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Lessons on the Strength of Snow and the Weakness of Parking Structures

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THE PARKING FACILITY MISCONCEPTION!

Since parking facilities are constructed of concrete and support these heavy passenger vehicles, they *must* be able to support all types of vehicles and heavy loads. They must be.....



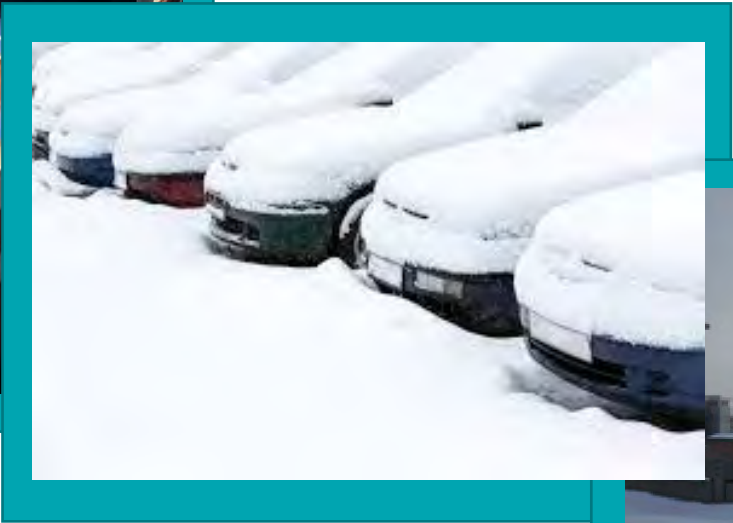
Parking facilities are some of the most lightly loaded storage facilities allowed by code.



SNOW AND SNOW REMOVAL CAN BE A REAL CONCERN



No Live Load - Minimal Snow Load



Live Load and Snow Load



Snow Load ++

TALKING POINTS (TABLE OF CONTENTS)

SNOW
DENSITY

DESIGN
LOADS

DAMAGE

REPAIRS

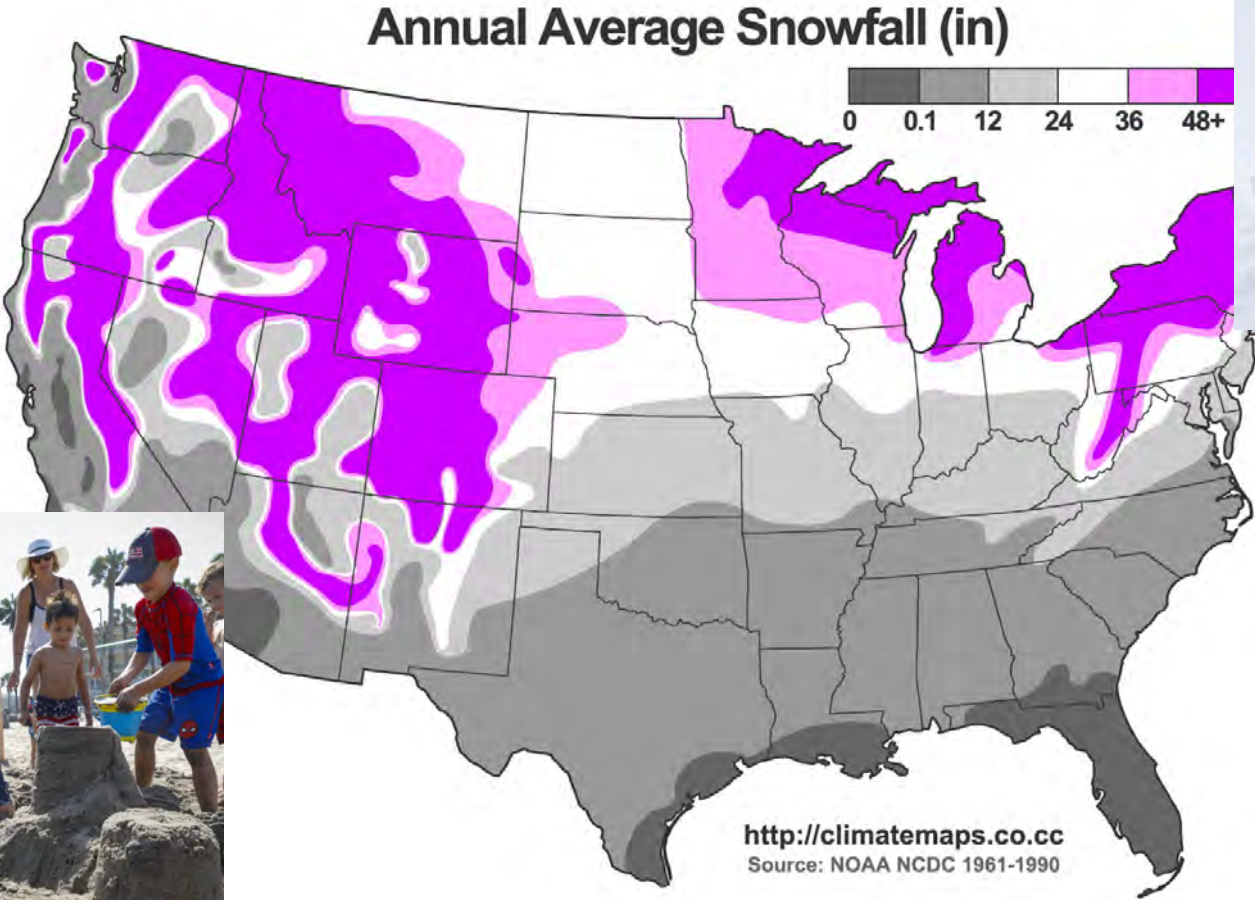
SNOW
REMOVAL

THE END

SNOW DENSITY



DOESN'T EVERYONE KNOW SNOW CAN BE HEAVY?

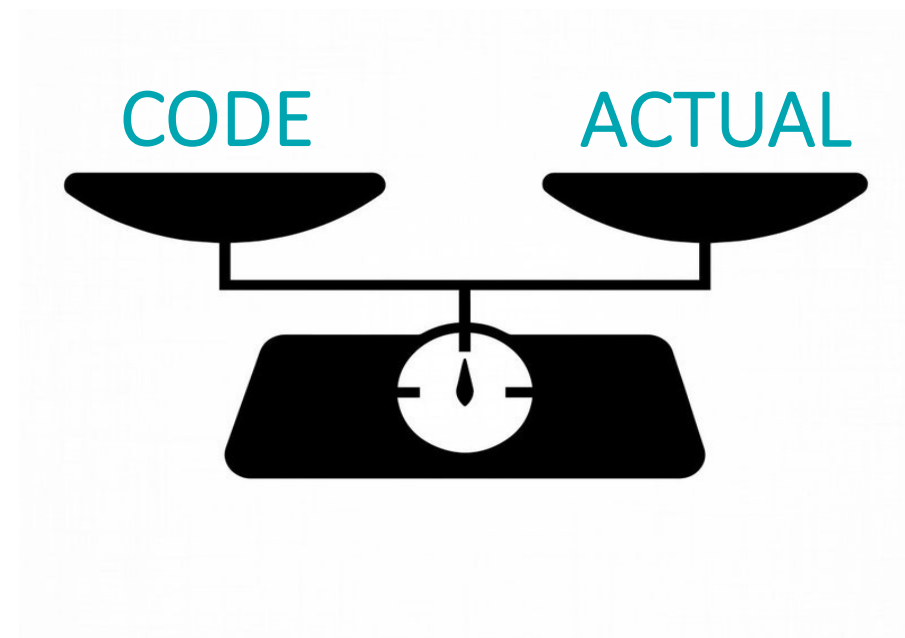


WHAT DOES SNOW WEIGH?

ASCE 7 provides code mandated weight of fallen snow, p_g
 g (snow density) = $0.13 p_g + 14$ but not more than 30 pcf

Density of packed snow varies greatly.

- New dry snow 5 pcf
- New damp snow 12 pcf
- Settled snow 18 pcf
- Wet firm snow up to 50 pcf
- Cubic Foot of water 62.4 pcf
- How high is the snow?



WHEN ACTUAL LOAD > CODE DESIGN LOADS



No Live Load
Packed and Piled Snow
+ Removal Equipment

=

OVER
ERROR!!
WEIGHT

DESIGN LOADS



DESIGN LOAD COMBINATIONS

Strength Design

$$1.2D + 1.6L + 0.5S$$

$$1.2D + 1.6S + L$$



Allowable Stress Design

$D + S$, include drift loading

$D + L$

$D + 0.75L + 0.75S$

Roof Live Load is not combined with Live Load on the same floor.

LIVE AND ROOF DESIGN LOADS

2018 International Building Code

Section 1607: Parking Garage Minimums



- Live Load (L) = **40 psf** (pre-2000 maybe 50 psf)
- Concentrated Load = **3000 lbs on a 4 ½" x 4 ½" area** (pre-2000 maybe 2000 lbs)
- Roof Live Load (L_r) = **20 psf** on stair and elevator tower roofs
 - local jurisdictions may have higher L and L_r requirements.

Always try to find original design for each structure – *who knows?*

SNOW DESIGN LOAD

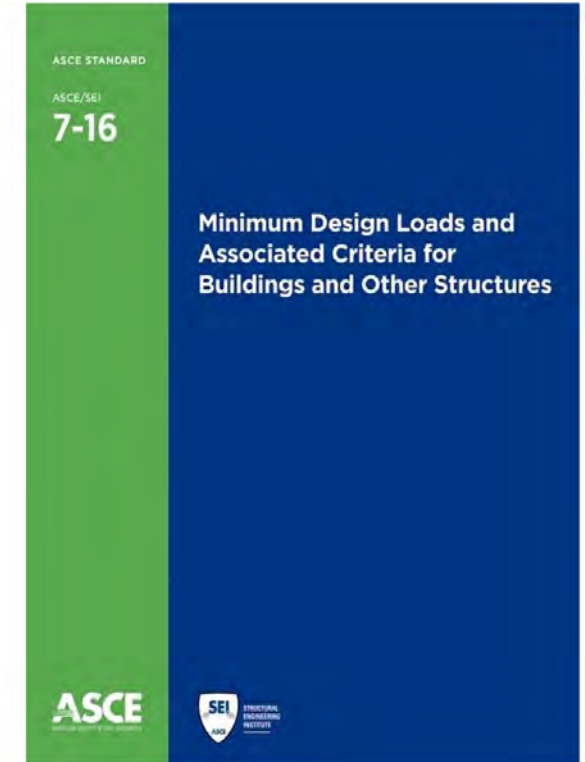
2018 International Building Code

Section 1608: Snow Load (along with ASCE 7, Chapter 7)

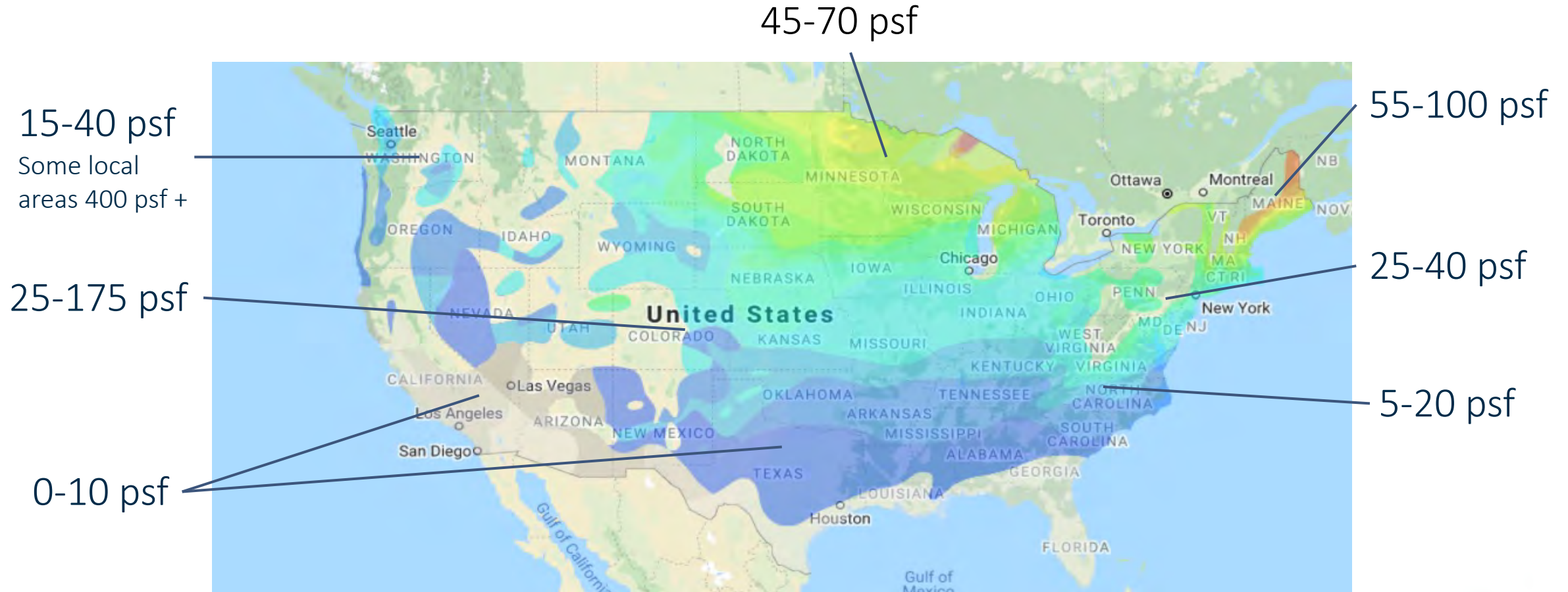
Flat roof snow load $p_f = 0.7 C_e C_t I_s p_g$

- C_e Exposure Factor, Typ 1.0
- C_t Thermal Factor, Typ 1.2
- I_s Importance factor, Typ 1.0
- p_g Ground snow load

flat roof snow load typically < ground snow load



WHAT IS THE AVERAGE DESIGN GROUND SNOW LOAD?



REMINDER: WET SNOW PILED 2'-0" HIGH CAN EQUAL 70 -100 psf

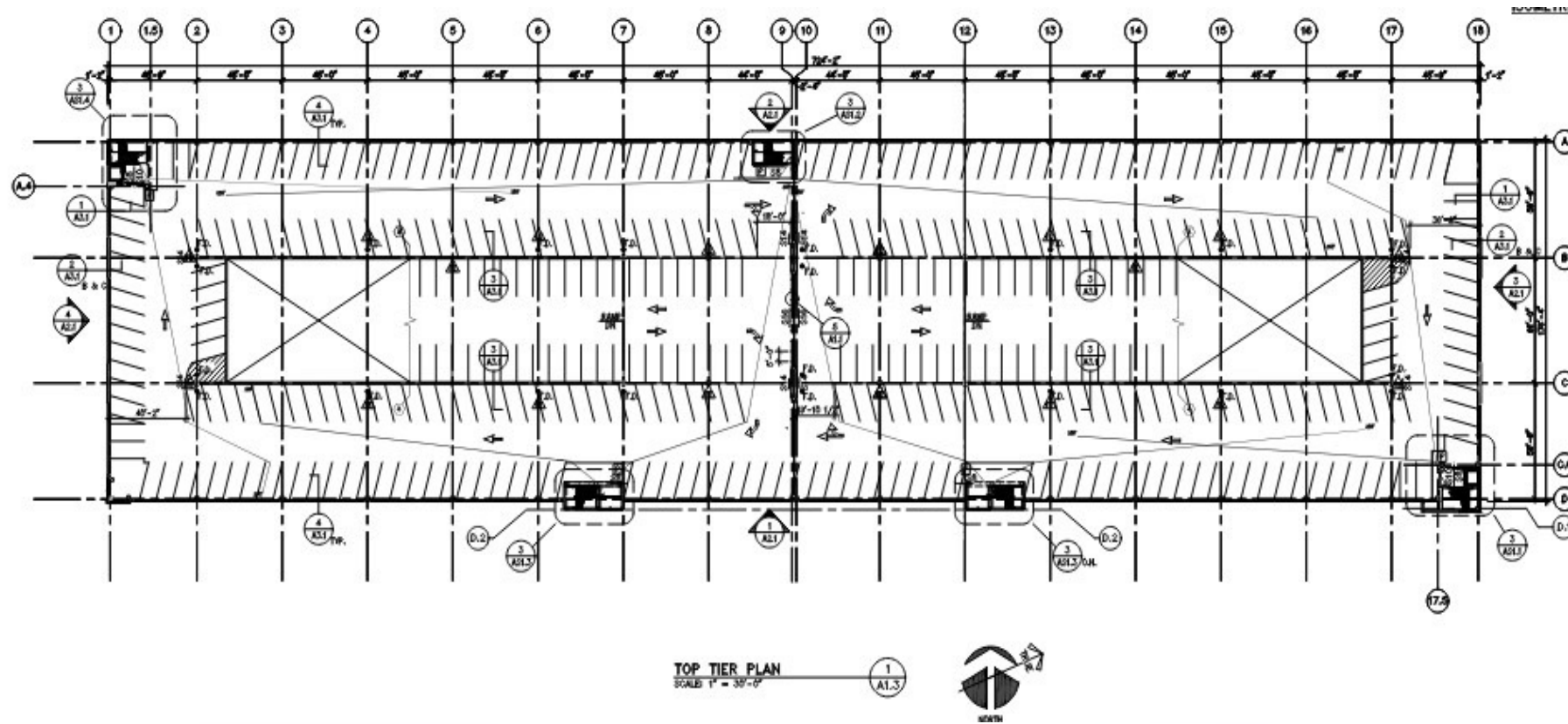
SNOW DAMAGE



WHAT CAN HAPPEN WHEN YOU PILE SNOW?

Case Study #1

- Parking structure footprint 720' x 174', 3 bays wide, 3 total levels
- Snow was piled in area shown during off hours – EMPTY GARAGE



SNOW PILED UP MIGHT COME DOWN!



Precast double tee flange and portions of tee stem



Expansion Joint



Diaphragm Steel

SNOW PILED UP MIGHT COME DOWN!

Shear failure of double tee stems



Successive collapse

Split Double Tee



WHAT CAME DOWN WILL NEED TO BE REBUILT



Slab-on-grade failure

Stabilization until repaired

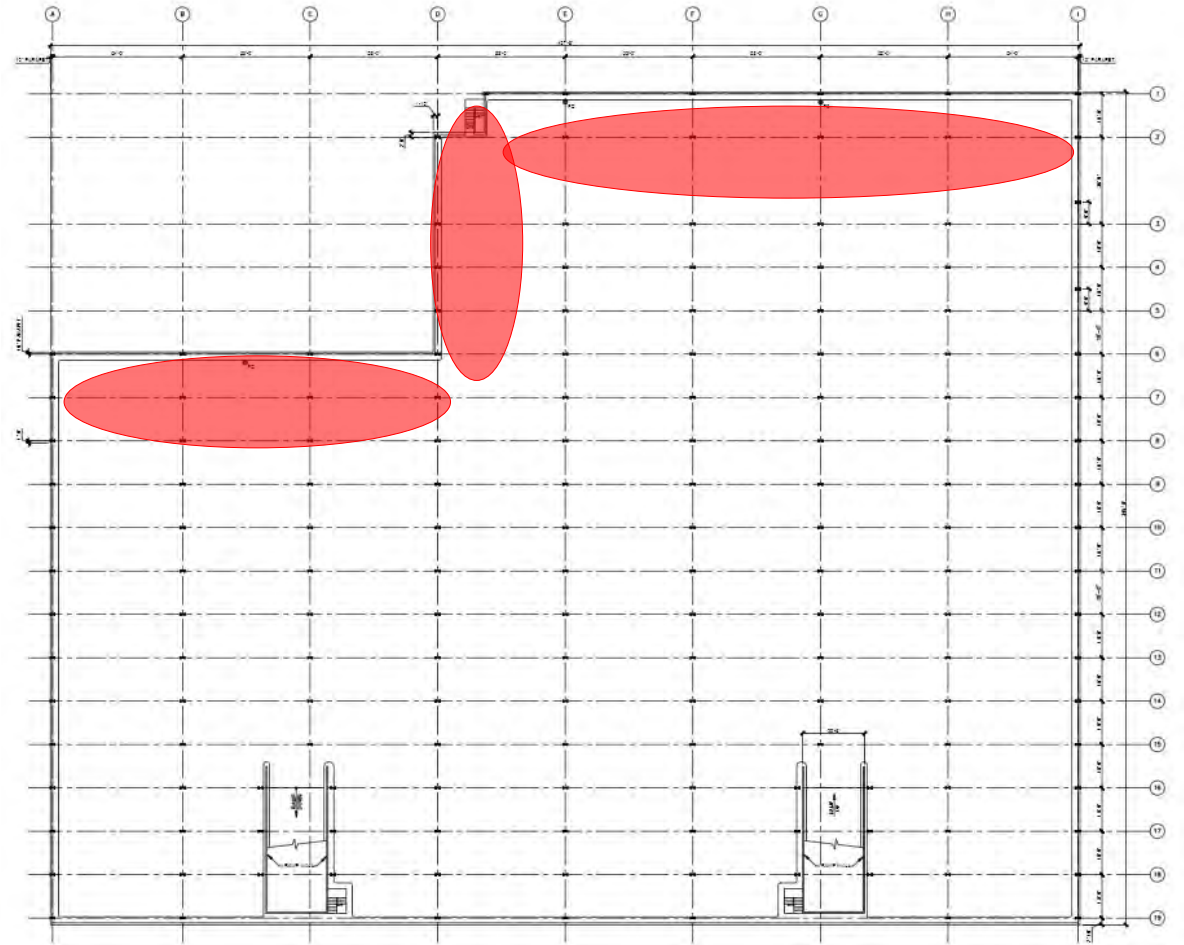


Operator survived with minor injuries.

WHAT CAN HAPPEN WHEN YOU PILE SNOW?

Case Study #2

- 1988 Single Story – Steel frame supporting precast ‘filigree’ planks and P/T topping slab – 5” total
- Snow piled during off hours – EMPTY GARAGE



SNOW OVERLOADING EVENT



~6' Deep pile
20' wide across back of garage

Beam buckling, broken connection
Shear studs ripped out of slab
Significant column deflection
Broken post-tensioned tendons

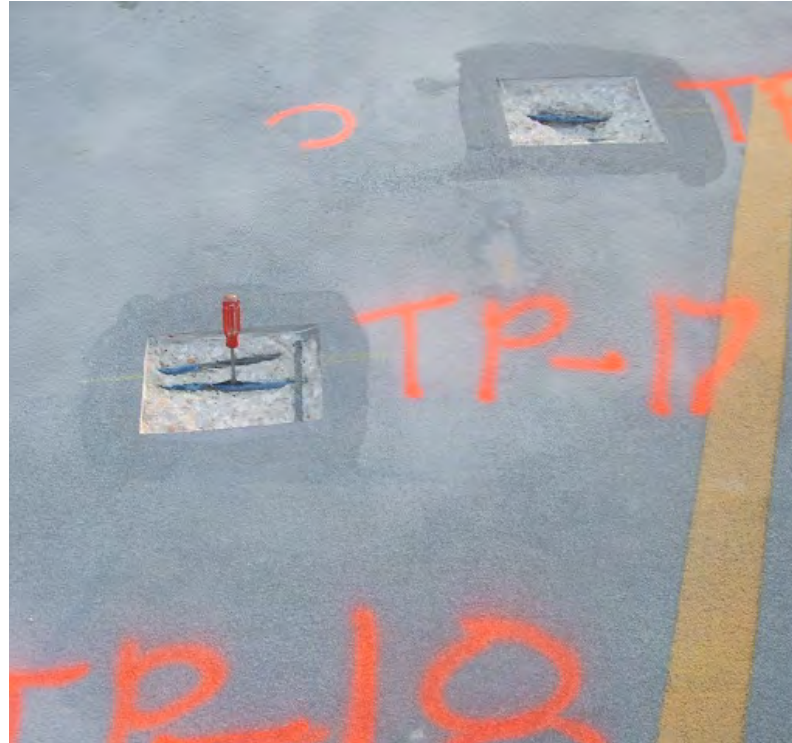


Shoring required for dead and
snow loads

SNOW OVERLOADING OF POST-TENSIONED SLAB



Deflection in area of beam failure



Broken tendons (closeup)



Broken tendons (full bay)

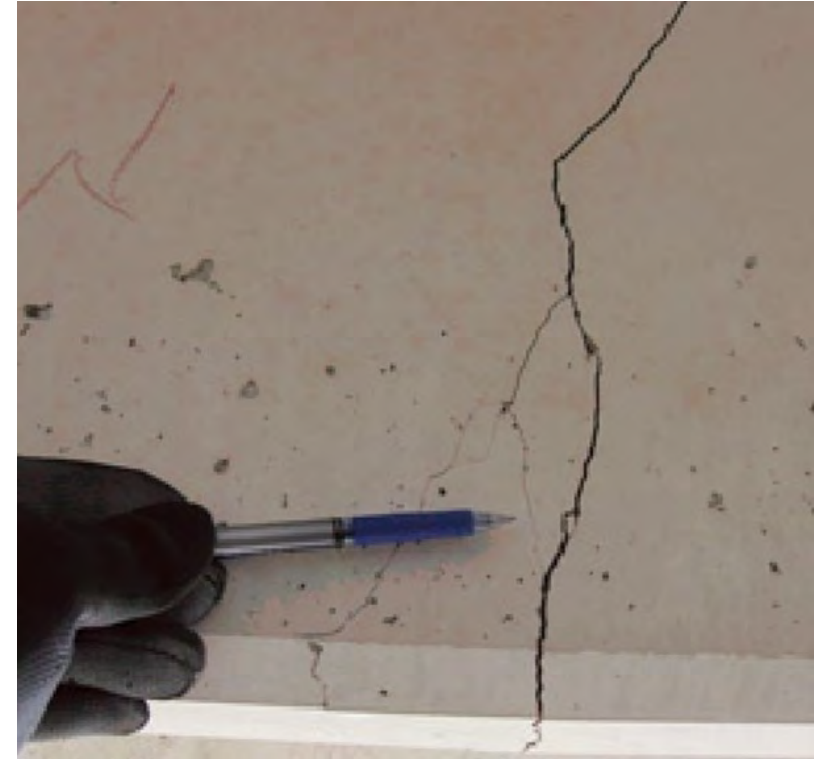
OTHER PRECAST DAMAGE DUE TO OVERLOADING



Shear cracking in tee stem



Shear cracking in spandrel panel



OTHER PRECAST DAMAGE DUE TO OVERLOADING



Split tee stem with deflection



Cracked corner of tee flange



Cracked corner of tee flange

OTHER PRECAST DAMAGE DUE TO OVERLOADING



Broken shear connection and cracking of tee flange



Cracking over each tee stem



Tee flange deflection and broken connections at joint

CAST-IN-PLACE WAFFLE SLAB DAMAGE



Cracking and deterioration in top slab



Cracking and deterioration in waffle slab



Cracking and deterioration in CIP beam

REPAIRS



CASE STUDY #1 – PRECAST REPAIR



Reused existing connections

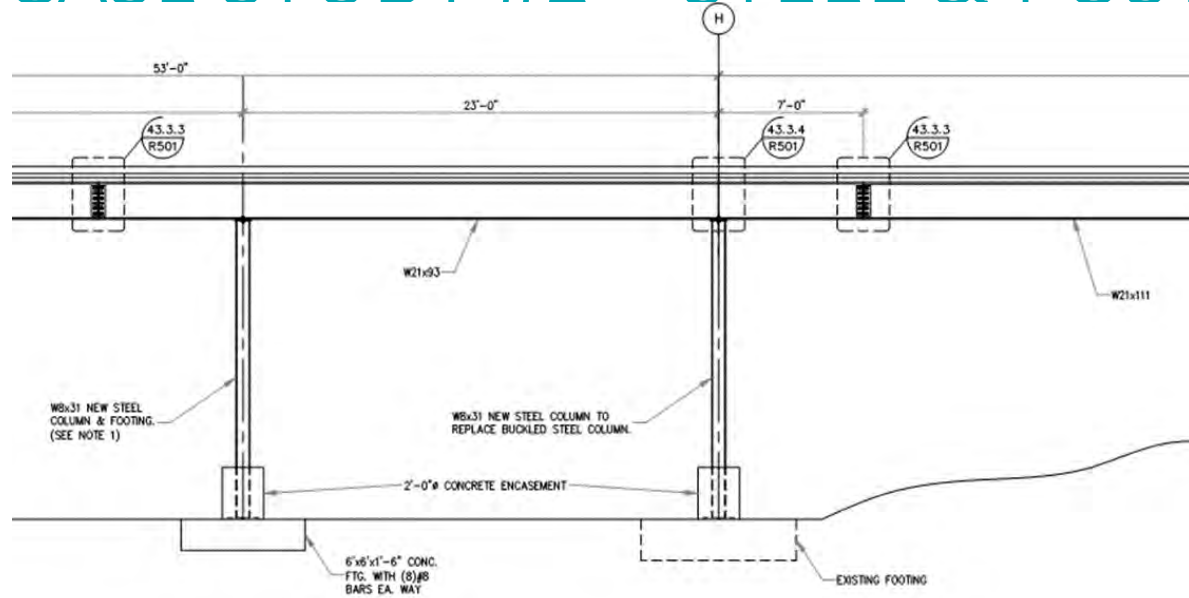


Removed CIP topping over all connections



Maintained existing inverted tee beams

CASE STUDY #2 – STEEL & POST-TENSIONING REPAIR



REPAIRS CONTINUED...



Crack injection in CIP joists



P/T repair at break



Stressing P/T repair at break

REPAIRS CONTINUED...



Tee to tee connections during replacement



Tee to Tee connections after replacement



Rebuilding damaged inverted tee beam

REPAIRS CONTINUED...



Buildout of damaged tee stem



Buildout of damaged tee stem



Rebuilt damaged tee stem

REPAIRS CONTINUED...



Tee to tee connections during replacement



Rewelded tee to tee connections and epoxy injection of cracks



Tee flange replacement in progress

REPAIRS CONTINUED...



Demolition of waffle slab system



Waffle slab replacement



Waffle joist replacement in progress

SNOW REMOVAL

SNOW DENSITY

DESIGN LOADS

DAMAGE

REPAIRS

SNOW
REMOVAL

THE END

SNOW REMOVAL PROCEDURE

Meet with Owner to discuss procedures

1. Our Preference: Close top level and let snow melt
2. Use de-icing products
3. Plow or push snow off deck
 - Snow chute or gate
 - Dump snow over the side
 - Haul it out

Do not pile snow on deck.



OVERCOMMUNICATE WITH THE SNOWPLOW OPERATOR

- Provide signage on top level panels
- Remind and encourage Owner to communicate the snow removal procedures BEFORE it snows
- Survey deck prior to Winter (like the auto body inspection when renting a car)



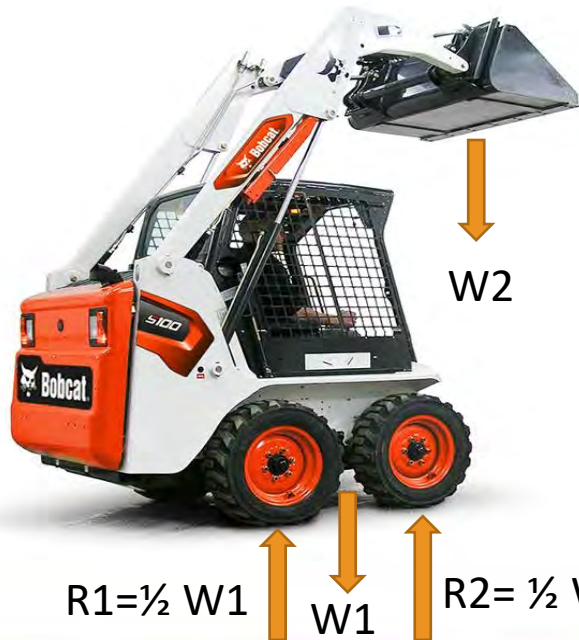
ADDITIONAL LAYERS OF PROTECTION

- Proper head knock bar
 - Clearance height
 - Weight limit
- Get buy-in from snow contractor
 - Discuss responsibility for damage
 - Conduct Fall/Spring walk-throughs



IF SNOW NEEDS TO BE REMOVED, *BE CAREFUL*

Equipment Name	Type	Operating Weight (lbs)
Bobcat S-70	Skid Loader	2975
Bobcat S-100	Skid Loader	4100
John Deere 328	Skid Loader	8580
John Deere 326	Skid Loader	8133
John Deere 318G	Skid Loader	6542
John Deere 320G	Skid Loader	7150
Kubota R530	Wheel Loader	9800
New Holland SL 185	Skid Loader	7099
New Holland 885lx	Skid Loader	7004
New Holland 985lx	Skid Loader	7775
John Deere 204L	Wheel Loader	11,806



IF SNOW NEEDS TO BE REMOVED, *BE CAREFUL*



Ford F150

Chevy 2500 4WD Reg Cab

Ford F250 Reg Cab

Ford F350

Pickup w/ Spreader

Pickup w/ Spreader

Pickup w/ Spreader

Pickup w/ Spreader

7800

9300

9900

14000



CONCLUSION!

Structures can only support the load they are designed for and no more.
As designers we need to communicate that information at every opportunity.



QUESTIONS

