Presentation Outline

- WJE Project Team
- Investigation Objectives & Approach
- Findings & Observations
  - Document Review
  - Site Observations
  - Laboratory Testing
  - Structural Analysis
  - Theory of Collapse
- Summary
WJE Project Team

- **Project Managers:** Matthew Fadden and Gary Klein (NB)
- **South Florida:** Alejandra Corona, Crisol Ortiz, Sedona Iodice, Brent Chancellor, Brian Calderone, Zack Sumislaski, Dirk Heidbrink
- **Document Review:** Audrey Ryan (LON), Elie Hantouche (CHI), Robert Kraus (SF)
- **Modeling:** Jeff Rautenberg (MIN), Tanner Swenson (MIN)
- **Geotech:** Swapna Danda (WDC), Rich Finno (Affiliated Consultant)
- **Site Visits/Observations:** Tarka Wilcox (DEN), Prateek Shah (SF), Daria VanAllman (WDC), Anna Quinn (HOU), Emmett Horton (WDC), Heba Elsayed (ATL), Brian Hill (ATL), Ryan Sitar (LA), Doug Stevie (NYC)
Investigation Objectives & Approach
1. Conduct an investigation that is sufficiently thorough to provide a credible independent opinion as to the cause of the collapse

2. Based on the investigation findings, provide expert services in defense of lawsuits against the condominium association (or pursuit of lawsuits against others)
Investigation Approach

- Document Review
- Site Investigation
- Laboratory Studies
- Structural Analyses

Root Cause
Findings & Observations

Document Review
A building had partially collapsed at ~1:30 am

100+ people were feared missing or dead

- 98 bodies were ultimately recovered

Cause was unclear

Investigation via social media/news/photos/videos
Building Description

- 12 story L-shaped structure with 136 units built in 1981
- Reinforced concrete flat plate construction
- Parking on lobby level and basement garage
- Pool deck terrace on the south side of the buildings
Codes and Design Standards (1981)

- South Florida Building Code 1979
- ACI 318-77: Building Code Requirements for Reinforced Concrete
Foundations

- 150-ton Franki piles, a.k.a. pressure-injected footings (PIFS)

Western Waterproofing performed:

- Planter waterproofing
- Paver installation
- Concrete structural repairs
2010-2011: Carousel Development and Restoration (CDR) – Concrete repairs

2012: Property Manager – Ongoing leakage through the pool deck

2013-2014: Scott Vaughn PE/Infinite Aqua – Repairs to the pool, garage ceiling, and planters

2017: G. Batista – Specifications and details for planter waterproofing repair
Abundant cracking and spalling in garage with calcium carbonate leaching

Timely repair recommended following ICRI recommendations

Previous repairs failing due to poor workmanship

Recommend entrance/pool decks slabs showing distress be removed in their entirety and replaced
Morabito Investigation – Deck Finish

Deck finish not as originally designed.
Morabito Investigation – Concrete Core Samples

Parking Deck

- Topping Slab
- Structural Slab

Not included in the original structural drawings

Pool Deck

- Tile and Mortar
- Topping Slab
- Structural Slab

Concrete Topping: 2.1
Varies, not shown in plan

Structural Slab: 9.5
9.5

*submittal not available, assumed to be as specified
Morabito Investigation - Planters
Morabito analyzed the slab along column line T and the punching shear results were exceeded in every calculation iteration.

### 2.11.2. Punching Shear Results

<table>
<thead>
<tr>
<th>Support</th>
<th>$V_u$ kip</th>
<th>$V_u$ psi</th>
<th>$M_{\text{unb}}$ k-ft</th>
<th>Comb</th>
<th>Patt</th>
<th>$\gamma_v$</th>
<th>$V_u$ psi</th>
<th>$\Phi V_c$ psi</th>
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<tr>
<td>1</td>
<td>80.05</td>
<td>31.9</td>
<td>195.51</td>
<td>U1</td>
<td>All</td>
<td>0.117</td>
<td>343.7</td>
<td>*EXCEEDED</td>
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<td>2</td>
<td>202.56</td>
<td>236.6</td>
<td>10.47</td>
<td>U1</td>
<td>All</td>
<td>0.415</td>
<td>244.8</td>
<td>*EXCEEDED</td>
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<td>3</td>
<td>133.15</td>
<td>183.2</td>
<td>-39.19</td>
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<td>All</td>
<td>0.422</td>
<td>217.6</td>
<td>*EXCEEDED</td>
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<td>4</td>
<td>164.83</td>
<td>192.5</td>
<td>12.83</td>
<td>U1</td>
<td>All</td>
<td>0.375</td>
<td>200.5</td>
<td>*EXCEEDED</td>
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<td>5</td>
<td>176.45</td>
<td>206.1</td>
<td>-18.39</td>
<td>U1</td>
<td>All</td>
<td>0.415</td>
<td>217.8</td>
<td>*EXCEEDED</td>
</tr>
<tr>
<td>6</td>
<td>133.61</td>
<td>183.9</td>
<td>6.98</td>
<td>U1</td>
<td>All</td>
<td>0.422</td>
<td>190.0</td>
<td>*EXCEEDED</td>
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<td>7</td>
<td>156.94</td>
<td>216.0</td>
<td>6.70</td>
<td>U1</td>
<td>All</td>
<td>0.422</td>
<td>221.8</td>
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<td>146.79</td>
<td>171.5</td>
<td>-25.71</td>
<td>U1</td>
<td>All</td>
<td>0.375</td>
<td>191.2</td>
<td>*EXCEEDED</td>
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<tr>
<td>9</td>
<td>178.11</td>
<td>180.7</td>
<td>16.77</td>
<td>U1</td>
<td>All</td>
<td>0.380</td>
<td>190.3</td>
<td>*EXCEEDED</td>
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<td>10</td>
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<td>30.7</td>
<td>-172.04</td>
<td>U1</td>
<td>All</td>
<td>0.117</td>
<td>299.8</td>
<td>*EXCEEDED</td>
</tr>
</tbody>
</table>
Bedroom locations overlooking pool deck

Apt 711
Rosie / Ring Video

Apt 611
Ileana Monteagudo

Apt 412
Cassie

Apt 111
Gabe Nir
## Event Timeline - June 24, 2021

<table>
<thead>
<tr>
<th>Time</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>~12:30 AM</td>
<td>Resident (Unit 111) hearing “construction” noise from garage</td>
</tr>
<tr>
<td>1:10 AM</td>
<td>Security Guard and Resident (Unit 111) heard loud crash, felt rumbling, saw white dust in the air</td>
</tr>
<tr>
<td>1:15 AM</td>
<td>Security Guard and Resident (Unit 111) heard very loud collapse, felt rumbling and the building sway, saw parking deck had collapsed and more dust</td>
</tr>
<tr>
<td></td>
<td>Guests at Bluegreen Resort (north of CTS) heard loud crash, felt rush of air from garage</td>
</tr>
<tr>
<td>1:18 AM</td>
<td>TikTok video shows large chunks of concrete debris on the floor of the garage. Debris is located approximately where terrace is attached to south side of the building (approx. Unit 111)</td>
</tr>
<tr>
<td></td>
<td>Unit 611 notices cracks in her wall and cannot open door. Escapes via west stairs.</td>
</tr>
<tr>
<td>1:20 AM</td>
<td>Unit 412 felt the building shaking, saw the pool deck had collapsed</td>
</tr>
<tr>
<td>~1:22 AM</td>
<td>Three columns on the south face of the building appear to fail near their bases. Area 1 immediately collapses</td>
</tr>
<tr>
<td></td>
<td>Area 2 collapses immediately after Area 1 spreading some debris to the north</td>
</tr>
<tr>
<td></td>
<td>Area 3 to the east stands briefly and collapses rotating at the base</td>
</tr>
</tbody>
</table>
1:22 AM - 8701 Collins Ave Video

~1:22 am

Did not collapse

WJE
Pool Deck Collapse

Approximate extent of collapsed pool deck

North
1:18 AM - TikTok Video
~1:15-1:22 AM - Unit 711 Ring Video
Findings & Observations

Site Investigation
Basement Slab Survey - Topography

Scale (inches)
CHAMPLAIN TOWERS SOUTH COLLAPSE INVESTIGATION:
Joint Protocol for Testing and Material Sampling – Collapse Site

In accordance with the Court Order dated September 1, 2021, this document presents the protocol for testing and material sampling at the collapse site (the “Protocol”) and has been developed considering input from involved Participants.

DEFINITIONS

- **Consultant** – Geosyntec Consultants, Inc., an independent consultant approved by the Receiver to coordinate, plan, oversee, and provide factual reporting as defined in this Protocol to the Experts/Participants. The Consultant will employ Testing Agencies and Contractors to meet the goals of the Protocol. Payment to Consultant for its fees and costs shall be paid by all Participants as defined in the "Payment of Costs" section below.

- **Contractor** – Company, or companies, approved by the Receiver to engage in providing construction, samples, borings, security, or other support for execution of the Protocol. The Contractors shall be engaged by the Consultant. Payment for services shall be remitted to Consultant for payment to Contractors. Payment for Contractors’ services shall be paid by all Participants as defined in the "Payment of Costs" section below.

- **Court** – Circuit Court of the 11th Judicial Circuit in and for Miami-Dade County, Florida.

- **Expert** – Engineers (or other disciplines) investigating the collapse on behalf of Participants.

- **Litigation** – *In Re: Champlain Towers South Collapse Litigation*, Case No. 2021-015089-CA-01, pending in the Eleventh Judicial Circuit Court in and for Miami-Dade County, Florida.
Estimated Subsurface Conditions
Column and Basement Slab Coring

Concrete core collected from a column

Concrete core collected from the basement slab
Rebar and Waterproofing Sampling

Steel sample collected from the south wall

Waterproofing testing at the pool deck
Primary Evidence Facility – South Bay

Majority of Items from Collapsed Portion

Majority of Items from Imploded Portion
PEF – Item 344 "Punched Slab"
PEF – Item 299 "Beam A"
PEF – Item 341 - 16x16 Column
Findings & Observations

Laboratory Testing
Concrete Petrography and Testing

Basement Slab Samples

- Concrete typical to Florida
  - Moderate w/c ratio (0.35-0.45)
  - Well mixed
  - Non-air entrained
- Corrosion consistent with that at concrete placement
- Low chlorides and carbonation
## Concrete Material Properties

<table>
<thead>
<tr>
<th>Location</th>
<th>Average Compressive Strength (psi)</th>
<th>Min. Specified Compressive Strength (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer Girder</td>
<td>3560</td>
<td>4000</td>
</tr>
<tr>
<td>Column M15.1</td>
<td>3785</td>
<td>6000</td>
</tr>
<tr>
<td>Column Q8</td>
<td>5820</td>
<td>6000</td>
</tr>
<tr>
<td>Pool Deck</td>
<td>4475</td>
<td>4000</td>
</tr>
<tr>
<td>Perimeter Wall</td>
<td>4280</td>
<td>4000</td>
</tr>
<tr>
<td>Shear Wall East</td>
<td>6600</td>
<td>6000</td>
</tr>
<tr>
<td>Shear Wall West</td>
<td>8155</td>
<td>6000</td>
</tr>
</tbody>
</table>
Steel Reinforcement

<table>
<thead>
<tr>
<th></th>
<th>Min. Specified (ASTM 615 Gr. 60)</th>
<th>Perimeter Wall (avg.)</th>
<th>Pool Deck (avg.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yield – ( F_y ) (psi)</strong></td>
<td>60,000</td>
<td>69,948</td>
<td>77,012</td>
</tr>
<tr>
<td><strong>Ultimate – ( F_u ) (psi)</strong></td>
<td>90,000</td>
<td>106,814</td>
<td>110,300</td>
</tr>
<tr>
<td><strong>Elongation (%)</strong></td>
<td>7-9 depending on bar size</td>
<td>12.4</td>
<td>12.9</td>
</tr>
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</table>
Findings & Observations

Structural Analysis
Punching Shear Failures
Pool Deck Slab Distress

Deflection

Column K13.1 (approx)

Wide Crack

Narrow Crack

Wide Crack

[Image of pool deck slab distress with annotations]

June 2, 202
K/13.1 Likely Slab Distress Mechanism

Column Line K – Looking West
Punching Shear

- Dependent on concrete strength ($f'_c$)
- Effective depth ($d$) and critical perimeter ($b_o$)
- $V_c = 4\sqrt{f'_c b_o d}$

Current research shows that:

- Dependent on amount of reinforcement and slab thickness
- A coefficient of 4 may be unconservative for low reinforcement ratios
Pool Deck – At Collapse
Pool Deck – At Collapse
### Pool Deck Punching Shear (K 13.1)

<table>
<thead>
<tr>
<th>As designed</th>
<th>At collapse</th>
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<tbody>
<tr>
<td><strong>Column Number</strong></td>
<td><strong>K 13.1</strong></td>
</tr>
<tr>
<td>Size (in x in)</td>
<td>16x12</td>
</tr>
<tr>
<td>Nominal $f'_c$ (psi)</td>
<td>4000</td>
</tr>
<tr>
<td>Clear Cover (in)</td>
<td>0.75</td>
</tr>
<tr>
<td>Factored Load (kip)</td>
<td>266</td>
</tr>
<tr>
<td>Reduced Nominal Capacity (kip)</td>
<td>155</td>
</tr>
<tr>
<td>Demand to Capacity Ratio</td>
<td>1.72</td>
</tr>
</tbody>
</table>
Concrete weaker under sustained loads

Typically ignored in design

Different stresses (i.e., shear, comp.) may have different behavior

Fig. 2—Stress-strain curves for concrete loaded in compression in various periods (Rusch)
As-Designed Positive Bending, 1.4D+1.7L, $\Phi = 0.9$
Demand-capacity ratios for negative bending, one-way shear, and punching shear at columns of interest

Demands:
- As-built planter geometry
- Assumed dead loads subject to change

Capacities:
- As-designed
  - clear cover = 0.75"
  - $f'c = 4000$ psi
  - $F_y = 60$ ksi
Full Building – Finite Element Model
Findings & Observations

Theory of Collapse
1. The pool deck to the south of the building fails
   ▪ Reported by the residents and in video documentation
   ▪ Observable punching shear failures

2. The failure of the pool deck applies horizontal forces to the building columns
   ▪ Horizontal forces are a result of bending forces and a possible catenary
   ▪ Strength is diminished by the step in the slab at the building

3. These forces fail the column at the south exterior wall resulting in a progressive and partial collapse of the tower

4. The remaining western portion remains due to the shear wall at the elevator core
Pool Deck/Lobby Level
Behavior of Slab after Punching Failures

South edge of property

Garage slab

Terrace slab collapses after punching at columns

Interior ground floor slab

South wall of building

Basement Garage slab

North
Slab Elevations
Progressive Collapse Mechanism

Case 1:
#11 bars per plan

REBAR CONFIGURATION IS PRELIMINARY AND REQUIRES VERIFICATION
Progressive Collapse Mechanism

Case 2: #11 bars shifted north

REBAR CONFIGURATION IS PRELIMINARY AND REQUIRES VERIFICATION

#11 bars
Mistakes that Appear to have Contributed

- Inadequate design of pool deck slab (especially punching shear)
- Excess weight on pool deck
  - Original concrete overlay not shown on drawings
  - Addition of pavers
  - Larger planters than shown on design drawings
- Shallow top reinforcement (decreasing effective depth)
- Engineers responsible for repairs failed to identify deficiency
Other Contributing Causes

- Long-term sustained load effects
- Low top reinforcement ratio (Code now requires more reinforcement)
- Water buildup in planters
- Corrosion (significance unclear)
$\sim1+\text{ Billion Dollar Settlement}$

- $\sim1$ billion from defendants
- $\sim120$ million for the sale of the land
- Economic loss: $96$ million dollars for property damage
- Wrongful death: $\sim900$ million
- Attorney fees: $\sim100$ million

Defendants:

- Securitas: $517$ million
- 87 Park Defendants: $272$ million
- Western Waterproofing: $25$ million
- CPR: $11$ million
- Maribito: $16$ million
- …and many others

$\sim1+\text{ Billion Dollar Settlement}$
Structural Engineering Going Forward...

- Awareness of our practice
  - ACI 318-77
  - Importance of checking with peers and mentors
- Law and Code Changes
  - Do more inspections matter?
  - Punching shear
- Future research needs
  - Punching shear, progressive collapse, etc.