.)
- 20% were attributed to structural design flaws by either EOR or a structural engineer retained by a contractor to design specific members
- Largest group of collapses involved steel structures (including scaffolding), followed by concrete & masonry structures, and then wood frames (example: roof trusses)

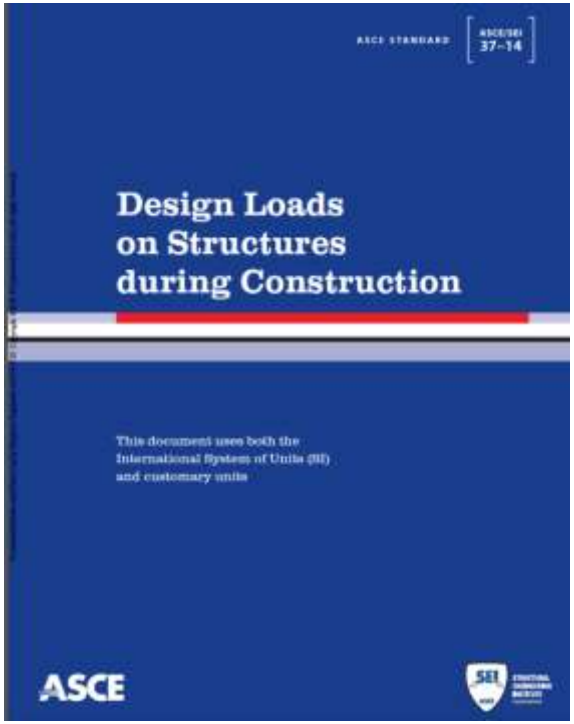
# Design Loads During Construction

**ASCE 37-14**

Design Loads on Structures during Construction

1st edition of Standard published 2002

Latest edition is 2014



# Design Loads During Construction

- **Purpose of ASCE 37-14 is to provide minimum design loads during construction of buildings and other structures**

**Scope is for**

- Partially completed structures
- Temporary structures

ASCE 37-14 Standard does <u>not</u>:

- Specify party responsible for design of temporary structures
- Specify party responsible for on-site supervision

# Design Loads During Construction

- **Types of Loads**
  - Dead
  - Live
  - Construction – equipment, materials, personnel
  - Environmental – wind, snow, rain, earthquake
  - Hydrotest – piping and/or equipment
  - Lateral earth pressure
  - Forces from interaction of partially completed structures and temporary supports or bracing

# Design Loads During Construction

- **Construction Loads**
  - Materials
  - Equipment
  - Personnel
  - Erection and Fitting forces
  - Dead load of permanent structures are included in Dead Load (D)

# Design Loads During Construction

- **Construction Material Loads**
  - Fixed (FML) – fixed in magnitude
  - Variable (VML) – loads that vary in magnitude during the construction process

  Area of application may be distributed or concentrated

  Example of variable loads:  stockpiling and stacking of rebar, roofing materials, drywall, etc.

  Example of fixed material load:  formwork once its installed

# Design Loads During Construction

- **Cast in Place Concrete**
  - Concrete placed in a form is initially considered as a material load
  - Once concrete gains sufficient strength so that forms and shoring may be removed then it becomes a DL

  Form pressure $C_c$ (lateral pressure) = wh (lbs/ft$^2$)

  w = unit weight of fresh concrete, lbs./ft$^3$

  h = depth from top of placement to point of consideration, ft.

  Specific formula for form pressure of concrete columns

# Design Loads During Construction

## Personnel and Equipment Loads

**Table 4-1. Minimum Concentrated Personnel and Equipment Loads**

| Action | Minimum Load[a] [lb (kN)] | Area of Load Application [in. × in. (mm × mm)] |
|---|---|---|
| [b]Each person | 250 (1.11) | 12 ×12 (300 × 300) |
| Wheel of manually powered vehicle | 500 (2.22) | Load divided by tire pressure[c] |
| Wheel of powered equipment | 2,000 (8.90) | Load divided by tire pressure[c] |

[a]Use actual loads where they are larger than tabulated here.
[b]The spacings of the 250-lb concentrated loads need not be less than 18 in. (457 mm) c. to c.
[c]For hard rubber tires, distribute load over an area 1 in. (25 mm) × the width of the tire.

# Design Loads During Construction

## Horizontal Construction Load, $C_H$

- Wheeled vehicles transporting materials, 20% for a single vehicle, or 10% for 2 or more vehicles of a fully loaded vehicle weight
- Equipment reactions, calculated or rated horizontal loads (whichever are greater)
- 50 lbs/person, applied at the level of the platform
- 2% of the total vertical load, need not be applied concurrently with wind or seismic load

# Design Loads During Construction

- **Working Surfaces – floors, decks, or platforms of temporary or partially completed structures subjected to construction loads**

**Table 4-4. Classes of Working Surfaces for Combined Uniformly Distributed Loads**

| Operational Class | Uniform Load[a] [psf (kN/m$^2$)] |
|---|---|
| Very Light Duty: sparsely populated with personnel, hand tools, very small amounts of construction materials. | 20 (0.96) |
| [b]Light Duty: sparsely populated with personnel, hand-operated equipment, staging of materials for lightweight construction. | 25 (1.20) |
| [b]Medium Duty: concentrations of personnel, staging of materials for average construction. | 50 (2.40) |
| [b]Heavy Duty: material placement by motorized buggies, staging of materials for heavy construction. | 75 (3.59) |

[a]Loads do not include dead load, D; construction dead load, $C_D$, or fixed material loads, $C_{FML}$.
[b]OSHA categories.

# Design Loads During Construction

**6.2.1 Design Wind Speed** The design wind speed shall be taken as the following factor times the basic wind speed in ASCE/SEI 7-10, except as required in Section 6.2.1.1.1.

| Construction Period | Factor |
|---|---|
| Less than six weeks | 0.75 |
| From six weeks to one year | 0.8 |
| From one to two years | 0.85 |
| From two to five years | 0.9 |

# Design Loads During Construction

Wind Design in Hurricane Prone Areas, two periods of time are considered for construction

- November 1 to June 30 (outside of hurricane season)
- July 1 to October 31 (during hurricane season). Note this definition is different than that used by the NHC, which is June 1 to November 30 for the Atlantic, Caribbean and Gulf of Mexico

*C6.2.1.1.1 Construction Period in Hurricane-Prone Areas*
The dates selected to represent the hurricane season are not intended to include all times when hurricanes are possible. The dates are intended to include the period when the most severe hurricanes are probable.

If the construction site is in the path of a known oncoming hurricane, it is considered prudent to brace for the full, unmodified wind load determined using ASCE/SEI 7-10.

# Design Loads During Construction

Hurricane Prone Areas, period from November 1 to June 30 (outside of hurricane season)

*6.2.1.1.1 Construction Period in Hurricane-Prone Areas* For construction between November 1 and June 30 (outside of the hurricane season), the basic wind speed of 115 mph (51 m/s) shall be permitted for structures sited near the Gulf Coast and Eastern Seaboard, where the ASCE/SEI 7-10 specified basic wind speed exceeds 115 mph (51 m/s) (3 second gust) (hurricane-prone areas). The 115 mph (51 m/s) wind speed is permitted to be reduced by the factors in Section 6.2.1 only for a construction period between November 1 and June 30. If the construction period shifts into the period between July 1 and October 31, the design shall be reviewed and modified, as appropriate, to conform to the requirements shown below for a construction period between July 1 and October 31.

# Design Loads During Construction

Hurricane Prone Areas, period from July 1 to October 31(during hurricane season)

Between July 1 and October 31, basic wind speed of 115 mph (51 m/s) shall be permitted for structures sited near the Gulf Coast and Eastern Seaboard, where the ASCE/SEI 7-10 specified basic wind speed exceeds 115 mph (51 m/s) (3 second gust) provided additional bracing is prepared in advance and applied in time before the onset of an announced hurricane. The 115 mph (51 m/s) wind speed shall not be reduced by the factors in Section 6.2.1 for the construction period. The bracing shall be designed for the full, unmodified wind load determined using the mapped wind speed and procedures found in ASCE/SEI 7-10.

# Design Loads During Construction

- **Example of Wind Speed calculations**
  - Project location: Theodore, AL (Mobile County)
  - Risk Category II, open frame structure
  - Construction duration: 6 months
  - V=159 mph (ASCE 7-10); source: ASCE Hazard Tool
  - Construction outside of hurricane season

    Use V = 115 mph x 0.8 (factor from 6.2.1) = 92 mph
  - Construction during hurricane season

    Use V = 115 mph with additional bracing

# Design Loads During Construction

- **Wind – Continuously Monitored Work Period**
  - Intended for periods of continuous rigging, erection or demolition that last for <u>one work day or less</u>
  - Example: lifting of girders, columns, façade panels, equipment may use temporary guy wires, struts, minimum number of fasteners, etc.
  - At end of work day the structure shall be made inherently stable or secured, to meet the requirements previously outlined

# Design Loads During Construction

- **Wind – Continuously Monitored Work Period (continued)**
  - For continuously monitored work periods a lower wind speed may be used
  - Wind speed to be used shall be based on the National Weather Service or another reliable source acceptable to the authority having jurisdiction
  - The basic wind speed shall not be less than the predicted wind speed adjusted to the 3-second gust speed multiplied by 1.26

# Design Loads During Construction

- **Framework without Cladding – effects of Shielding**
  - Even though design wind speed during construction may be lower than for the completed structure, the total wind load may actually be higher due to the cumulative effect of wind acting on more surfaces
  - For common arrangements of elements in typical open frame and temporary structures the shielding effects are small
  - Most severe wind loads on an open structure include components of load in both principal directions

# Design Loads During Construction

- **Framework without Cladding – effects of Shielding (continued)**

  Load reductions due to shielding

  - The loads on the first 3 rows of elements along the direction parallel to the wind shall not be reduced for shielding
  - The loads on the 4th and subsequent rows shall be permitted to be reduced by 15%
  - Wind loads shall be calculated for all exposed interior partitions, construction materials, equipment

# Design Loads During Construction

- **Framework without Cladding – effects of Shielding (continued)**
  - Calculations shall be performed for each primary axis of the structure
  - For each calculation, 50% of the wind load calculated for the perpendicular direction shall be assumed to act simultaneously

# Design Loads During Construction

## Thermal Loads

Provisions shall be made for thermal distortions of the structure and architectural components. Formula is based on the following:

- Largest horizontal dimension between expansion joints of the erected structures
- Difference of temperatures when the the structure is erected and exposed temporarily to ambient temperatures; consider both high and low temperature extremes

# Design Loads During Construction

- **Structural Analysis**
  - Load combinations may use strength design or allowable stress design
  - Load combinations are not all inclusive
  - Design should be based on the load combination(s) causing the most unfavorable effect
  - ASCE 37-14 Standard is similar to ASCE 7-10 in that wind loads have been reduced from 1.0W to 0.6W

# Design Loads During Construction

- **Allowable Stress Design – additive combinations**

The following basic combinations shall be investigated as a minimum:

$$D + C_D + C_{FML} + C_{VML} + L \qquad (2\text{-}8)$$

$$D + C_D + C_{FML} + C_{VML} + C_P + C_H + L \qquad (2\text{-}9)$$

$$D + C_D + C_{FML} + C_{VML} + 0.6W + C_P + L \qquad (2\text{-}10)$$

$$D + C_D + C_{FML} + C_{VML} + 0.7E + C_P + L \qquad (2\text{-}11)$$

$$0.6D + C_D + (0.6W \text{ or } 0.7E) \qquad (2\text{-}12)$$

where D = dead load in place at the stage of construction being considered, L = live load, which may be less than or greater than the final live load, and W = wind load computed using the design velocity factor where appropriate per Section 6.2.1.

# Design Loads During Construction

- **Load Combinations Using Strength Design**

$$1.4D + 1.4C_D + 1.2C_{FML} + 1.4C_{VML} \qquad (2\text{-}2)$$

$$1.2D + 1.2C_D + 1.2C_{FML} + 1.4C_{VML} + 1.6L \qquad (2\text{-}3)$$

$$1.2D + 1.2C_D + 1.2C_{FML} + 1.4C_{VML} + 1.6C_P + 1.6C_H + 0.5L \qquad (2\text{-}4)$$

$$1.2D + 1.2C_D + 1.2C_{FML} + 1.4C_{VML} + 1.0W + 0.5C_P + 0.5L \qquad (2\text{-}5)$$

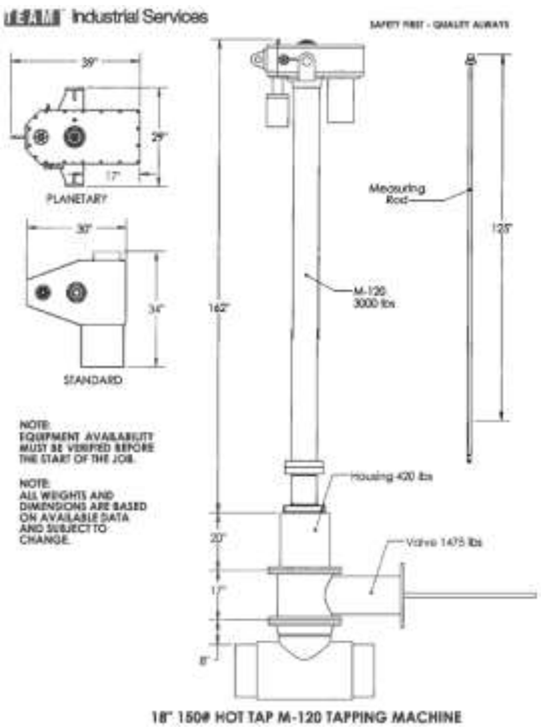
$$1.2D + 1.2C_D + 1.2C_{FML} + 1.4C_{VML} + 1.0E + 0.5C_P + 0.5L \qquad (2\text{-}6)$$

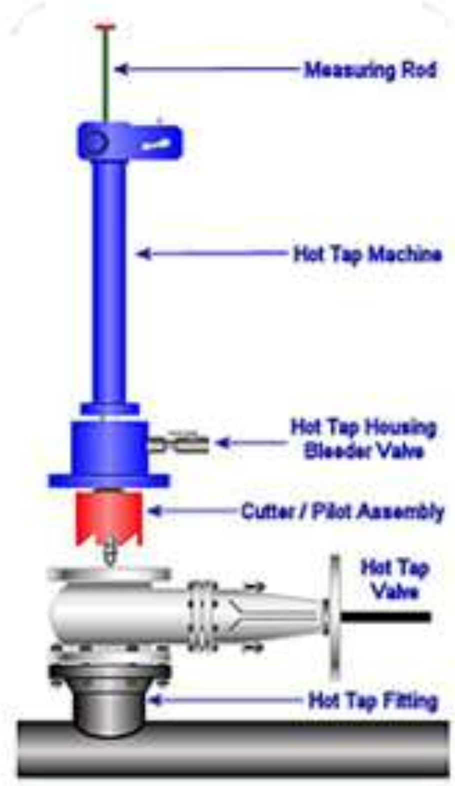
$$0.9D + 0.9C_D + (1.0W \text{ or } 1.0E) \qquad (2\text{-}7)$$

where D = dead load in place at the stage of construction being considered, L = live load, which may be less than or greater than the final live load, and W = wind load computed using the design velocity reduction per Section 6.2.1.

# Design Loads During Construction

- **Example Industrial Project, Support of hot tap machine above existing pipe rack; $C_p$ = 4,900 lbs**




Existing pipe

# Design Loads During Construction

## Failure during Construction

University of South Alabama, Mobile, AL
Indoor Football Practice Facility collapse on July 22, 2017

Photograph 19: The majority of the concrete pile caps are cracked.

# Design Loads During Construction

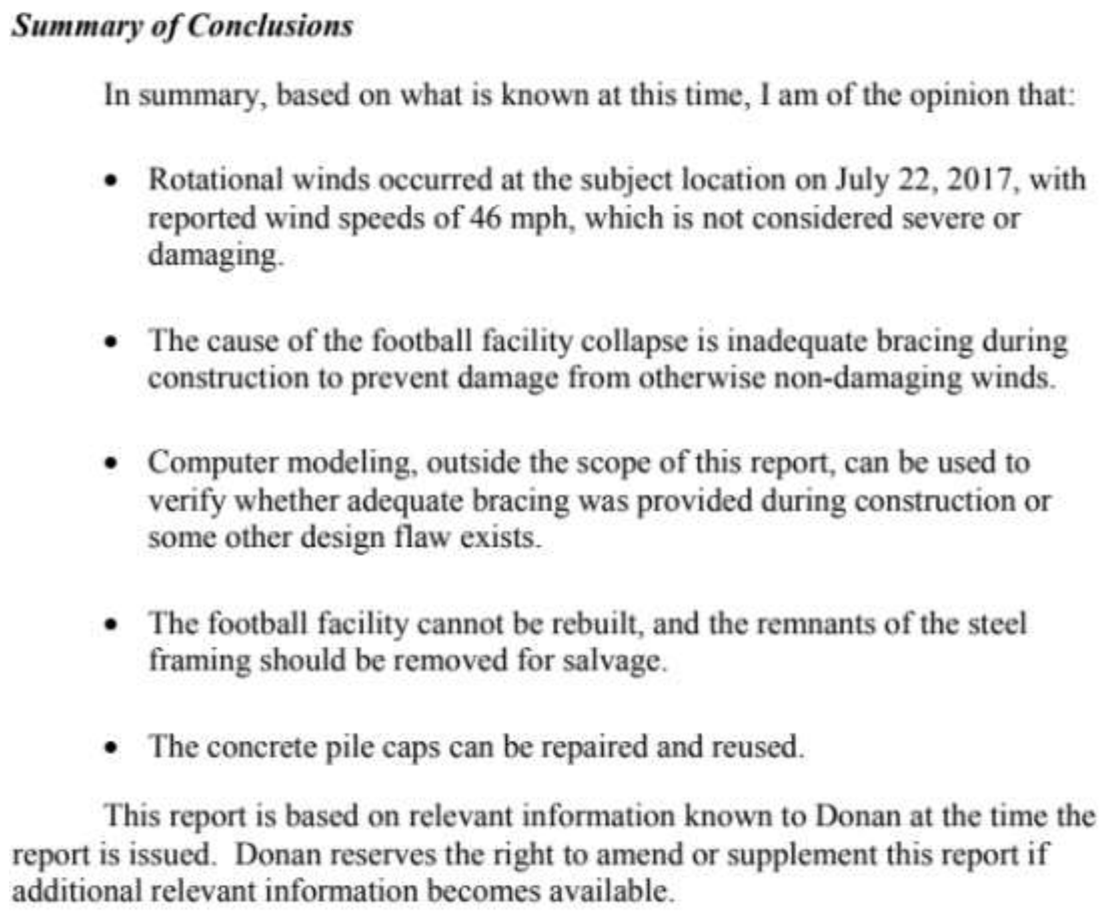
Photograph 8: Diagonal rod bracing is installed in the west sidewall, between the third and fourth rigid frame columns from the north side of the building.

Photograph 18: The majority of the anchor bolts are sheared, either above or below the base plate of the rigid frame columns.

University of South Alabama, Mobile, AL
Indoor Football Practice Facility collapse on July 22, 2017
No injuries or fatalities – Contractor was not working at the time of collapse

# Design Loads During Construction

Conclusion on Report of Investigation of Collapse at University of South Alabama



***Summary of Conclusions***

In summary, based on what is known at this time, I am of the opinion that:

- Rotational winds occurred at the subject location on July 22, 2017, with reported wind speeds of 46 mph, which is not considered severe or damaging.
- The cause of the football facility collapse is inadequate bracing during construction to prevent damage from otherwise non-damaging winds.
- Computer modeling, outside the scope of this report, can be used to verify whether adequate bracing was provided during construction or some other design flaw exists.
- The football facility cannot be rebuilt, and the remnants of the steel framing should be removed for salvage.
- The concrete pile caps can be repaired and reused.

This report is based on relevant information known to Donan at the time the report is issued. Donan reserves the right to amend or supplement this report if additional relevant information becomes available.

Note that Building Collapsed at estimated wind speed of 46 mph

# Design Loads During Construction

Hard Rock Hotel construction site in New Orleans Partial collapse on 10/12/19 – 3 fatalities & several injured

# Design Loads During Construction

- Numerous investigations are underway including OSHA; no final reports have been issued as of March 6, 2020
- Hard Rock hotel partial collapse – possible causes
  - Insufficient shoring supports and/or removal of shoring too early
  - Change of metal form deck from initial design
  - Not allowing enough time for concrete to cure
  - Material defects

  Controlled implosion of remainder of building planned for April 2020 or later