

CONGRESS FEM 2010
30 SEPTEMBER- 2 OCTOBER

ISTANBUL



Seismic Aspects of Warehouses The USA Research on Earthquake Response

By

Teoman Pekoz, PhD

Consultant to the RMI

Professor Emeritus Cornell University

Presentation Outline

- **Information Exchange with Europe and within Europe (covered by previous speakers)**
- **Video on US Approach (8 Minutes)**
 - **Shake Table tests**
 - **Base Isolator Approach**
- **FEMA Document**
- **New (2010) RMI Specification and Connection Testing**
- **Current research**
 - **Down aisle stiffness**
 - **Cross Aisle stiffness**
 - **Column base fixity**

RIDG-U-RAK VIDEO

FEMA - 460

- Features



Seismic Considerations for Steel Storage Racks Located in Areas Accessible to the Public

FEMA 460 – September 2005



2010 RMI SPECIFICATION

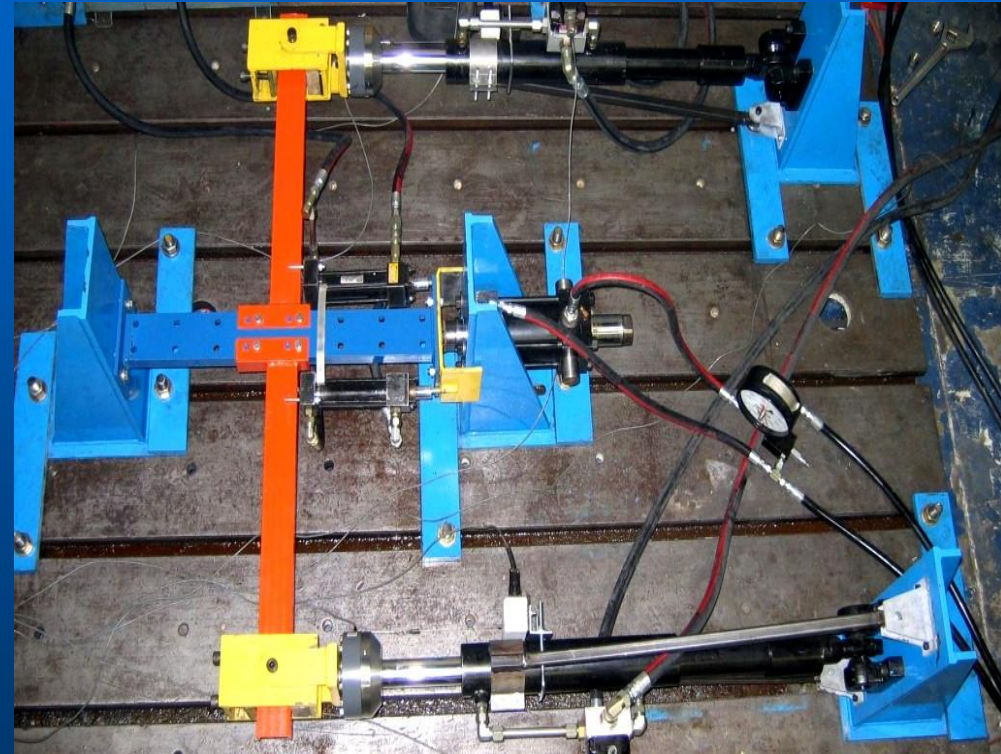
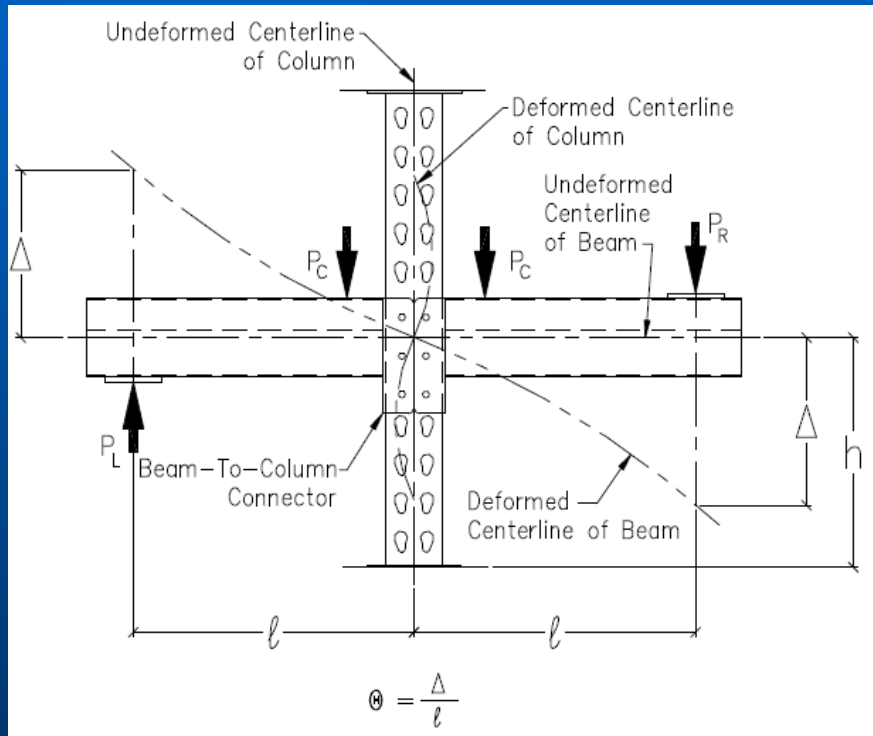
- Features



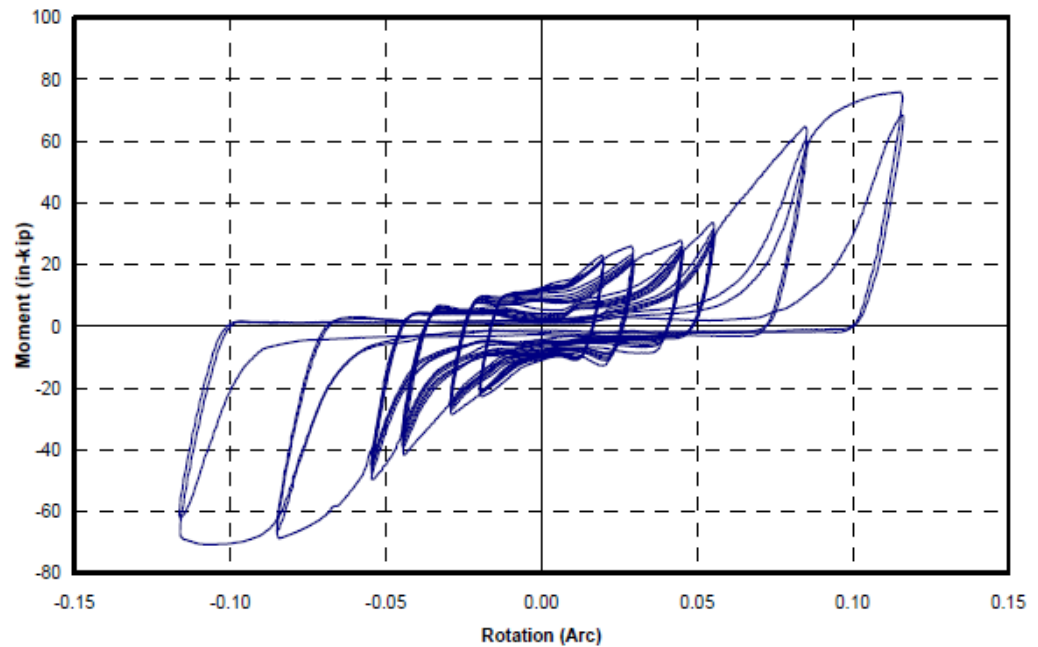
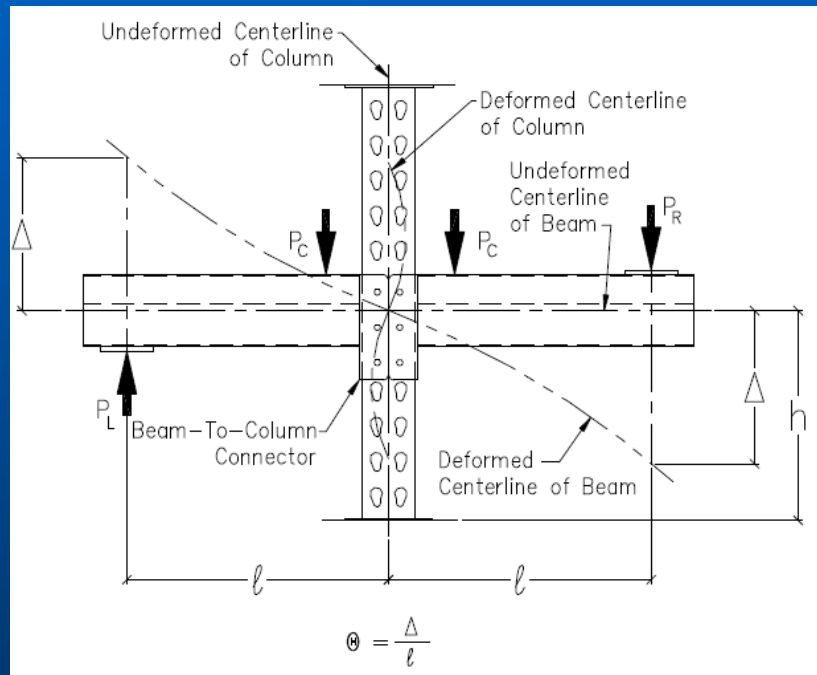
2008 Version from

<http://www.mhia.org/vango/core/orders/product.aspx?catid=32&productid=65>

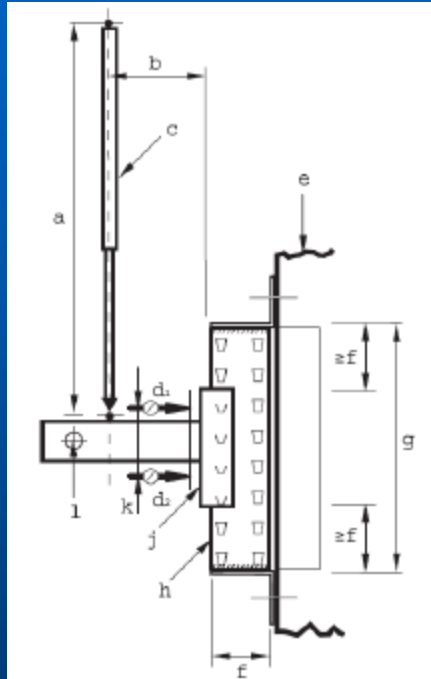
Hysteretic behavior testing



Hysteretic behavior

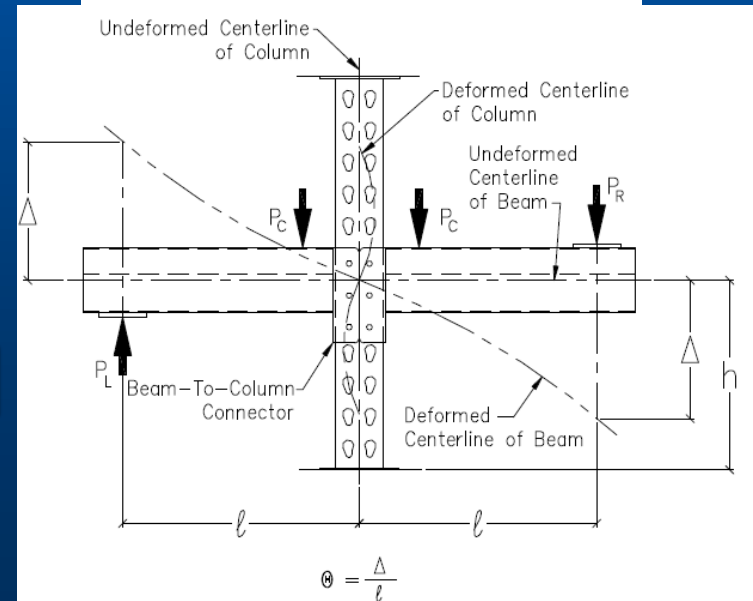
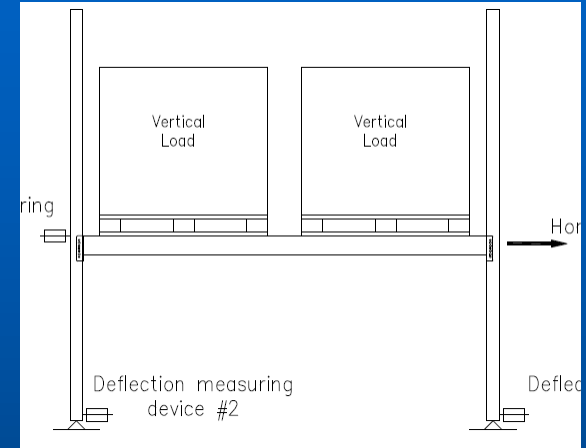


Determining Joint Moment-Rotation Relationship



FEM

RMI



CURRENT AND PLANNED US RESEARCH

- **Planned In-Warehouse Earthquake response observation**
- **Lateral Stiffness studies**
 - **Down aisle**
 - **Cross aisle**
 - **Column base fixity study**

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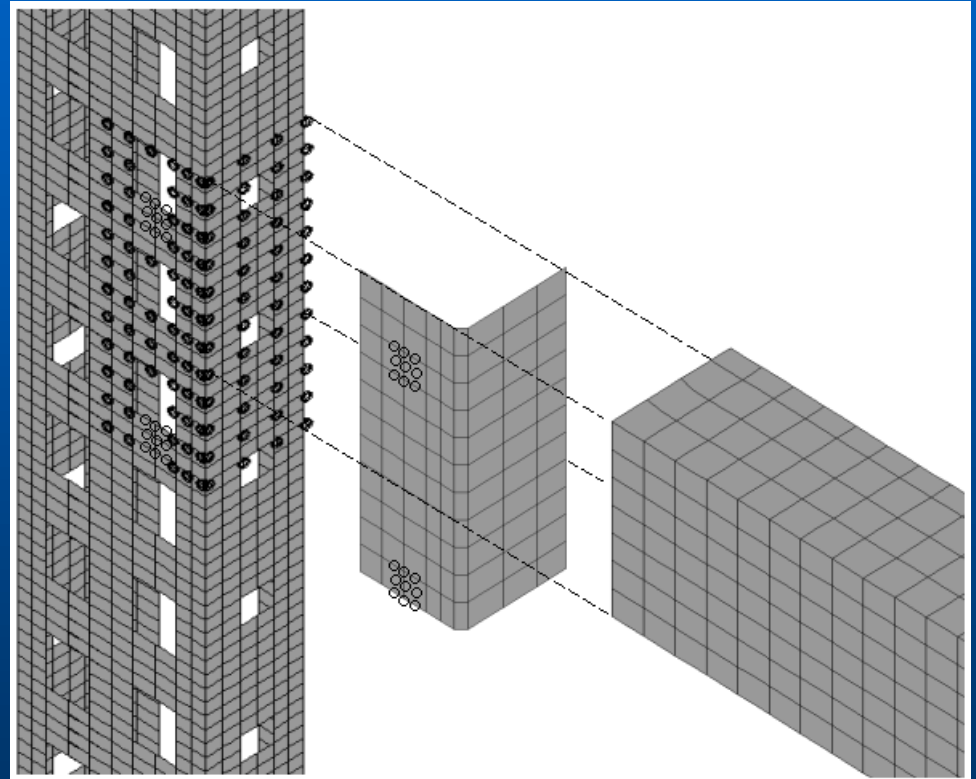
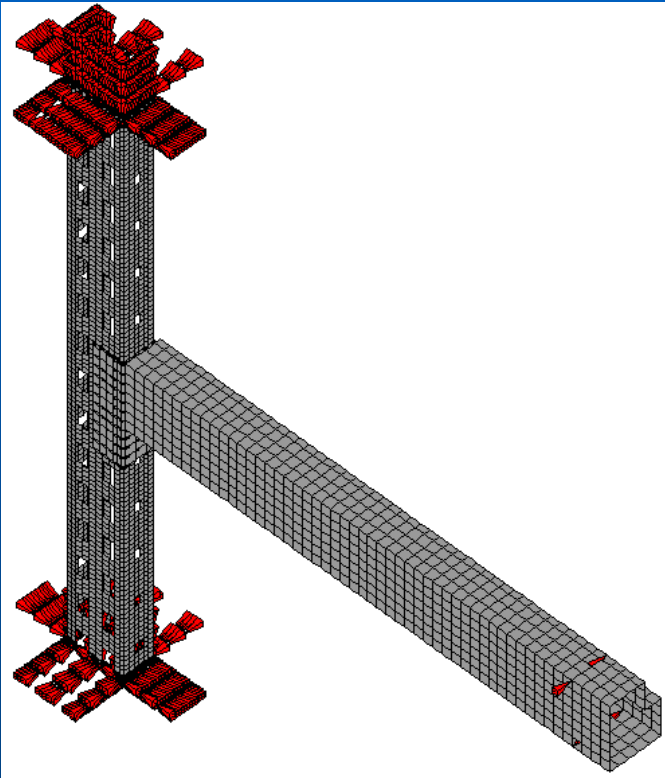
Acknowledgement

- **Work carried out part of an on ongoing work (since 1973) to develop and improve RMI Specification**
- **Support of RMI is acknowledged**
- **Parallel and coordinated work in Europe**

Scope

- **Standards and Specifications idealize semi-rigid joint moment-rotation behavior as linear**
- **The study is aimed at representing the true non-linear moment – rotation behavior**

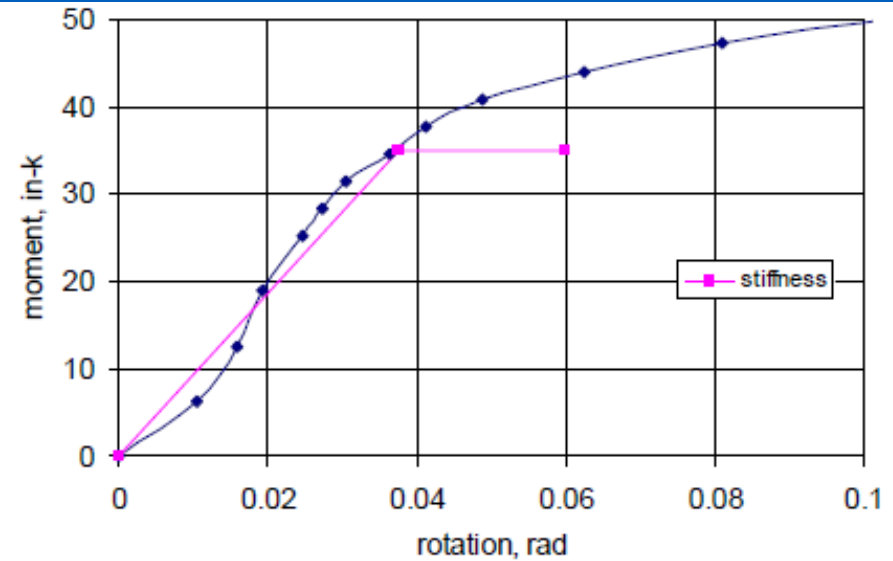
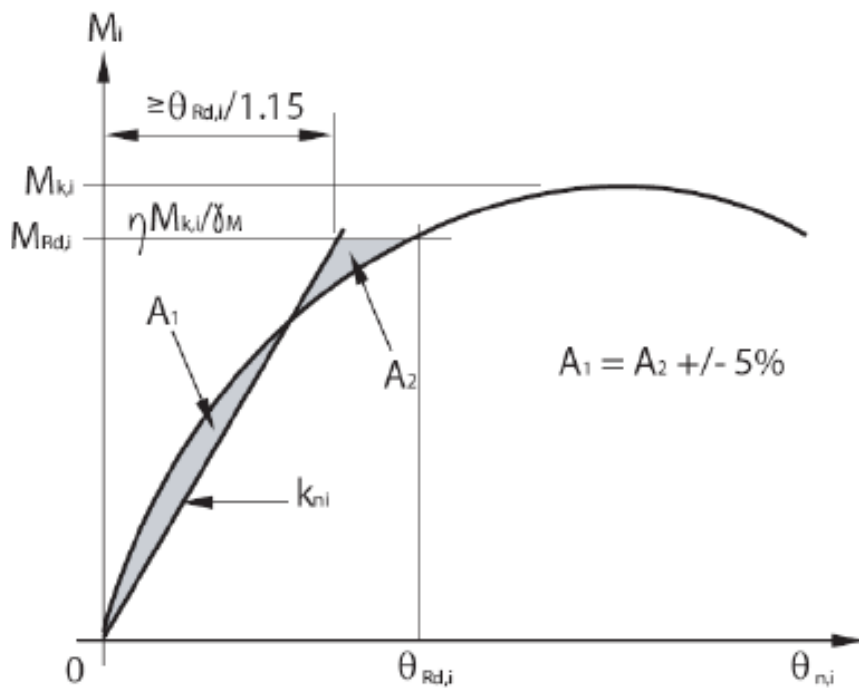
FEM Simulation of Connection Test



FEM Simulation of Connection Test

VIDEO

Linearizing Joint Moment-Rotation Relationship



Assumed $M_{Rd} = 35$ in-k, calculated stiffness $k_d = 931$ in-k/rad
 (1 in = 25.4 mm, 1 k = 4.45 kN)

Portal frame

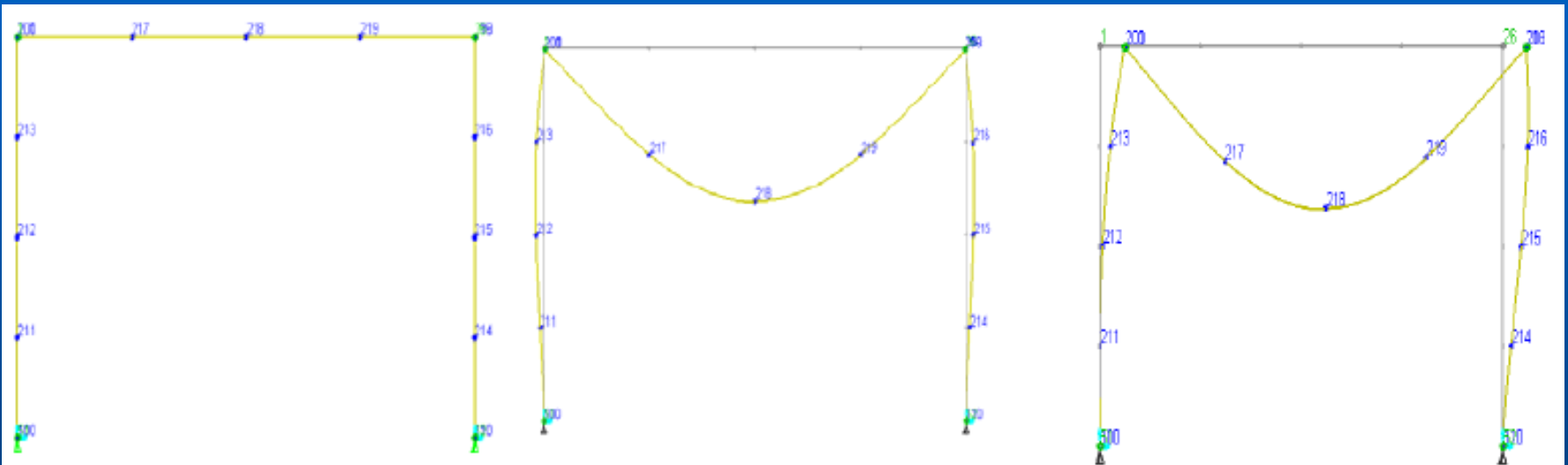
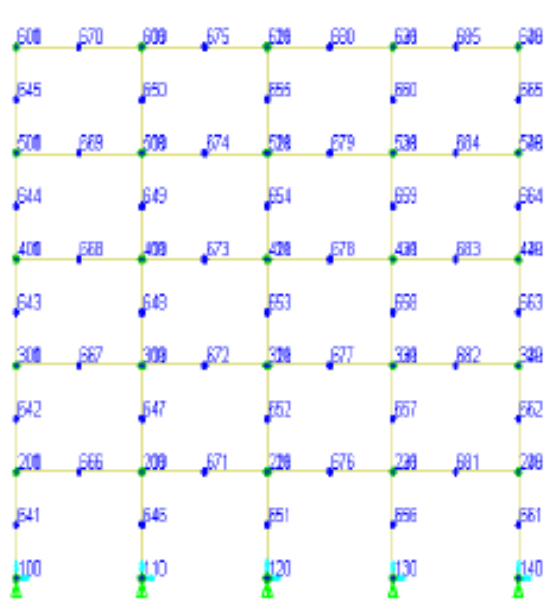


Fig. 5 Portal Frame

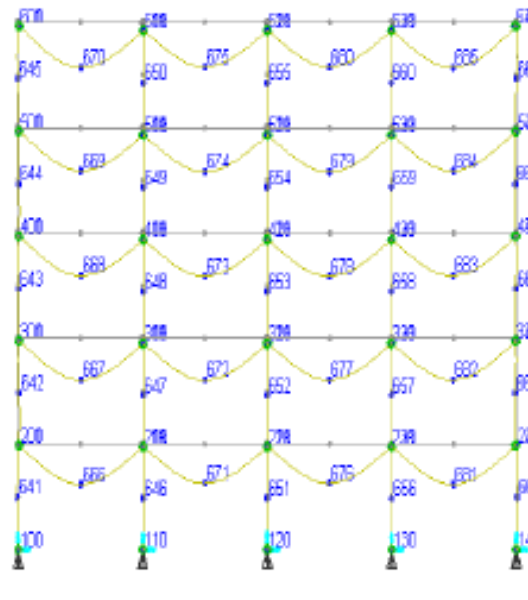
Load Case a: Vertical loads on the beam

Load Case b: Load Case a + horizontal load at beam level

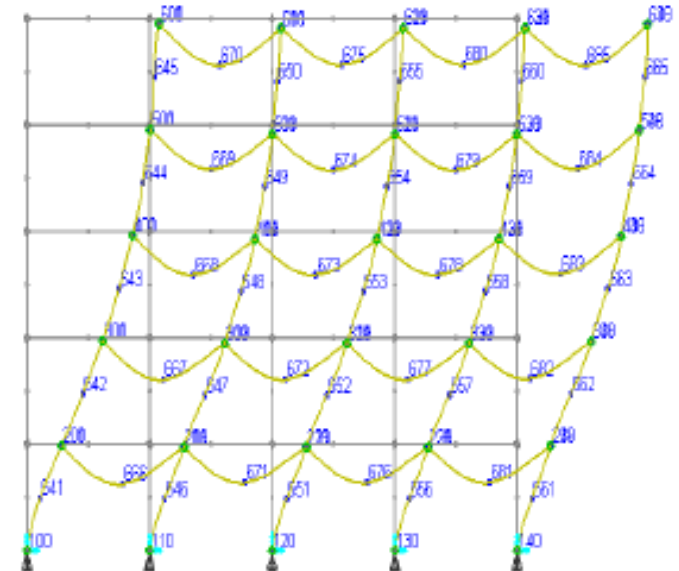
Multi story multi-bay frame



Initial shape



Load Case a



Load Case b

Fig. 7 Portal Frame

Load Case a: Vertical loads on the beam

Load Case b: Load Case a + horizontal load at each beam level

LARSA – 4D DEMONSTRATION

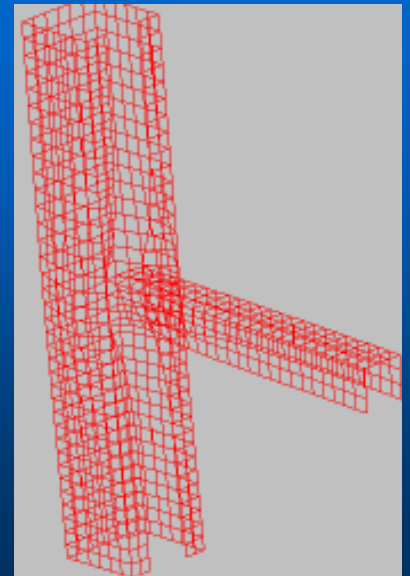
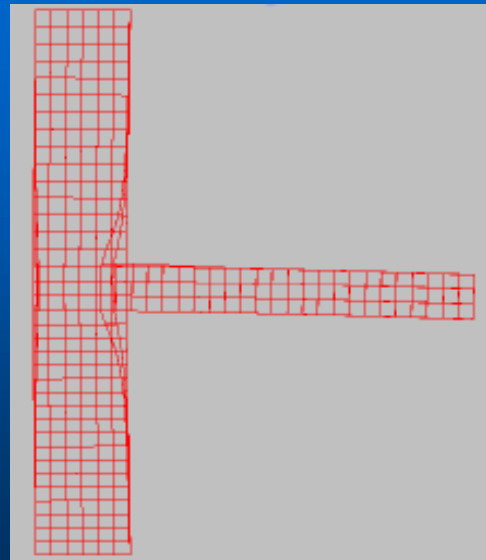
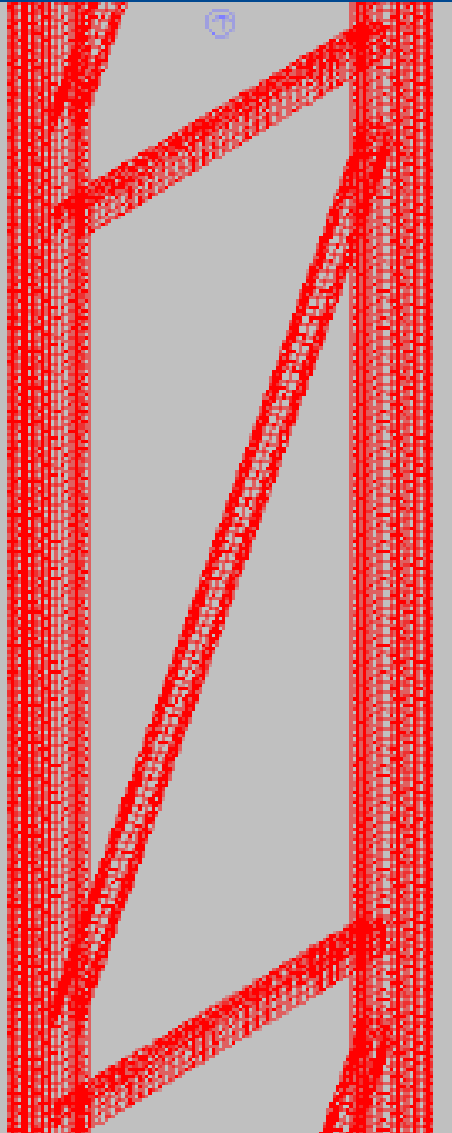
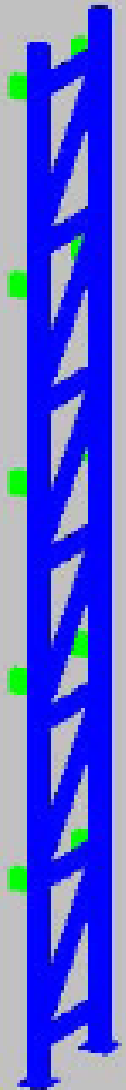
CROSS AISLE STIFFNESS



Objective

To minimize the need for shear testing

CROSS AISLE STIFFNESS



LARSA – 4D DEMONSTRATION

SUMMARY AND CONCLUSIONS