Buffalo Broadway Market Redevelopment

Structural Evaluation and Testing Program of Existing Columns

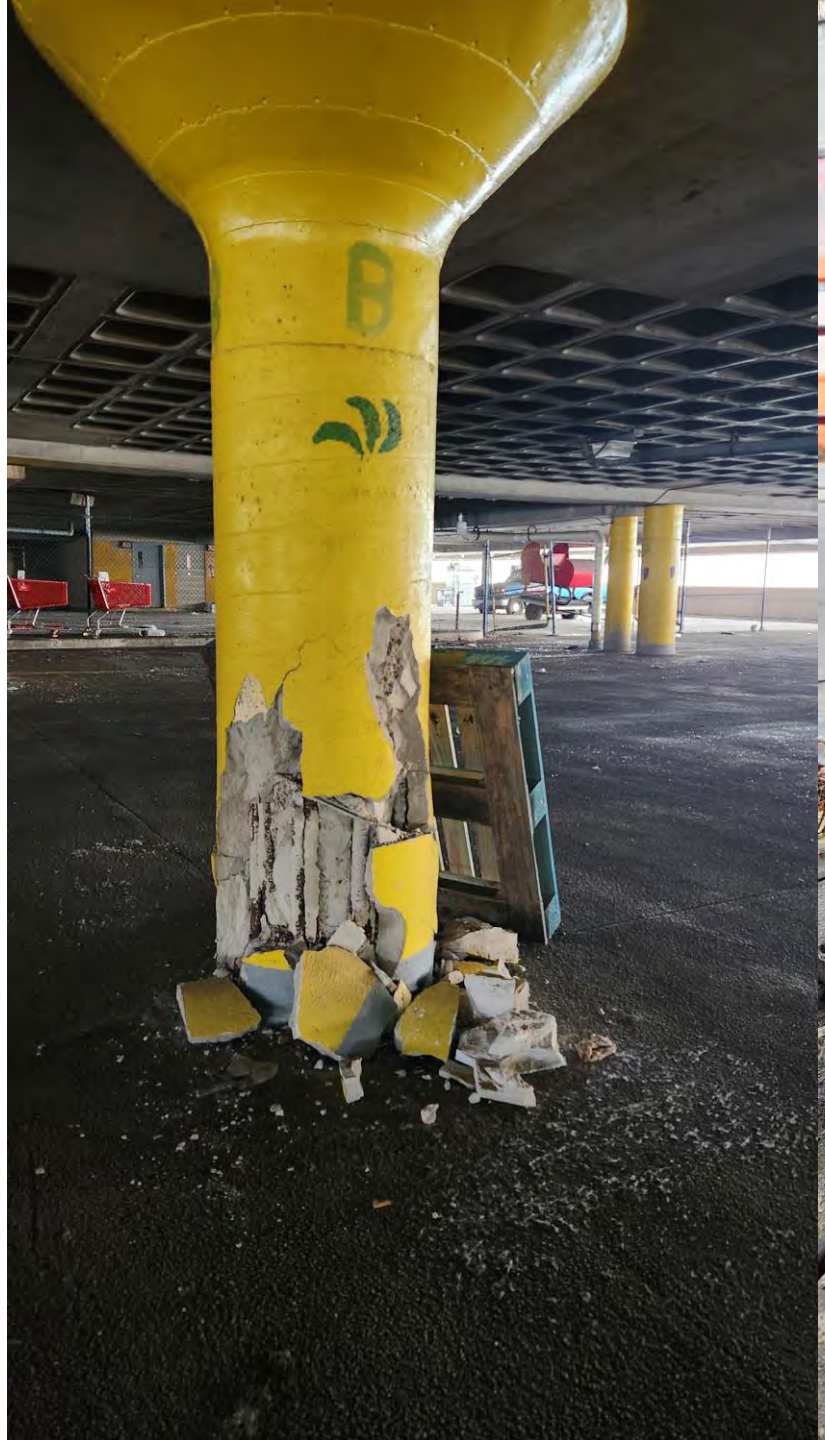
July 25, 2024

We set out to study the existing structure with the goal of identifying the root causes of the deterioration of the columns and to inform the possible repair schemes, following two parallel paths of work:

1. Probing and Material Testing Program, by Atlantic Testing Laboratories (ATL)

2. Structural Evaluation:
    A. Modeling of the existing structure.
    B. Load and strength evaluation, including thermal loads.

LERA



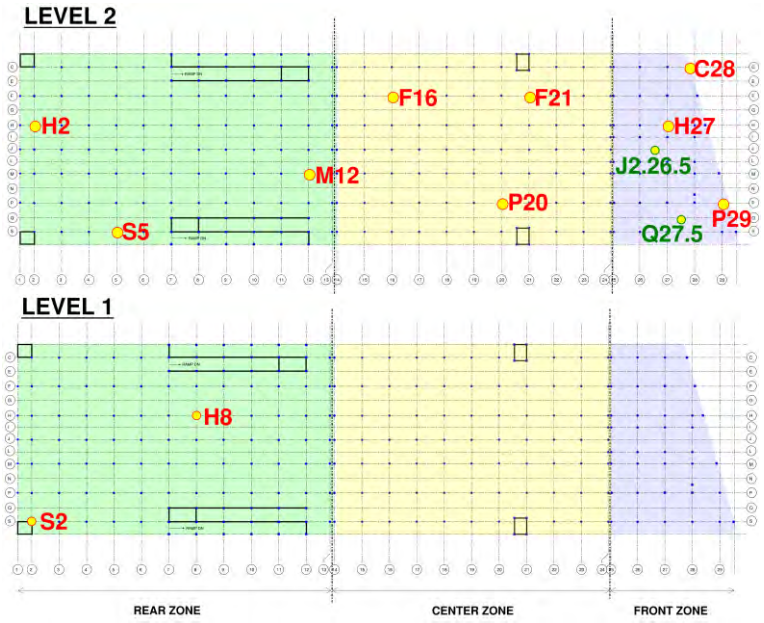
Probing and Material Testing Program

Cores were drilled and extracted between April 29th and May 2nd, 2024.

The following cores where taken:

- 22 cores from 11 columns
  - Level 2: 18 cores from 9 columns
  - Level 1: 4 cores from 2 columns

- 2 cores from Roof slab



Probing and Material Testing Program

Reports by Atlantic Testing Laboratories (ATL)

PETROGRAPHIC EXAMINATION OF CONCRETE

FLYNN BATTAGLIA ARCHITECTS
BROADWAY MARKET
999 BROADWAY, BUFFALO, ERIE COUNTY, NEW YORK

A WBE Certified Company

PREPARED BY:

ATLANTIC TESTING LABORATORIES, LIMITED
6431 U.S. Highway 11
Canton, NY 13617

PREPARED FOR:

CHRISTOPHER LESS
DESIGN LEADER
FLYNN BATTAGLIA ARCHITECTS
617 MAIN STREET, SUITE 401
BUFFALO, NEW YORK 14203

ATL REPORT NO.: BT302PA-02-06-24

JUNE 20, 2024

ATLANTIC TESTING LABORATORIES

WBE certified company

WATER-SOLUBLE CHLORIDE IN MORTAR OR CONCRETE
ASTM C 1218

PROJECT INFORMATION

Client: Flynn Battaglia Architects
Project: Broadway Market
ATL Report No.: BT302CCL-01-05-24
Report Date: May 31, 2024

Sample Id.	Depth of Sample (in)	Chloride by Mass of Concrete (%)
Column M-12 (L) - 2nd Floor	2	0.539
Column S-5 (L) - 2nd FLoor	2	0.021
Column H-2 (L) - 2nd FLoor	2	0.018
Column F-16 (L) - 2nd FLoor	2	0.014
Column S-2 (L) - 1st FLoor	2	0.213
Column H-8 (L) - 1stFLoor	2	0.028
Column P-20 (L) - 2nd FLoor	2	0.730
Column F-21 (L) - 2nd FLoor	2	0.106
Column C-28 (L) - 2nd FLoor	2	0.018
Column H-27 (L) - 2nd FLoor	2	0.011
Column P-29 (L) - 2nd FLoor	2	0.025
Column Q-27.5 (L) - Roof	2	0.145

Sample depth refers to the depth below the top of core.

The American Concrete Institute (ACI) has established limits on chlorides for corrosion protection of reinforcement, based on exposure (ACI 318-19, Table 19.3.1.1). Exposure class C2 is defined as "Concrete exposed to moisture and an external source of chlorides from deicing chemicals, salt, brackish water, seawater, or spray from these sources".

Based on the requirements of ACI 318-19, the maximum water soluble chloride ion content, in percent by weight of cement, for exposure class C2 is 0.15 for non-prestressed concrete and 0.06 for prestressed concrete (ACI 318-19, Table 19.3.2.1). To convert chloride values of percent by mass of concrete to percent by mass of cement, multiply percent chloride by 100/P, where P is the percent of cementitious materials in concrete.

Reviewed By: _____ Date: May 31, 2024

ATLANTIC TESTING LABORATORIES

WBE certified company

PROJECT INFORMATION

Client: Flynn Battaglia Architects
Project: Broadway Market
ATL Report No.: BT302CCL-01-05-24
Date Tested: May 31, 2024

DRILLED CONCRETE CORES
ASTM C 42/C39

Core ID	Depth of Core (in)*	Average Length (in)	Average Diameter (in)	Length to Diameter Ratio	Area (in^2)	Calculated Density (pcf)	Total Load (lbs)	Strength Correction Factor	Unit Load (psi)
Column P-29 (U) - 2nd Floor	3.5 - 6.3	2.80	2.70	1.04	5.73	140.1	70,967	0.88	10,900
Column H-8 (U) - 1st Floor	0 - 3.5	3.46	2.71	1.28	5.77	151.5	56,735	0.93	9,140
Column P-20 (U) - 2nd Floor	0 - 3.8	3.80	3.68	1.03	10.64	138.5	98,348	0.88	8,130

REMARKS:
*Depth referenced from top of core
No defects noted in caps or cores
The cores were tested the as received.

Reviewed By: _____ Date: 05/31/24

ATLANTIC TESTING LABORATORIES

WBE certified company

PROJECT INFORMATION

Client: Flynn Battaglia Architects
Project: Broadway Market
ATL Report No.: BT302CCL-02-05-24
Date Tested: June 12, 2024

DRILLED CONCRETE CORES
ASTM C 42/C39

Core ID	Depth of Core (in)*	Average Length (in)	Average Diameter (in)	Length to Diameter Ratio	Area (in^2)	Calculated Density (pcf)	Total Load (lbs)	Strength Correction Factor	Unit Load (psi)
Column M-12 (U) - 2nd Floor	0 - 7.8	6.50	3.69	1.76	10.70	139.7	97,724	1.00	9,130
Column S-5 (U) - 2nd Floor	0 - 8.3	6.75	3.68	1.83	10.64	135.7	68,755	1.00	6,460
Column H-2 (U) - 2nd Floor	0 - 4.1	3.15	3.68	0.86	10.64	141.3	85,383	0.87	6,980
Column F-16 (U) - 2nd Floor	0 - 8.3	6.76	3.69	1.83	10.70	139.5	80,607	1.00	7,530
Column S-2 (U) - 1st Floor	0 - 8.0	6.99	3.68	1.90	10.64	138.9	76,017	1.00	7,140
Column F-21 (U) - 2nd Floor	0 - 8.3	6.98	3.69	1.89	10.70	140.9	81,451	1.00	7,610
Column C-28 (U) - 2nd Floor	0 - 8.3	7.13	3.69	1.93	10.70	141.1	103,608	1.00	9,680
Column H-27 (U) - 2nd Floor	0 - 7.3	5.13	2.71	1.89	5.77	139.5	26,006	1.00	4,510
Floor Slab J.2-26.5	0 - 3.8	2.78	2.71	1.03	5.77	144.3	60,861	0.88	9,280

REMARKS:
*Depth referenced from top of core
No defects noted in caps or cores.
The cores were tested the as received condition.
Sample at Column H-2 (U) did not meet minimum length-to-diameter ratio of 1.0 as required in ASTM C39.

Reviewed By: _____ Date: 06/20/24

LERA

Probing and Material Testing Program

LERA's Concussions from ATL's Reports

1. The core samples show a high concentration of chlorides.
   This contributes to the deterioration of the columns.

Chloride Test Results

Sample ID	Chloride by mass Of cement (%)
M12	3.59
S5	0.14
H2	0.12
F16	0.09
S2	1.42
H8	0.19
P20	4.87
F21	0.71
C28	0.12
H27	0.07
P29	0.17
Q27.5	0.97

Most columns show high concentration of chloride > 0.15%

ACI 318 Chloride Limits

Table 19.3.2.1—Requirements for concrete by exposure class

Exposure class	Maximum w/cm[1,2]	Minimum f'_c, psi	Additional requirements		Limits on cementitious materials
			Air content		
			Maximum water-soluble chloride ion (Cl^-) content in concrete, percent by mass of cementitious materials[9,10]		
			Nonprestressed concrete	Prestressed concrete	Additional provisions
C0	N/A	2500	1.00	0.06	None
C1	N/A	2500	0.30	0.06	
C2	0.40	5000	0.15	0.06	Concrete cover[11]

0.15% Chloride Limit per ACI 318-19 19.3.2

LERA

Probing and Material Testing Program

LERA's Concussions from ATL's Reports

2. The air content in the concrete is low.
   This also contributes to the deterioration of the columns.

Air Void Test Results

	Core H-8U	Core S-2L	Core C-28L	Core F-16L	Core H-2L	Core H-27L	Core S-5L	Core P-20U	Core Q27.5	Core P-20L	Core M-12L	Core P-29L
Magnification	65	80	80	76	70	65	82	69	75	80	75	76
Total Number of Points	1200	1425	1313	1350	1350	1425	1425	1350	1213	1425	1350	1200
Distance Between Points (in.)	0.0667	0.0667	0.0667	0.0667	0.0667	0.0667	0.0667	0.0667	0.0667	0.0667	0.0667	0.0667
Total Length of Traverse (in.)	80.00	95.00	87.53	90.00	90.00	95.00	95.00	90.00	80.87	95.00	90.00	80.00
Area Analyzed ($in.^2$)	10.0	12.0	11.0	11.0	11.0	12.0	12.0	11.0	10.0	12.0	11.0	10.0
Void Frequency (voids/in.)	2.075	5.368	1.291	2.922	10.556	0.842	7.095	0.644	1.496	0.758	5.722	1.513
Air Content (%)	1.8	3.3	1.6	2.3	6.1	1.8	5.1	1.0	1.6	0.8	4.0	1.9
Paste Content (%)	37.6	31.5	37.4	39.2	30.5	29.6	27.5	39.8	33.6	33.3	37.5	38.7
Specific Surface ($in.^2/in.^3$)	453	651	323	509	695	185	554	249	363	360	572	316
Paste-Air Ratio	20.5	9.6	23.4	17.1	5.0	16.2	5.4	38.4	20.4	39.5	9.4	20.2
Spacing Factor (in.)	0.0192	0.0095	0.0284	0.0158	0.0067	0.0425	0.0086	0.0454	0.0239	0.0317	0.0108	0.0273

All samples show low air content < 6.5%

ACI 201.2 Air Content Limit

Table 4.2.3.2.4—Recommended air contents

Nominal maximum aggregate size, in. (mm)	Air content, percent*	
	Exposure Class F1	Exposure Class F2 and F3
3/8 (9.5)	7	7.5
1/2 (12.5)	7	7
3/4 (19)	6.5	7
1 (25)	6.5	6.5
1-1/2 (37.5)	6	6.5
2 (50)	6	6
3 (75)	5	5.5

Probing and Material Testing Program

LERA's Concussions from ATL's Reports

3. The concrete strength is higher than advertised in the drawings. This is a good thing.

Air Void Test Results

Core ID	Depth of Core (in)*	Average Length (in)	Average Diameter (in)	Length to Diameter Ratio	Area (in^2)	Calculated Density (pcf)	Total Load (lbs)	Strength Correction Factor	Unit Load (psi)
Column M-12 (U) - 2nd Floor	0 - 7.8	6.50	3.69	1.76	10.70	139.7	97,724	1.00	9,130
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ACI 562 Concrete strength evaluation from samples

6.4.3 *Concrete*—The cores shall be selected and removed in accordance with ASTM C42 and ASTM C823. The equivalent specified concrete strength f_{ceq} shall be calculated using Eq. (6.4.3).

$$f_{ceq} = 0.9\overline{f}_c\left[1 - 1.28\sqrt{\frac{(k_c V)^2}{n} + 0.0015}\right] \qquad (6.4.3)$$

Evaluated concrete strength: 6,557psi

> 3,750psi design concrete strength

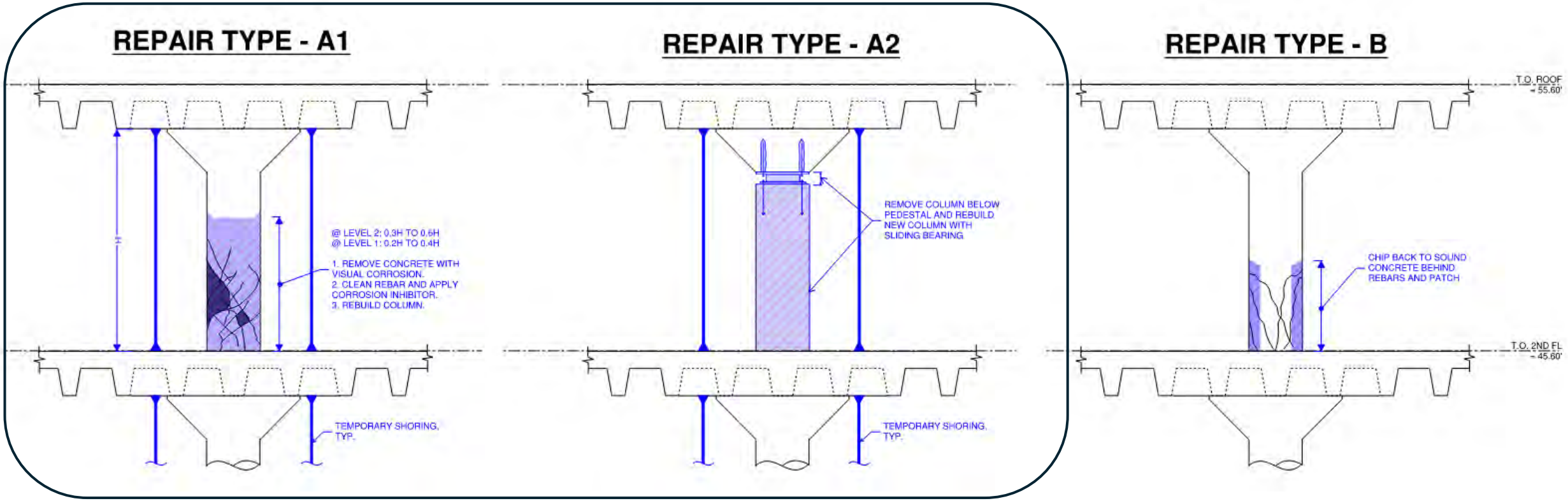
LERA

Probing and Material Testing Program

LERA's Concussions from ATL's Reports

These findings confirm that the damaged concrete in the columns needs to be removed, replaced, and protected against future damage, consistent with our preliminary repair schemes shown in sketch SK-03.

It is likely that all columns will require full repair, as we now don't anticipate much, if any, simple patching (Type B).

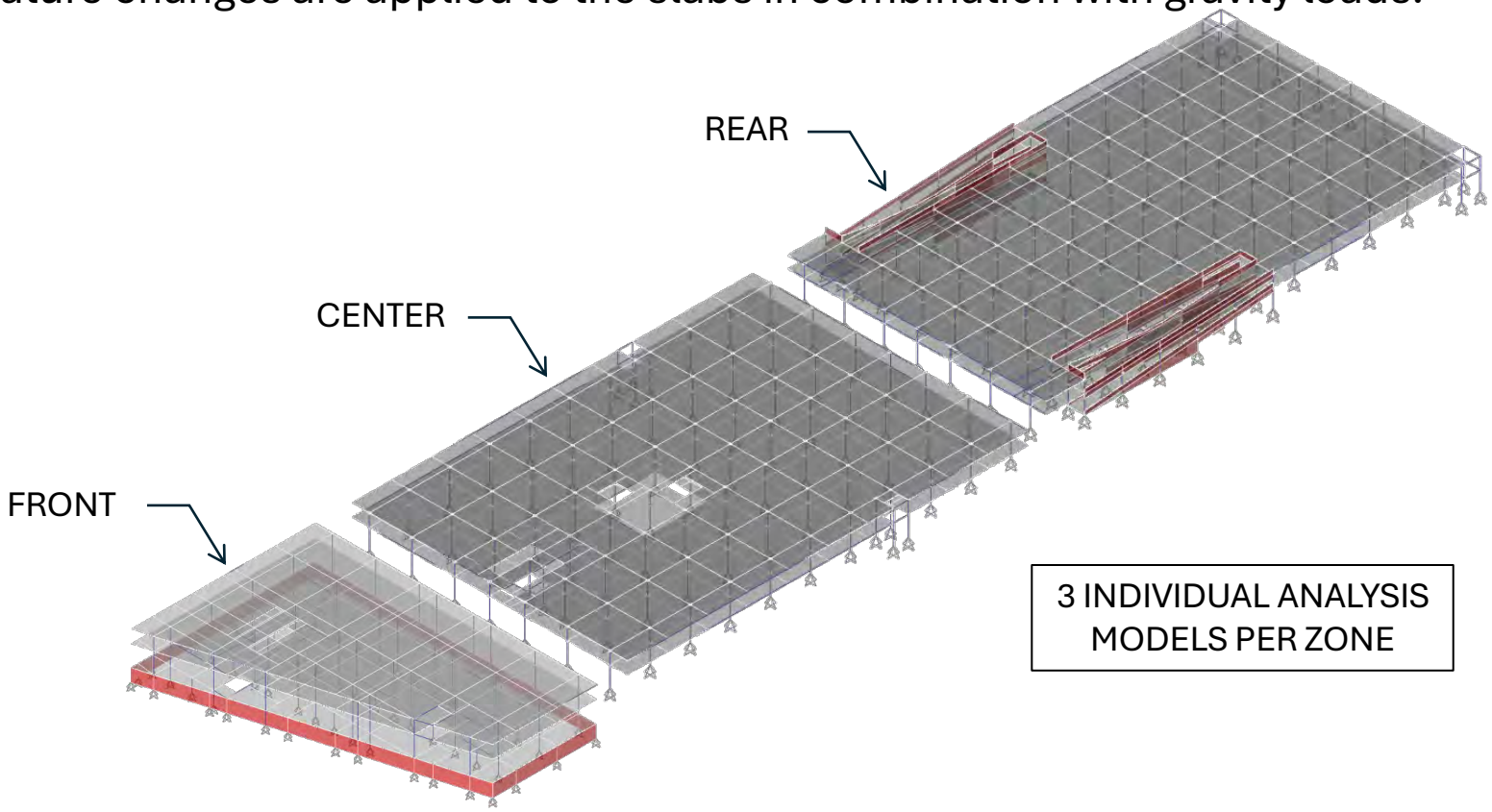


LERA

Structural Evaluation

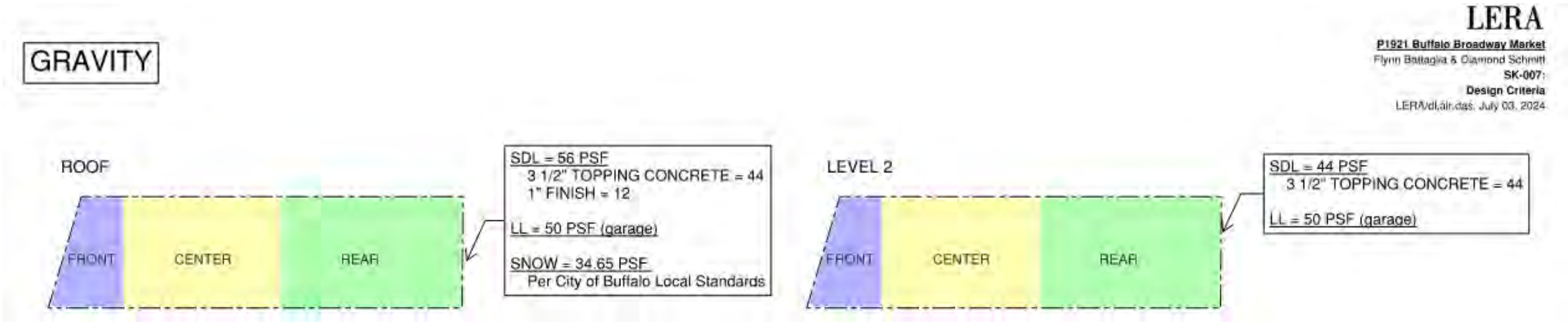
We suspect that thermal expansion and contraction of the slabs contribute to the deterioration of the columns by inducing loads that generate overstresses.

To evaluate this, we built analysis models for the entire building to study the performance of the structure when different temperature changes are applied to the slabs in combination with gravity loads.



Structural Evaluation

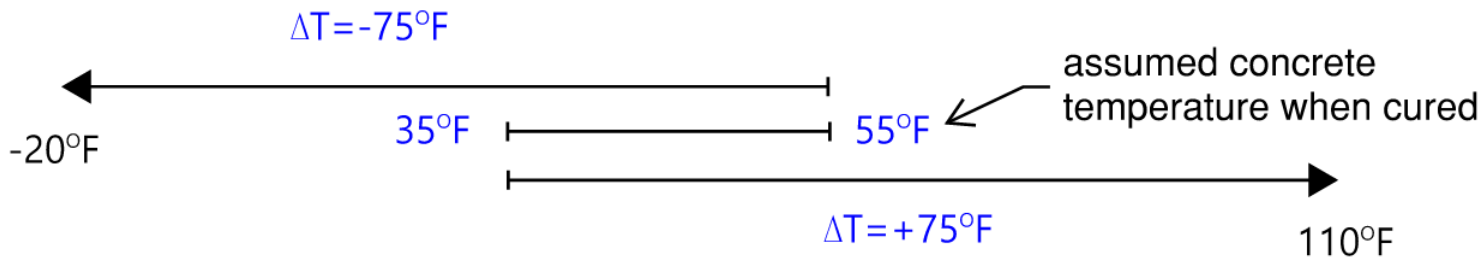
Gravity Loads



Structural Evaluation

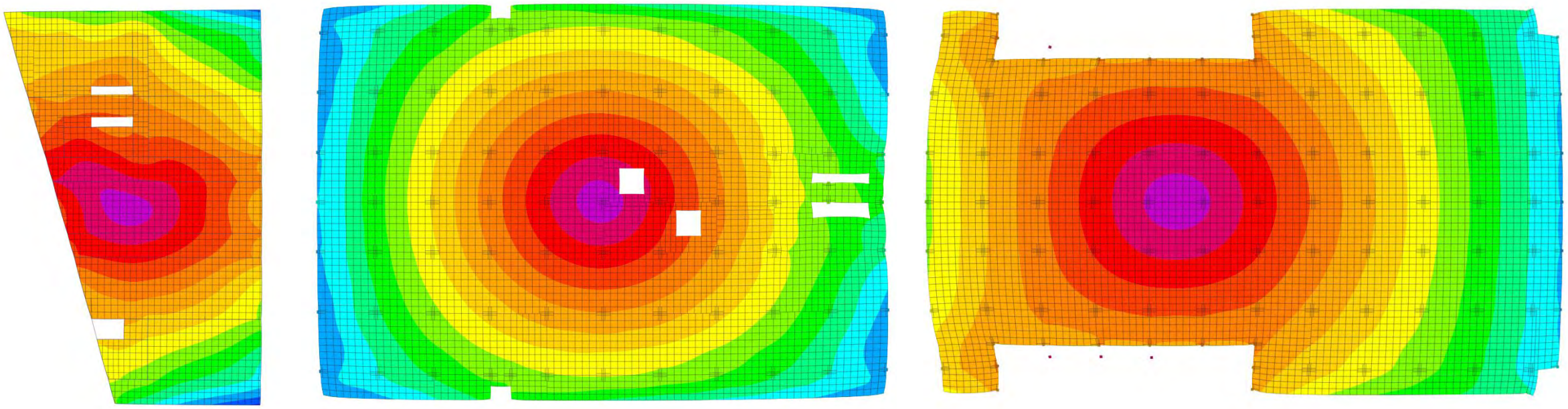
Thermal Loads

NOTE: ASSUMED BUFFALO HISTORIC TEMPERATURE: VARYING -20°F TO 110°F
(source: https://www.weather.gov/buf/BUFRecords)



Structural Evaluation

Thermal Expansion and Contraction of Floor Slabs



FRONT

CENTER

REAR

LERA

Structural Evaluation

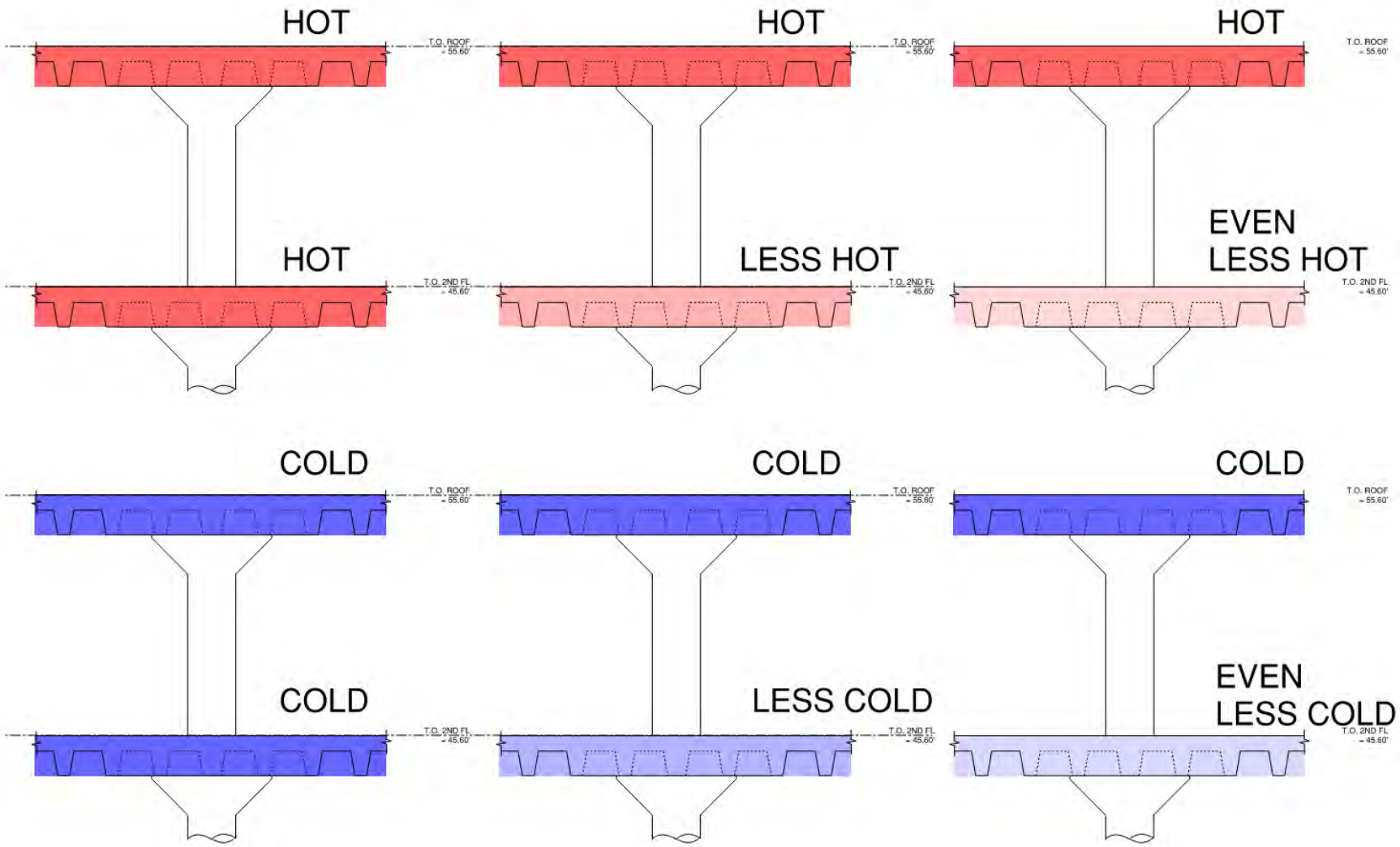
Temperature Differential Between Roof and Level 2 Slabs

+75 F

+75 F to +0 F

-75 F

-75 F to -0 F

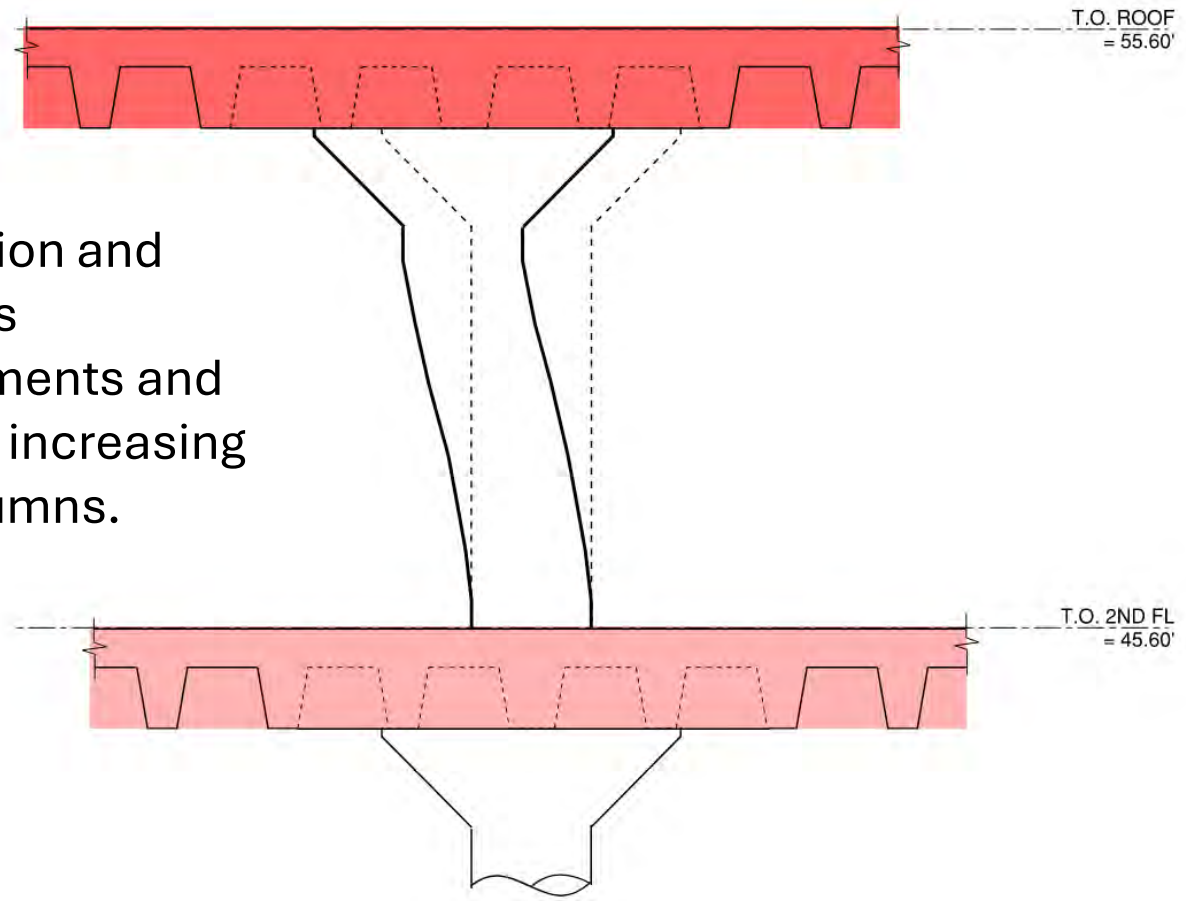


LERA

Structural Evaluation

Temperature Differential Between Roof and Level 2 Slabs

The differential expansion and contraction of the slabs introduce bending moments and shears in the columns, increasing the stresses in the columns.



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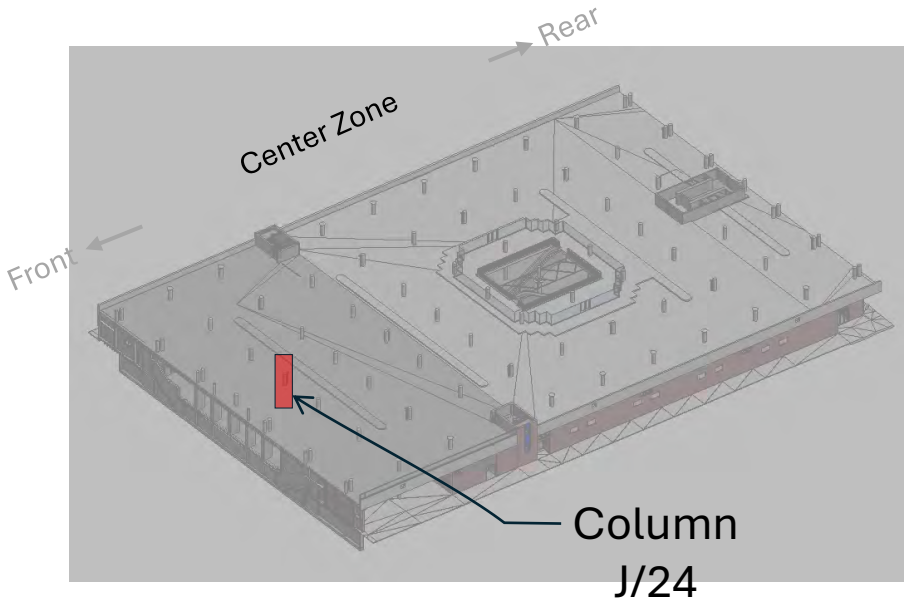
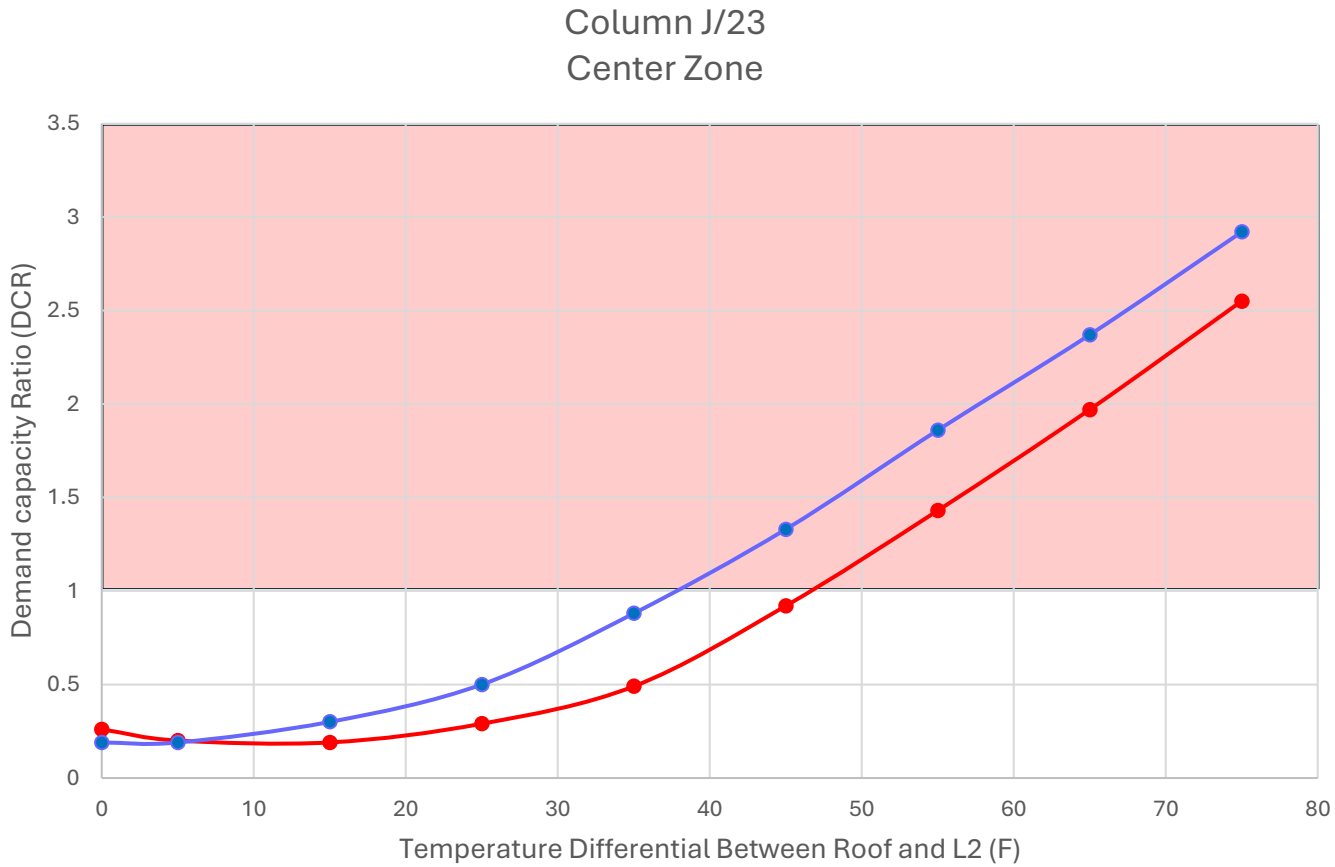
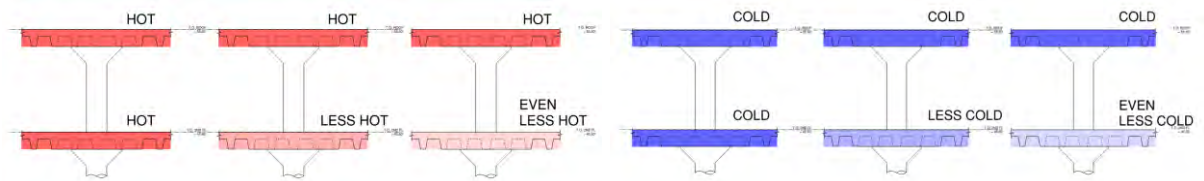
Structural Evaluation

For every column, we can calculate the Demand Capacity Ratio as a function of the temperature differential between the Roof and Level 2 slabs (example below).

A DCR greater than 1.0 indicates that the column is overstressed.







Structural Evaluation

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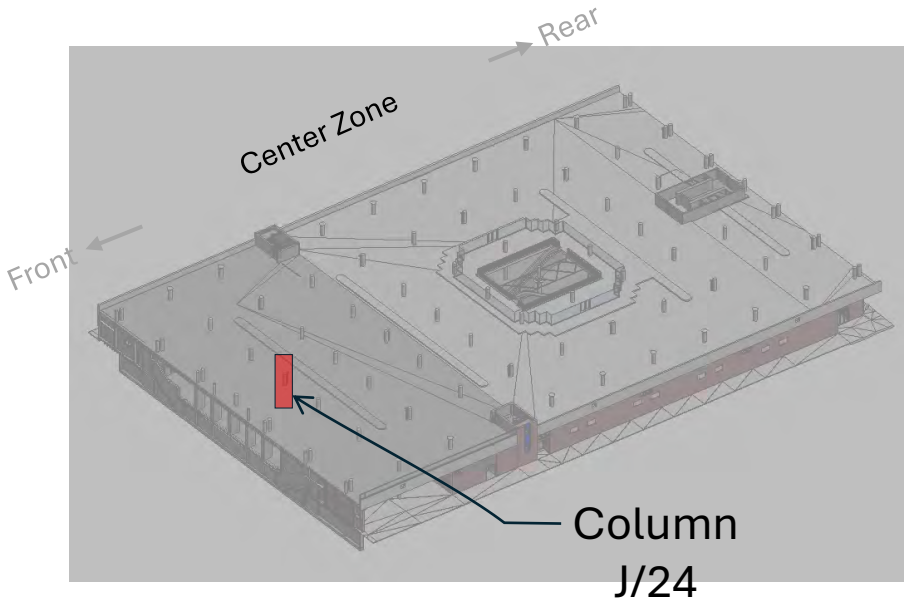
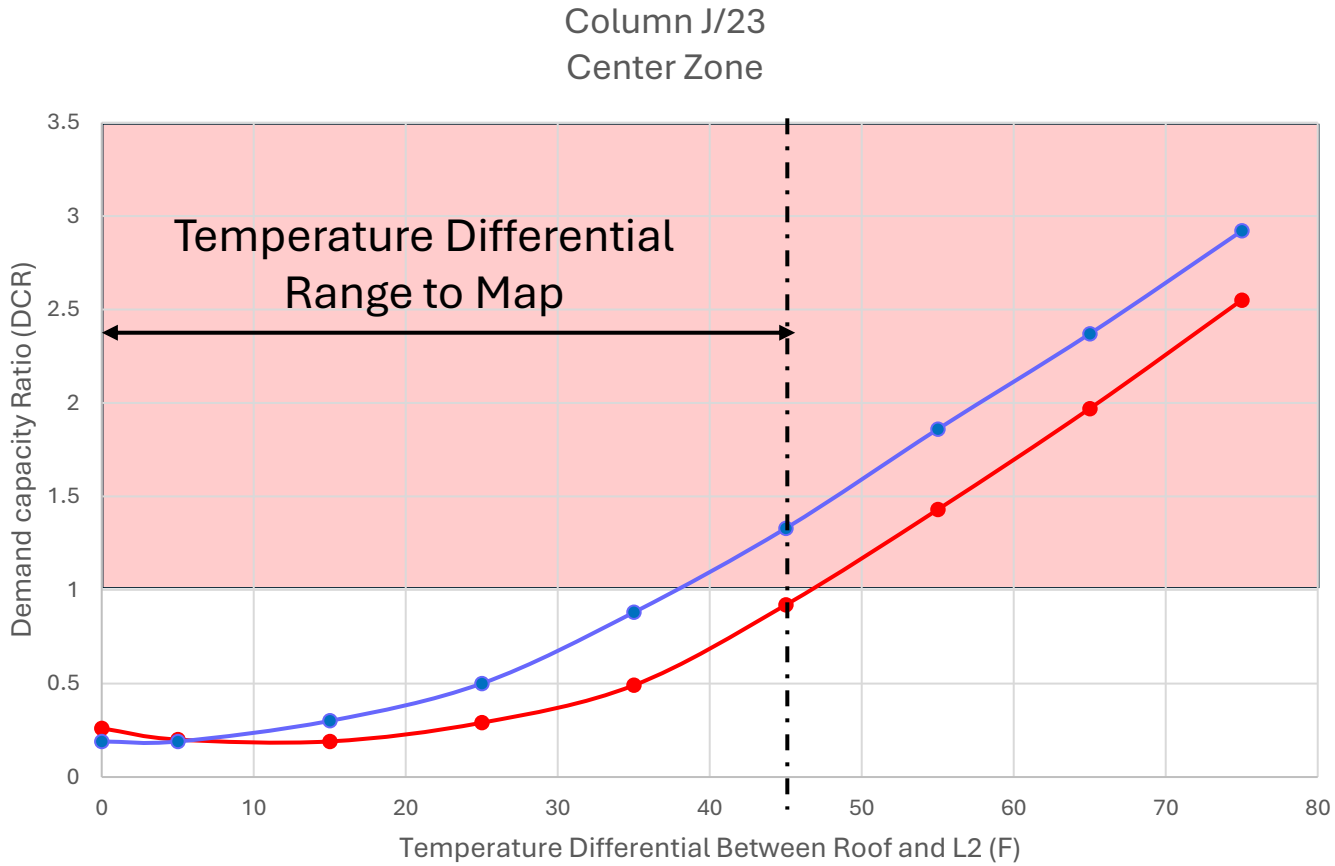
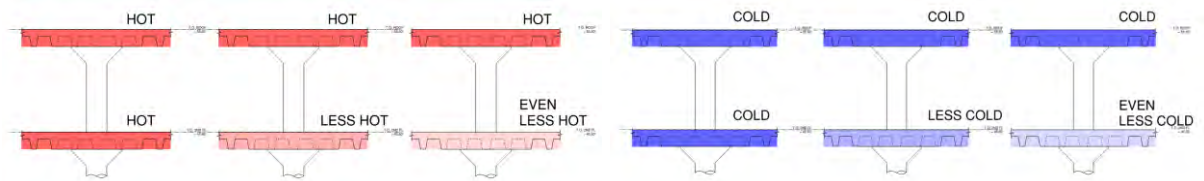
A DCR greater than 1.0 indicates that the column is overstressed.



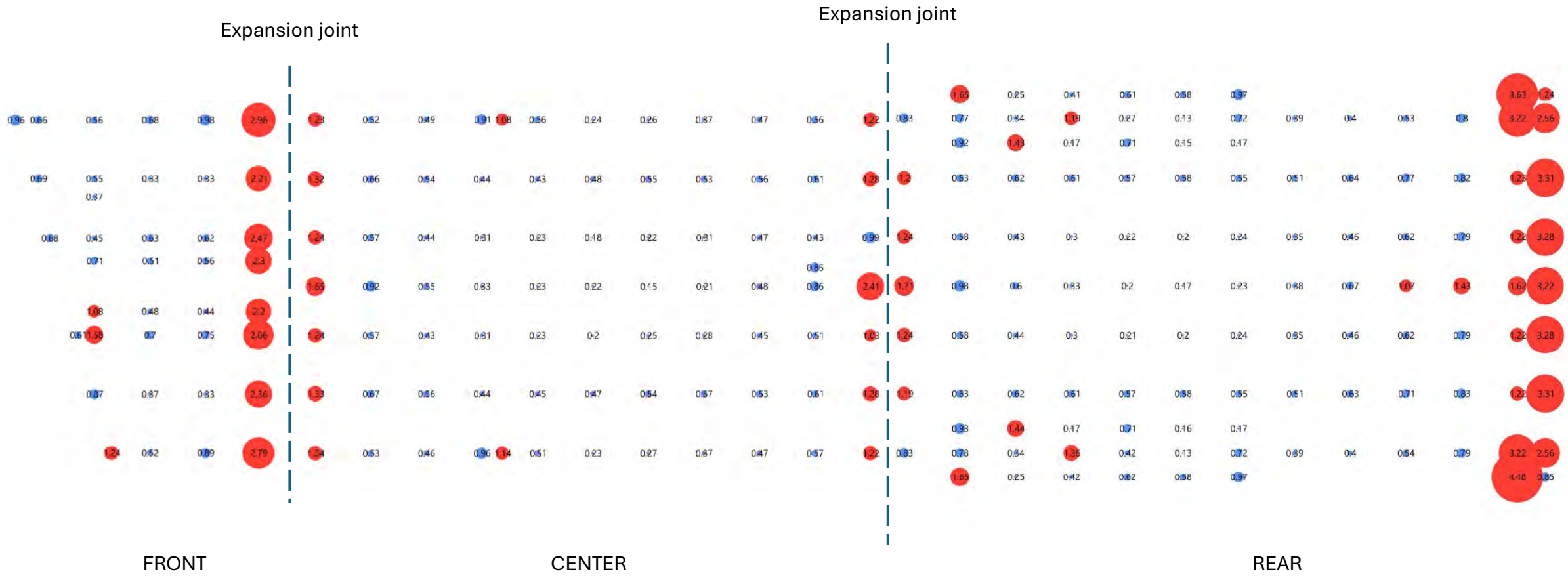




LERA

Structural Evaluation

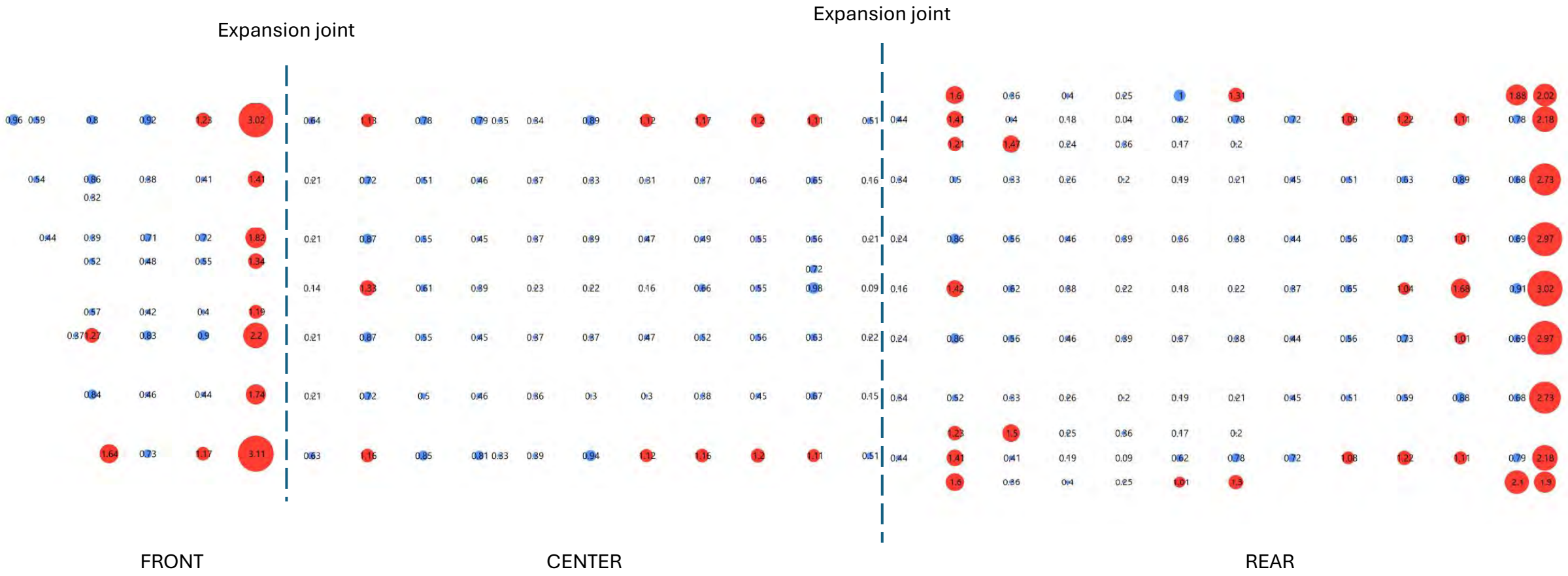
Summer – T_{roof} = +75°F , T_{L2} = + 30 °F (ΔT = 45 °F)



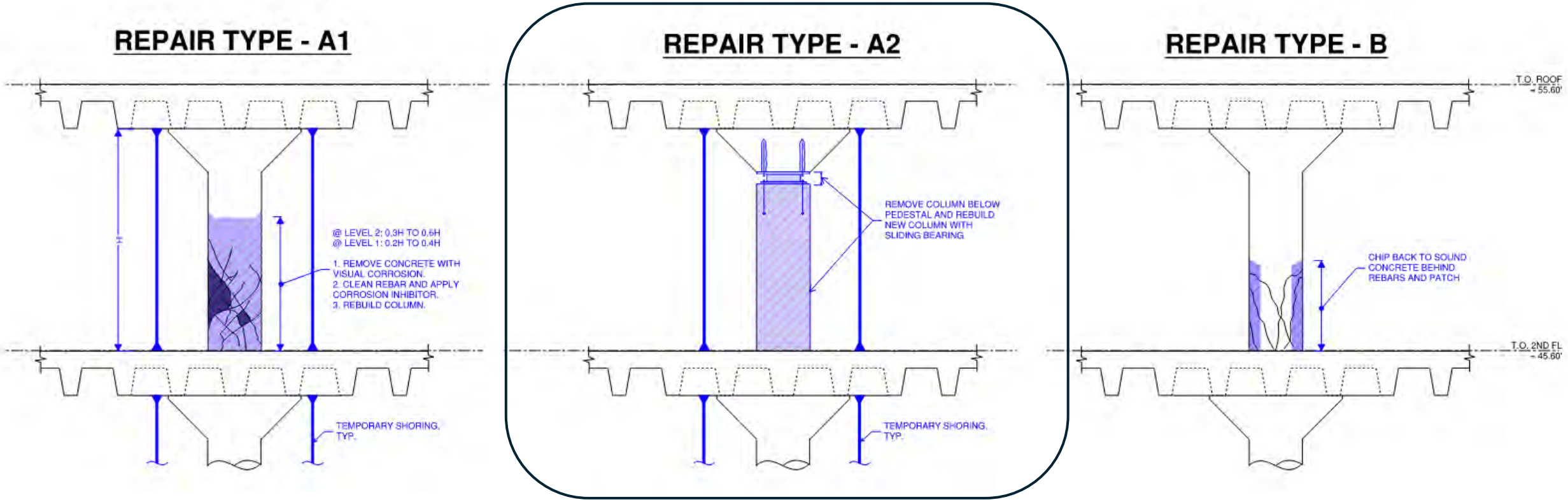
LERA

Structural Evaluation

Winter – T_{roof} = -75°F , T_{L2} = -30 °F (ΔT = 45 °F)

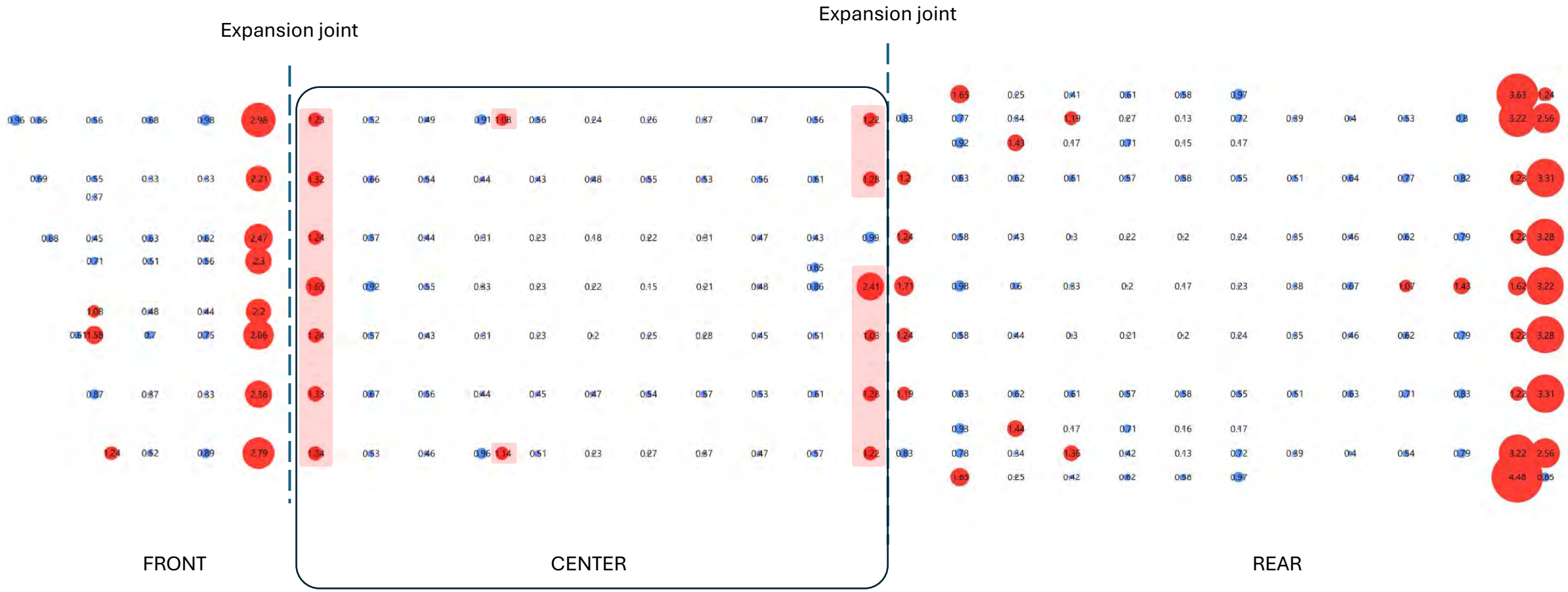


Structural Evaluation



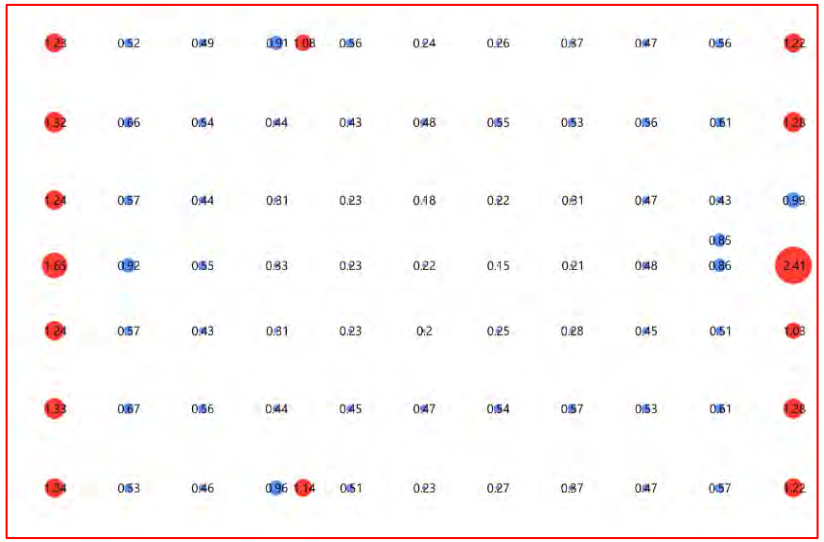
Structural Evaluation

Summer – T_{roof} = +75°F , T_{L2} = + 30 °F (ΔT = 45 °F)

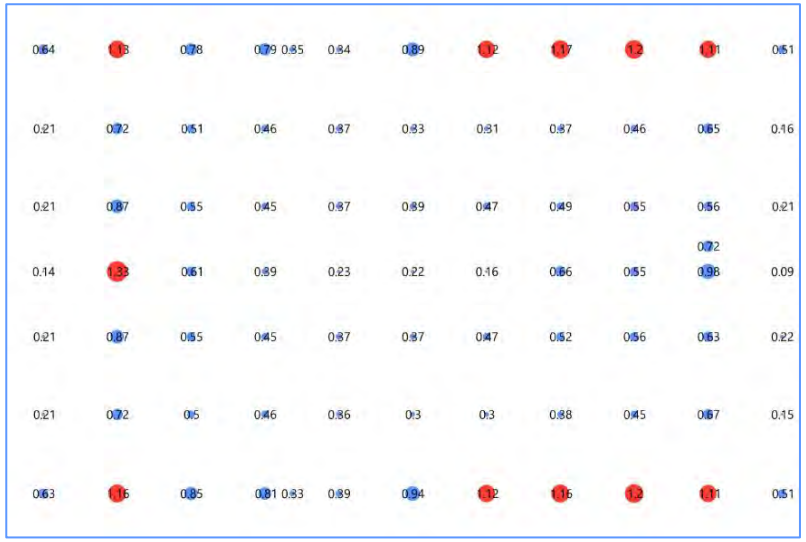


Structural Evaluation

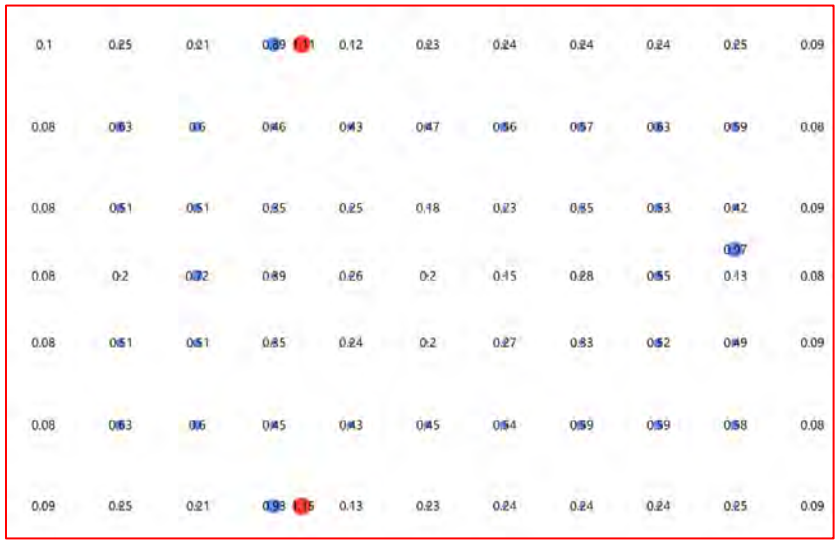
Summer

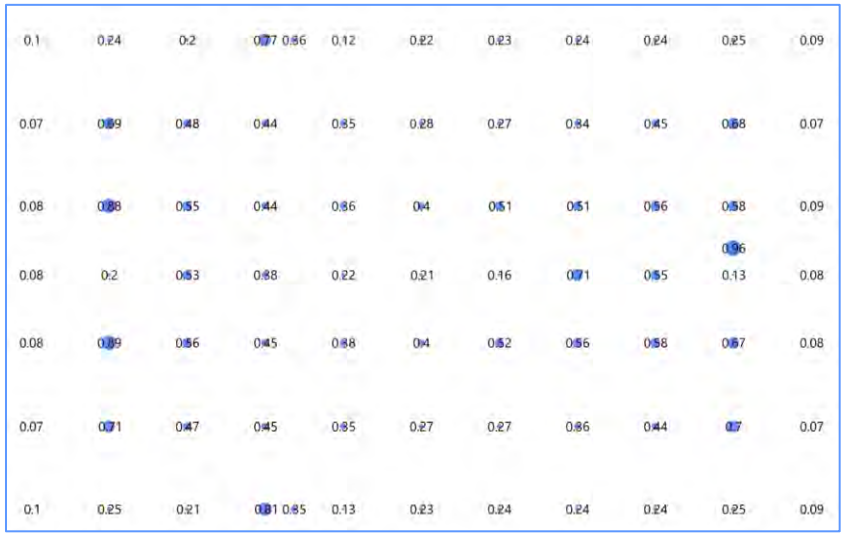


Winter



Sliding bearings





LERA

Conclusions

The core samples show a high concentration of chlorides. This contributes to the deterioration of the columns.

The air content in the concrete is low. This also contributes to the deterioration of the columns.

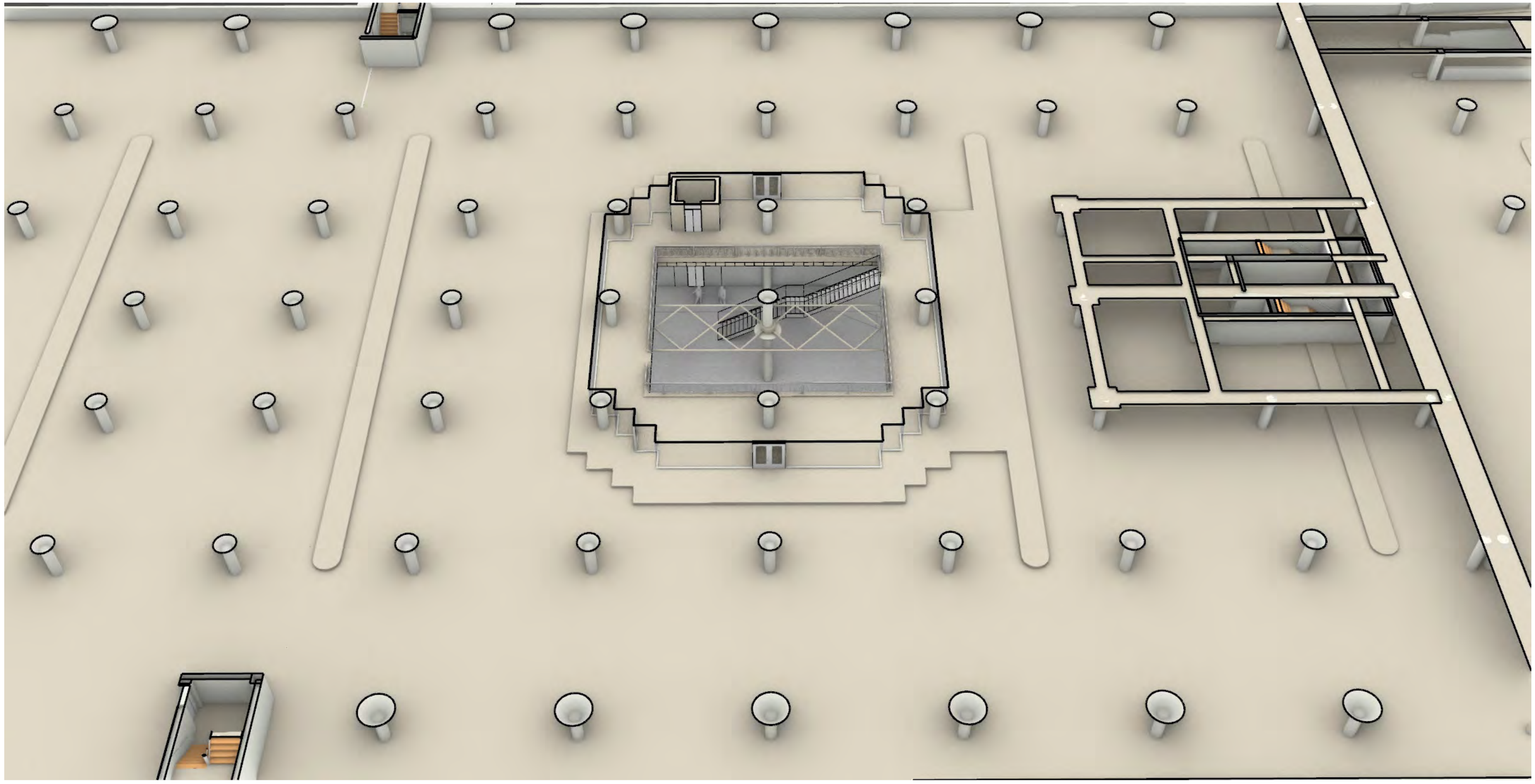
The concrete strength is higher than advertised in the drawings.

Our analysis indicates that the thermal expansion and contraction of the slabs induce stresses in the columns that, in some cases, overstress the columns.

The columns with the larger stresses are generally on the perimeter of each section of the building.

We find that when the two slabs experience different temperature changes (when there is a temperature differential between the two slabs) the stresses in the columns increase.

Our analysis suggests that the building may benefit from releasing the top of some columns, as we previously anticipated.

Plan Section Perspective | LEVEL 2

diamond schmitt