

Seattle Central Library

**Applied Architectural Structures
Case Study Report
(ARCH 631)**

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Photo Credits: Scott Norsworthy (<http://scottnorsworthy.com/Seattle-Public-Library>)

Introduction

The Library is a twenty-eight branch system. Our interest in the Seattle Central Library building is primarily because of the structural systems implemented and the importance of it being located in a seismic UBC Zone 3. It would therefore be of great interest to understand how the structure is responsive in lateral loading conditions. The fact that the structure has a minimal use of columns makes it intriguing enough to investigate and understand the support systems that hold it all together and make it efficient.



Project Data

Architects: OMA + LMN

Landscape Architects: Inside/Outside
Jones & Jones

Location: Seattle, WA, USA

Coordinates: 47° 36' 24" N, 122° 19' 58" W

Key Personnel: Rem Koolhaas and Joshua Prince-Ramus (Partner-in-Charge), with Mark von Hof-Zogrotzki, Natasha Sandmeier, Meghan Corwin, Bjarke Ingels, Carol Patterson

Consultants: Arup, Bruce Mau Design, Davis Langdon, Dewhurst Macfarlane, Front, HKA, Hoffman Construction, Inside/Outside, Jones & Jones, Kugler Tillotson, Magnusson Klemencic, McGuire, Michael Yantis, Pielow Fair, Quinze & Milan, Seele

Electrical Engineer: Kugler Tillotson Associates

Structural Engineer: Magnusson Klemencic Associates, Arup

Construction Company: Hoffman Construction Co.

Client: Seattle Public Library

Budget: US \$169.2 M

Floors: 11 + 1 basement level

Area: 38,300.0 sf

Project Year: 2004

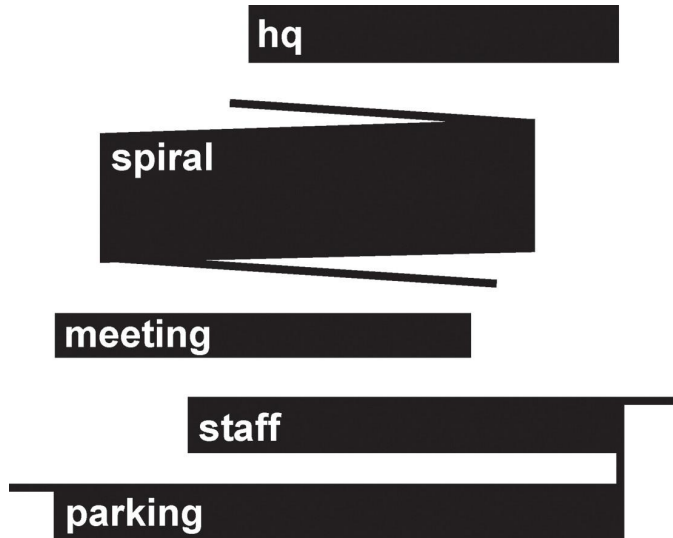
Years of Construction: 1999-2004

Introduction

Seattle Central

Library in a Nutshell

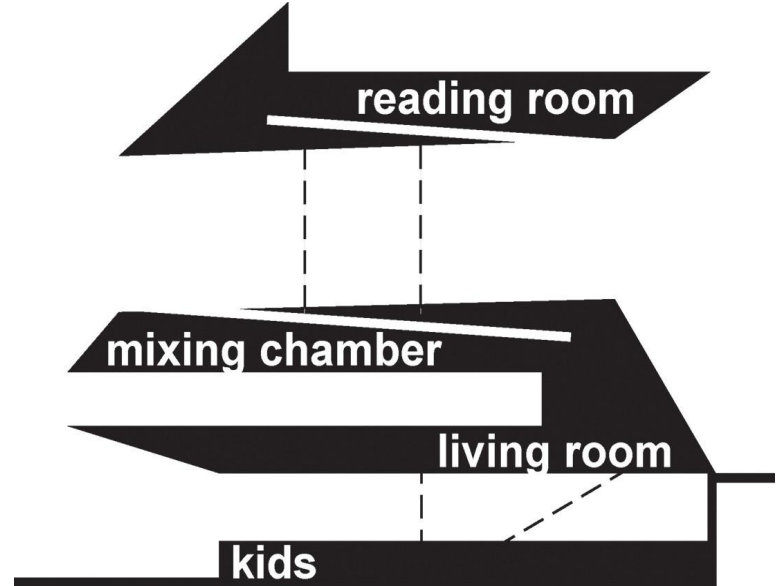
The Seattle Central Library was opened to public in May 2004. It has an area of 38,300 square feet that includes the reading room, mixing chamber, meeting platform, living room, staff floor, children's collection and an auditorium. Its parking covers an area of 4,600 square feet.



Picture Credits: OMA (Archdaily.com)

Awards

- The AIA National Architecture Award ,2005
- Platinum Award from ACEC
- Silver rating from the US Green Building Council.



Picture Credits: OMA (Archdaily.com)

Background

- The Seattle city government adopted the Seattle Public Library as a branch in 1890 and operated from several locations at downtown. The fire of January 2nd 1901 destroyed the Yesler Mansion and brought an unfortunate end to the library.
- German-born and trained architect P.J. Weber's Beaux-Arts design was selected by the city council for rebuilding the library. This was funded by the philanthropist Andrew Carnegie. The Library was dedicated to him by the city council and the establishment was renamed to Central Library Carnegie on December 6th 1906.
- Overtime patrons were stirred due to lack of space in the library and demanded a remodeling of the building. Extension did not make things less unsettling for them. A second Library was proposed and was finally sanctioned in the year 1958. The contract was awarded to two architecture firms, Lloyd W. Johnson Co. and the Morrison-Knudsen Co. Inc. in a partnership. The second library opened in the year 1960.
- After rebuilding the library twice the third proposal was made in the year 1990 with an intent to double the square footage. The budget of this proposal was 196.4 million dollars. The award winning architect Rem Koolhaas and LMN Architects local to Seattle was selected to design the building. Construction started in the year 1999 and the building opened to public in the year 2004.



The Public Library in the 1890's
– www.seattlemag.com
Photo Credits – IMLS Digital
Collections & Content



The Public Library moved to the
Yesler Mansion
– www.seattlemag.com
Photo Credits – Wiki Commons



P.J. Weber designed the
Carnegie Library in 1903.
library.www.seattlemag.com



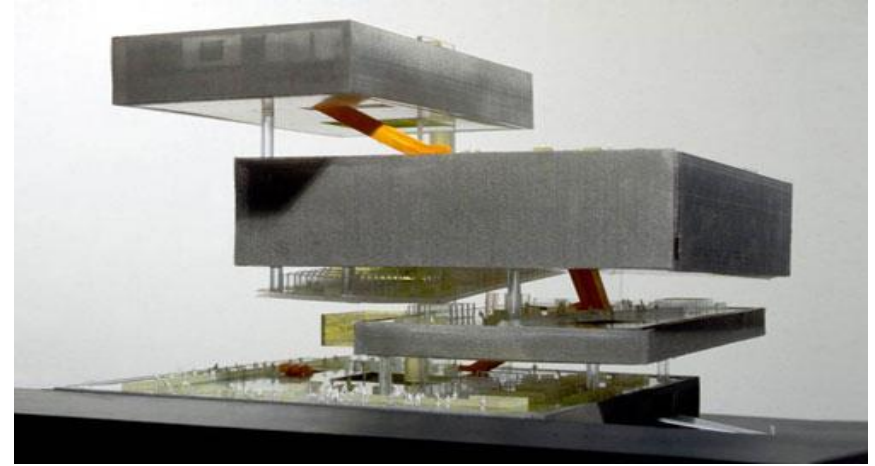
In the 1930's, the community
pushed for the Carnegie library
to be replaced for even more
space.
www.seattlemag.com



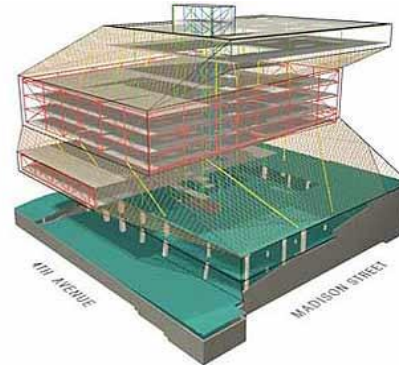
Present day Seattle Central
Library
Photo Credits: Philippe Ruault

Concept

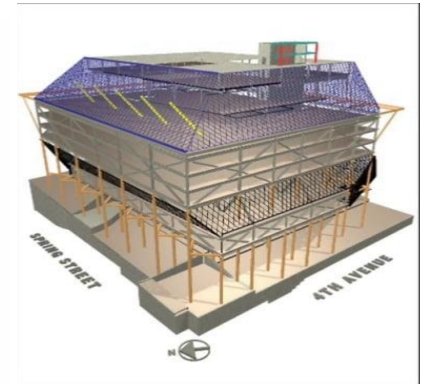
- The central idea of the project was to reinvent the library as a hub that would host information in varying forms of media.
- The Library is distributed as a central spiral instead of a conventional arrangement of books and other media.
- The debatable and elegant study of form followed by has been implemented.
- The program was divided into five major platforms stacked vertically all in an effort to interact differently with the surrounding spaces.
- Two main structural systems were implemented, the first being a perimeter truss supported by inclined columns with a platform cantilever of 1.32 meters and the second being diamond shaped exoskeleton connected to the roof trusses.



OMA



Archdaily.com



Magnusson Klemencic Associates

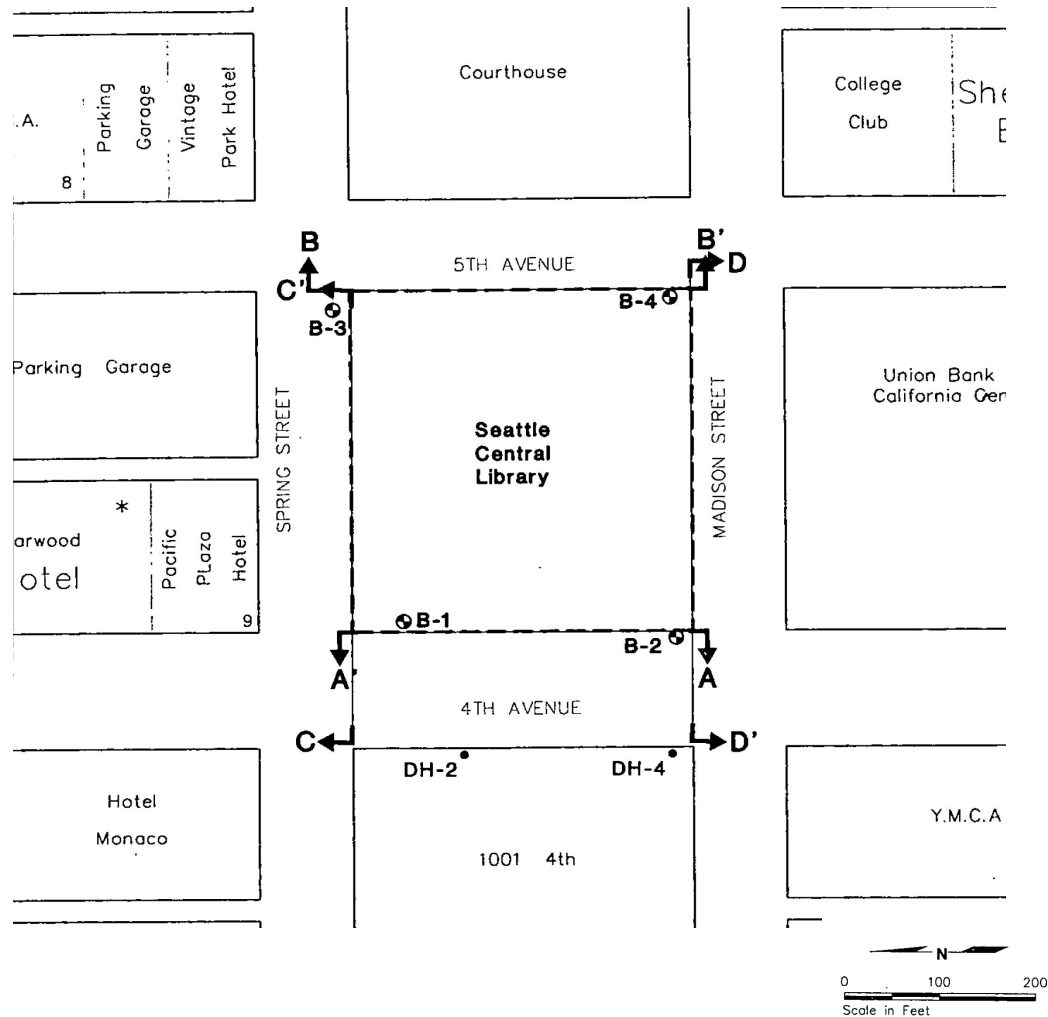
Soil Conditions

Geotechnical Data

Hart Crowser - January, 2001

Report :

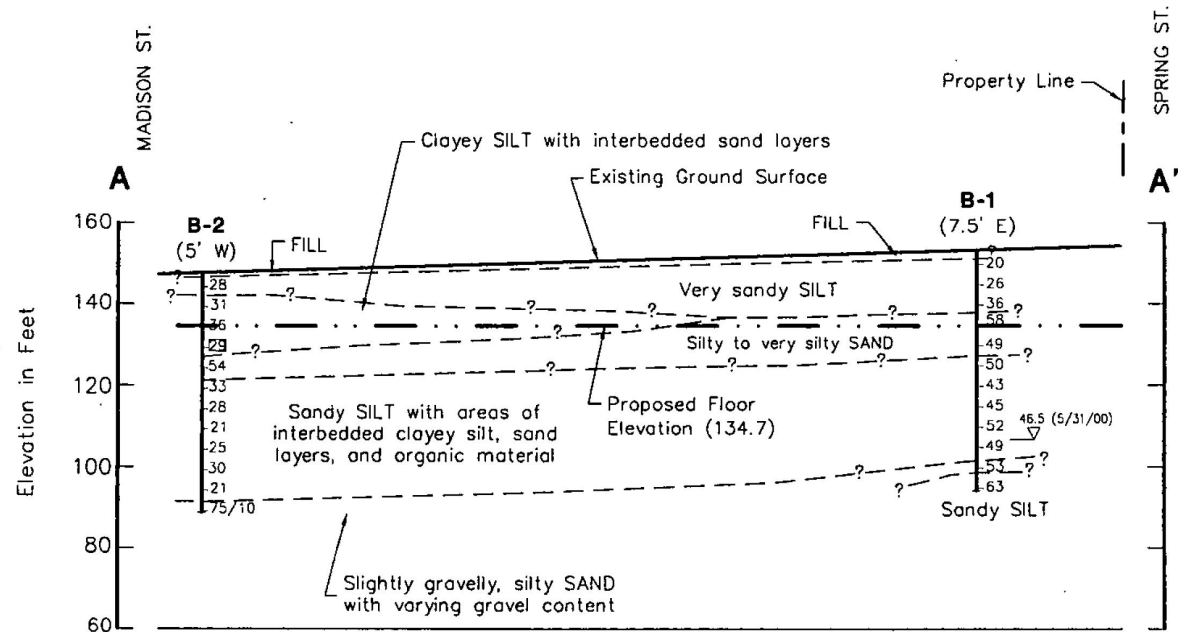
- 4 sections (A, B, C, D)
- 4 bores (B-1, B-2, B-3, B-4 by Hart Crowser)
- 2 bores (DH-2, DH-4 by Shannon and Wilson)



Soil Conditions

Section A shown

- Majority of site contains stiff-to-hard silt with fill
- Fill is disturbed soil from prior excavation activity and is not suitable for foundation support
- Stiff-to-hard silt is sufficient for foundation support, and increases in integrity as depth increases
- Geotechnical report recommended the site an intermediate, class C-D, and found that liquefaction and ground rupture from fault activity were not necessary design considerations



B-1 Exploration Number
(7.5' E) (Offset Distance and Direction)

Exploration Location

46.5 (5/31/00) ▽

Water Level in Feet (Date)

23

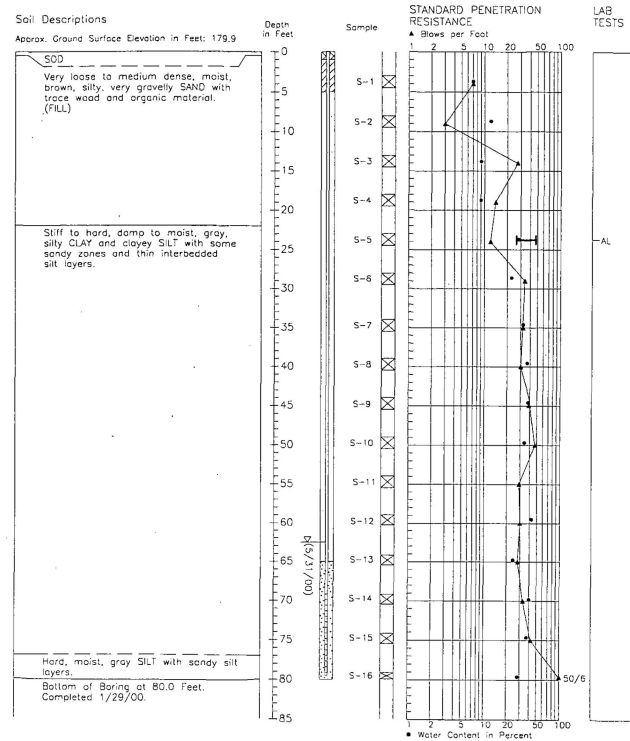
Standard Penetration Resistance
in Blows per Foot

0 40 80
Scale in Feet

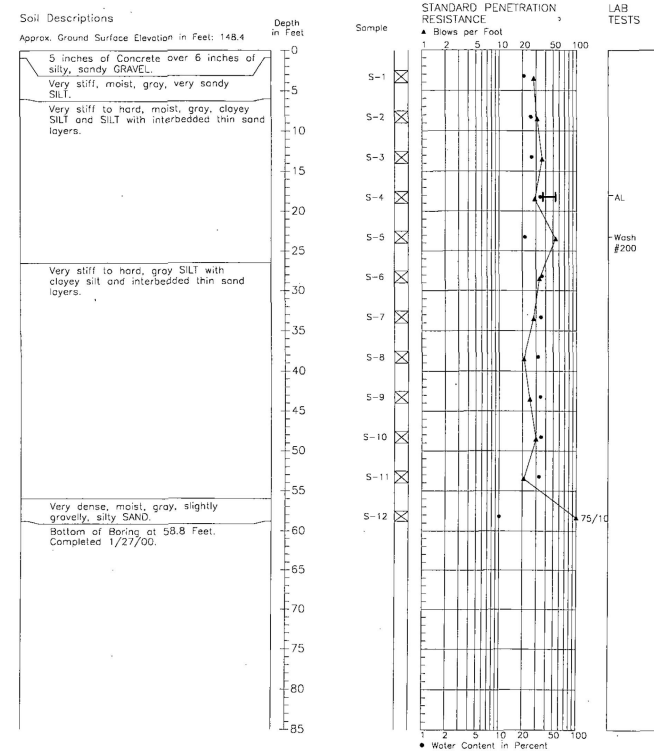
Note: Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

Soil Conditions: Boring Logs

- Ground sections and boring logs indicate bedrock lies below the deep foundation
- Deep foundation friction piles used



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.



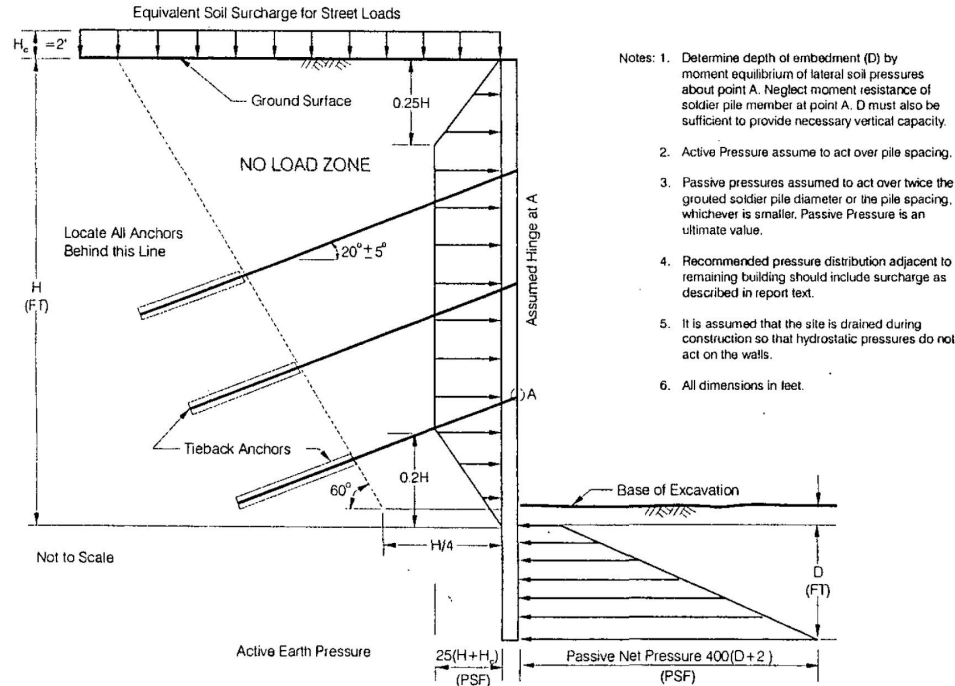
1. Refer to Figure A-1 for explanation of descriptions and symbols.
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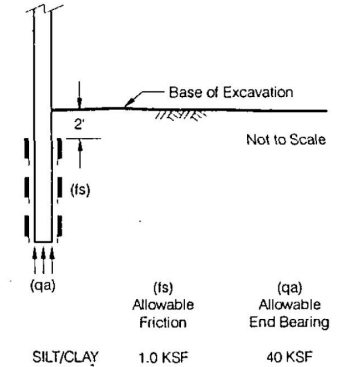
Excavation: Retention & Support

- Use of existing basement walls as temporary supports for construction of new subgrade walls
- Use of soldier piles & drilled tie-backs

A. General Soil Pressures - No Load Zone



B. Vertical Capacity of Soldier Pile



Recommended Minimum Embedment Depth
10 Feet below Base of Excavation

C. Tentative Anchor Pullout Resistance

	Friction (Adhesion)
SILT/CLAY	1.0 KSF

Verify with Load Test to 200% of Design Stress Level.
See Text.

Shallow Foundation Support

Spread footings on hard silt and clay

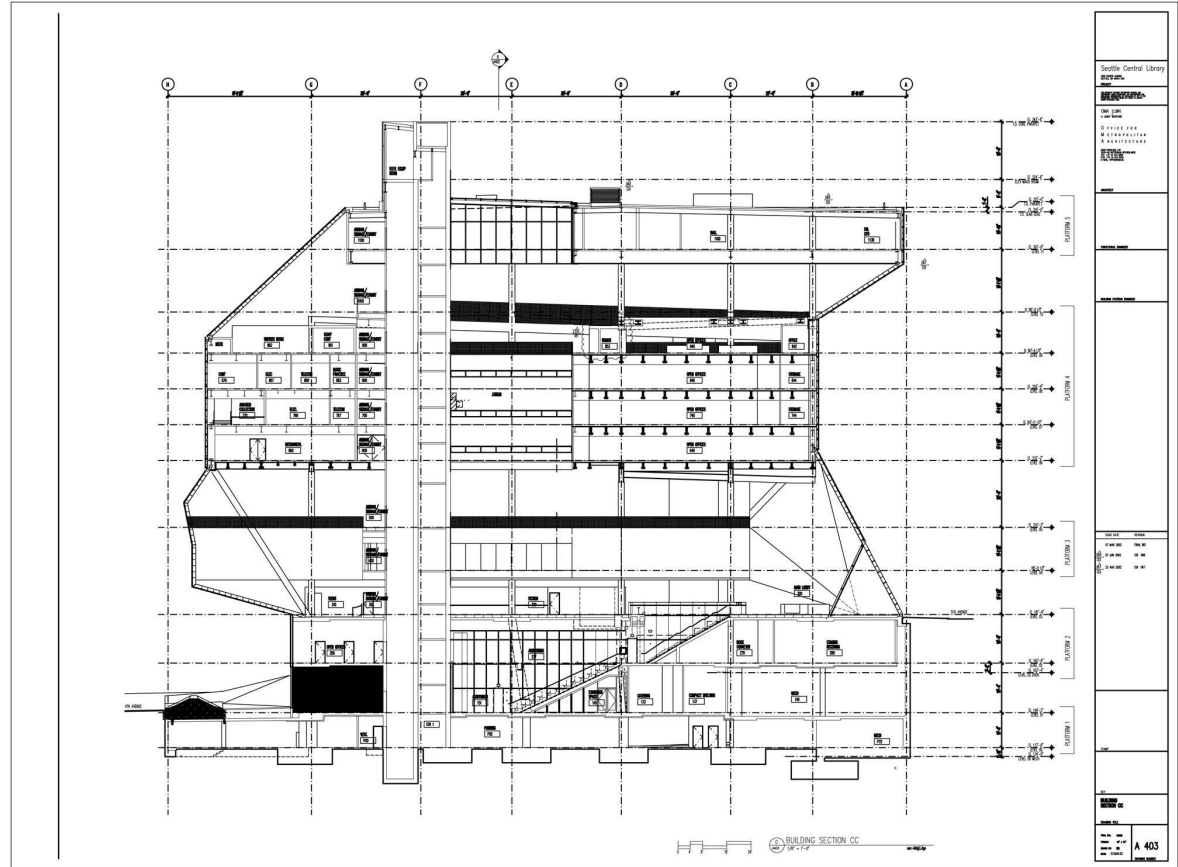
Net allowable bearing capacity :

- no more than 8 ksf within 60 feet of 4th Avenue
- no more than 10 ksf at all other locations

Settlements of less than 1-½ inches

Deep Foundation Support : Auger cast piles

- 18 inch diameter
- minimum 50 foot length
- allowable compressive capacity
 - ◆ 280 kips
- expected settlements: less than one inch
 - ◆ pile groups supporting 3,000 and 6,000-kip loads



Code Requirements

→ Seismic Design

- ◆ 1997 Uniform Building Code
 - $C_a = 0.34$
 - $C_v = 0.50$
- ◆ 2000 International Building Code
 - $S_s = 1.49$
 - $S_l = 0.53$
 - $F_a = 1.0$
 - $F_v = 1.4$

→ Seattle Building Code

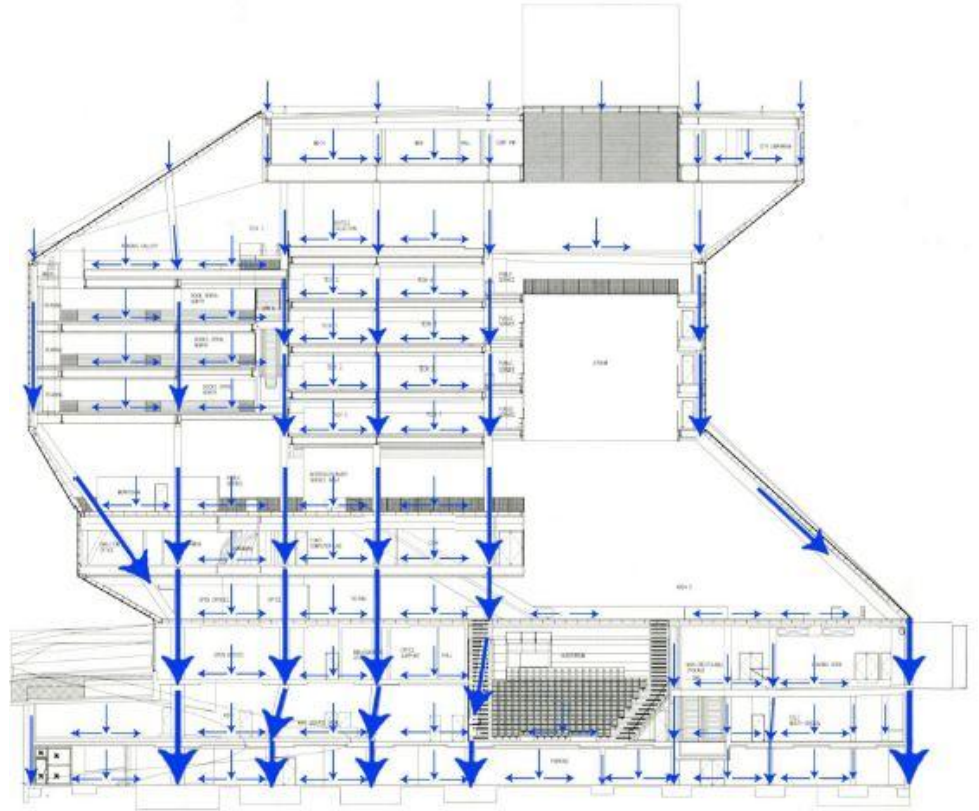
- ◆ Library occupancy use minimum loads
 - Corridors above first floor
 - 80 psf distributed
 - 1000 lbs concentrated
 - Reading rooms
 - 60 psf distributed
 - 1000 lbs concentrated
 - Stack rooms
 - 150^{b,m} psf
 - 1000 lbs



Picture Credits: <http://www.reinerdejong.com/2012/04/seattl-public-library/>

Structural System

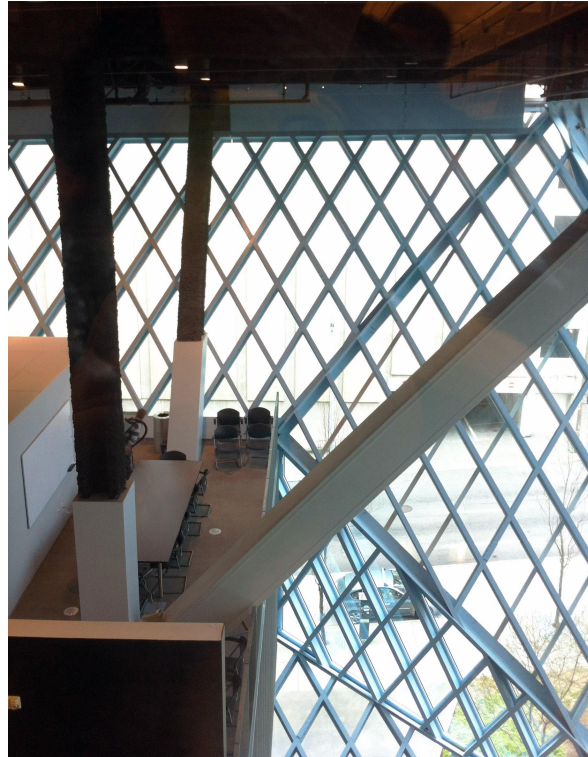
- The structure is composed of both load-bearing and seismic systems.
- Uses two different layered structural systems with a central concrete core that provides much of the structural rigidity.
- The load-bearing system, in the form of columns and beams, supports the elevated platforms containing program spaces.
- The seismic structure is steel arranged in lattice-like geometry, connects platform to platform providing bracing.



Gravity Load Tracing

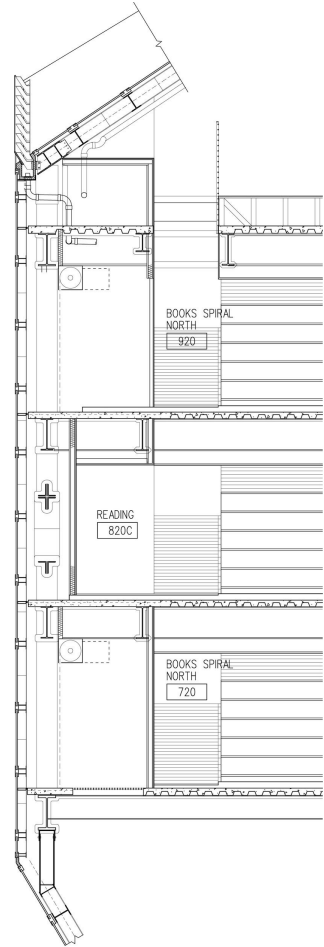
Structure Materials

- Total concrete - 18,400 cubic yards; rebar: 2,050 tons.
- Total steel - 4,644 tons / W12x22 for steel diagrid
- Total pieces of exterior glass - 9,994; square footage of exterior curtain wall: 126,767
- Flat glass plates: 10.16cm side width and 17.78cm base height
- About half of the building's panes are triple-layered glass with an expanded metal mesh sandwiched between the two outer layers. The mesh, aluminum sheet metal that is cut and stretched, reduces heat and glare.



Lateral Loads & Connections

- Diagrid exoskeleton: steel grid provides the lateral system of the building, perimeter trusses are interconnected and support the glazing and diagrid.
- Steel members up to 84 ft in length
- Bolted gusset plates and welded members
- Lacking transverse angles for columns allow loads to be carried more efficiently from the points of maximum stress to the nearest support columns.
- Sloped columns were used in plane of seismic movement.

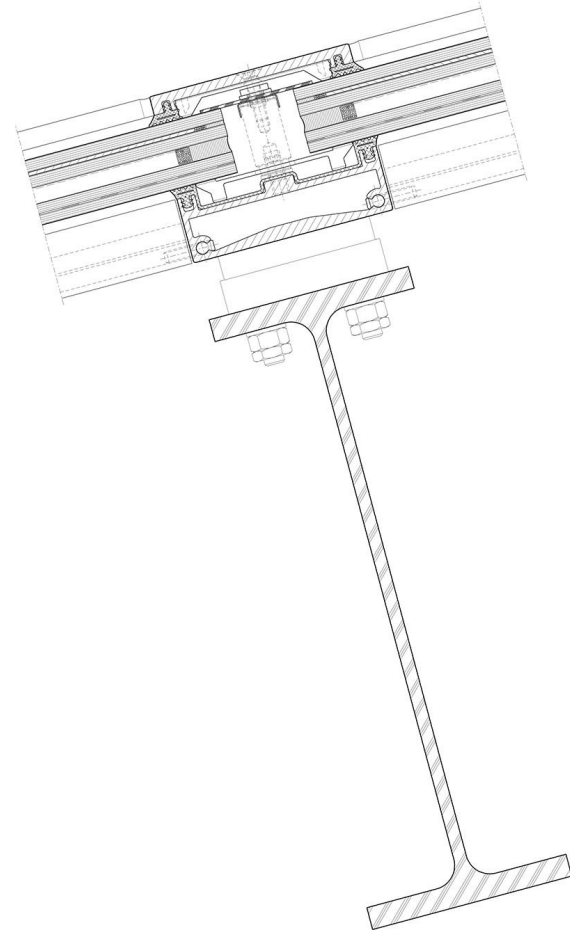


Mullion System

The Building is comprised of two different types of Mullion system: Typical, and vertical.

The typical mullion system consists of a mullion system which slopes in both an overslung and underslung orientation. The system's overall depth is small due to being supported on seismic steel, on the other hand, the thickened aluminum section allows for greater ability in spanning and fewer support connections.

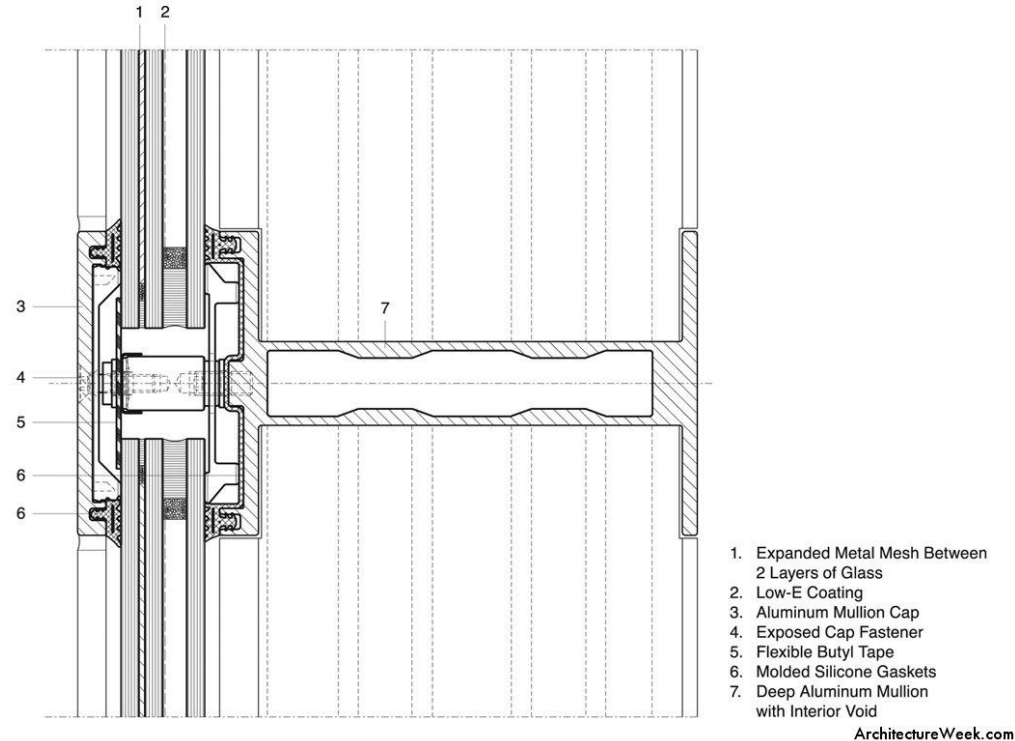
Screw-within-a-screw attachment binds the mullion system's multiple components while allowing for sequenced installation of each component, and it also reduces the number of connection points that are needed.



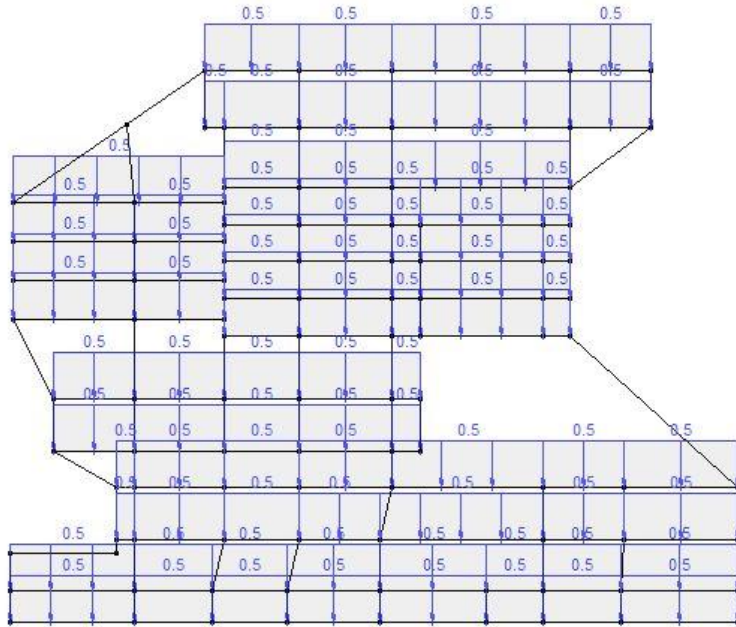
Vertical Mullion System

At the vertical glass facades, a different mullion system had to be developed. On the contrary to the sloping facades, the vertical facade does not use seismic steel for structural support. A deeper aluminum mullion is designed to be used for these areas, which would withstand lateral loading while spanning along a diagonal from floor to floor.

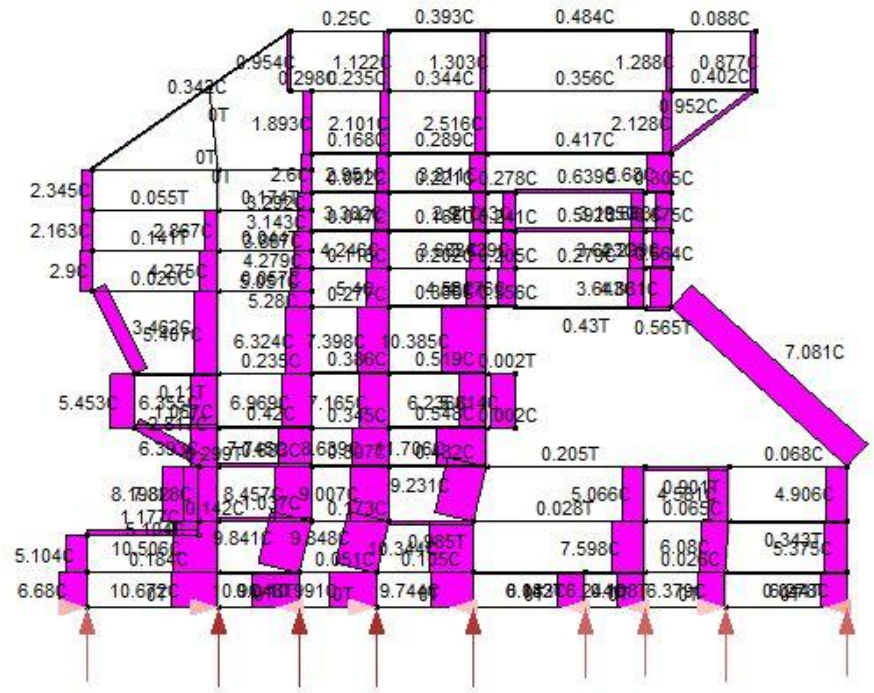
Armatures which are connected to the structure support the vertical weight of the facet. Threaded rod attachments located along the edge of each floor transfer Lateral bracing. Responding to thermal movement of the curtain wall system, the threaded rods are sized in the way they can flex. They also provide tolerance adjustment.



Multiframe Analysis

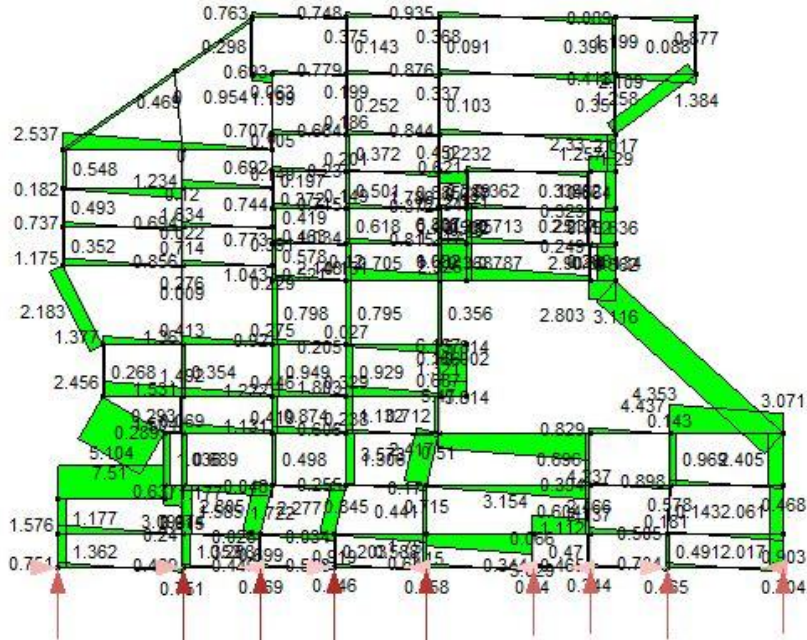


Gravity Loads Multiframe Analysis

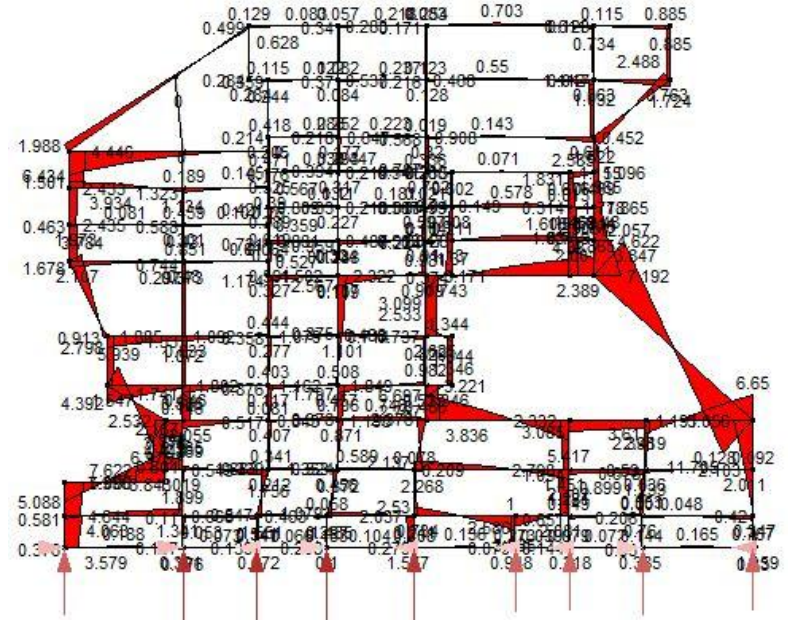


Axial load diagram

Multiframe Analysis



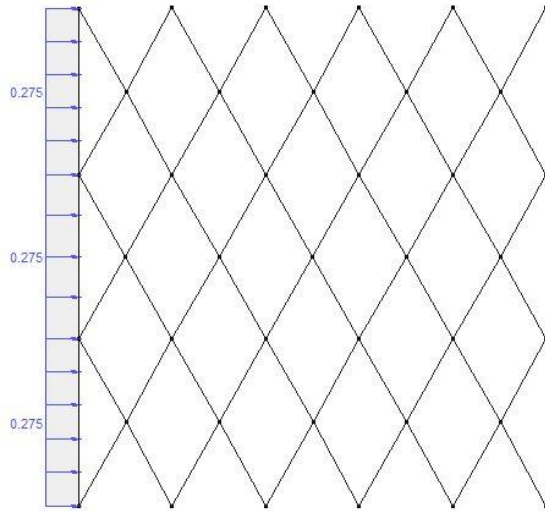
Shear Diagram



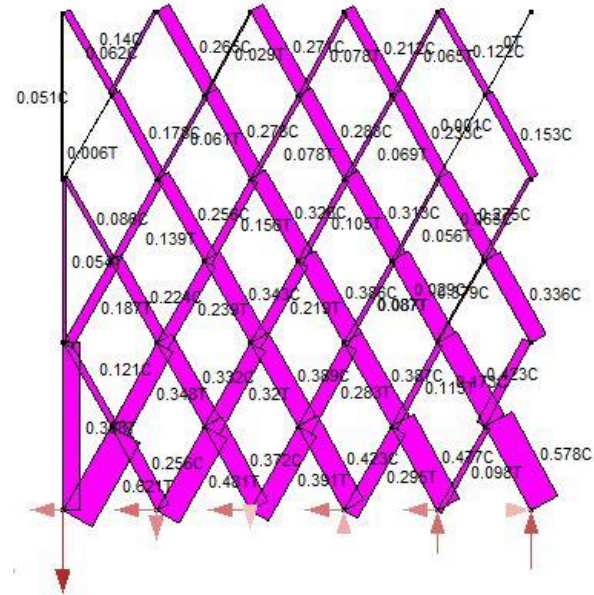
Moment Diagram

Multiframe Analysis

- Total lateral load from one side = $7.6 \text{ lb/ft}^2 * 24145 \text{ ft}^2 / 4 = 47,775.5 \text{ lb}$
- Distributed load along the edge = $47,775.5 \text{ lb} / 174 \text{ ft} = 275 \text{ lb/ft}$

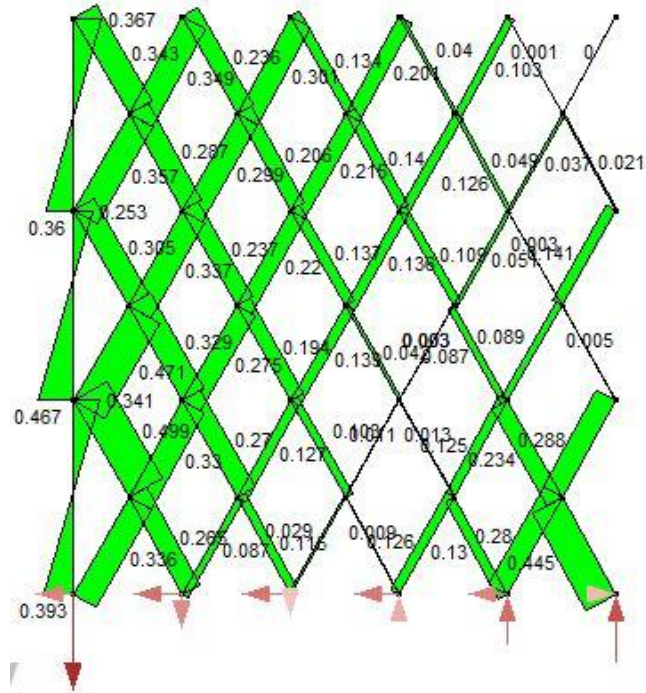


Wind load Multiframe Analysis

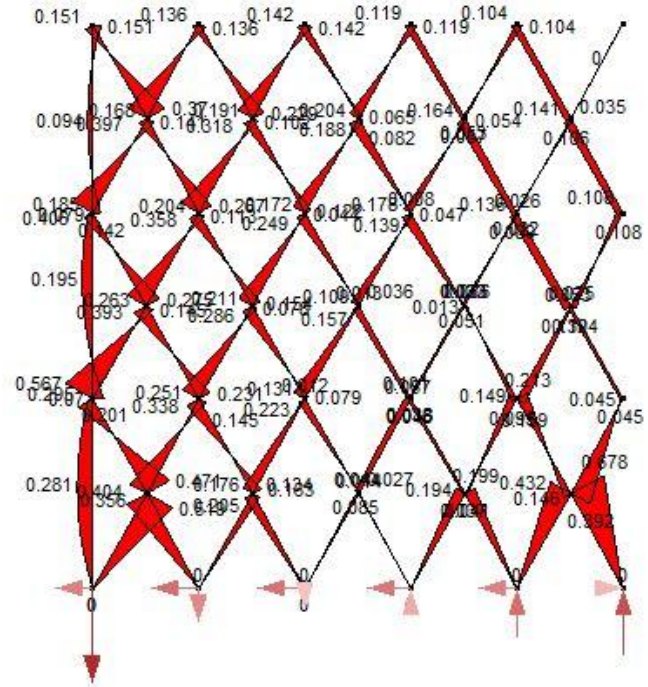


Axial load diagram

Multiframe Analysis



Shear diagram



Moment diagram

Thank you Rem Koolhaas



Citations

1. Kubo, Michael, and Ramon Prat. 2005. *Seattle Public Library, OMA/LMN*. n.p.: Barcelona :bActar, 2005. *Texas A&M University General Libraries, EBSCOhost*
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5. Hart Crowser, *Geotechnical Engineering Design Study: Seattle Central Library, Seattle, Washington* prepared for Seattle Public Library (January 16, 2001).
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7. "Seattle Central Library Curtain Wall Design | LMN Architects." LMN Architects. Accessed November 25, 2015. <http://lmnarchitects.com/case-study/seattle-central-library-curtain-wall-design>.
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