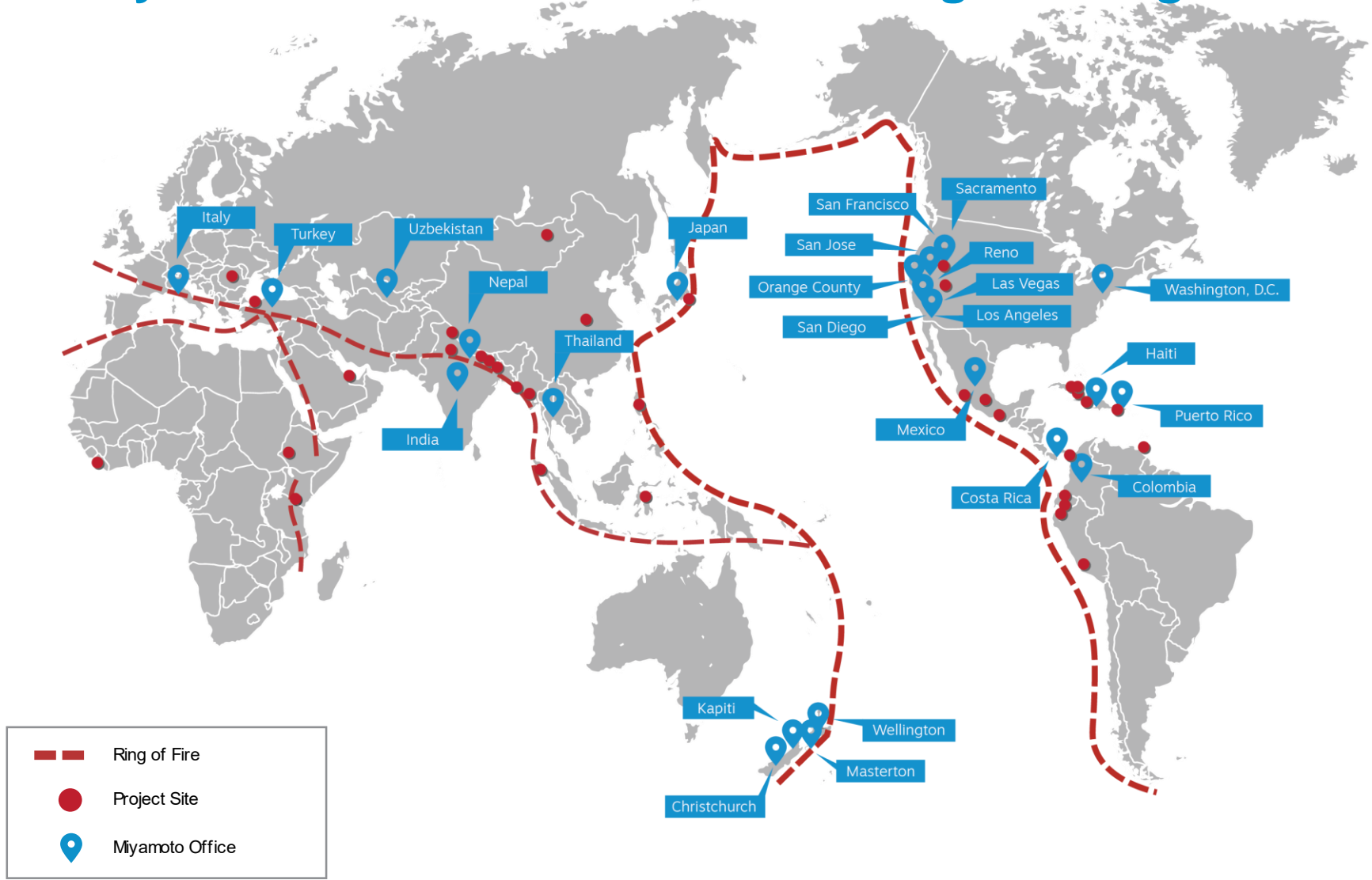


# *Post-Earthquake Repair and Strengthening of Historical Palace in Nepal*

Dr. Kit Miyamoto, SE  
Achyut Khanal, PE

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save lives, impact economies

# Miyamoto International locates along the Ring of Fire





## Nepal: 2015 Earthquakes

Nepal experienced two major earthquakes on April 25 and May 12, 2015 at magnitudes of 7.8 and 7.3 respectively.

Number of people killed  
As of 25 May 2015

**8,658**

Number of people injured  
Source: UNRCO/Gov. of Nepal

**21,150**

INTERACTIVE MAP

EARTHQUAKES AND AFTERSHOCKS

PEOPLE KILLED BY DISTRICT

PEOPLE INJURED BY DISTRICT

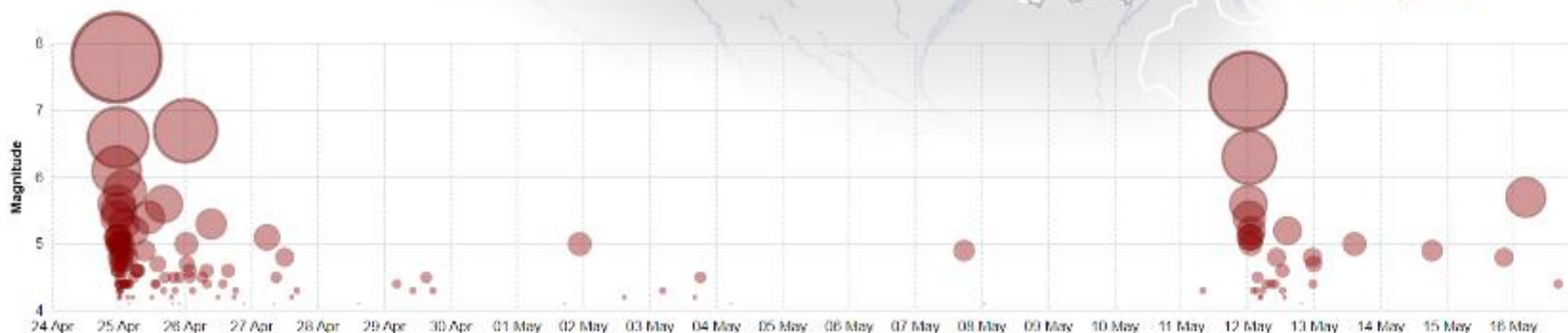
PEOPLE KILLED AND INJURED BY DISTRICT

Number of people killed | Number of people injured

limited to the top 15 districts

Kathmandu	1,218	7,830
Sindhupalchok	3,428	1,568
Lalitpur	182	3,052
Bhaktapur	332	2,101
Nuwakot	1,061	522
Kabhrepalanchok	318	1,179
Dhading	732	735
Gorkha	440	952
Rasuwa	596	771
Dolakha	168	643
Makawanpur	33	229
Sindhuli	14	228
Ramechhap	39	133
Chitawan	9	143
Solukhumbu	19	104

EARTHQUAKES AND AFTERSHOCKS Source: USGS



- Rana Palace built in 1907
- Located in the most prominent square in capital
- UNESCO World Heritage Site





- Destroyed by 2015 earthquake
- Abandoned for 2 years

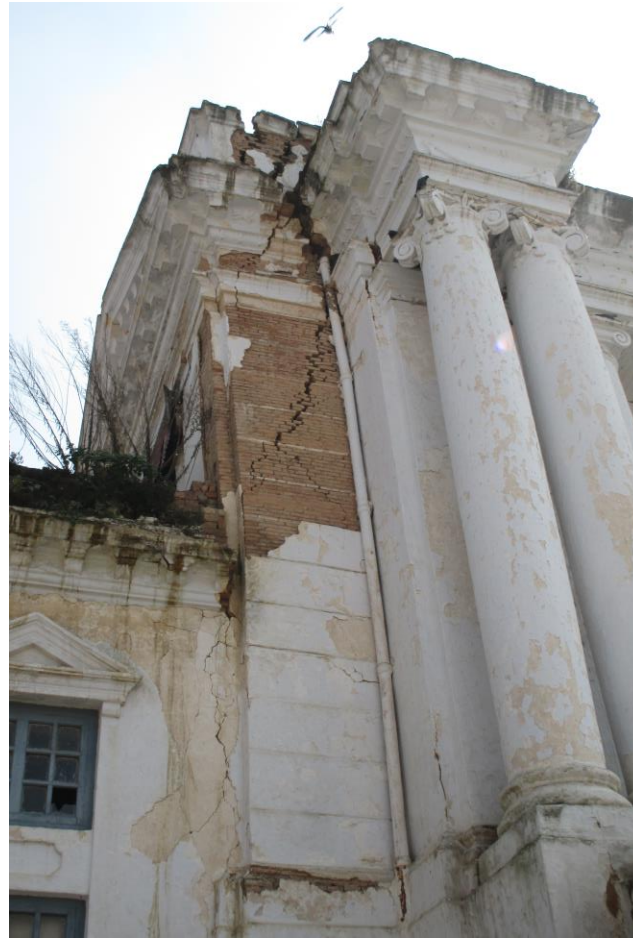


- Collapse of the corner structures
- Failure of the columns and parapet





- Out-of-plane failures



- Wall bulging













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nonprofit engineering experts

## GADDI BAITHAK BEFORE 2015 EARTHQUAKE



Support of the United States Government



Government of Nepal  
Department of Archaeology

### Restoration of the early 20th-century Gaddi Baithak

U.S. Ambassadors Fund for Cultural Preservation

MIYAMOTO RELIEF HAS BEGUN THE RESTORATION OF THE GADDI BAITHAK. THE RESTORATION WORK INCLUDES THE RESTORATION OF EARTHQUAKE-DAMAGED AREAS AND THE DESIGN STRENGTHENING OF THE BUILDING USING BOTH TRADITIONAL METHODS AND STATE-OF-THE-ART ENGINEERING TECHNOLOGY TO BRING BACK THE GADDI BAITHAK TO ITS FORMER GLORY.

Built in 1908 by Prime Minister Chandra Shumsher, this neoclassical European-style building was built as an extension to the royal palace and formed part of the King's residence. Later it became the center from which the King ruled and settled the affairs of the country - hence it's correct, Gaddi Baithak, which means the Royal Seat. It was also the place at which the King greeted foreign guests - from Heads of State to Ambassadors and other high-ranking foreign officials. The Gaddi Baithak is located at the heart of Kathmandu in Narayanhiti Durbar - a UNESCO World Heritage site and forms part of Nepal's rich cultural heritage.

This project is funded by the United States Government through the U.S. Ambassadors Fund for Cultural Preservation (AFCP). It was the largest AFCP grant awarded globally in 2016. Miyamoto Global Disaster Relief Nepal is the project implementation partner.

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through engineering experts



Support of the United States Government

U.S. AMBASSADORS FUND  
FOR CULTURAL PRESERVATION



Government of Nepal  
Department of Archaeology

### Restoration of the early 20th-century Gaddi Baithak

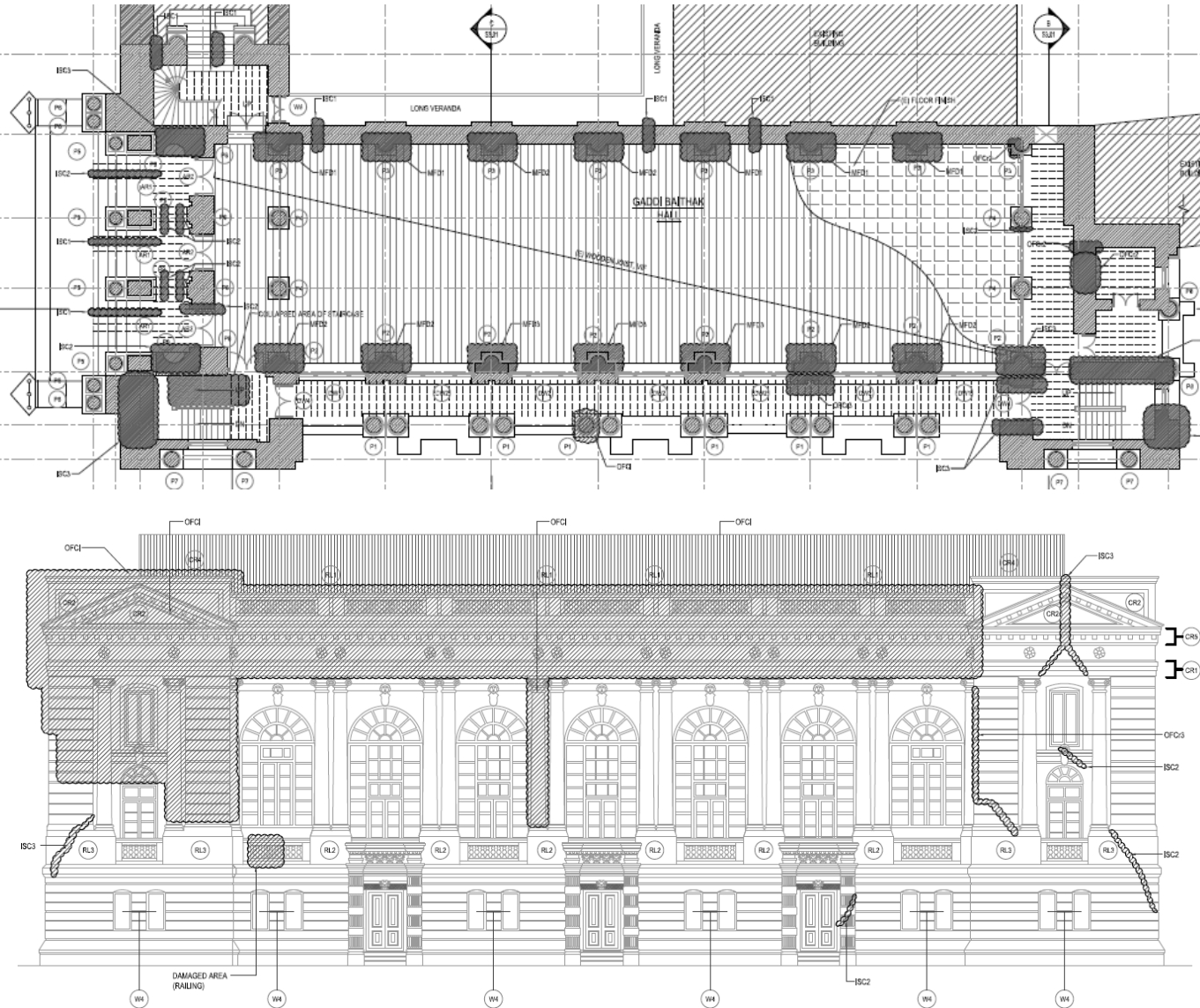
U.S. Ambassadors Fund for Cultural Preservation

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through engineering experts







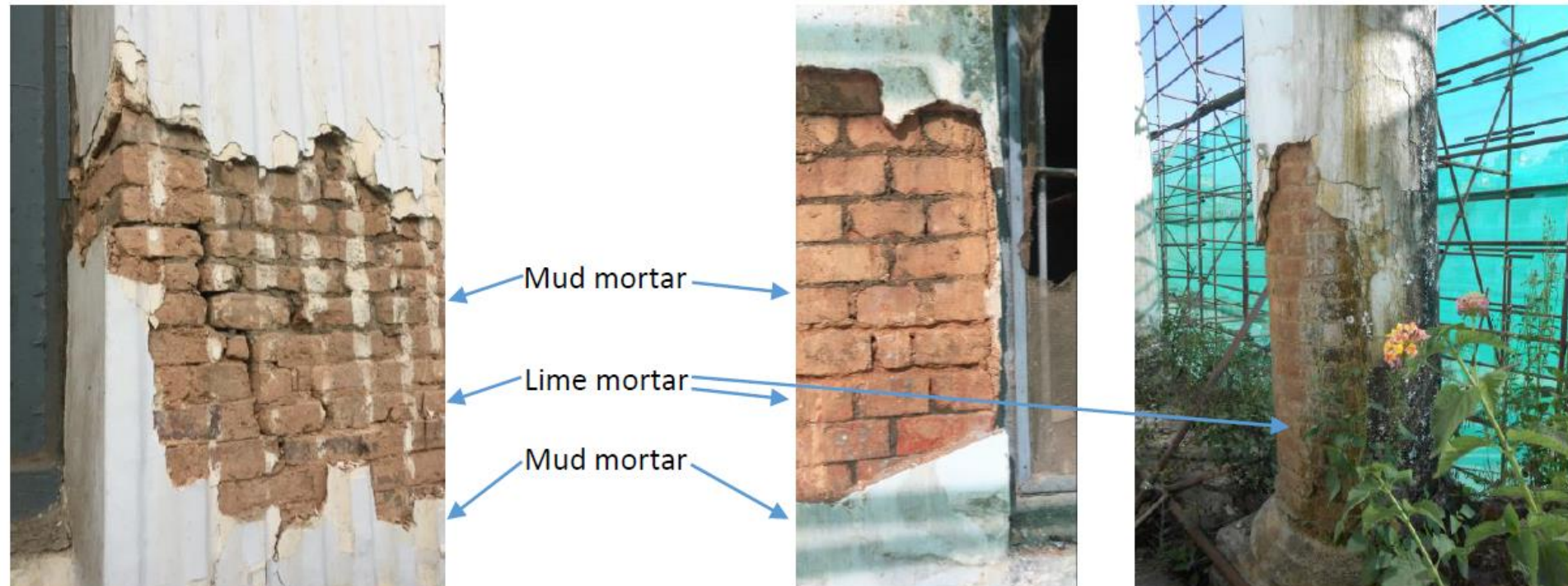


## LEGEND

NOTATION	DESCRIPTION
OFCr	OUT OF PLANE FLEXURAL CRACKS
OFCI	OUT OF PLANE FLEXURAL COLLAPSE
MFD	MID HEIGHT OUT OF PLANE FLEXURAL DAMAGE
ISC	INPLANE SHEAR CRACK
DCC	DIAGONAL CRACK OF CORNER.
GCR	GABLE END WALL CRACK
WS	WALL SEPARATION
1-MINOR	HAIR LINE CRACK < 1 CM
2-MEDIUM	1 CM TO 5 CM
3-MAJOR	5 CM > ABOVE

# Masonry work

Lime mortar in a few distinct locations. Parapet walls and columns contain solely lime mortar. Lime mortar within brick walls at horizontal intervals of approximately 1.8m.





# Timber

- Roof Truss
- Ceilings and floors





## Steel

- Reinforcing connection of timber truss
- Strap for ceiling
- Reinforcing strap to walls (potentially added after 1934 earthquake)

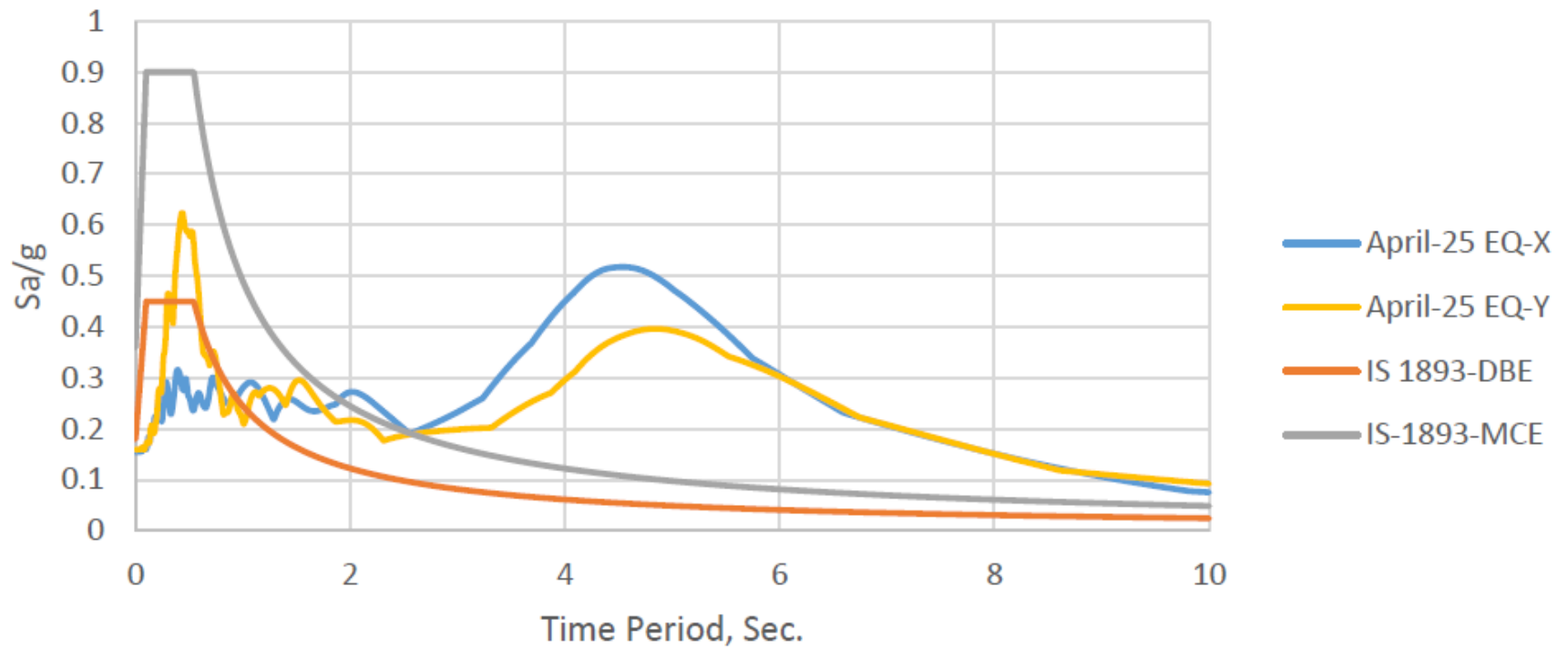


## Tin

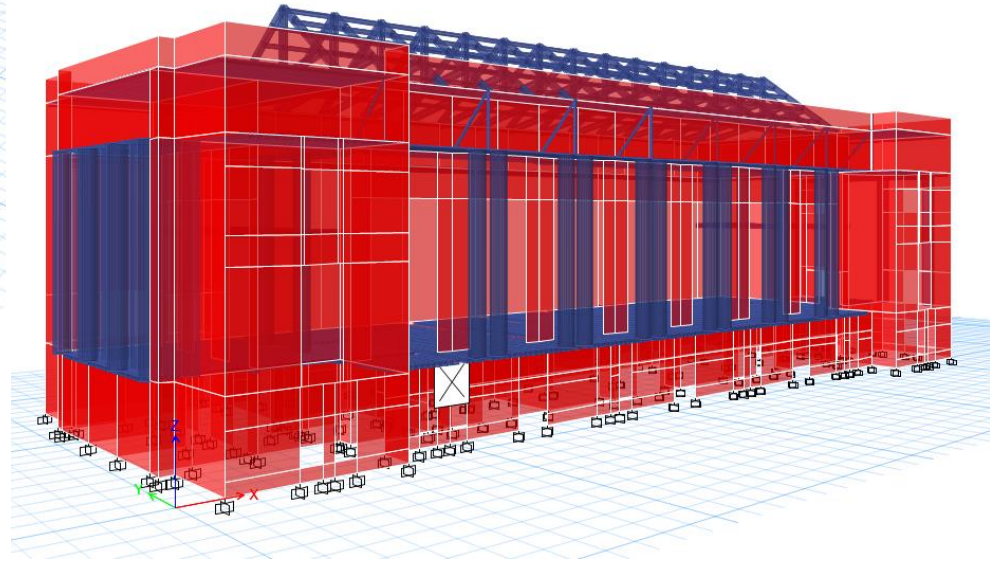
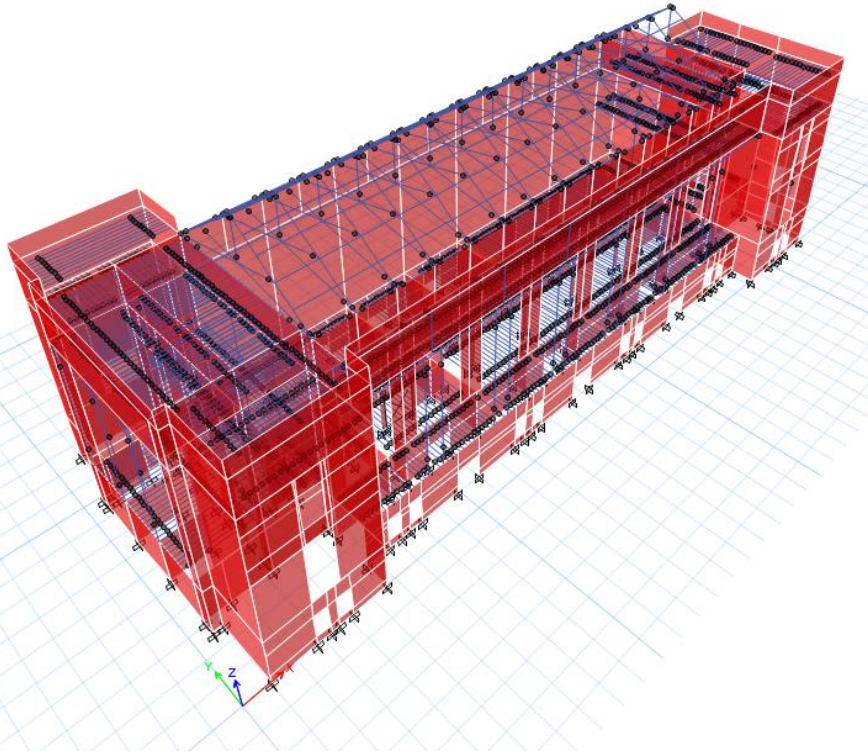
- Ornamental metal sheet



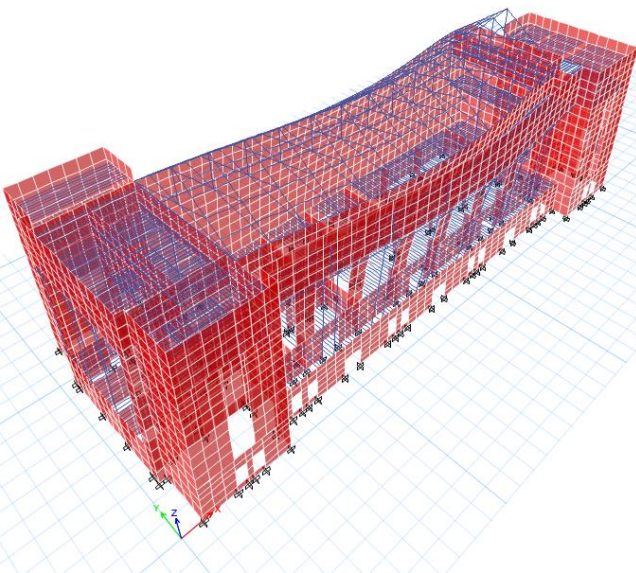
### IS Code and April-25 EQ Nepal



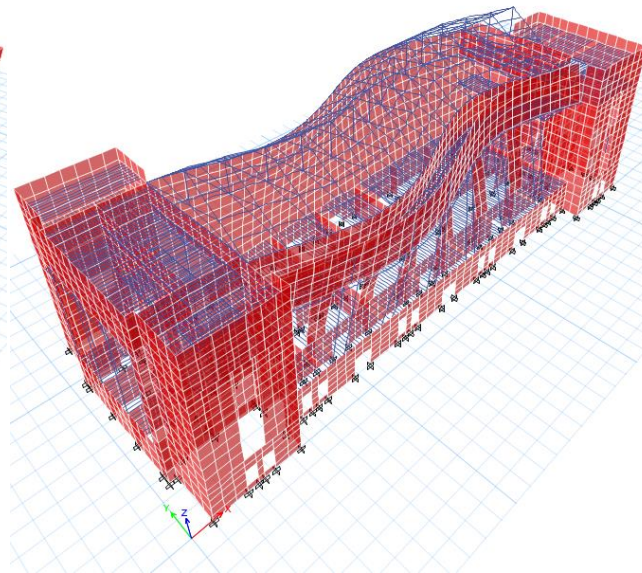




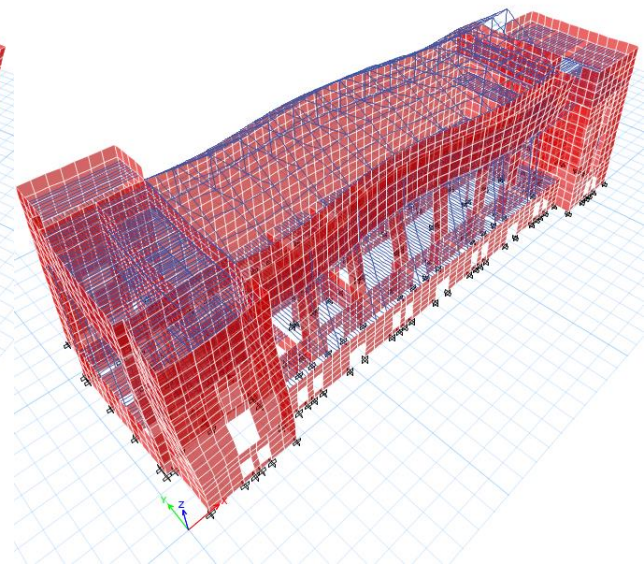
Mode Shape (Modal) - Mode 1 - Period 1.332



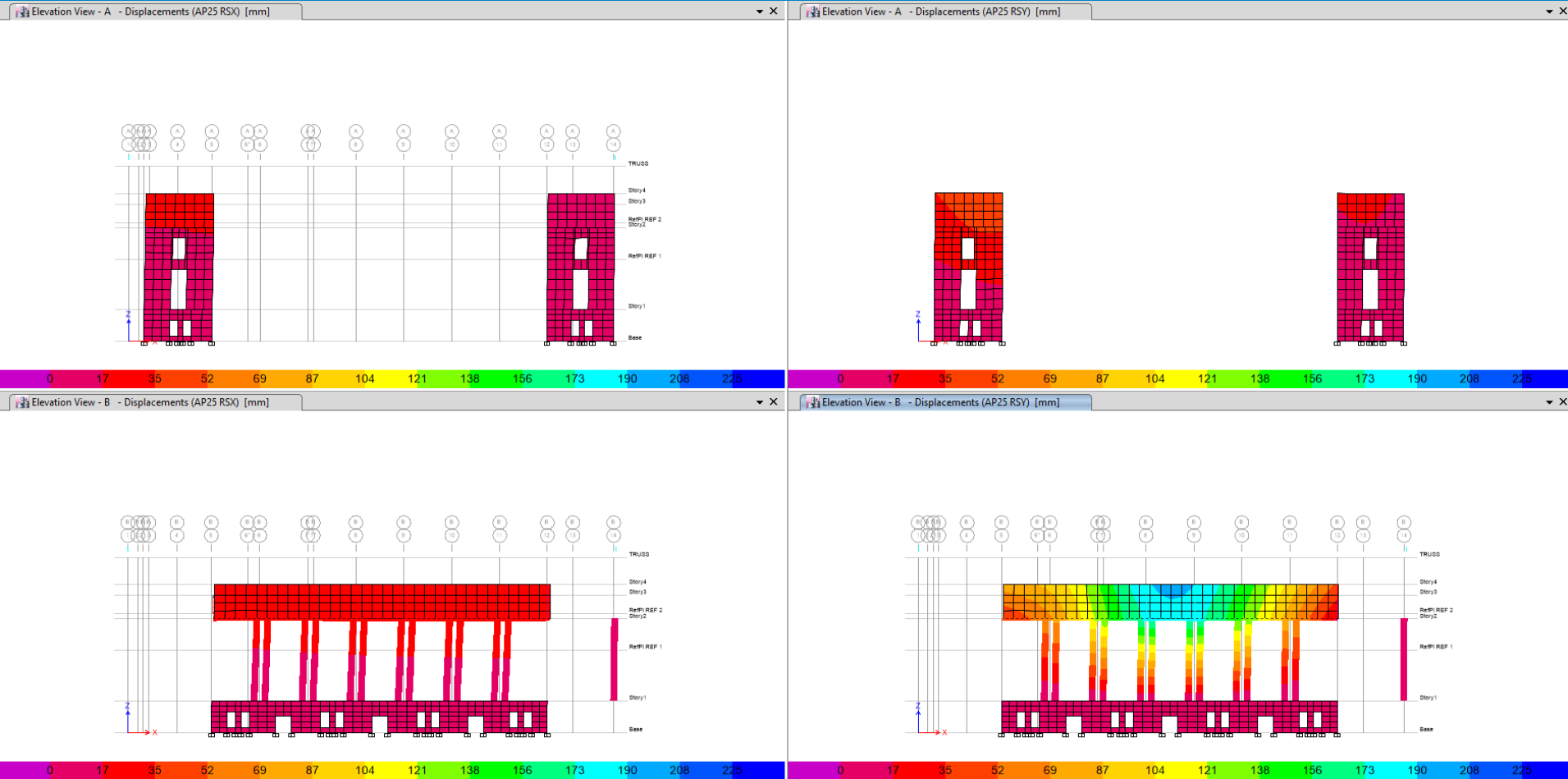
Mode Shape (Modal) - Mode 3 - Period 0.714



Mode Shape (Modal) - Mode 4 - Period 0.503

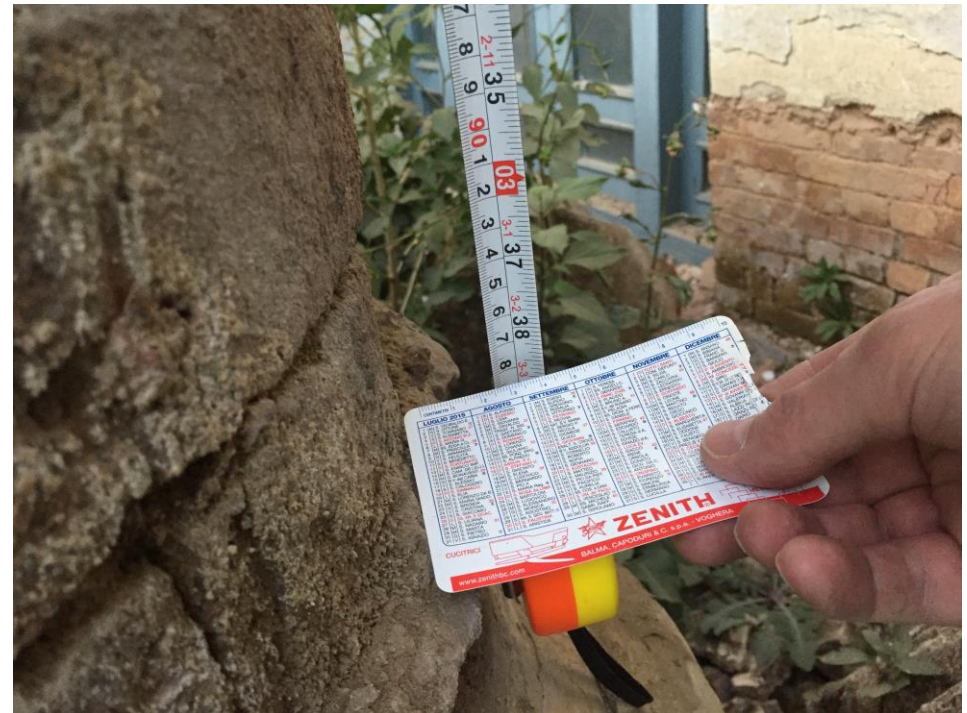


- 3 fundamental mode: 1.33, 0.71, 0.50 sec

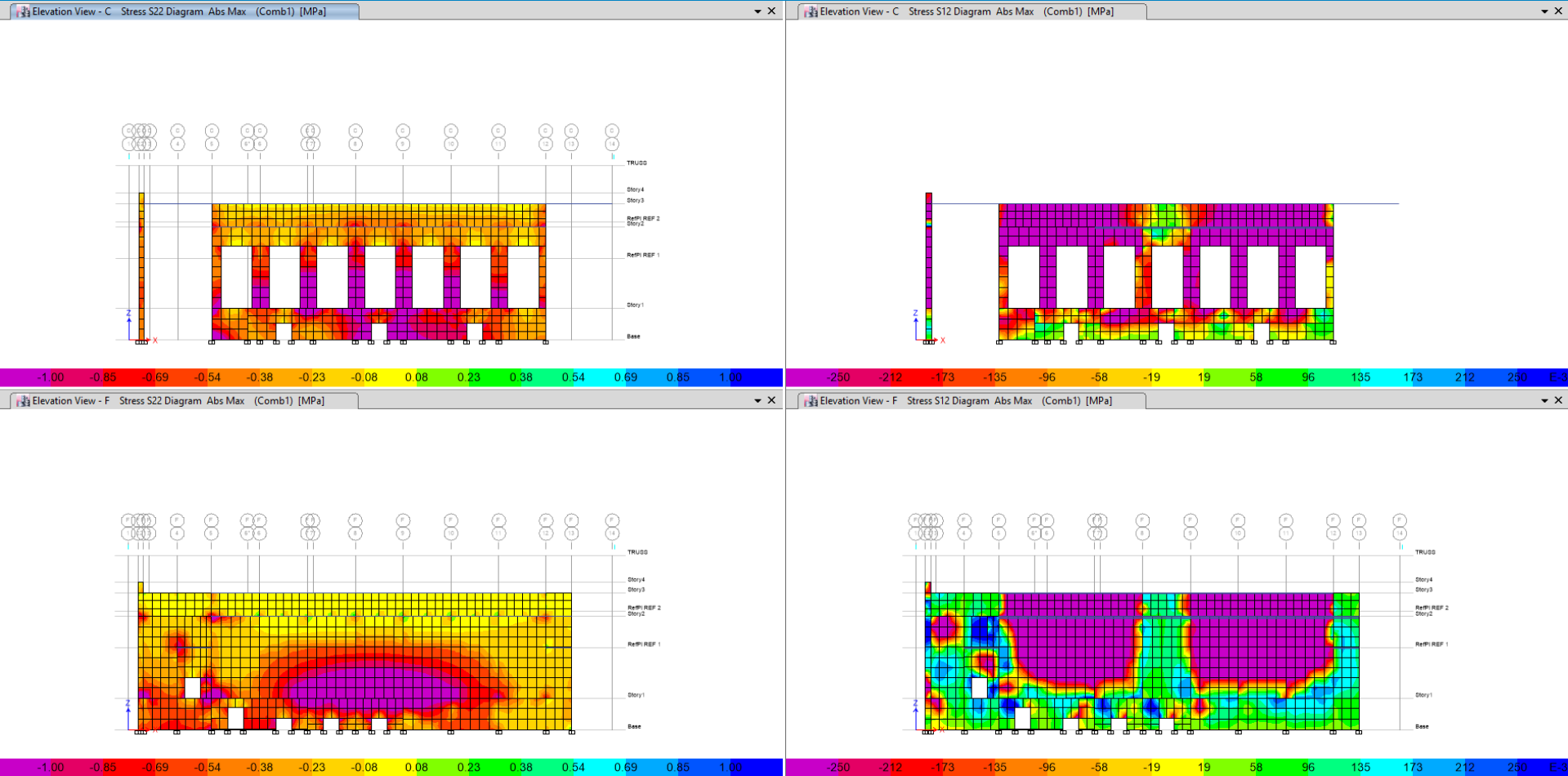


- Max parapet out of plane displacement due to April 25 response spectrum: 197 mm (8 inches)
- Max column tip displacement due to April 25 response spectrum: 180 mm
- drift ratio 1.8%





- Actual column displacement measured in site: 195 mm



- Envelop of DL+LL+/-EL(A25)
- compression ( $\sim 3.0 > 0.87$ )
- shear stress ( $\sim 0.6 > 0.2$ ) exceeding in large areas

# Intervention approach

## **Option 1**

### **Engineering Approach:**

- Modern construction material, e.i. Concrete & steel
- Incorporating such structural system to conventional construction, such as brick.
- Retrofitting of structure

## Intervention Option 1





## Intervention approach

### **Option 1**

#### **Engineering Approach:**

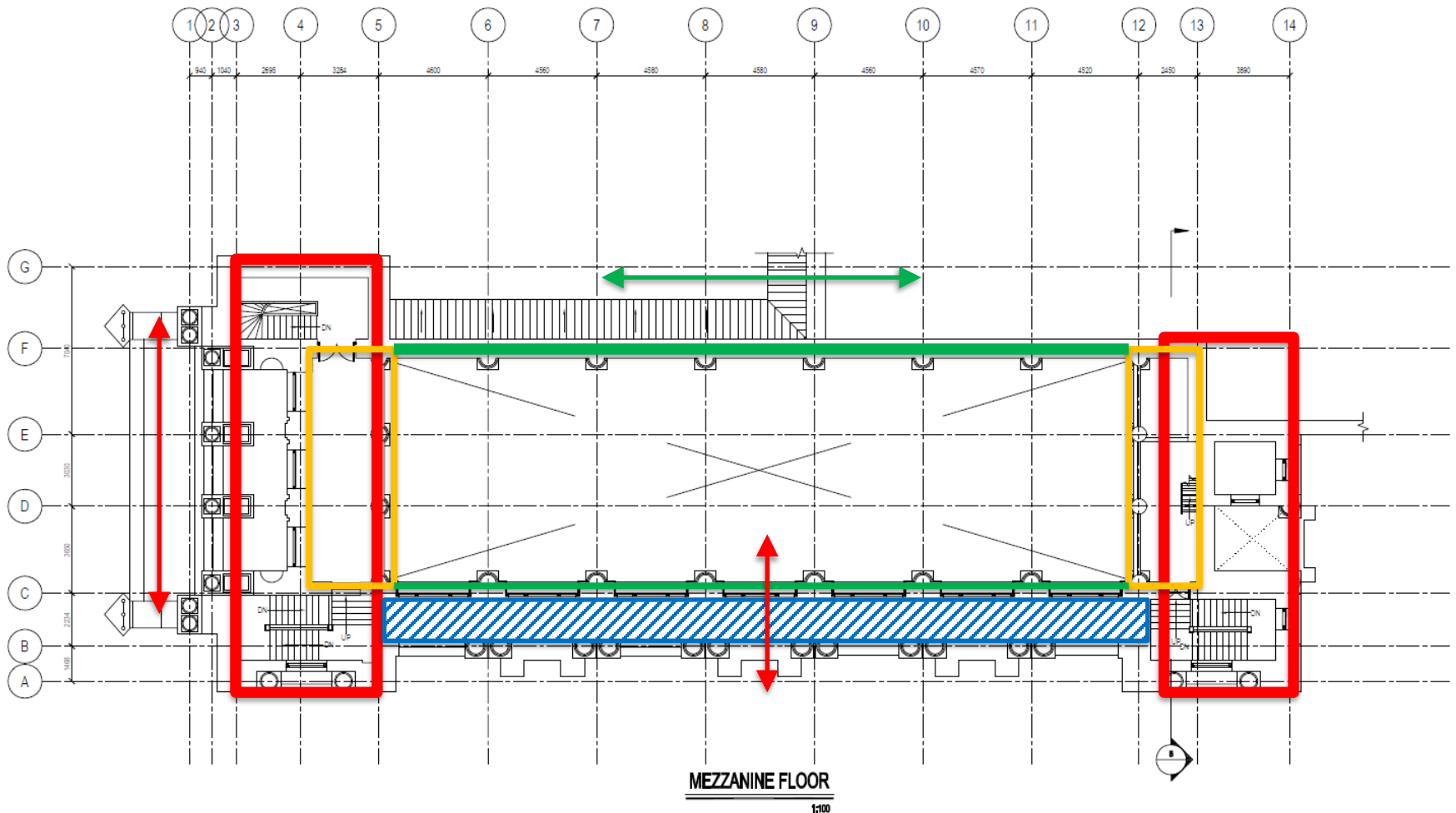
- Theory of modern construction material, e.i. Concrete & steel
- Calculation technique for these material
- Incorporating such structural system to conventional construction, such as brick.

### **Option 2**

#### **Enhancement of Original Construction Technology:**

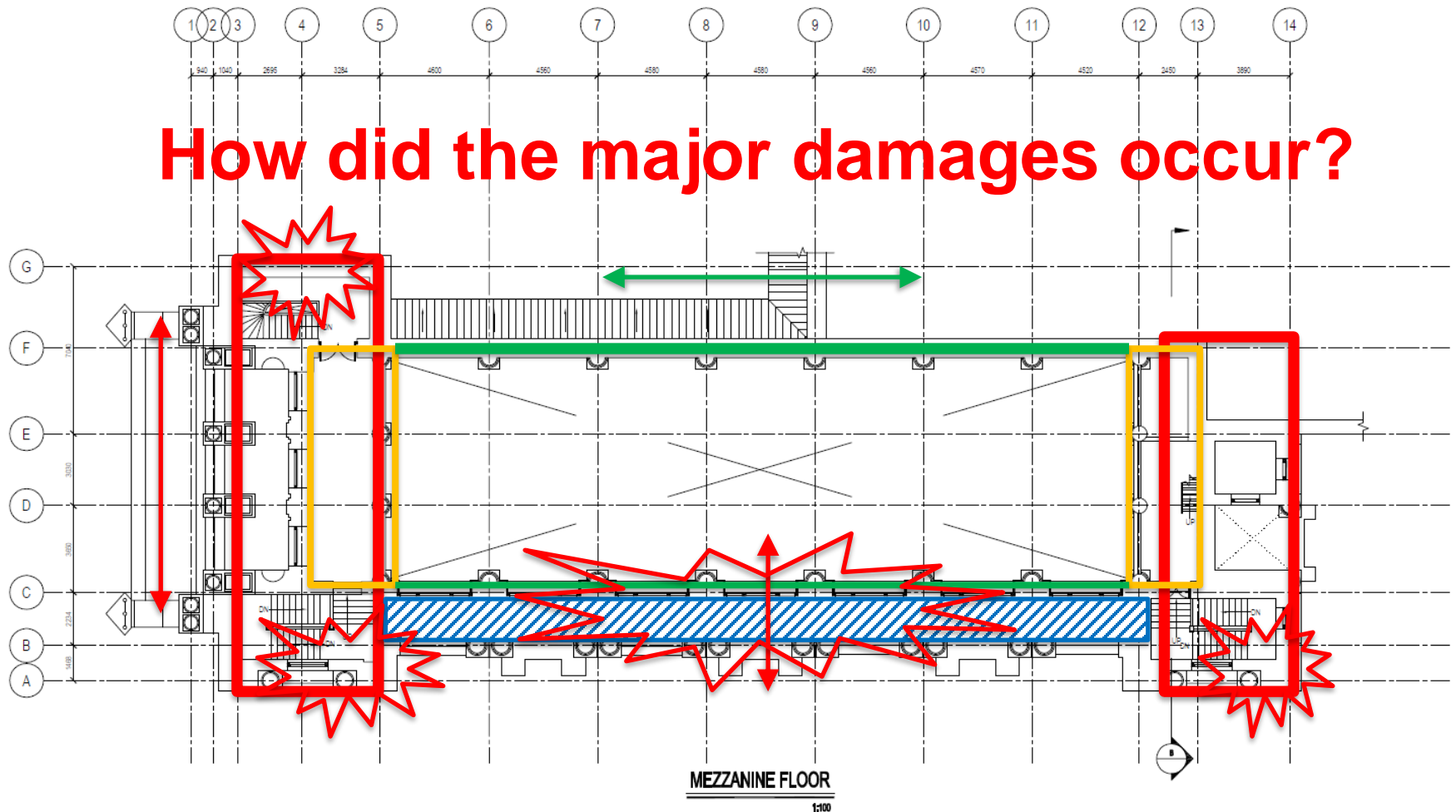
- Understand traditional resistant system
- Understand why and what went wrong
- Follow the traditional system; Keep what worked well
- Retrofitting of CULTURE and HISTORY

# Rigid boxes + Mezzanine + Long wall + Diaphragm ( Transitional zone ) ( cornice level )

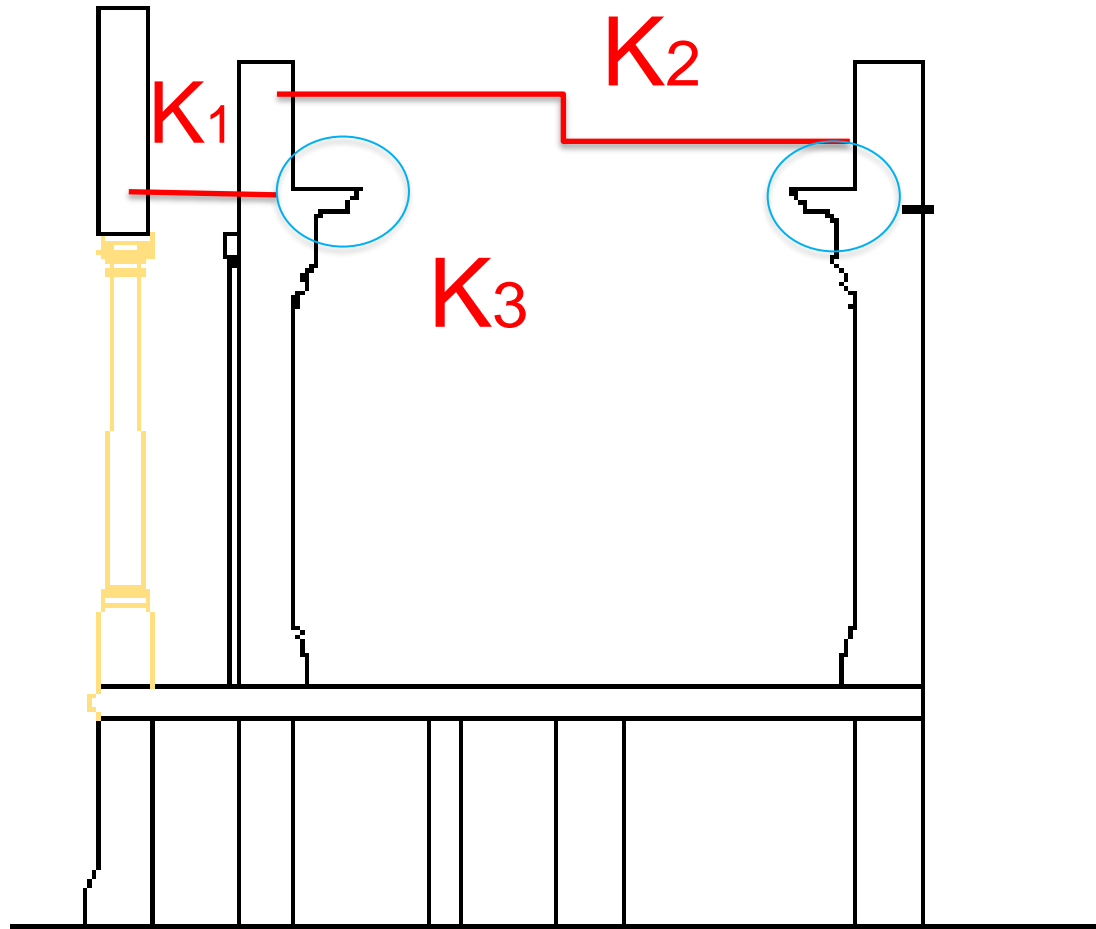




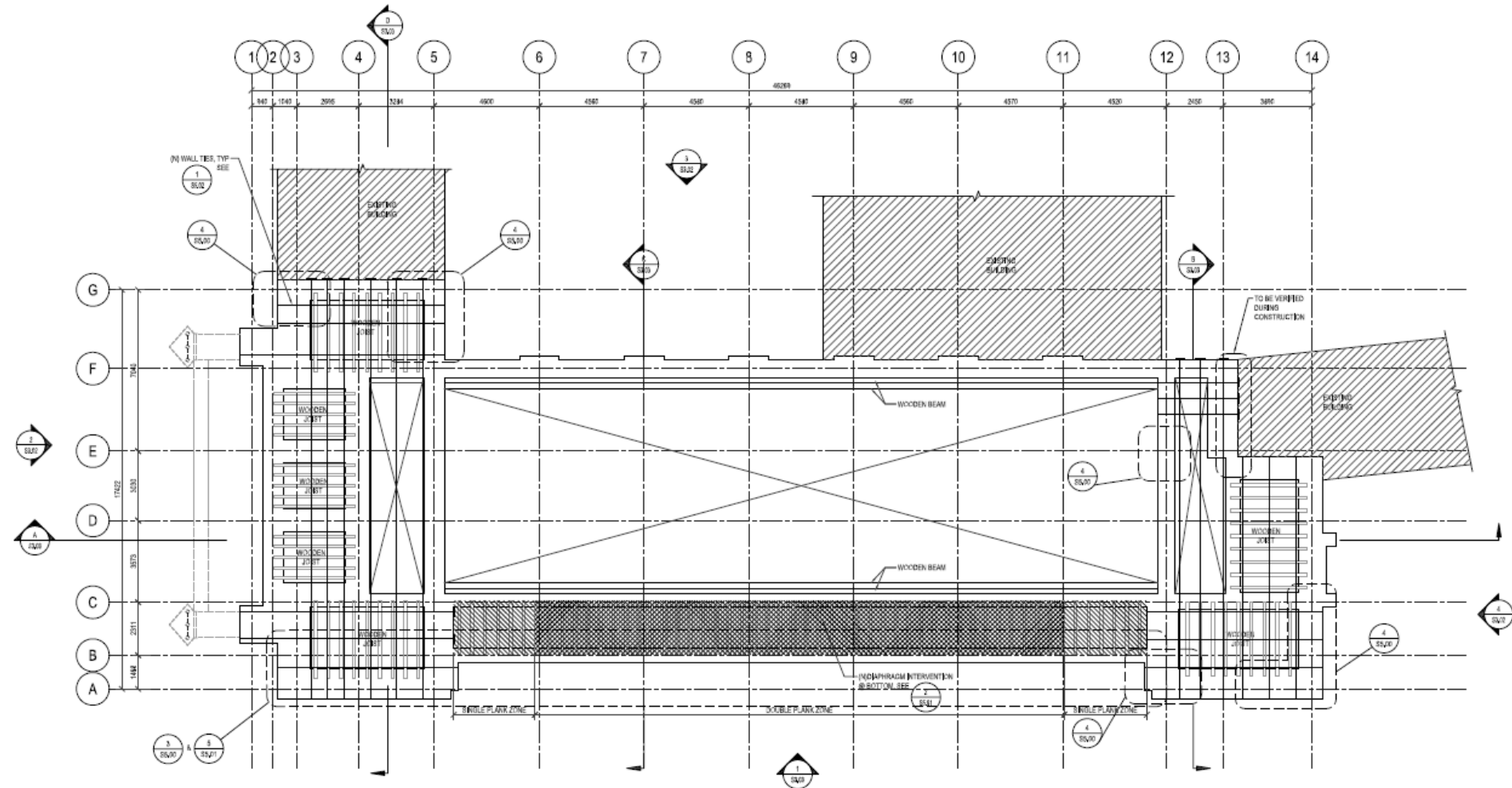
**Rigid boxes + Mezzanine + Long wall + Diaphragm**  
( Transitional zone ) ( cornice level )



# Restoring proper combination of spring effects



# Restoration/intervention of arcade diaphragm (K1)



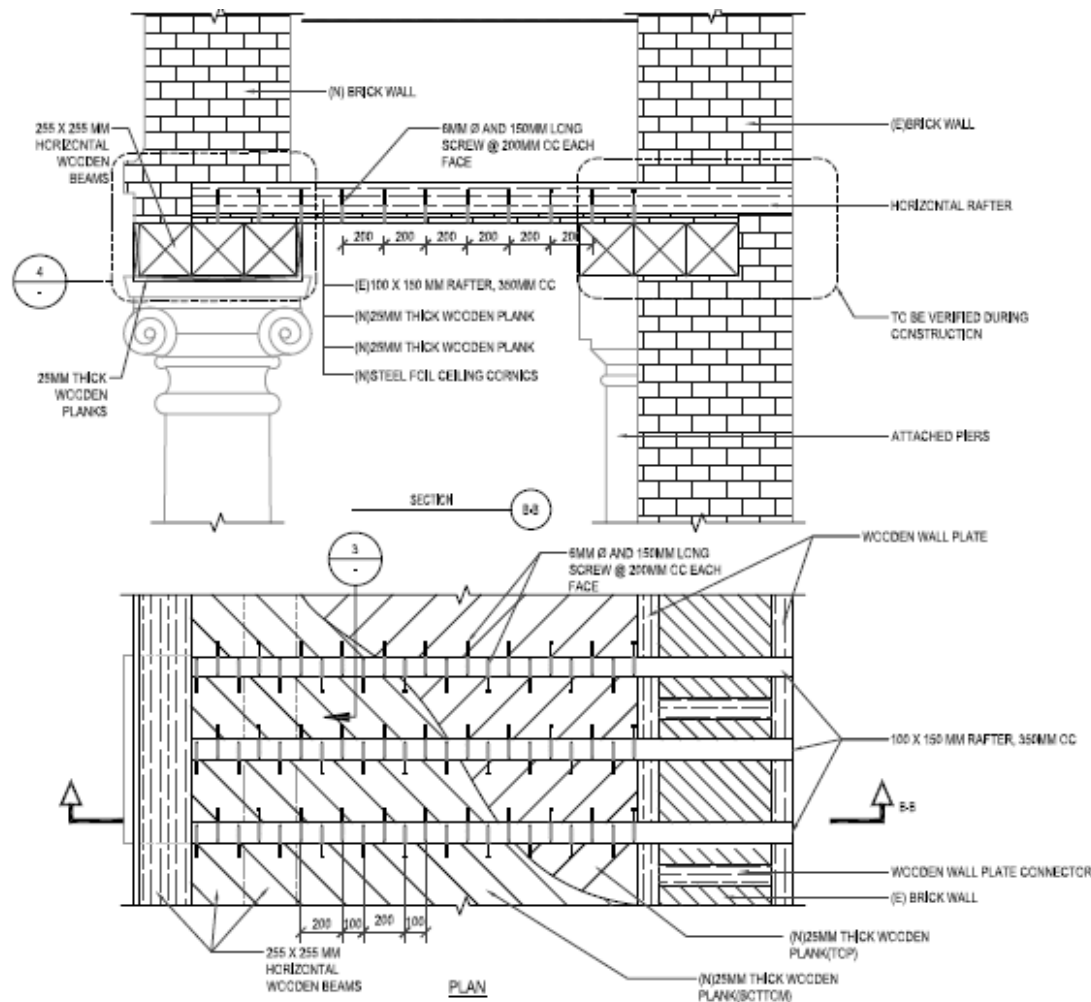
CEILING FLOOR PLAN

1/100

NOTE: CONTRACTOR TO VERIFY ALL DIMENSIONS ON SITE.



- Detail of diaphragm interventions

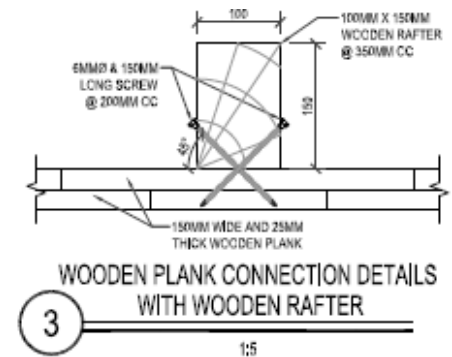


### DIAPHRAGM CONNECTION DETAILS

2

NOTE: PRE-DRILLING THE TIMBER IS HIGHLY RECOMMENDED TO PREVENT SPLITTING OF THE WOOD.

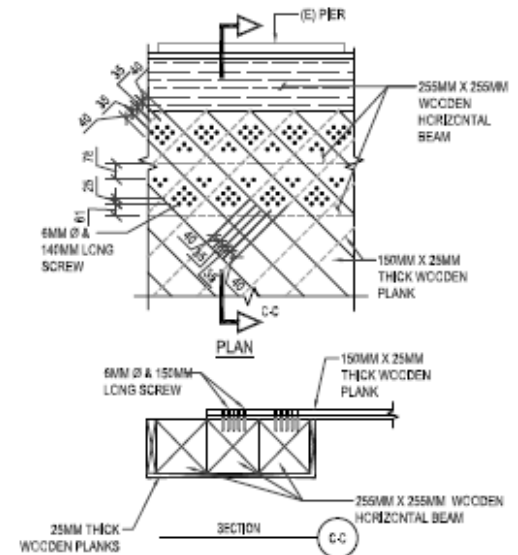
1:20



WOODEN PLANK CONNECTION DETAILS  
WITH WOODEN RAFTER

(3)

1:5



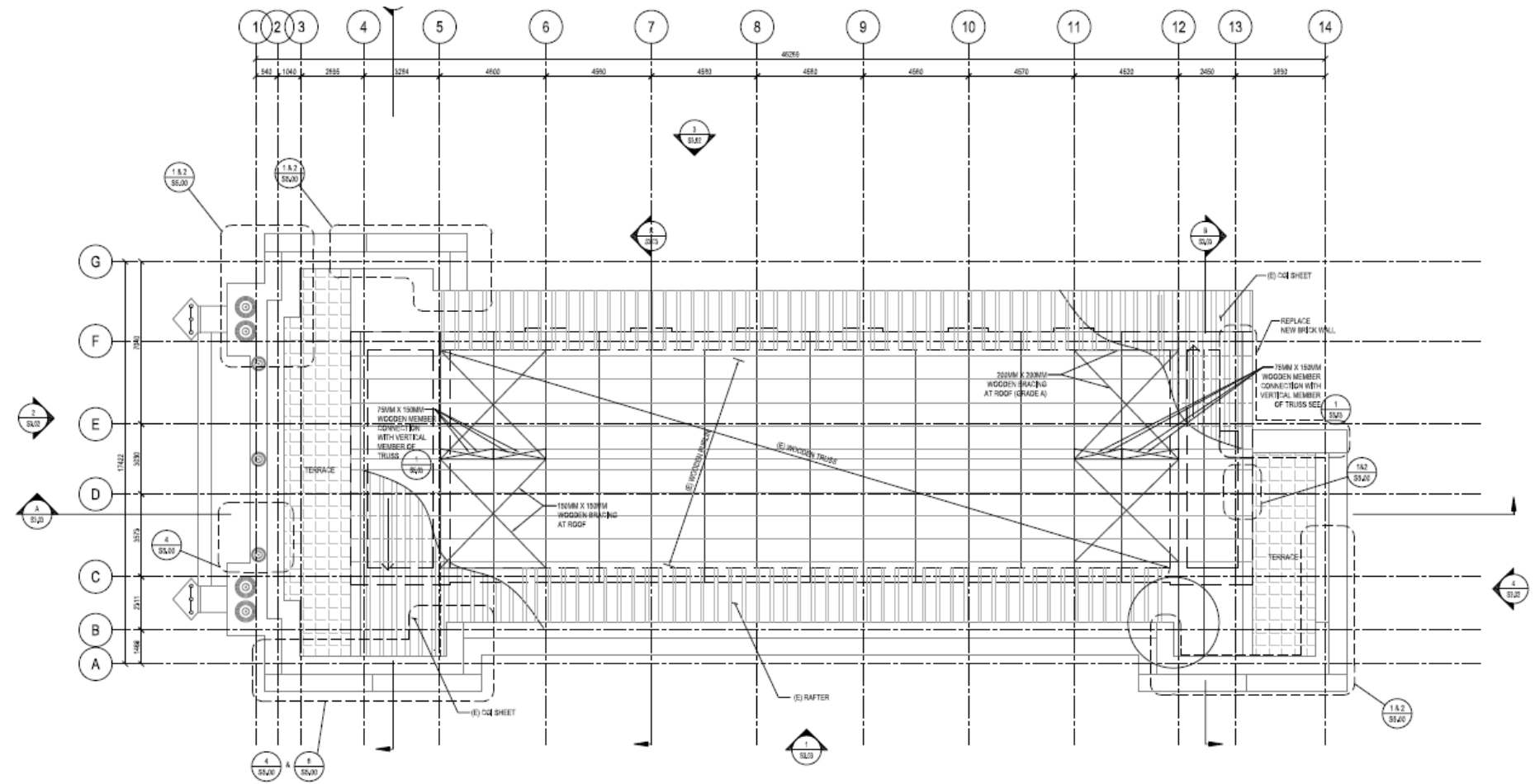
### PLANK TO BEAM CONNECTION DETAILS

(4)

NOTE: PRE-DRILLING THE TIMBER IS HIGHLY RECOMMENDED TO PREVENT SPLITTING OF THE WOOD.

## Restoration/Improvement of Truss-Wall interaction (K2)

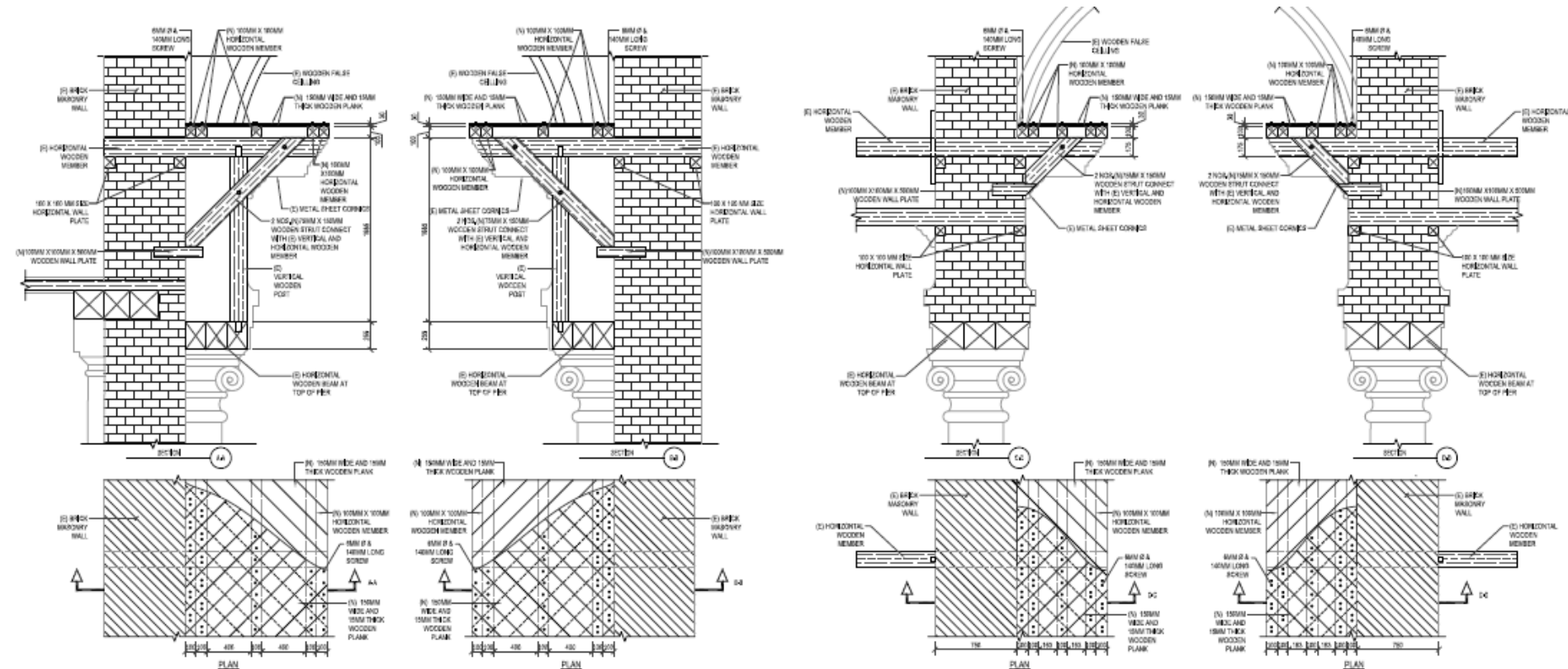
(enhancing timber roof beam function  
enhancing bracing effect of ceiling)



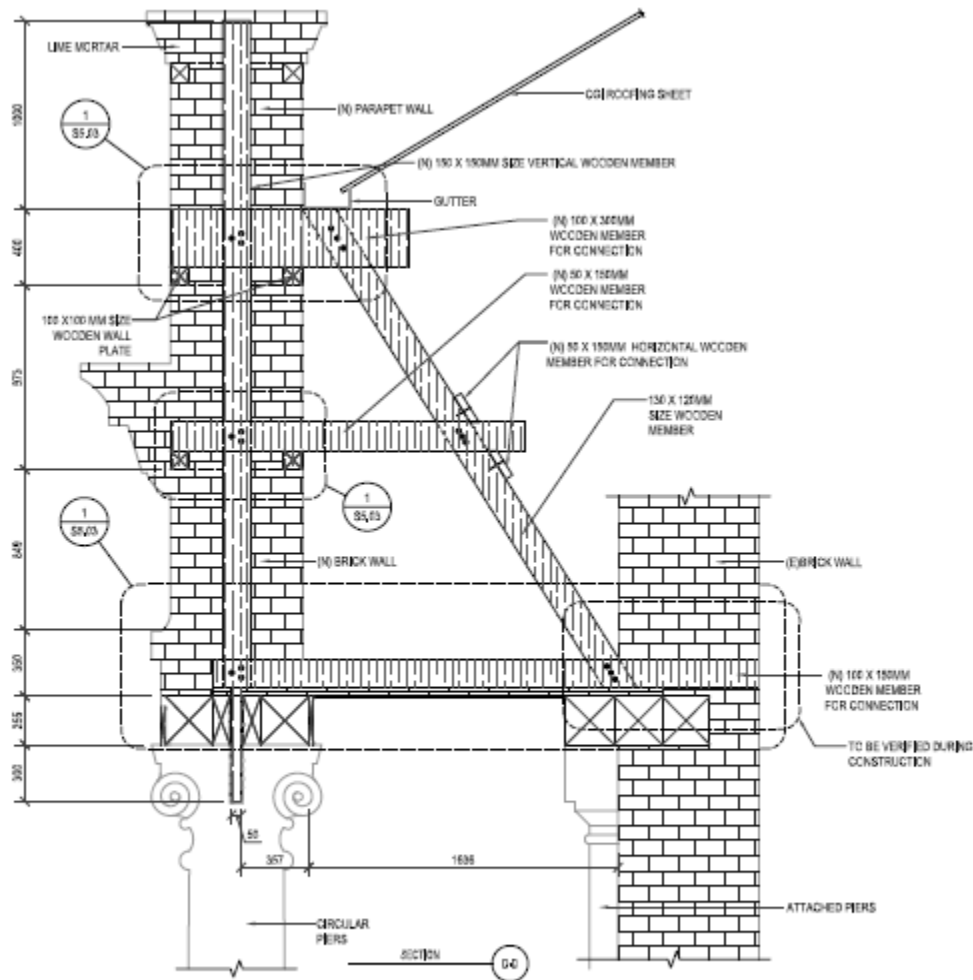
Architectural floor plan of a building with a grid system (Columns 1-14, Rows A-G). The plan shows a central hall area with a double layer of 151 mm wide and 19 mm thick wooden slats, and a central horizontal term x term wooden joist. The plan includes a staircase, a terrace above, and various structural elements like columns and beams. Dimensions are provided for various sections, and a note indicates that a retrofit is necessary for the structure.



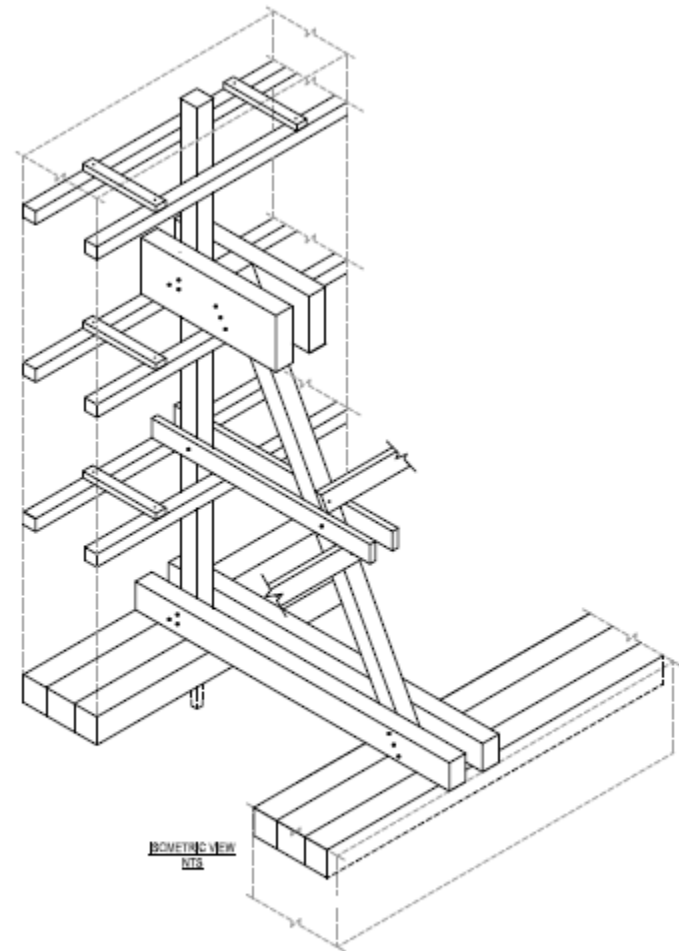
# Detail of Band diaphragm (k3)



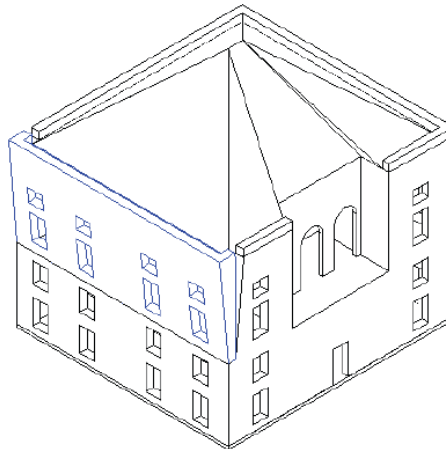
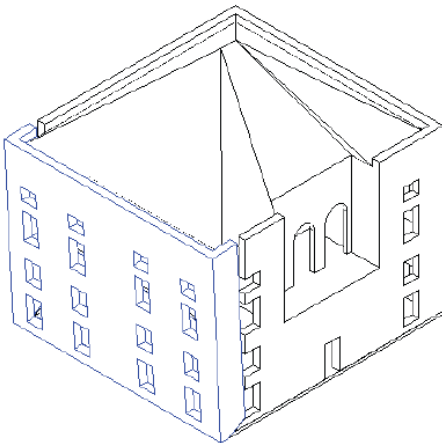
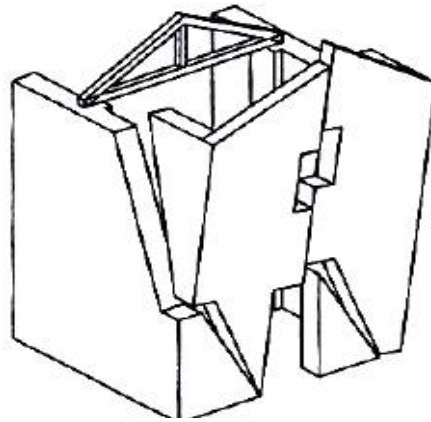
## Local interventions (prevention of parapet fall)



### CONNECTION DETAILS OF BRACING

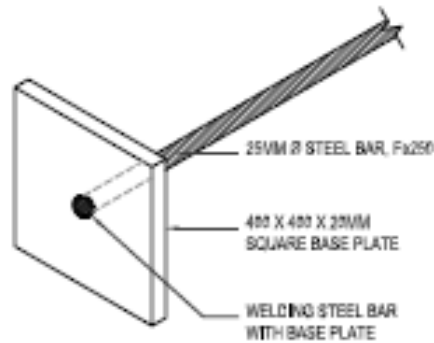


## Steel rod to keep box action

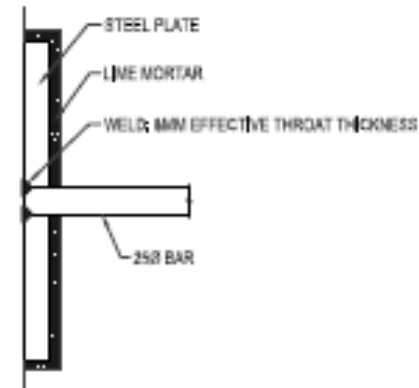




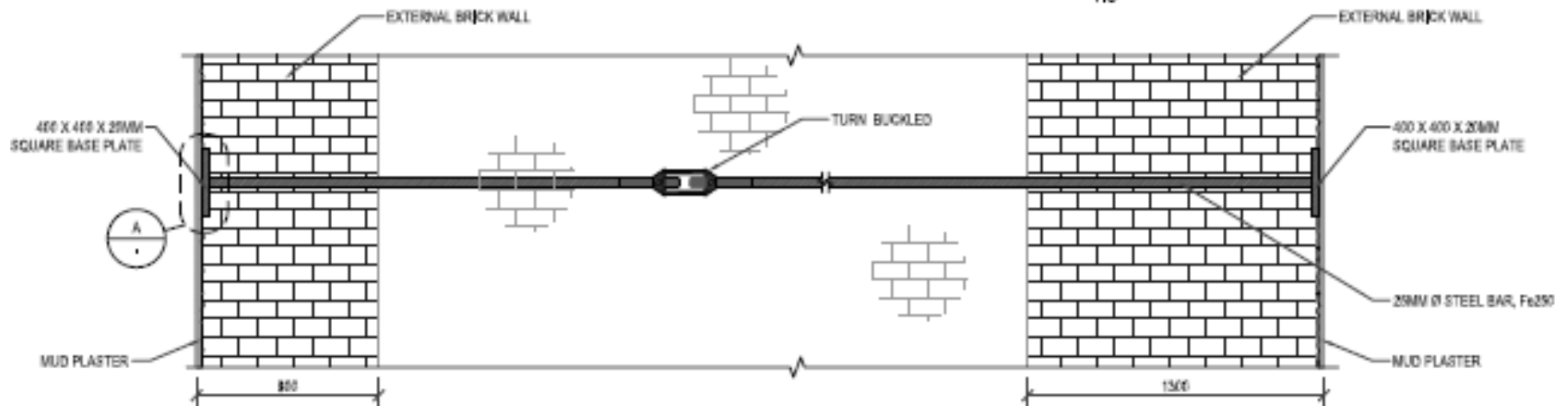
# Typ. Detail of steel rod interventions



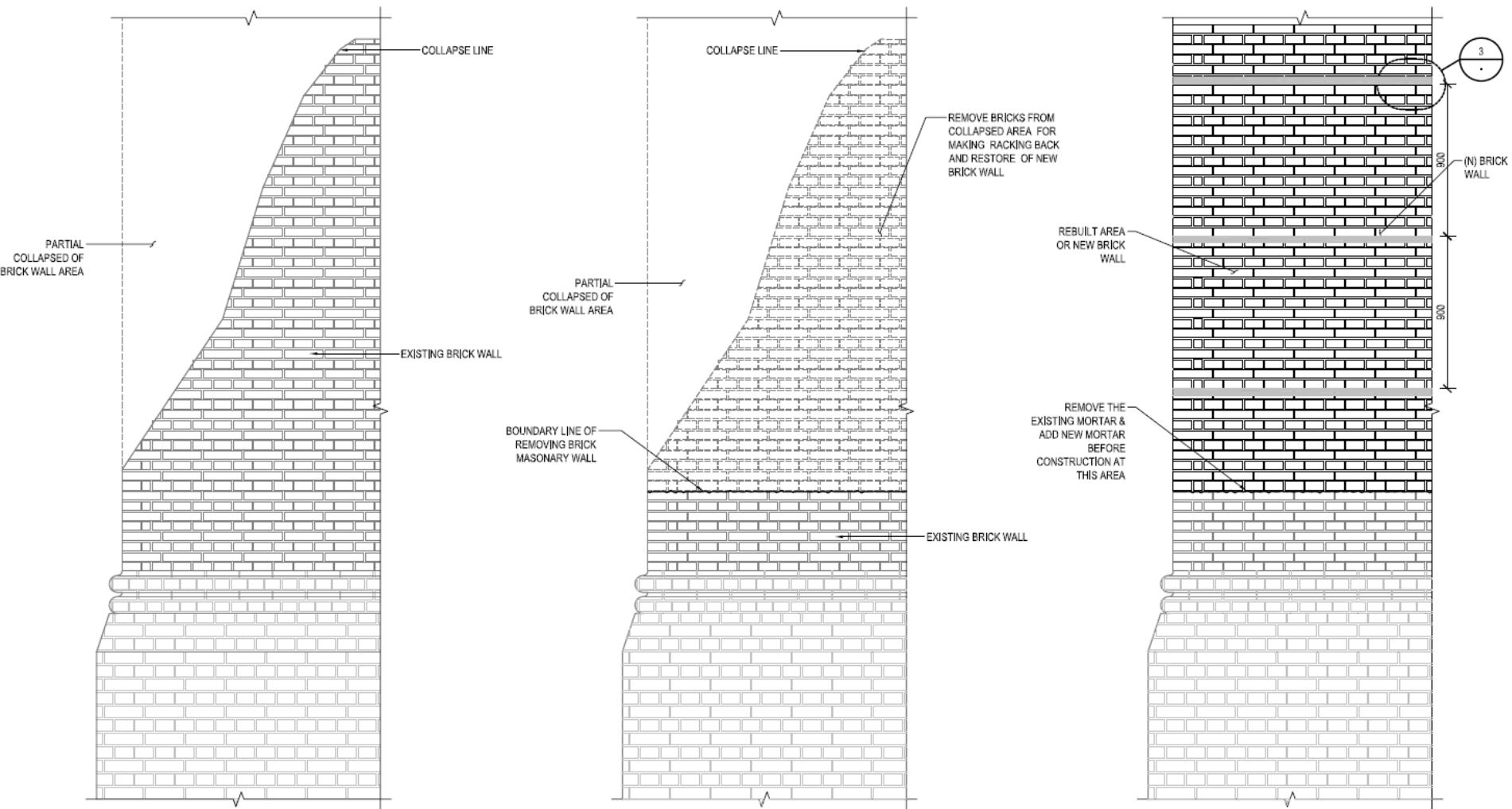
**DETAILS AT A**  
1:10



**CONNECTION DETAIL**  
1:5

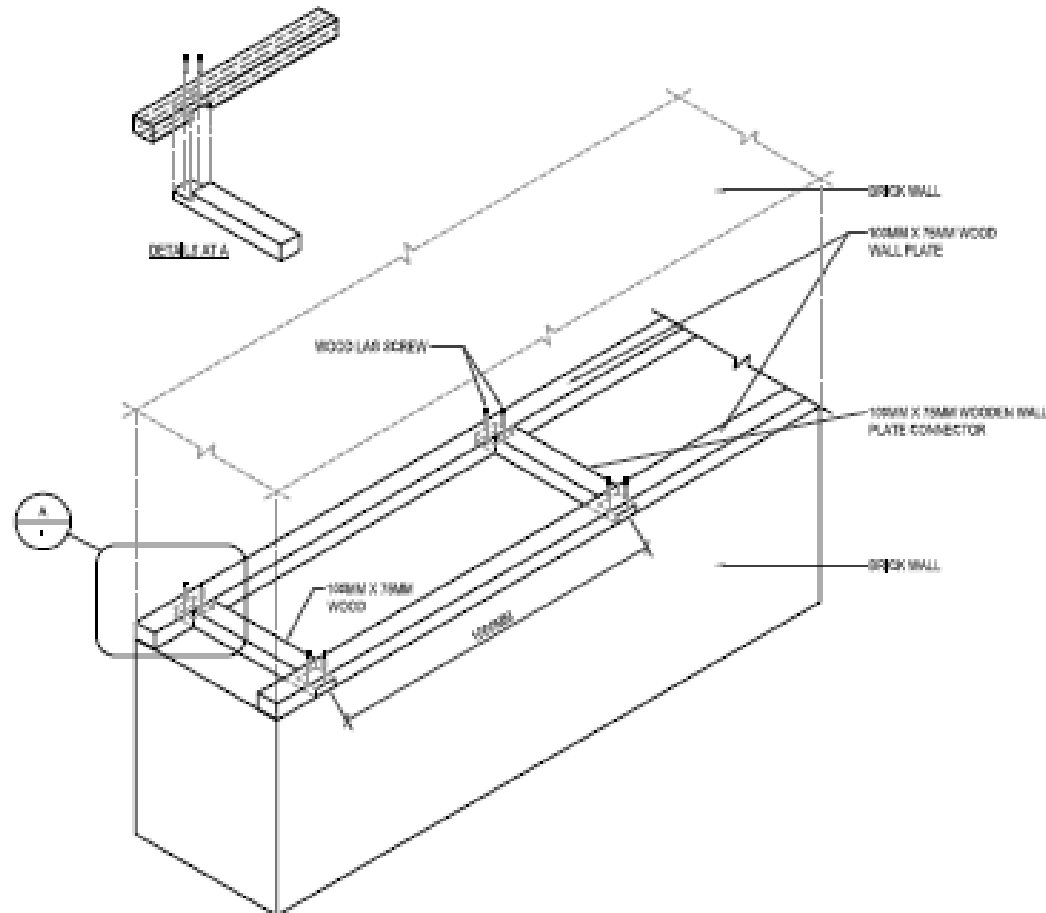


**WALL TIE DETAIL**



# Wood band in rebuilt brick wall

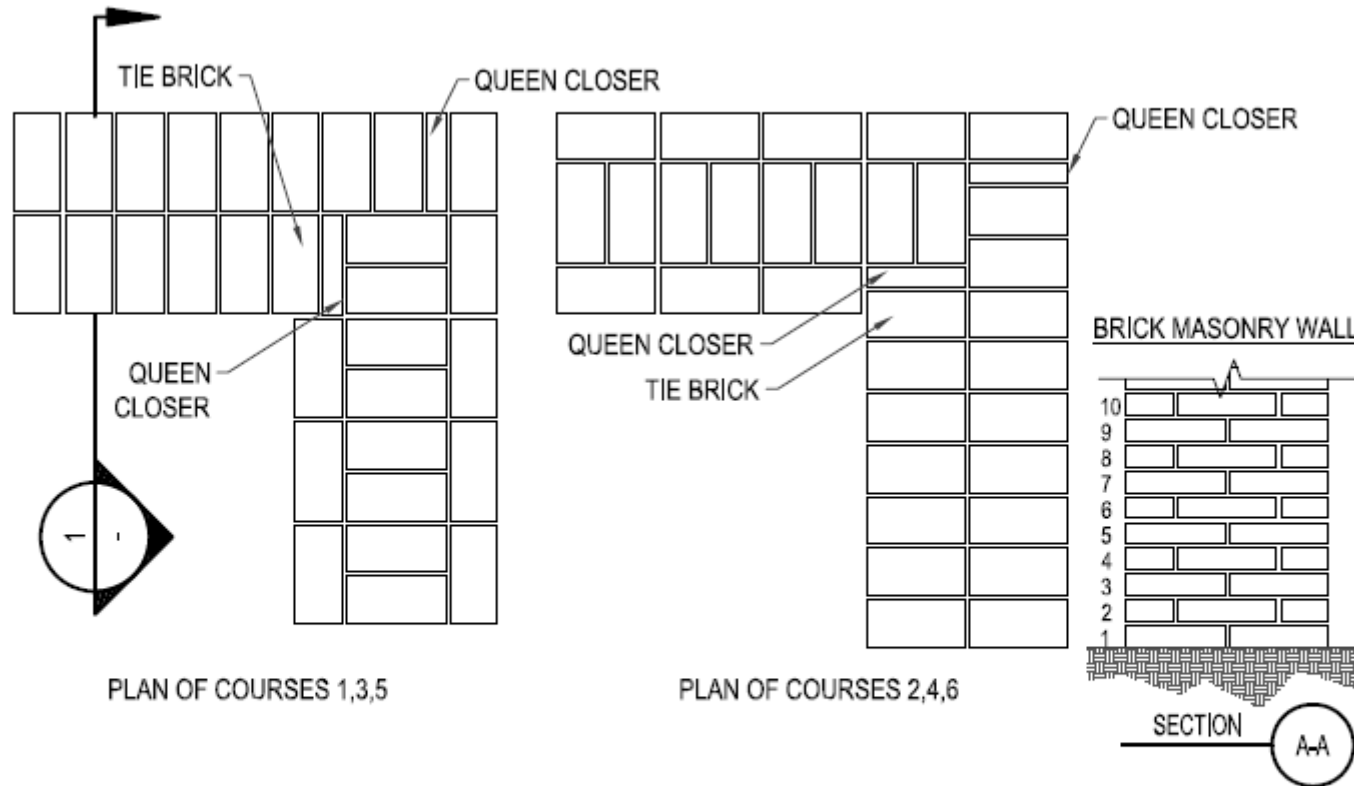
## Improve confinement of brick wall

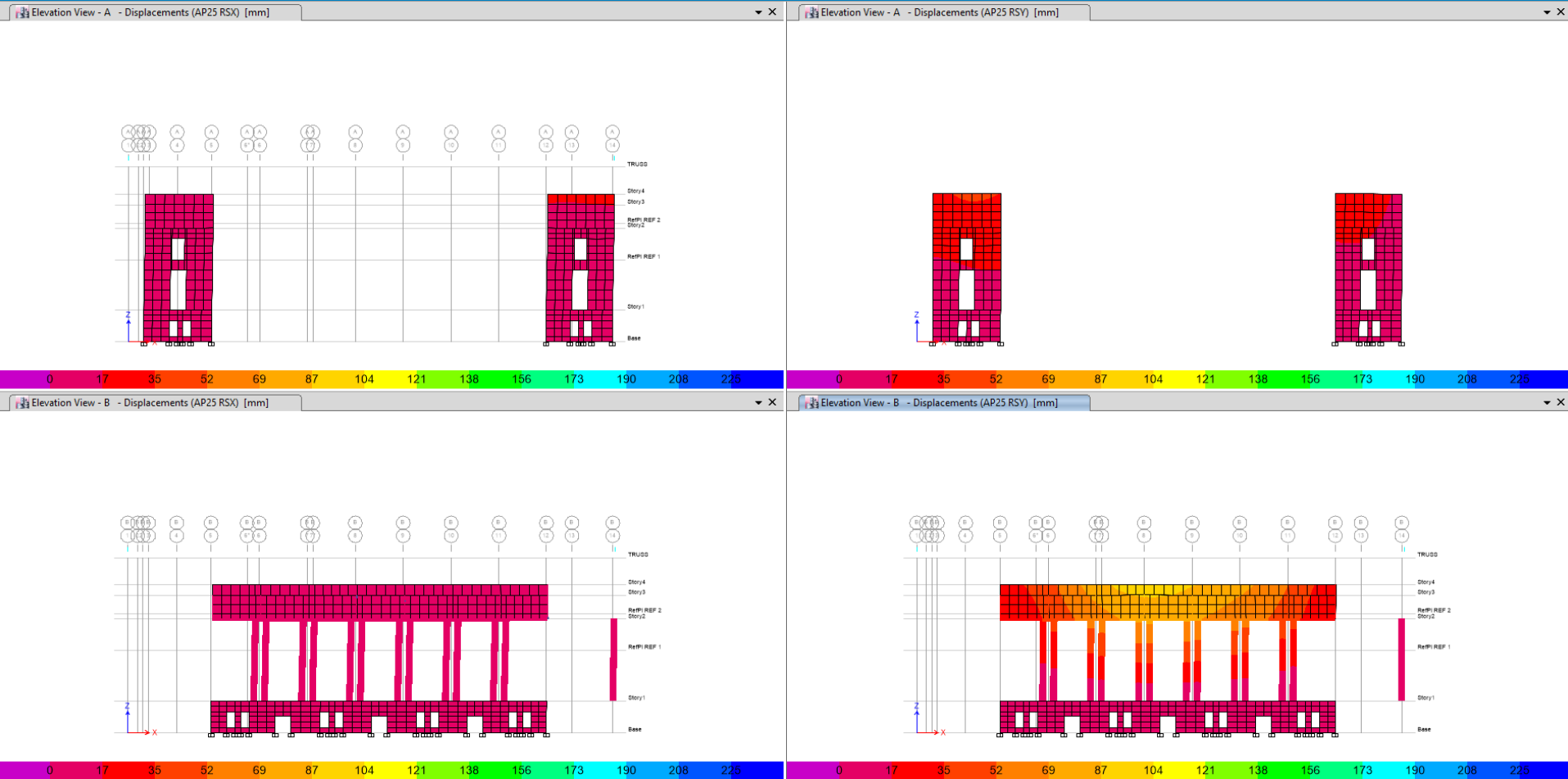




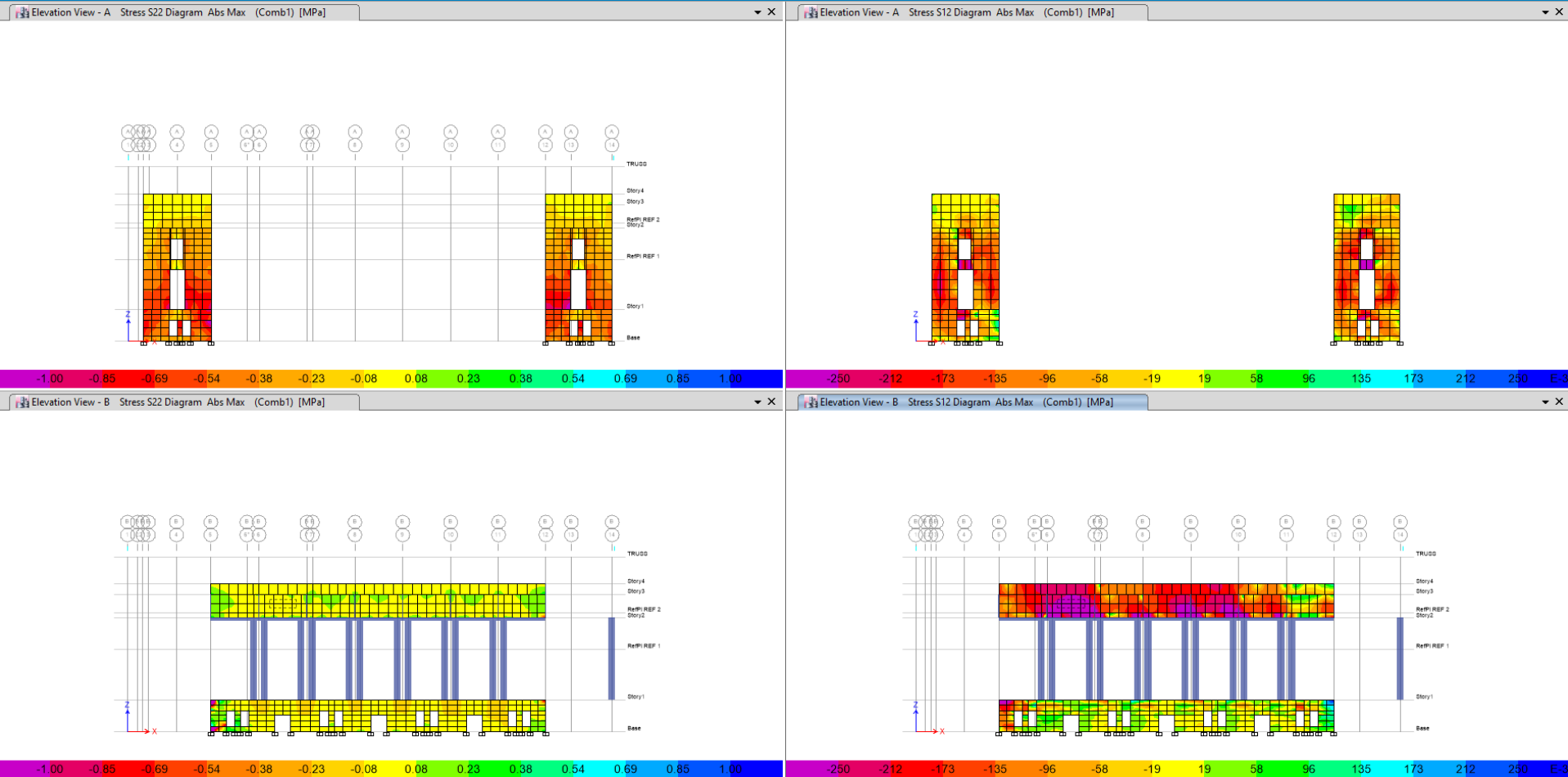
# Inter Connection of South Parapet Corner

## Improve interlocking effects between adjacent parapet





- Max parapet out of plane displacement due to April 25 RS: 93 mm (4 inch)
- Max column tip displacement due to April 25 RS: 74 mm
- drift ratio 0.84%

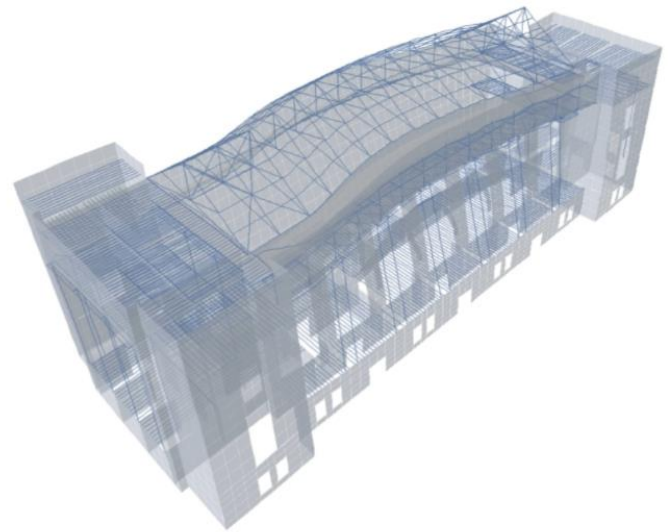
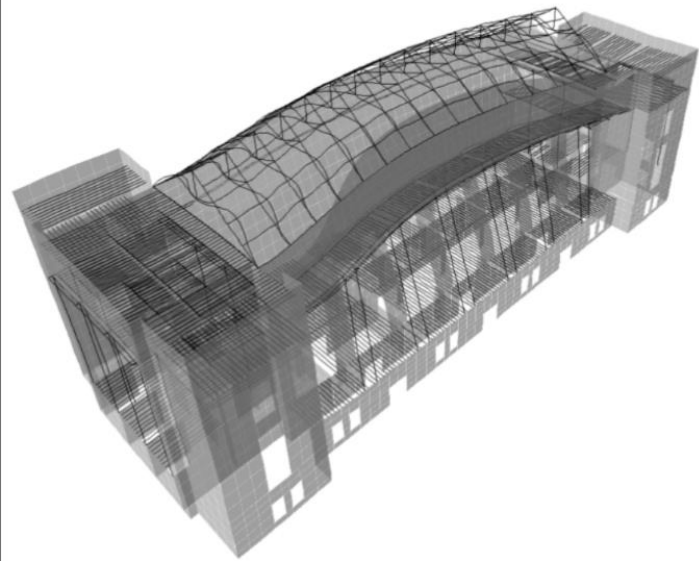


- Envelop of DL+LL+/-EL(A25)
- compression ( $< \sim 0.87$ )
- shear stress ( $< \sim 0.2$ ) exceeding area localized



Performance Base Comparison under A25 RS

	w/o interventions	w/ interventions
Drift ratio	1.8%	0.84%
Compression stress in pier	3.0 MPa	1.7 MPa
Shear in parapet	0.6 MPa	0.3 MPa





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## President of Nepal Bidhya Devi Bhandari visited the Gaddi Baithak reconstruction







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AWARDS**





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