The Guthrie Theater

Tina Chanady
Scott Kapczynski
Winnie Lam
David Pearce

Photo: Yoshio F.
The Guthrie Theater

Location:
  – Minneapolis, MN
  – Banks of the Mississippi River

Year Completed:
  – 2006

Architect:
  – Jean Nouvel

Purposes:
  – To replace old Guthrie Theater built in 1963, which is currently being demolished

Construction Materials:
  – Steel, concrete, and glass

Photo: Philippe Ruault
Program & Function

Floor Area: 285,000 sq. ft.
- Three Theaters
- Theater administration spaces
- Educational spaces
- Production program spaces
- Restaurant
- Bar

Photos: Yoshio F.
Uniqueness

The “Endless Bridge”
- 178 foot Cantilever stretching toward the river
  - One of the longest occupiable cantilevered spaces in the world
  - 50 feet above the roadway
  - Canopy for first floor lobby
  - Balcony for second and third floors
  - Gives impressive views of the river, a waterfall, and Minneapolis
Guthrie Layout
Theater Structure

- Lateral stability is provided by the metal roof deck and braced frames located at the exterior walls.
Cantilever Structure
Basic Structural Elements
Cantilever Dimensions
Use of deep pier foundation system that is anchored into limestone:

- Prevents overturning and sliding
- Reduces vibration from surrounding site
Structure

- Framed box truss
- Rigid connections
Lateral Resisting Mechanisms

- Vertical bracing restrains cantilever from overturning
- Prevents swaying
Lateral Resisting Mechanisms

- Lateral loads are transferred from concrete slab diaphragm to truss members to the vertical bracing system to the ground
- K-bracing on the top and bottom of the box truss provides stability
- Rigid joints used for connections
- Redundant system composed of diagonal bracing and rigid joints increases lateral stability
Dead Load

Total Weight of steel:
- 7502 linear feet of steel
- W14 x 730 members
7501 ft x 730 lb/ft = 5,476,533 lbs

Total Weight of Concrete:
- 2.5 inches over 3 inch metal decking
- Concrete Density: 150 lb/ft$^3$
- Volume of Concrete: 28,350 ft$^2$ x 4 in = 9451 ft$^3$
- Weight of Concrete: 9451 ft$^3$ x 150 lb/ft$^3$ = 1,417,650 lbs

Combined Load:
- 5,477 k + 1,418 k = 6,895 k
Load Tracing

- **Roof Plane**
- **Box Truss**
- **Brace**
- **Fulcrum Column**
- **Ballast Pad**
- **Drilled Piers**
Simplified Analysis

Axial Forces

Shear Forces
Simplified Analysis

Moment Forces

Deflection
Multi-frame Analysis: Axial Forces

Dead Load

3819 KIPS

4114 KIPS

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>P (KIP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4113.9</td>
</tr>
<tr>
<td>2</td>
<td>3819.7</td>
</tr>
</tbody>
</table>

Axial
Multi-frame Analysis: Shear Forces

DEAD LOAD

SHEAR

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>Yy (KIP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>429.7</td>
</tr>
<tr>
<td>2</td>
<td>164.5</td>
</tr>
</tbody>
</table>
Multi-frame Analysis: Moment Forces

DEAD LOAD

-1411.53 KIP/FT

-1668.9 KIP/FT

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>M_θ (KIP FT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1668.9</td>
</tr>
<tr>
<td>2</td>
<td>-1411.53</td>
</tr>
</tbody>
</table>
Multi-frame Analysis: Torsion Forces

**DEAD LOAD**

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>Tx (KIP/FT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.76</td>
</tr>
<tr>
<td>2</td>
<td>10.8</td>
</tr>
</tbody>
</table>
Multi-frame Analysis: Deflection

Dead Load
Lateral Load

Wind Load:
- Cantilever surface area: 4,826 ft
- Using Basic Wind Speed: 100 mph
  \[ P_w = 0.00256 \times v^2 \]
  \[ = 0.00256 \times (100 \text{ mph})^2 \]
  \[ = 25.6 \text{ lb/ft}^2 \]
- Total force = 4,826 ft\(^2\) \times 25.6 \text{ lb/ft}^2 = 123,545.6 \text{ lb}
- Find Uniform Distributed Load:
  Total Length = (52 ft \times 5) + (32 ft \times 5) = 420 ft
  Uniform Dist. Load = 123,545.6 lb / 420 ft = 294 lb/ft
Multi-frame Analysis: Axial Forces
Multi-frame Analysis: Shear Forces

LIVE LOAD

-23.9 KIPS

-23.6 KIPS

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>Vz (KIP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-23.9</td>
</tr>
<tr>
<td>2</td>
<td>-23.6</td>
</tr>
</tbody>
</table>

SHEAR
Multi-frame Analysis: Moment Forces

LIVE LOAD

MOMENT

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>Moment (KIP/FT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-545.73</td>
</tr>
<tr>
<td>2</td>
<td>-413.12</td>
</tr>
</tbody>
</table>
Multi-frame Analysis: Deflection

Lateral Wind Load
Conclusion

• Structural system: box truss is an appropriate selection because it has an occupiable space, uses material efficiently, and provides rigidity for long spans.

• Lateral resisting mechanism: Diagonal bracing, diaphragms, and horizontal and vertical braces transfer lateral forces efficiently and without infringing on the occupiable space.

• Foundation: Provides stability, balances overturning forces of cantilever, and transfers loads to the ground.
References


