

ATSUSHI IMAI MEMORIAL GYMNASIUM

LOCATION – ODATE , AKITA , JAPAN

ARCHITECT – SHIGERU BAN

STRUCTURAL ENGINEER – TIS & PARTNERS

TEAM MEMBERS:

CHEREK, KEVIN

HANDIQUE, SARIKA

KARUNAKARAN, PUDHUMA BHARATHI

PILANKAR, AAROHI

SHENDE, SOUMITRA

INTRODUCTION & BACKGROUND



SHIGERU BAN



- Shigeru Ban is a global architect
- Work reflects blend of his **American architectural training** and his **native Japanese influences**.
- Adopts a construction method in which the **structure is integrated** into an over all design.
- Innovative **exploration and Integration** of materials so as to enhance their structural potential.
- Materials ranging from **Paper, wood, bamboo** and **steel**.





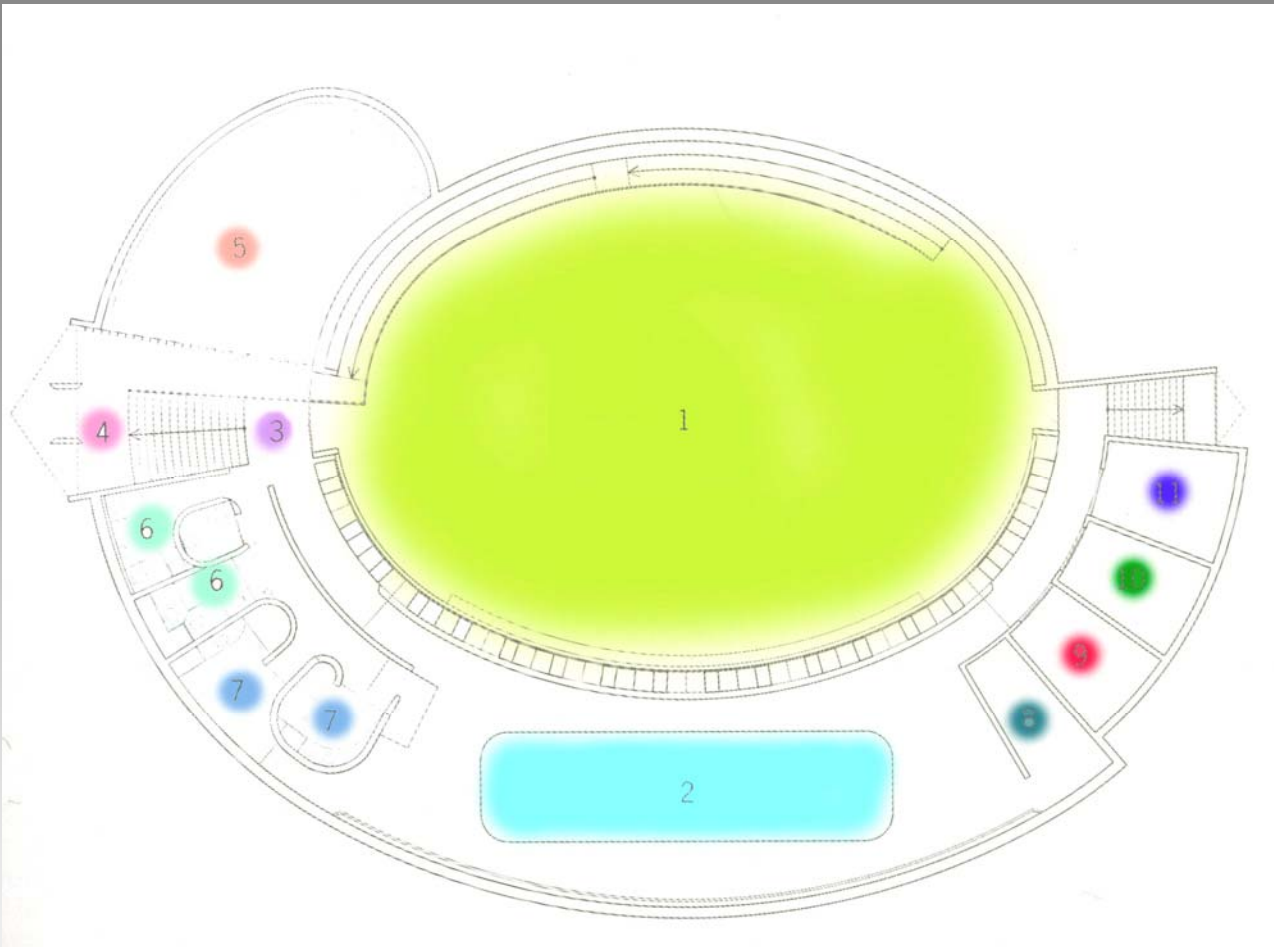
- Project completion date : August 2002
- Set in a context of a private house and two storey regional hospital building
- The main volume of the structure functions as a **gymnasium** as well as concert hall and annex spaces of the ellipse contain swimming pool, changing room and piano room.
- 980 square meter space enclosed by an **elliptical dome**.
- The dome is constructed with **LSL** (laminated strand lumber) and steel pipe members
- It has classic styles of Japanese **technical purism** by means of a construction method characteristic of technological globalization process.
- The main structure is placed **underground**, only the dome and the eaves of the two entrances are visible
- The region is known for its heavy **snowfall** piling up to shoulder heights.
- The **aesthetic structural components** enhances the lighting quality of the space.

ATSUSHI IMAI MEMORIAL GYMNASIUM

DESCRIPTION OF PROJECT



SPACE AND ACTIVITIES WITHIN THE BUILT FORM

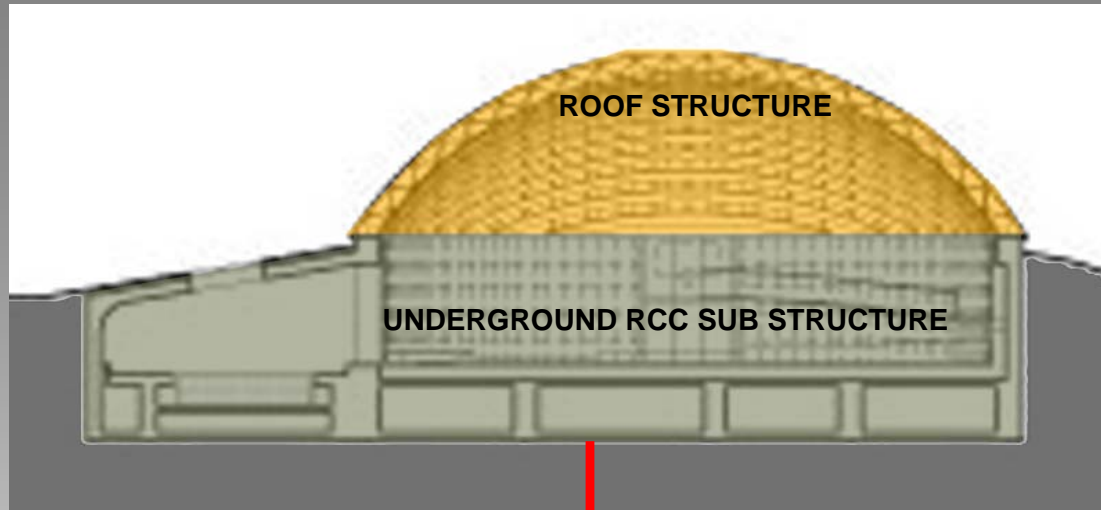


PLAN OF GYMNASIUM

- 1 Arena
- 2 Pool
- 3 Entrance hall
- 4 Entrance
- 5 Piano room
- 6 Washroom
- 7 Changing room
- 8 Pool storage
- 9 Water treatment room
- 10 Boiler room
- 11 Water tank room

LEGEND

IDENTIFYING TWO TYPES OF STRUCTURAL SYSTEMS

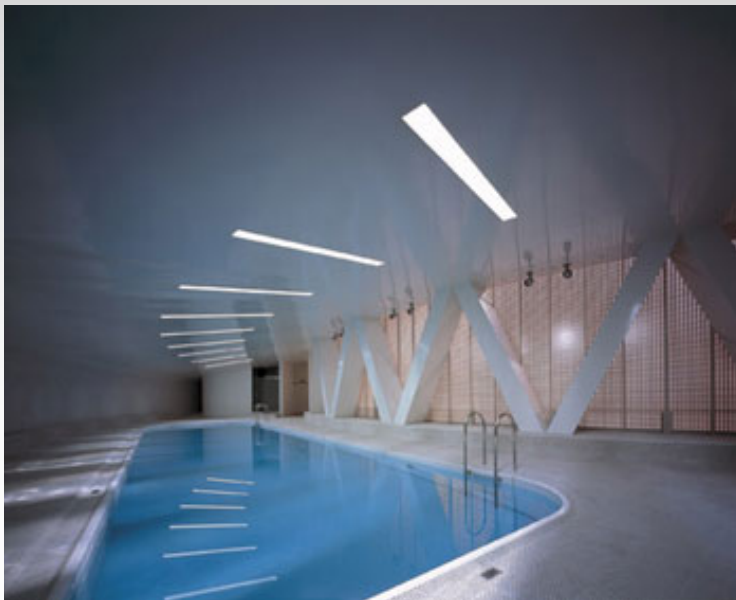


RCC SUB STRUCTURE

ROOF STRUCTURE

RCC BRACING AND RETAINING WALLS

MULTISKINNED ELLIPTICAL GRID DOME

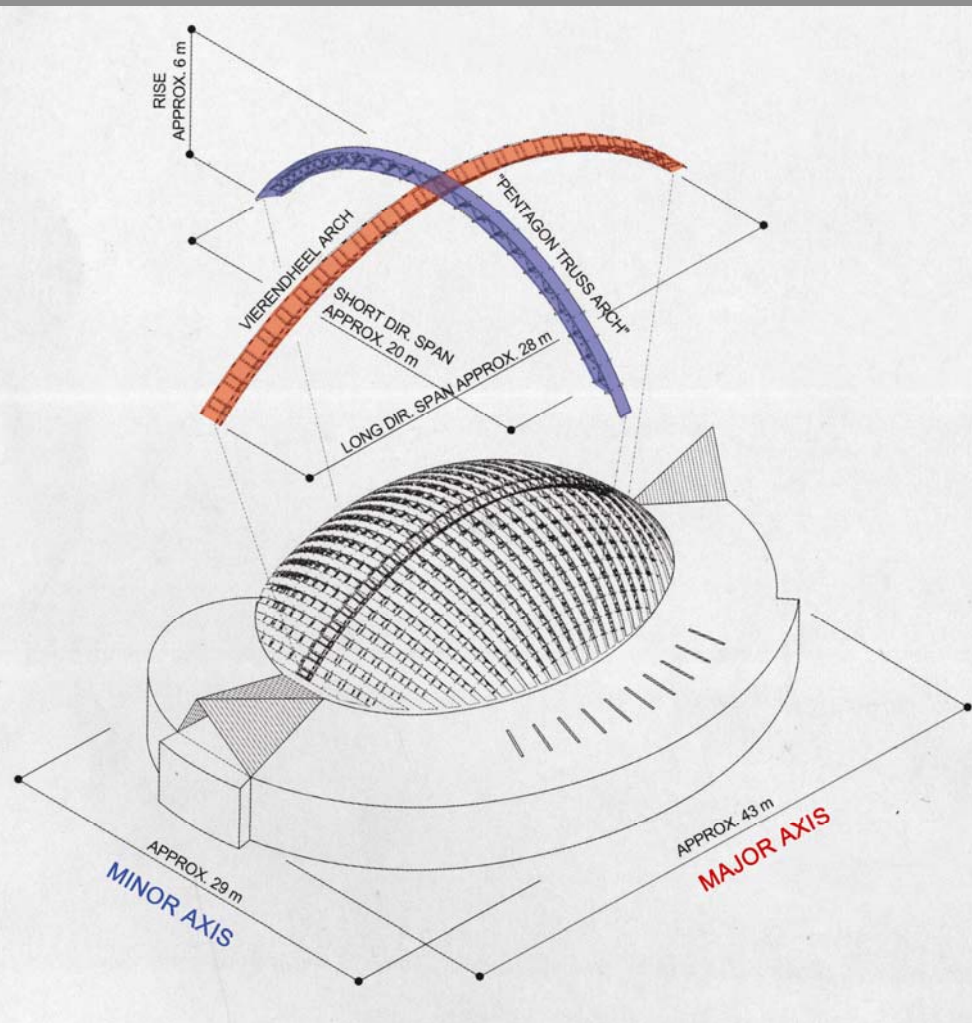


UNDERSTANDING THE STRUCTURE



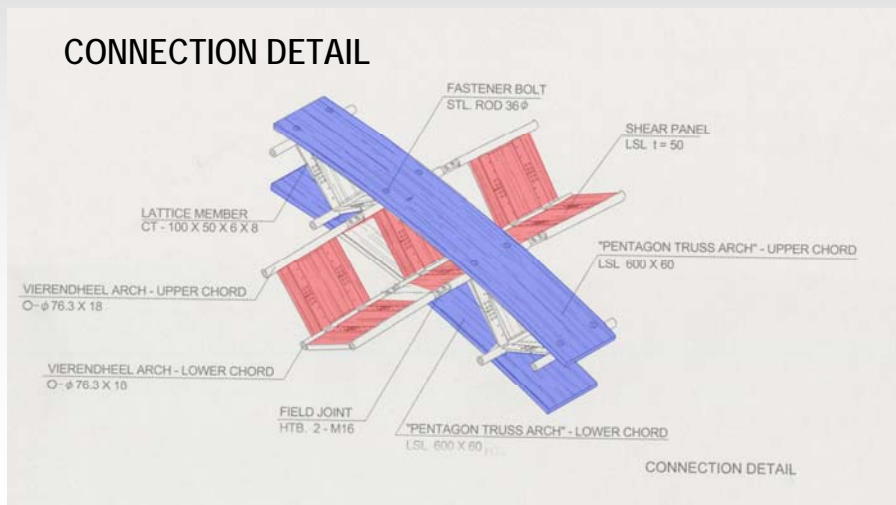
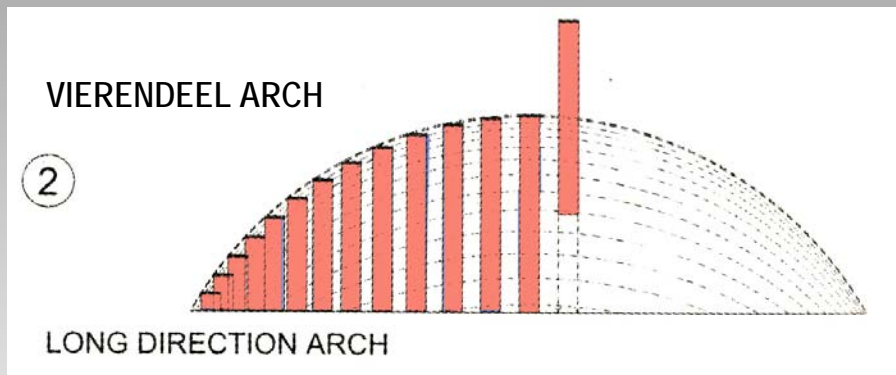
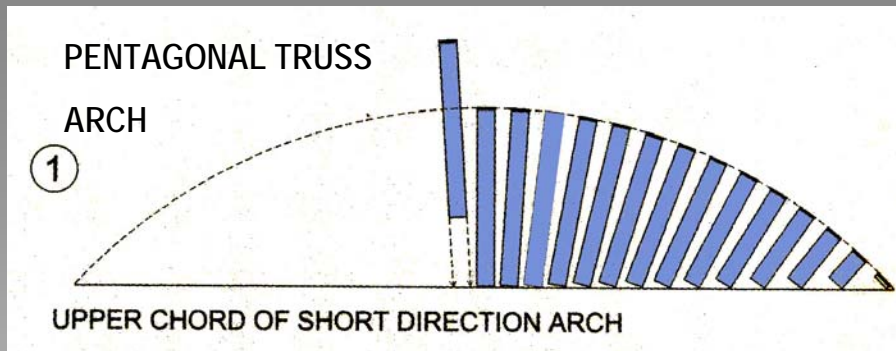
SELECTED STRUCTURAL SYSTEM FOR ANALYSIS

ROOF STRUCTURE OR MULTISKINNED ELLIPTICAL GRID DOME



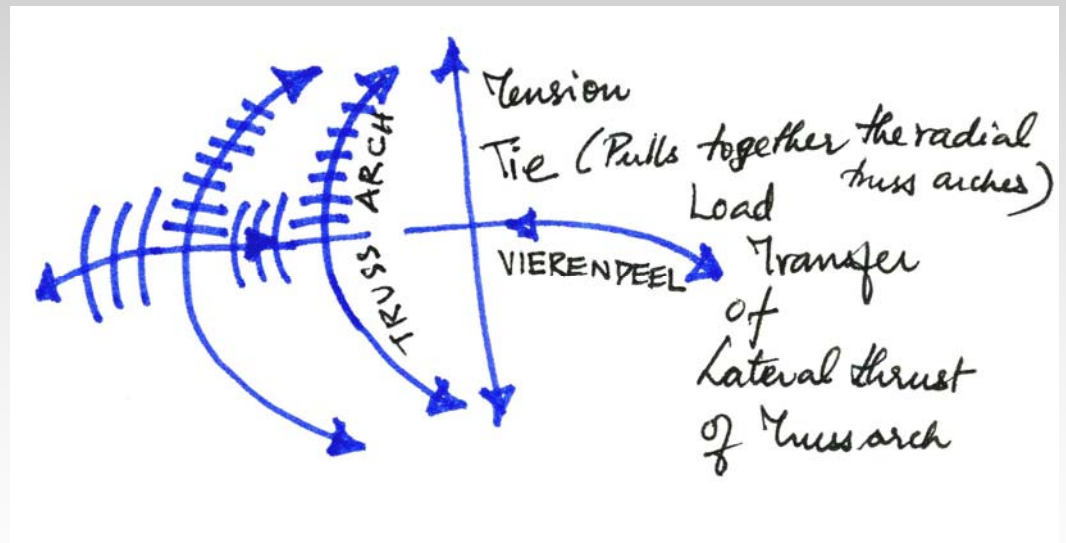
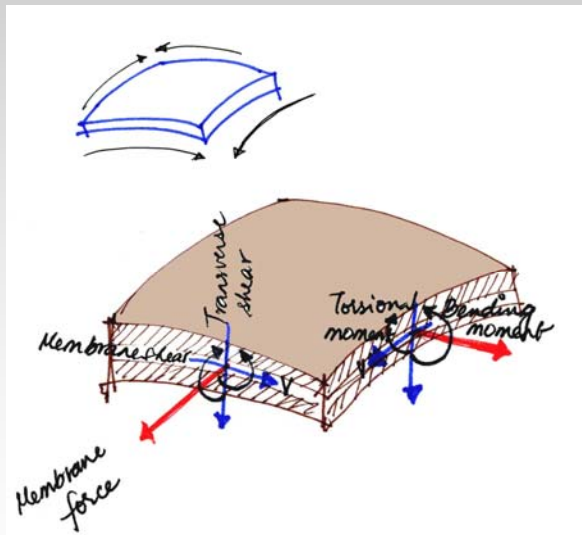
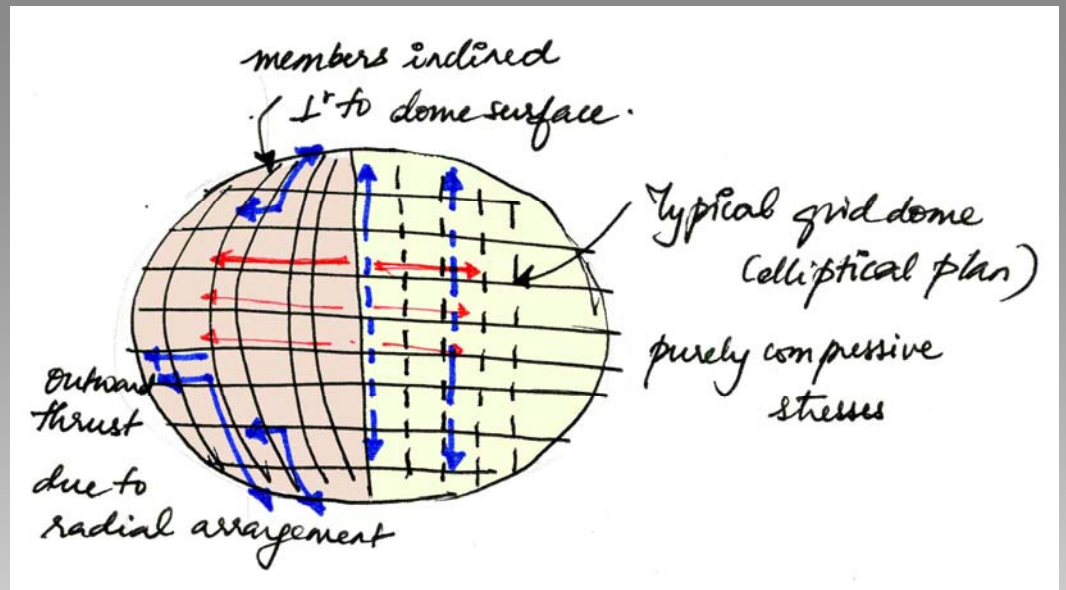
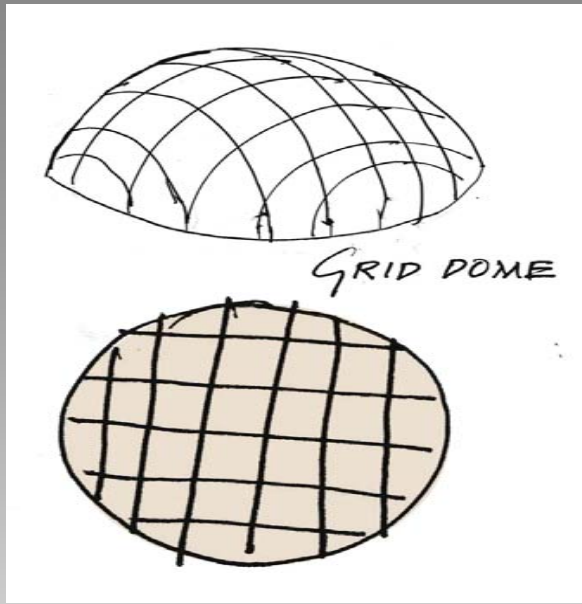
- To analyze we selected the dome of the structure, which can be identified as a grid dome. A structural system of reinforced wood or LSL that works like a skeleton in a vertebrate.
- The plan of the dome is elliptical and is supported by 2 sets of arches.
 - TRUSSED ARCHES ALONG THE MINOR AXIS
 - VIERENDEEL ARCHES ALONG THE MAJOR AXIS
- The load is distributed along the geometric continuity of the curved surface of interlocking arches where it is met with the elastic response of the joints which harmonize the distribution of induced loads.
- The arches along the longer side are set at an angle such that they work as lattice members.

IDENTIFYING COMPONENTS OF THE GRID DOME SYSTEM

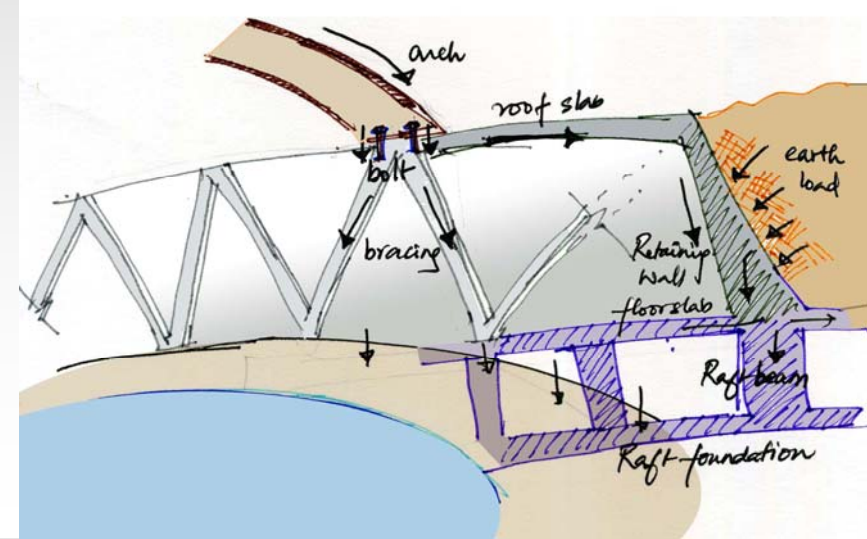
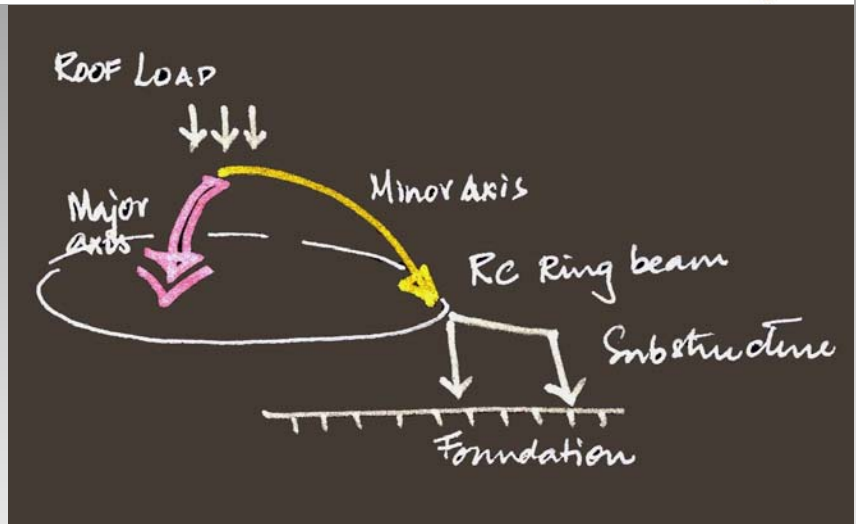
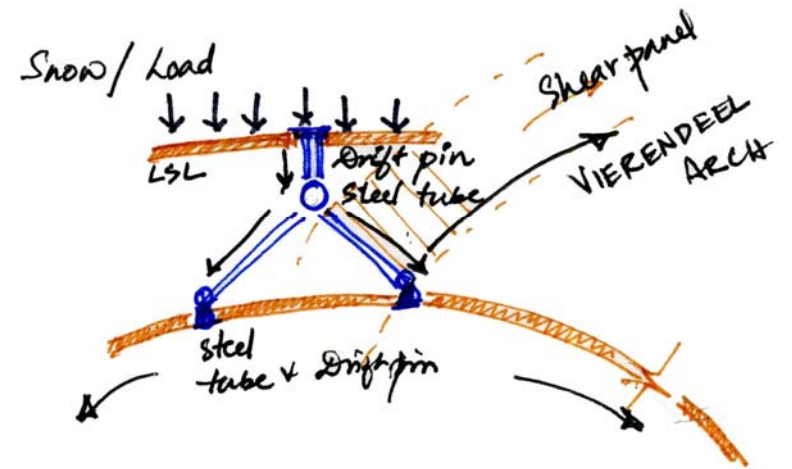
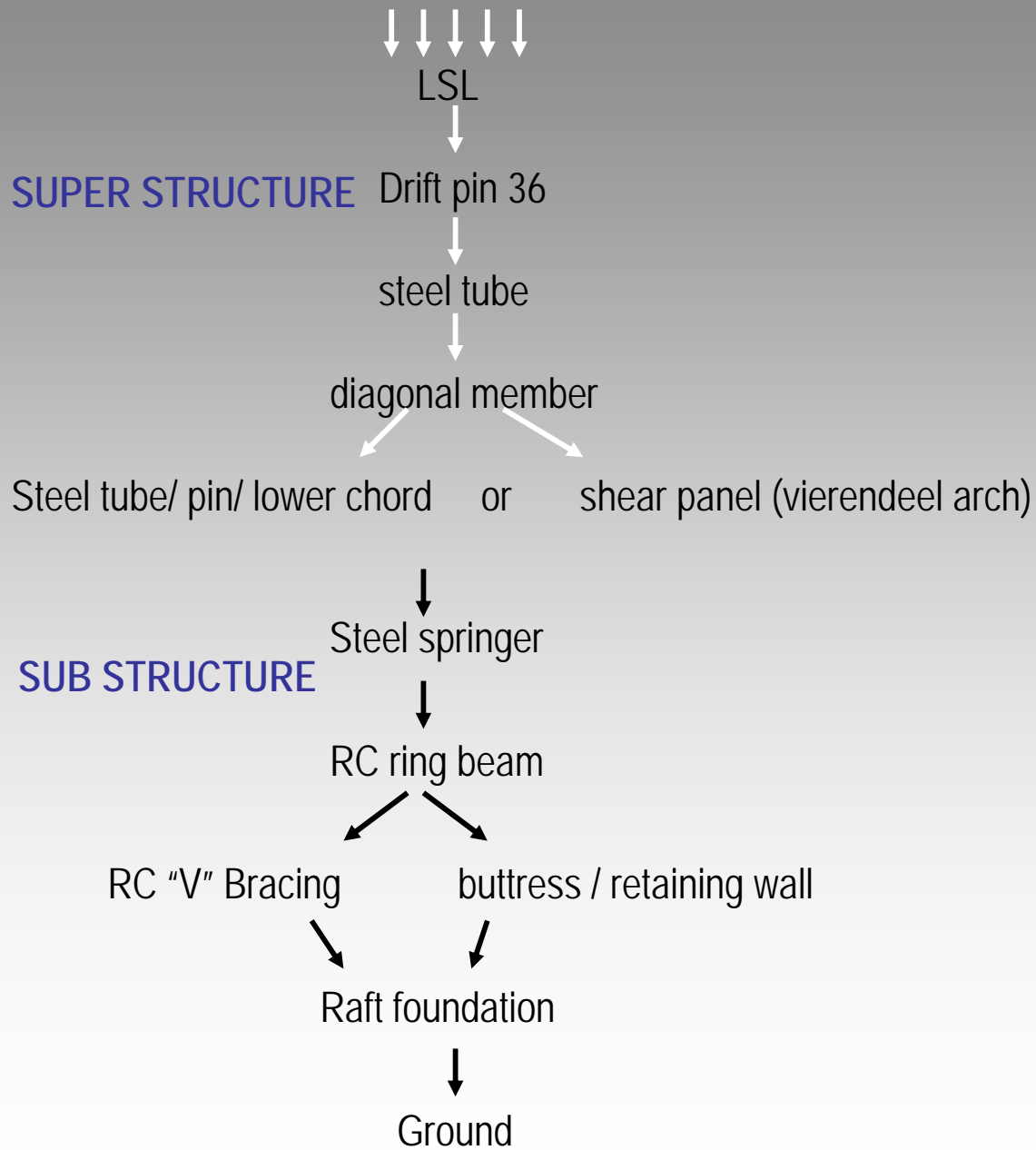


- Arches spanning in one direction generate lateral stability for arches in other direction
- Pentagonal trussed arch along minor axis provide space within themselves for Vierendeel arches spanning along major axis
- Interconnection of two arches in opposite direction generates multi skinned grid dome as one structure.
- The whole assembly is then covered with strips of light weight polycarbonate sheets thus allowing diffused light to enter the space.
- Both Arches are composed of LSL (Laminated Strand Lumber) and steel pipe sections and plates.
- Shear panels made out of LSL hold together 3 chords of Vierendeel Arch and prevent torsion between the members.

STRESSES IN THE ARCH AND LSL



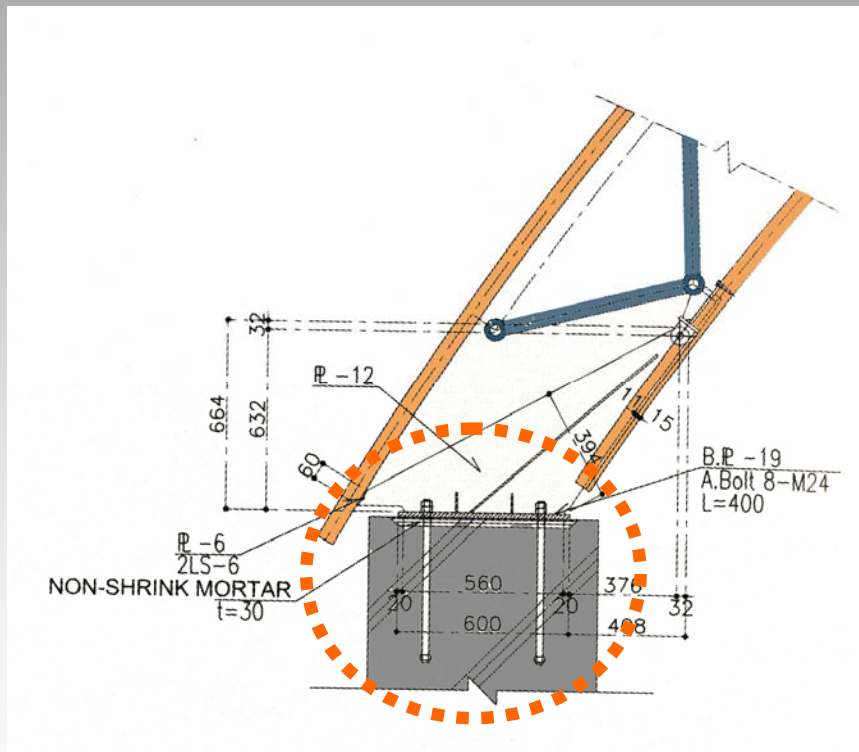
LOAD TRANSFER



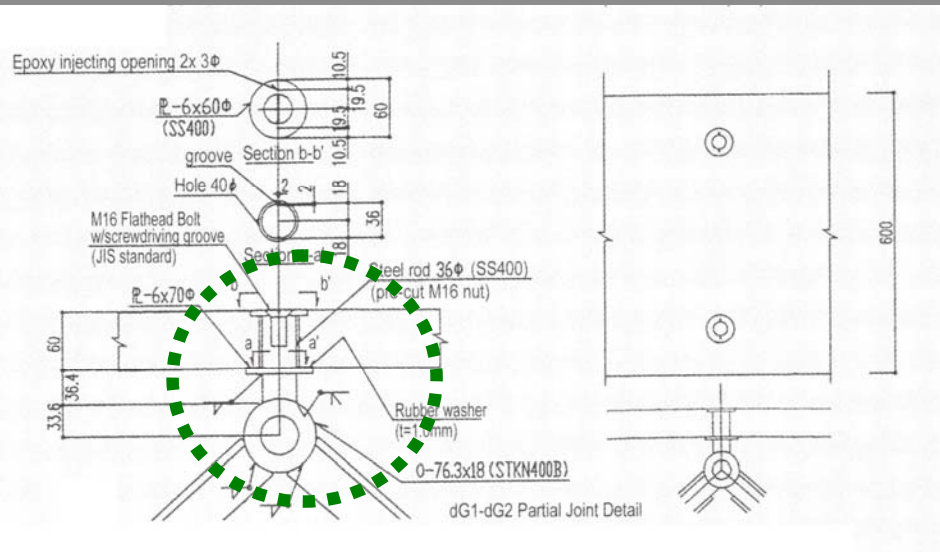
CONNECTION DETAILS

- Connection of arch to base:

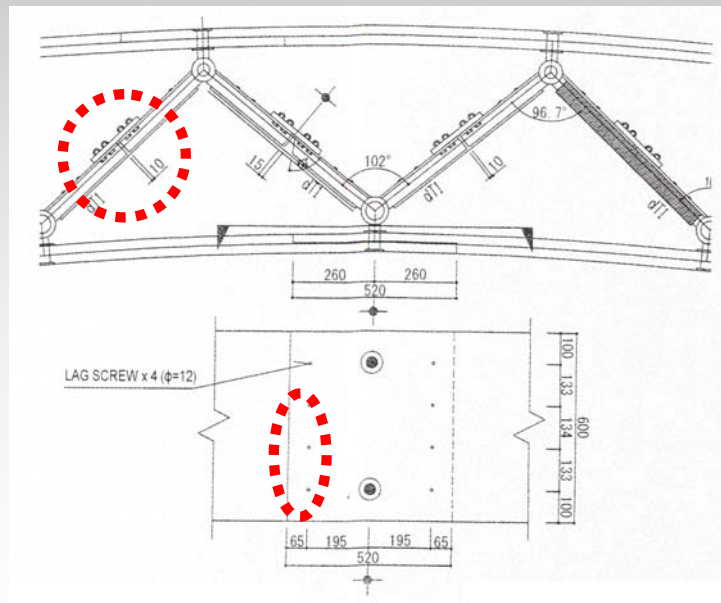
Arch rests on RC ring beam with steel Springer laid with non shrink mortar and bolted with A Bolt B M- 24 L-400



CONNECTION DETAILS



- Connection between chords of truss arch and truss arch to Vierendeel arch:
By means of common lattice members with CT 100 x 50 x 6 x 8 and LSL (t=50)
Drift pins (steel rod 36 Ø SS 400 pre-cut M16 nut) to allow movement



- Connection within lamina of the LSL :
Lag screw 12 Ø

LOAD ANALYSIS



LOAD ANALYSIS

TYPES OF LOADS:

- **Dead load :**

Self weight of the grid dome structure

Self weight of LSL= 0.68 g/cc

Self weight of Steel sections and screws = 0.69 to 0.71 g/cc

Self weight of Polycarbonate sheet covering

- **Live load:**

Snow load is a **major concern** since the area receives heavy snow fall ranging from 75 centimeters to 225 centimeters in a season.

- **Wind load:**

Not a major Concern since most of the built structure except roof dome is underground.

Roof dome will have to withstand upward drift in case of suction effect created by wind.

- **Lateral Earth pressure load:**

Since most of the structure is underground, Lateral earth pressure is resisted by RCC retaining walls.

- **Seismic Load:**

Odate, Japan where the structure is located comes under **200km earthquake depth zone**

SNOW LOAD ANALYSIS

The gymnasium is located an area of **heavy snowfall**, so two full scale trussed arches were constructed and Loaded to simulate normal snow accumulation (**uniformly distributed load**) and snow drifts (**Unevenly distributed loads**)

Uniformly Distributed Load:

Average snowfall = 150 centimeters in winter

Load to be borne by roof dome structure = 450 kg/ sq. meter (150 cms. depth x 3 kg/ sq. meter / cms.)

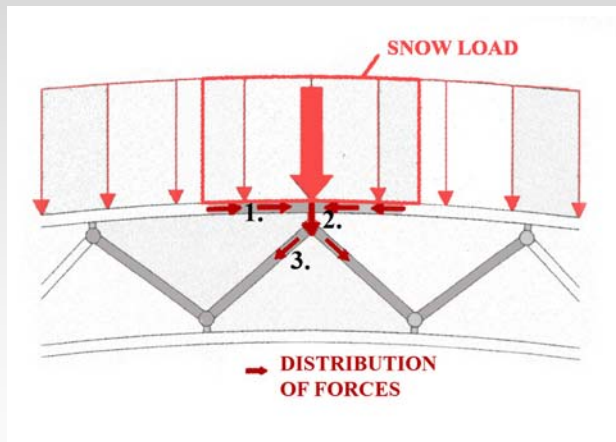
Unevenly Distributed load:

Variation in snow fall-

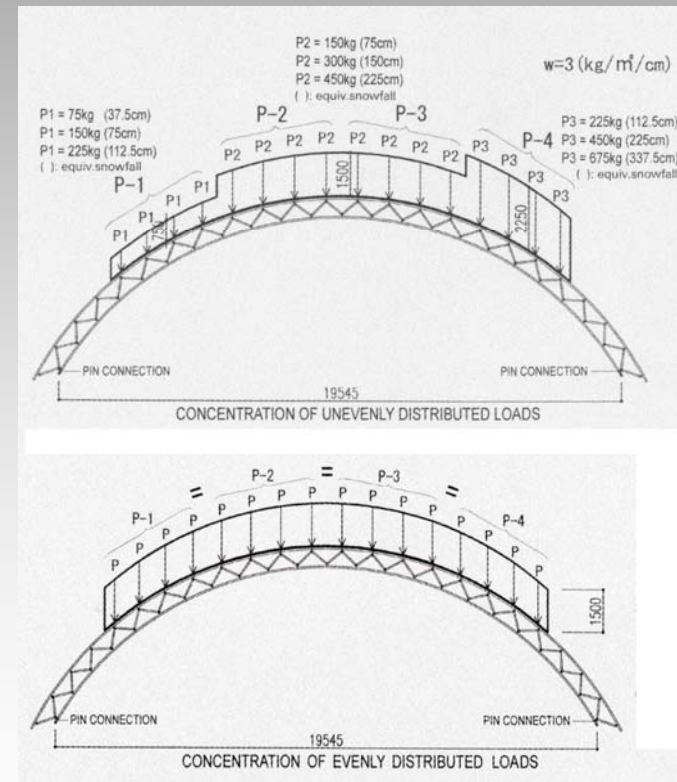
75 cm.....147kg/ sq. meter

150 cm....294 kg/ sq. meter

225 cm....441 kg/ sq. meter



1. LSL
(Thickness=60 mm)
2. 36mm dia. steel rod
3. 78.5mm dia. Steel tube

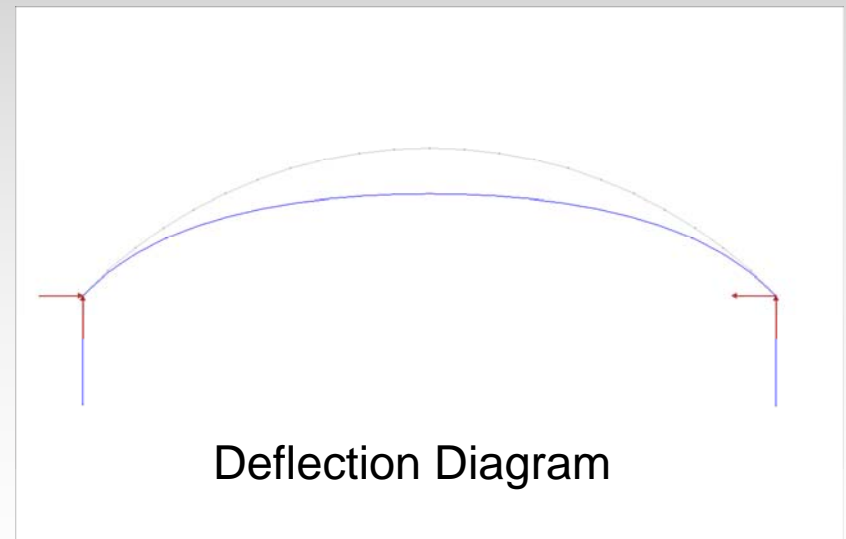
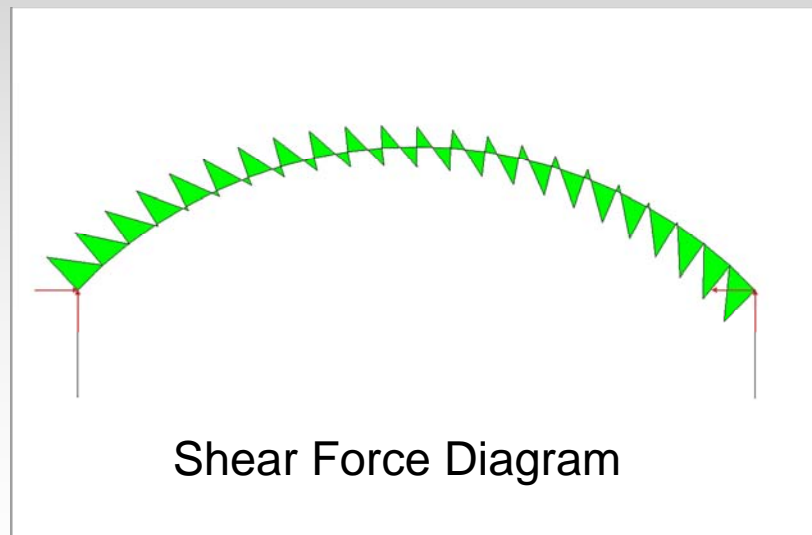
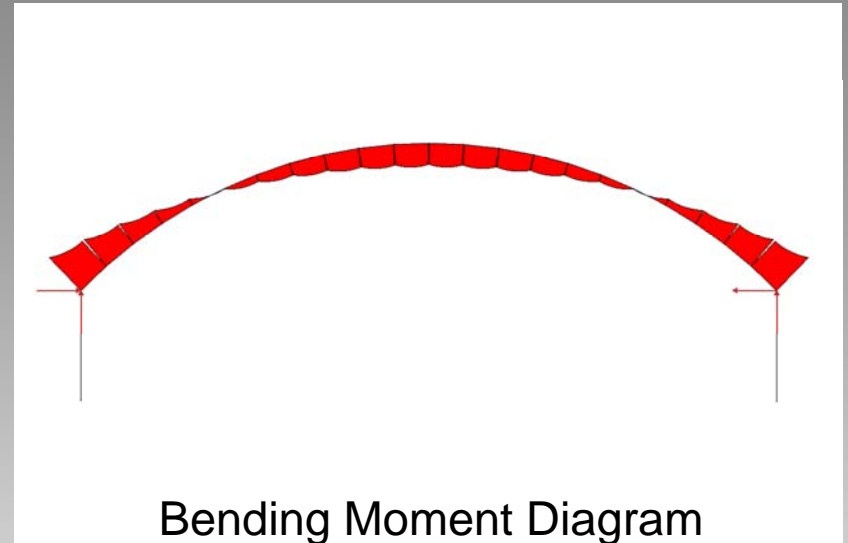


SNOW LOAD FORCE DISTRIBUTION

SNOW LOAD TESTING METHOD

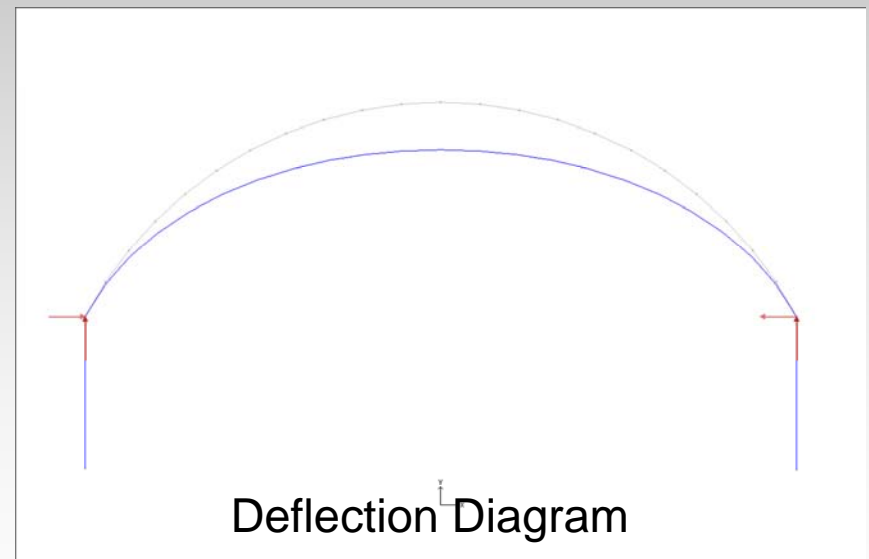
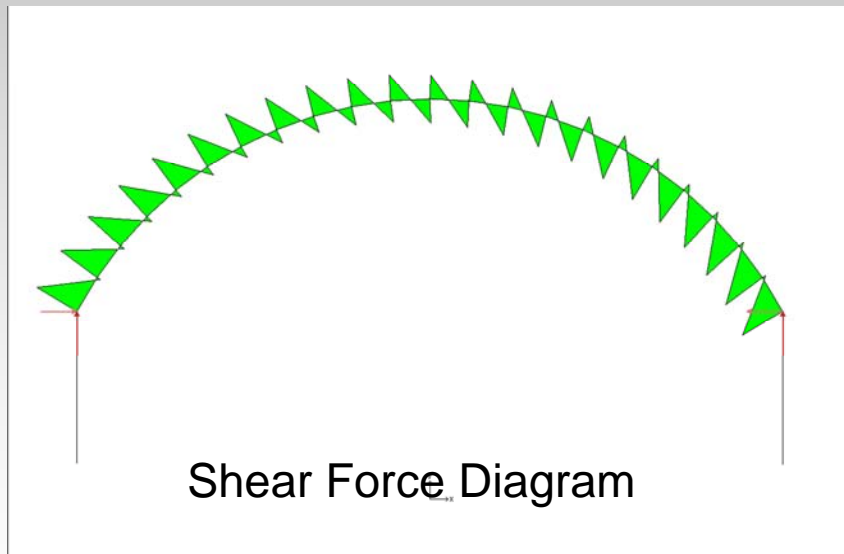
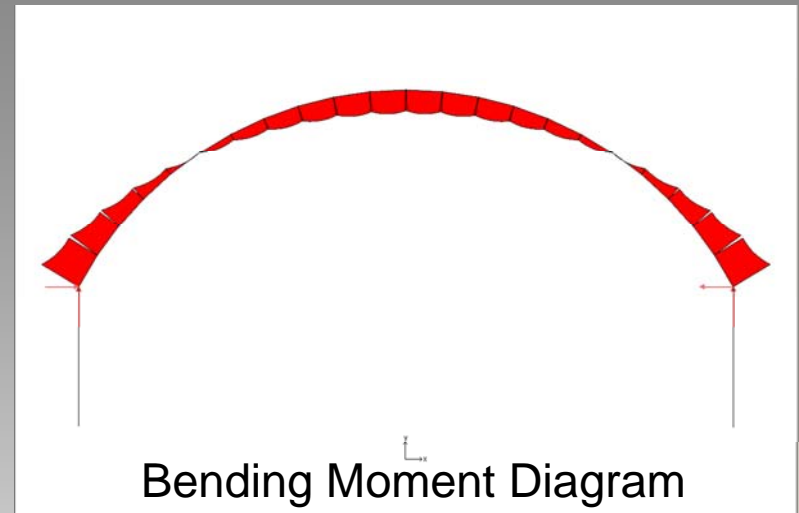
MULTIFRAME ANALYSIS FOR SNOW LOAD

ARCH ALONG MAJOR AXIS
VIERENDEEL ARCH

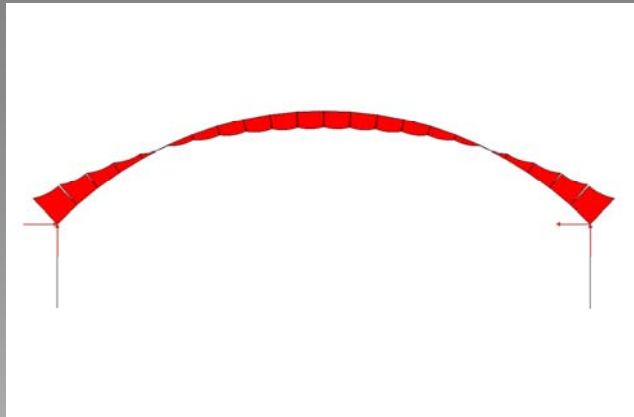


MULTIFRAME ANALYSIS FOR SNOW LOAD

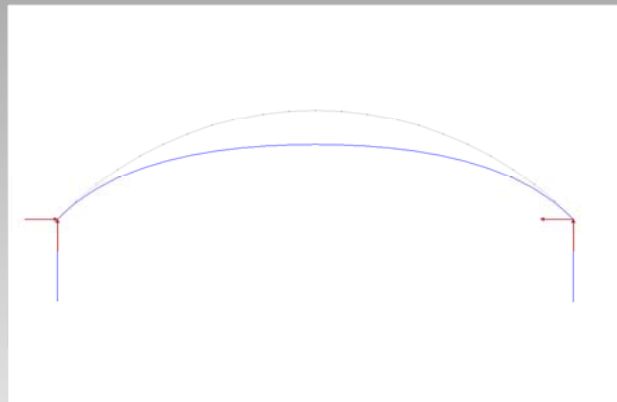
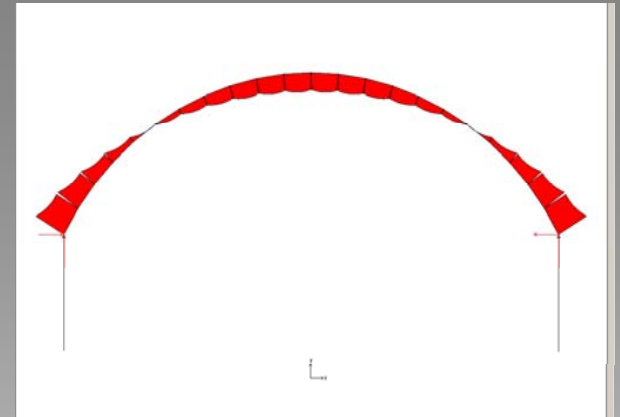
ARCH ALONG MINOR AXIS
TRUSS ARCH



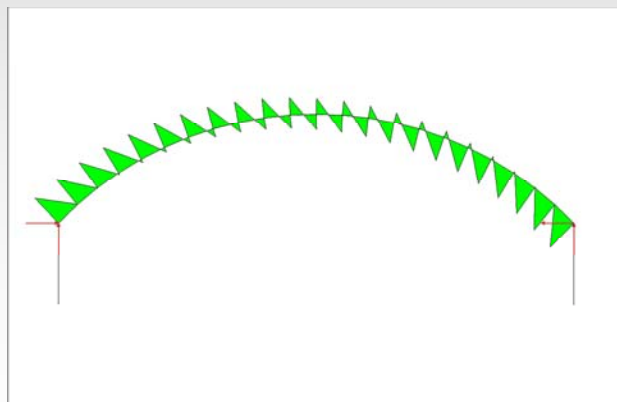
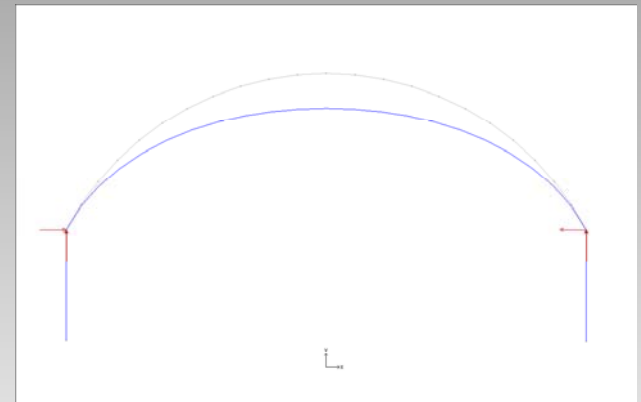
MULTIFRAME ANALYSIS FOR SNOW LOAD



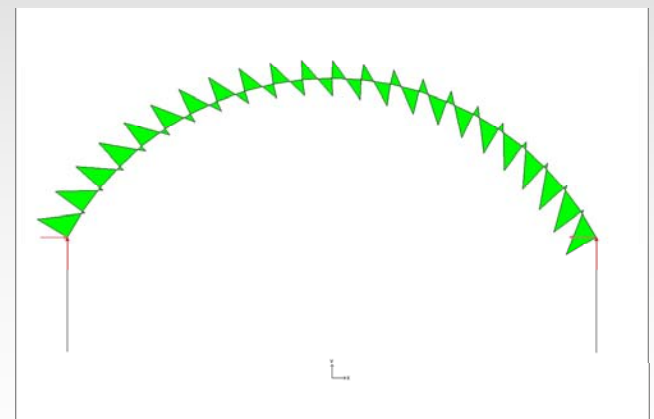
Bending Moment



Deflection



Shear Force



ARCH ALONG MAJOR AXIS

ARCH ALONG MINOR AXIS

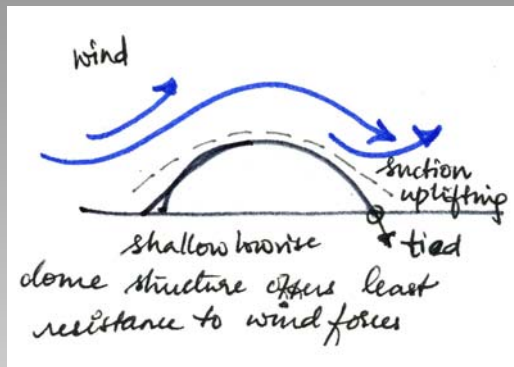
LATERAL LOADS & RESISTING SYSTEM

Lateral loads :

Wind load:

Retaining Earth load

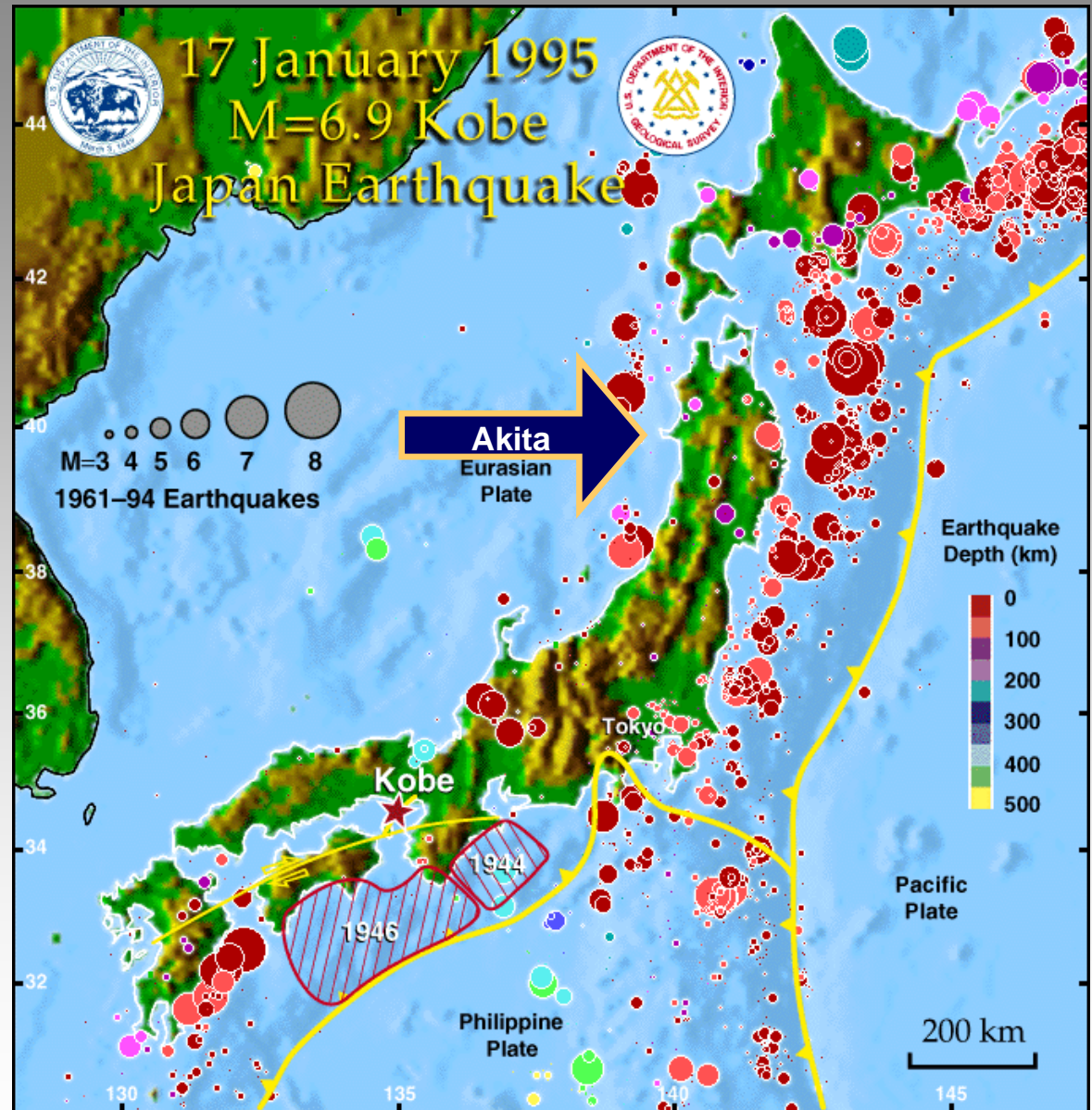
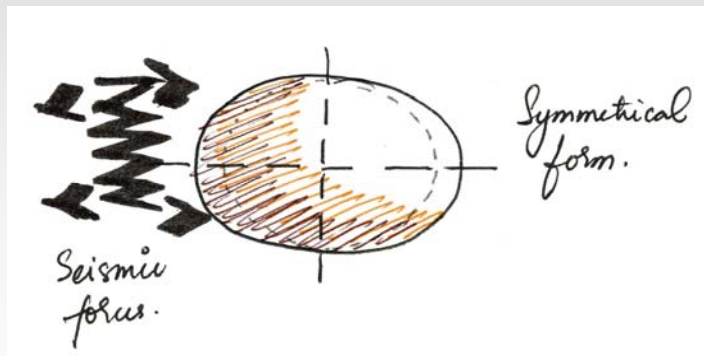
Seismic load



Seismic load:

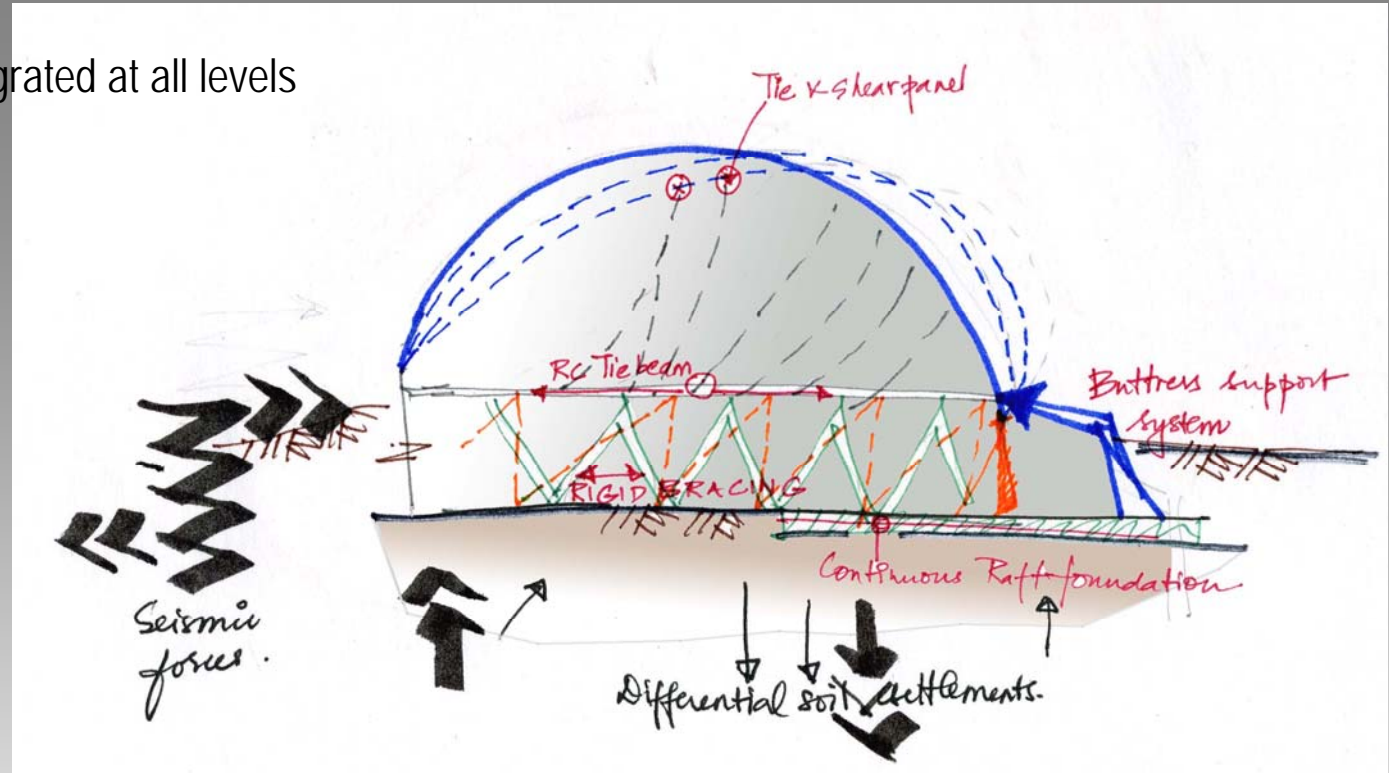
Earthquake depth = 200 km

M= approx 4



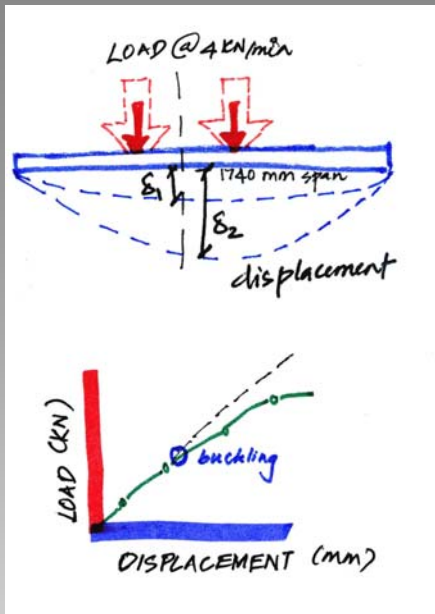
LATERAL LOADS & RESISTING SYSTEM

Lateral resisting system is integrated at all levels



- **Shear panels** of Vierendeel arch help tie the truss arch
- **Ring beam** ties the arches at the base
- The outer structure of the base acts like **haunches** of the main arch system, and loads get transferred as in a buttress via the beams to retaining walls
- **Lateral V bracing** below the ring beam also helps to tie & to resist the arch thrust

PRELIMINARY TESTS PERFORMED ON THE SAMPLES



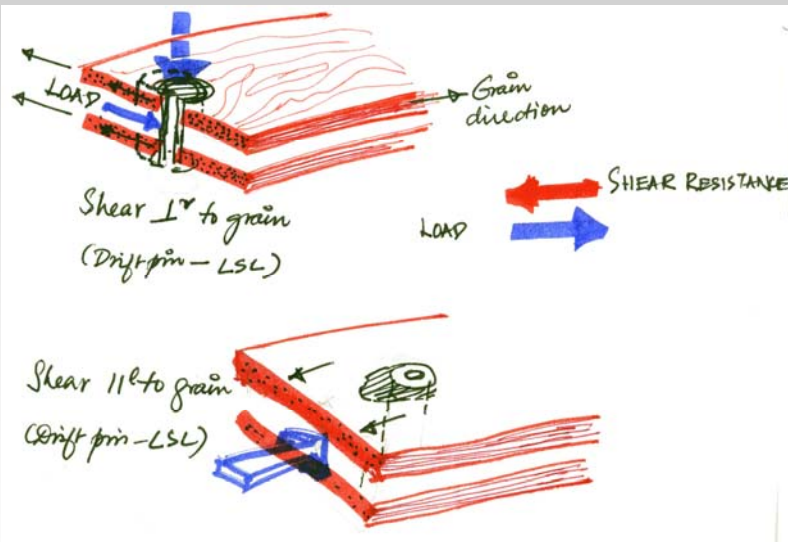
LSL BENDING TEST

Lamina specimens (convex, concave, and straight) were tested for their bending strength.

Results:

LSL bending strength= 494 kgf / cm²

Strength was not dependent on the curvature of the LSL.



SINGLE SHEAR LSL TO STEEL CONNECTION TEST

Drift pin shear tests in directions parallel and perpendicular to the grain.

Results:

Yield strength= 3095 kgf / cm²

Yield load and stiffness perpendicular to grain were nearly half of those specimens parallel to the grain.

FIELD JOINT CONNECTION TENSION TEST:

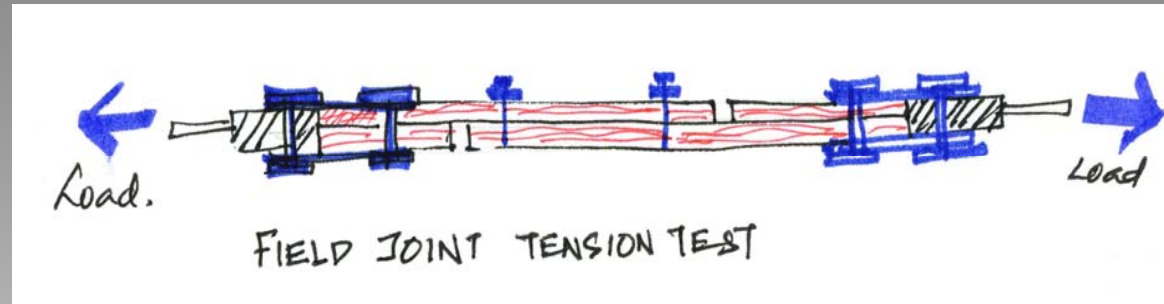
The drift pins & lag screws were clamped and pulled apart applying load (parallel and perpendicular to grain).

Results :

Tensile strength:

Drift pin : 202300 kg /cm (parallel), 88900 kg/cm (perpendicular)

Lag screw : 124400 kg/ cm (parallel) , 4370 kg/cm (perpendicular)



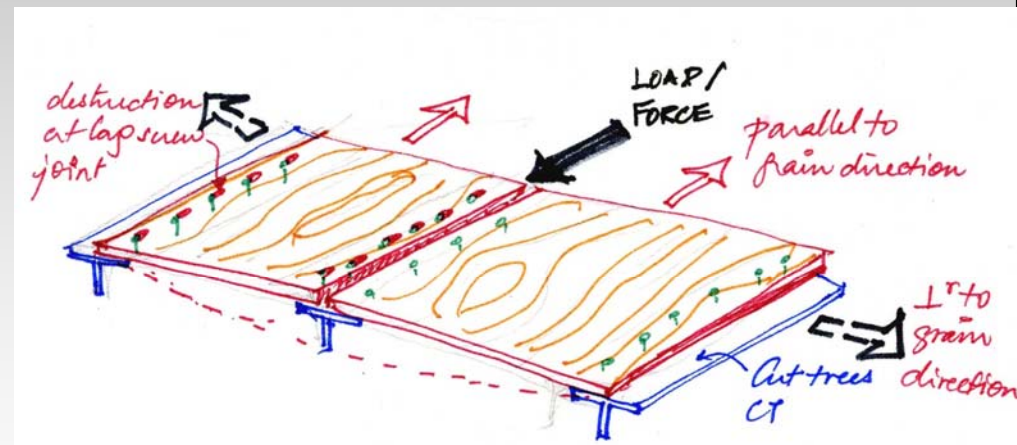
SHEAR STIFFNESS OF LSL PANEL:

Two LSL panels with 7mm dia hole were connected using CT and lag screws.

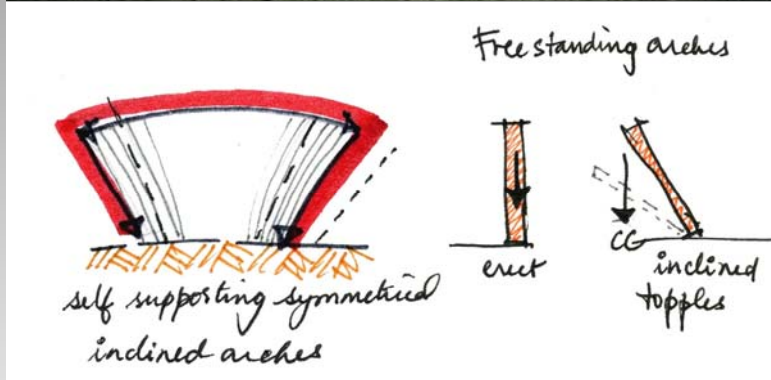
Results:

Shear stiffness= 3980 kgf/cm

Destruction was concentrated at lag screws.



CONCLUSIONS



- Choice of Double Skin Grid Dome structure facilitates **higher span to depth ratios** of the member.
- **Logical solution to the form.**
Overall form / geometry of the built structure is very suitable for resisting lateral loads such as Seismic load and lateral thrust created by snow load on dome structure.
- Choice of materials such as LSL ,Steel and their careful integration facilitates **light weight superstructure** in an earthquake prone region like Japan.
- Structural system and choice of material generates high levels of spatial aesthetics.



Thank You..