Lecture in Department of Civil & Architecture School of UPT

May 2003

LESSONS LERNEAD FROM RECENT EARTHQUAKES:

OBSERVED DAMAGE AND NEW TYPES OF STEEL CONNECTIONS

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1st Part – OBSERVED DAMAGE FROM EARTHQUAKES

2nd Part – EXPERIMENTAL DAMAGE OBTAINED FROM LABORATORY TESTS

3rd Part – BEHAVIOUR OF DIFFERENT TYPE OF CONNECTIONS

1st Part

OBSERVED DAMAGE FROM RECENT EARTHQUAKES

Buckling of Bracings, (Kobe Earthquake 1995)

Soft storey mechanism of intermediate story due to higher modes of vibration

Kobe Earthquake, 1995)

Soft storey mechanism of intermediate story due to higher modes of vibration

Brittle failure of bracing,due to high strain rate of the seismic action (Kobe Earthquake, 1995)

Brittle failure of box column, formed from welded plates, due to high vertical component of the seismic action, (Kobe Earthquake, 1995)

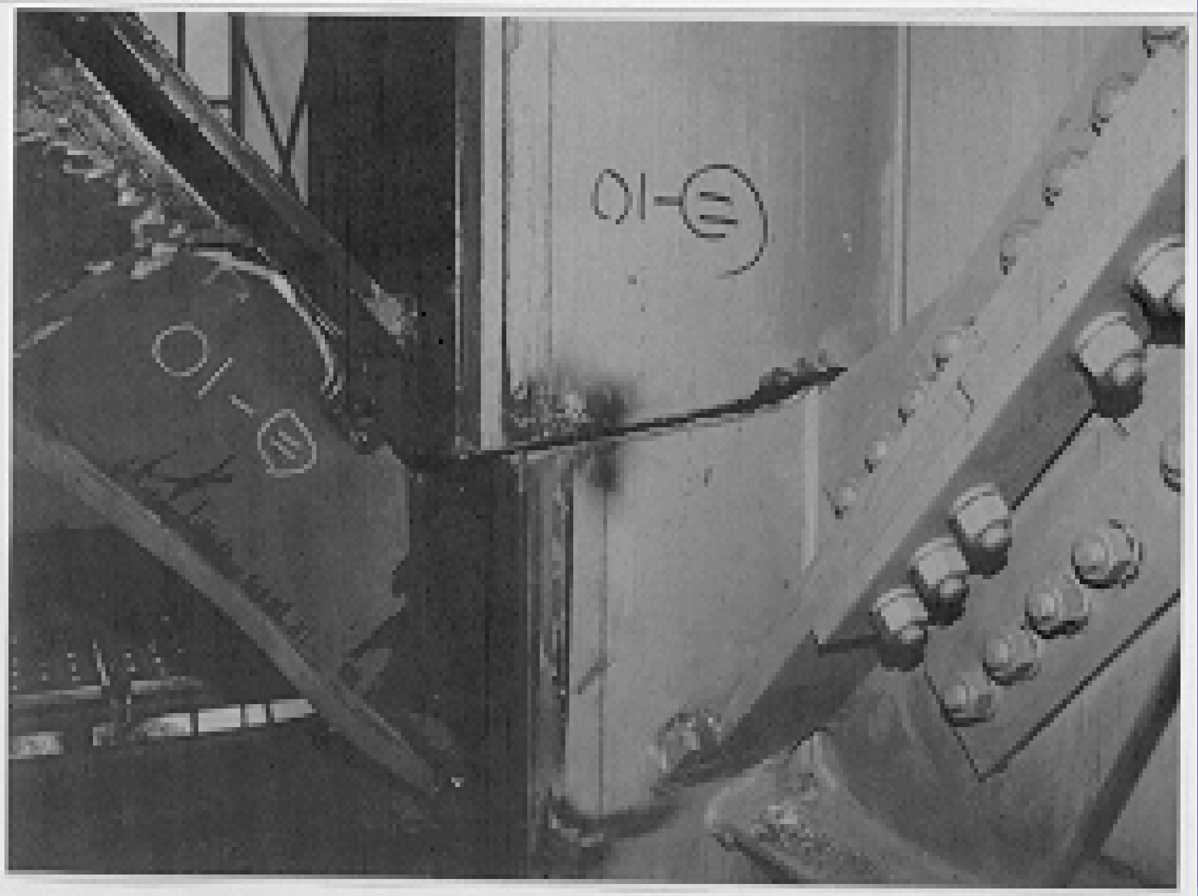


Fig. 6.133 Failed connection in braced tower

Brittle failure of box column, formed from welded plates, due to high strain rate of the seismic action, (Kobe Earthquake, 1995)

Excessive sway due to fracture of slender braces

(Kobe Earthquake, 1995)

Fig. 6.91 Excessive sway due to fracture of slender braces

Tily up of a steel building

(Kobe Earthquake, 1995)

Hole Ovalization of slender bracings formed from rods (Northridge, 1994)

Failure of cladding in industrial building (Northridge, 1994)

Panel zone yielding and local bucling of column flange

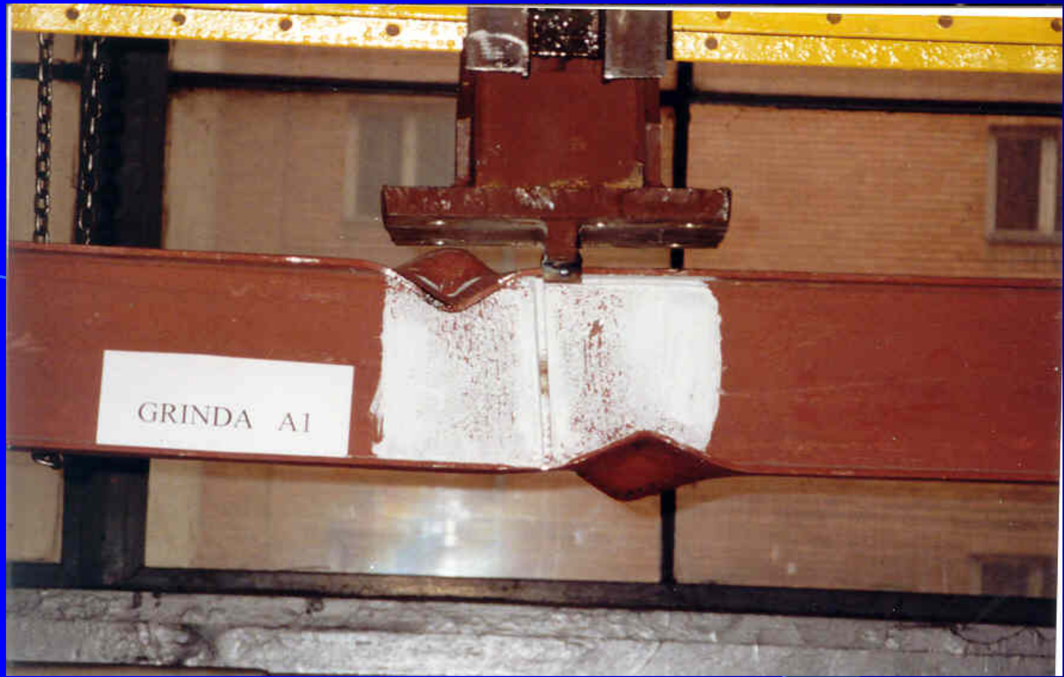
Earthquake of Taiwan

2nd Part

Experimental Damage Obtained from Laboratory Tests

Local buckling of beam flanges. A type of plastic hinge working as a filter, absorbing seismic energy, in case of severe actions

(Mateescu-Anastasiadis 1998)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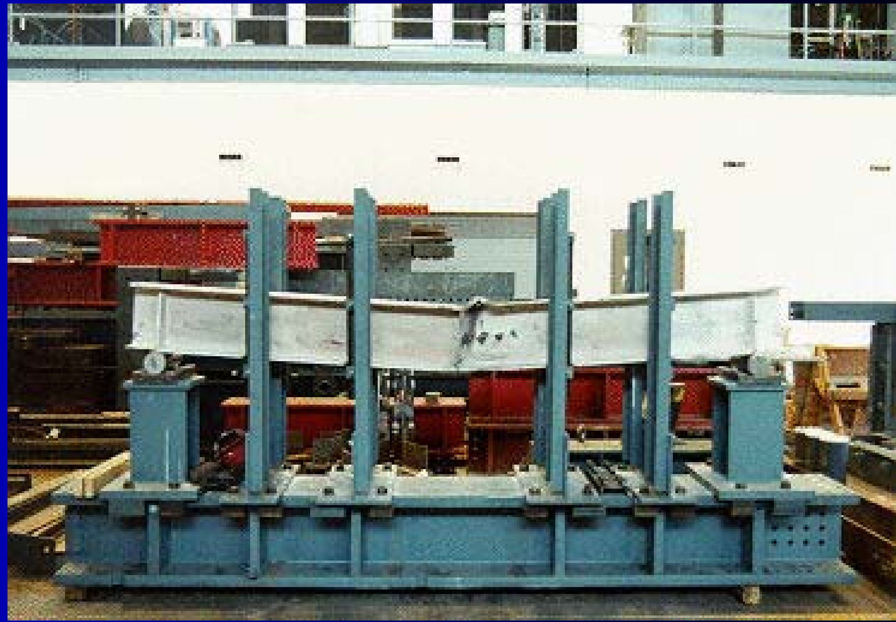
Local buckling of
beam flanges.
Symetric bucling of
upper flanges



Brittle failure of a steel circular peir simulating damage from Kobe Earthquake in Laboratory

SAC Program, USA.

The main target of SAC Program was to reproduce in laboratory condition the failures observed in Northirdge earthquake

Brittle damage frequently observed at the bottom beam flange

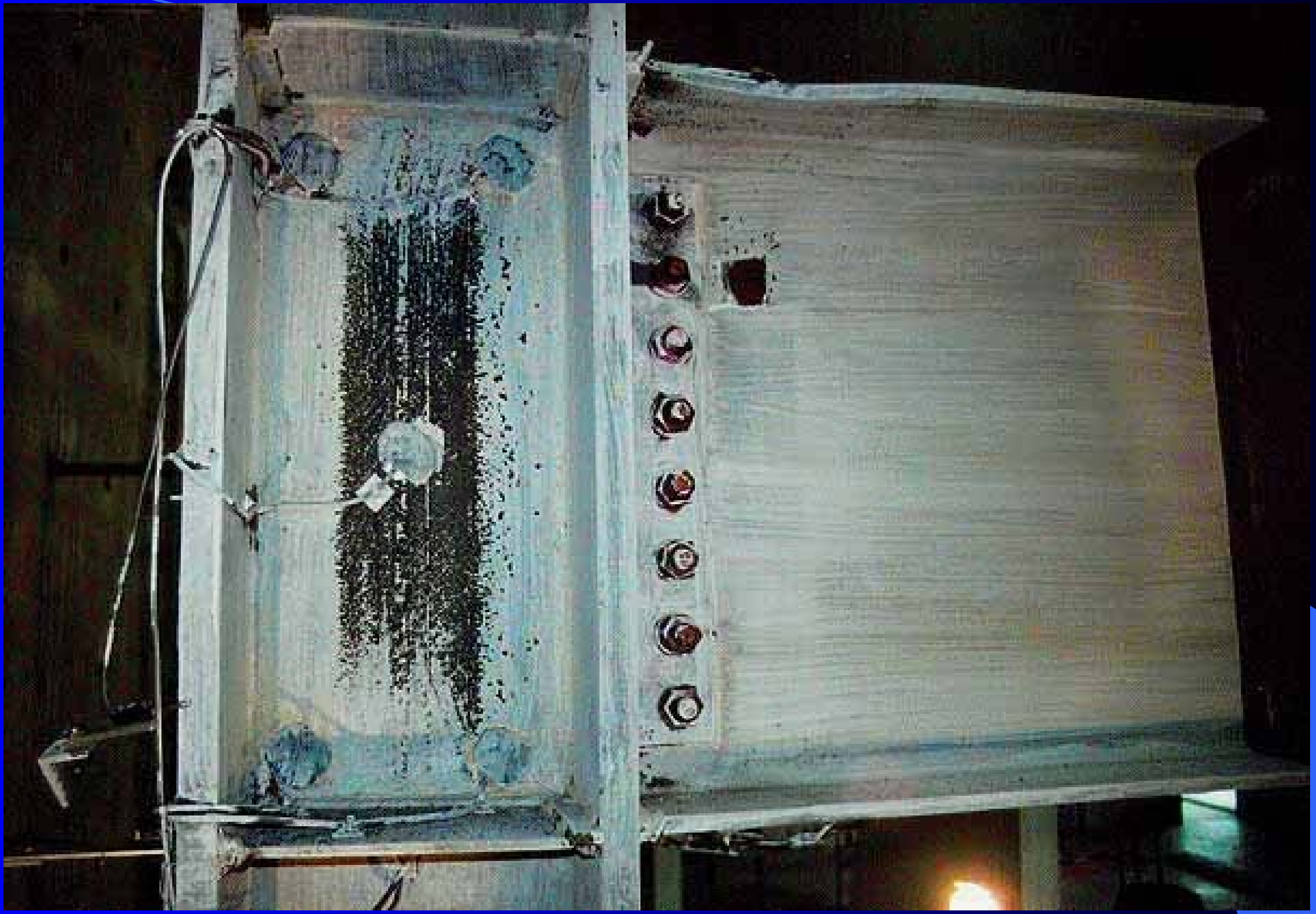
Brittle damage through base metal of the column flange

and panel zone

Brittle damage through base metal

of the column flange

Local brittle damage at the interface of the beam – column connection



Panel zone yielding. Works as a filter against local brittle failures reducing the stress at the beam to column connection

3rd Part

BEHAVIOUR OF DIFFERENT NEW TYPE CONNECTIONS DEVELOPED AFTER NORTHRIDGE AND KOBE EARTHQUAKES

TWO MAIN STRATEGIES WERE DEVELOPED

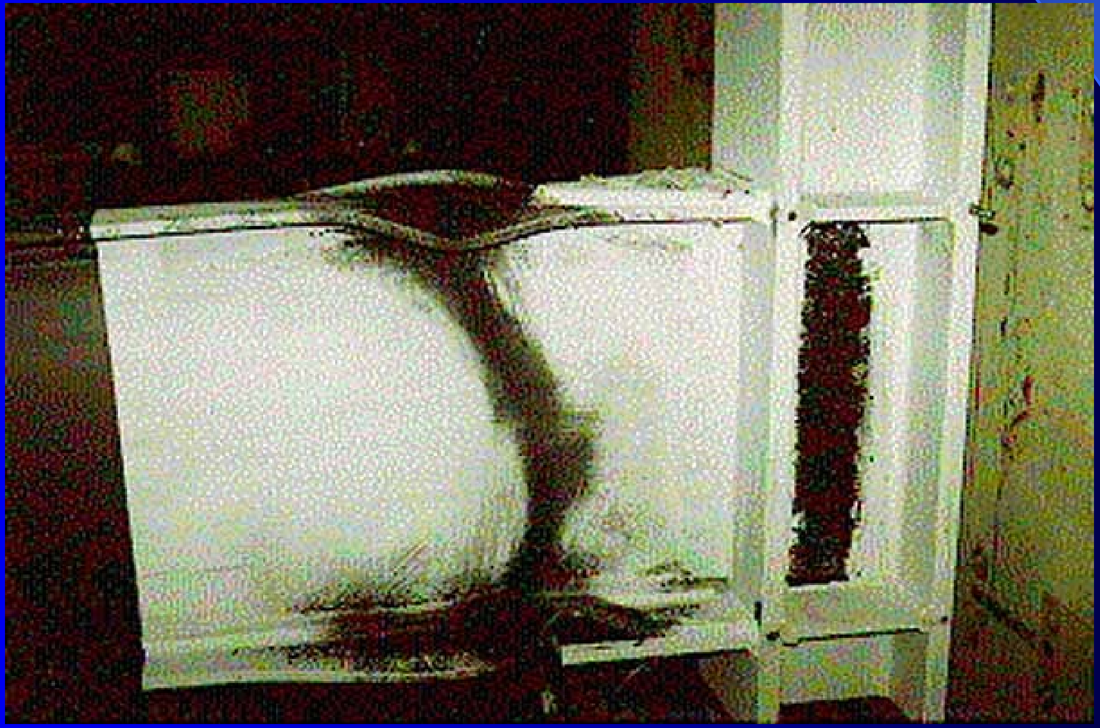
- **THE STRENGTHENING SOLUTION**
- **THE WEAKENING SOLUTION**

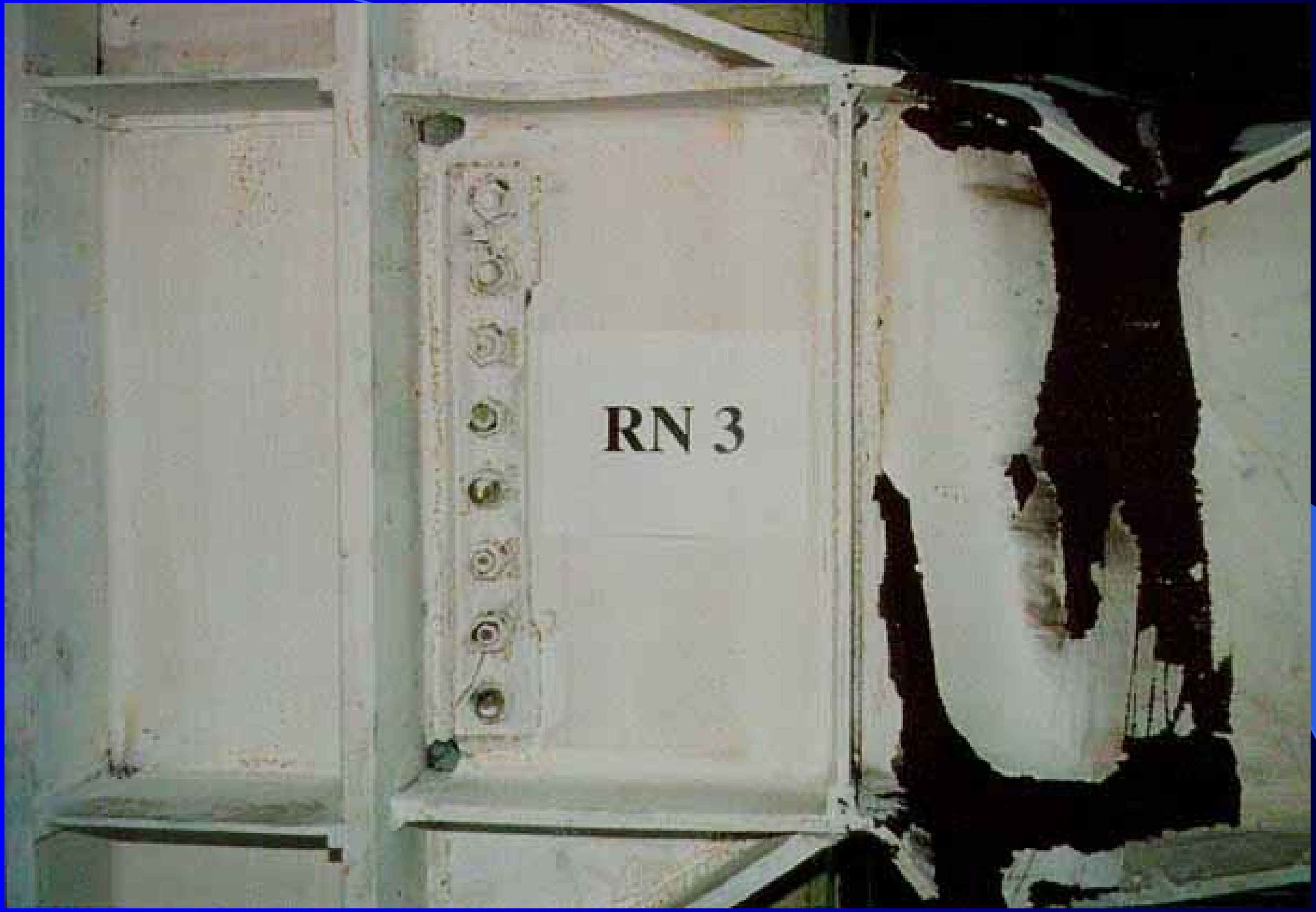
A THIRD CHOICE COULD BE NON CONVENTIONAL CONNECTIONS USING SPECIAL DEVICES ABSORBING ENERGY(Dampers, etc)

THE STRENGTHENING SOLUTION

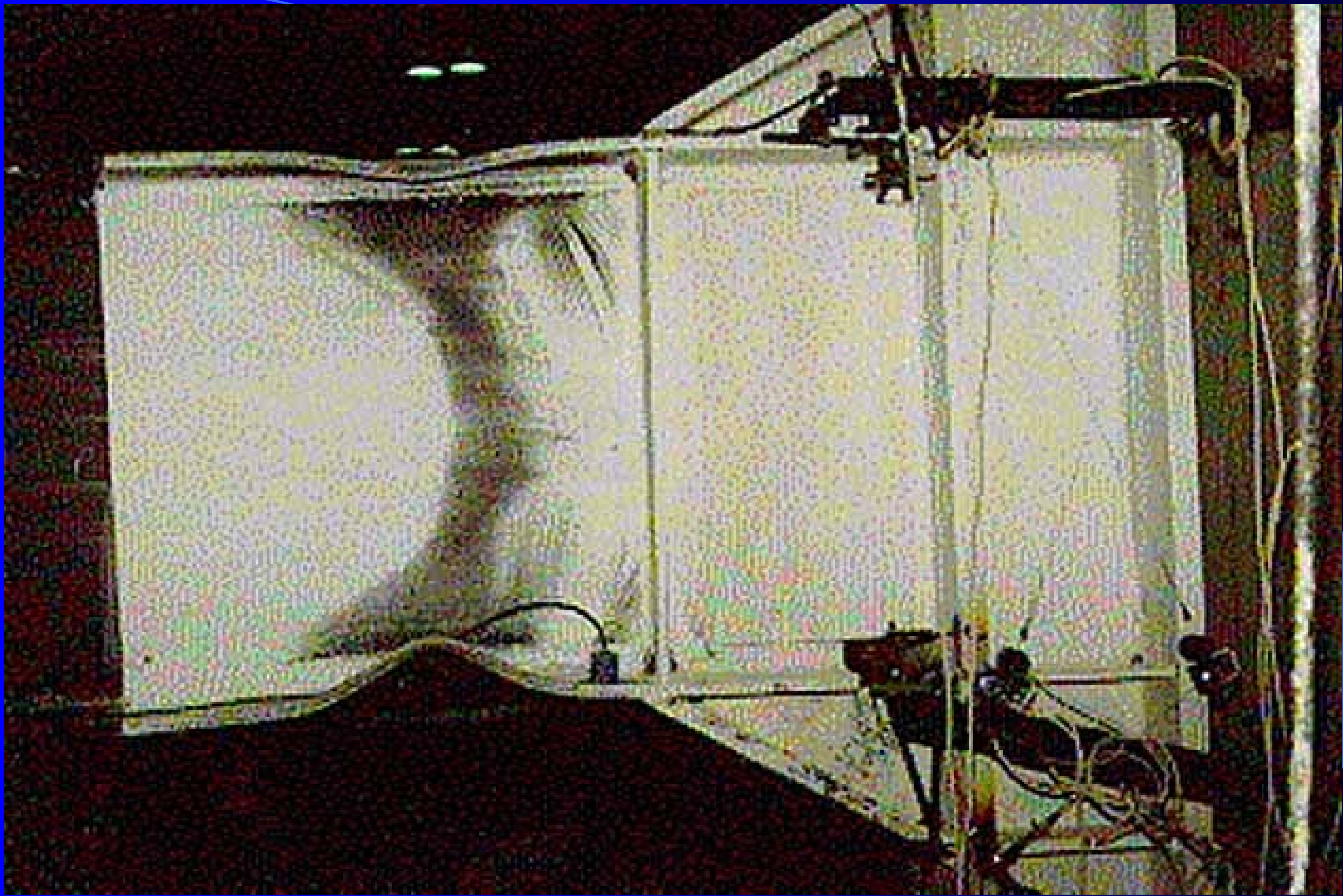
The aformentioned solution moves the formation of the plastic hinge at some distance from the highly stressed zone (interface of beam to column connection)

Sometimes has the disadvange to develop strong beam, due to the interaction with the r/c slab, developing an undiserd mechanism of strong beam-weak column

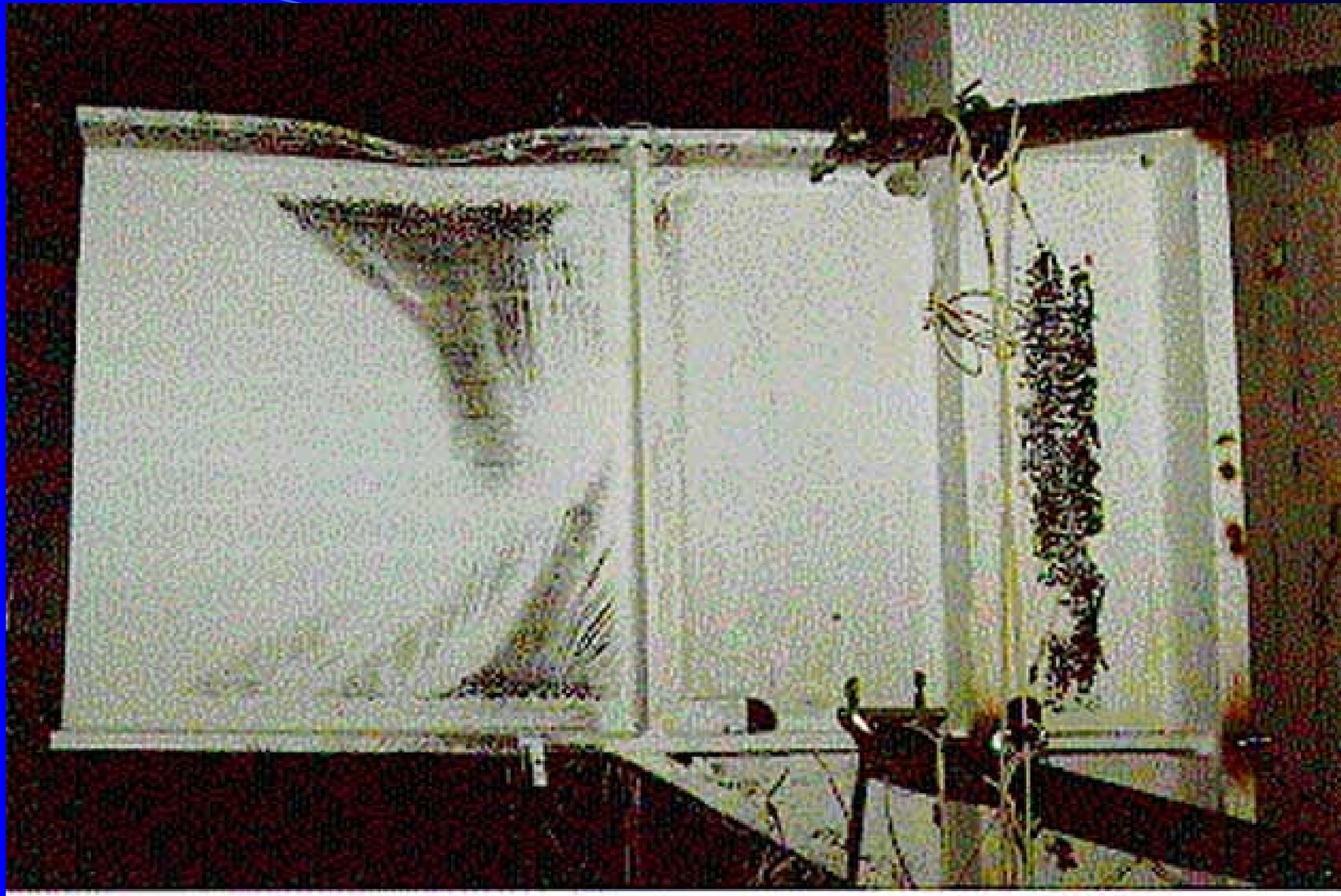




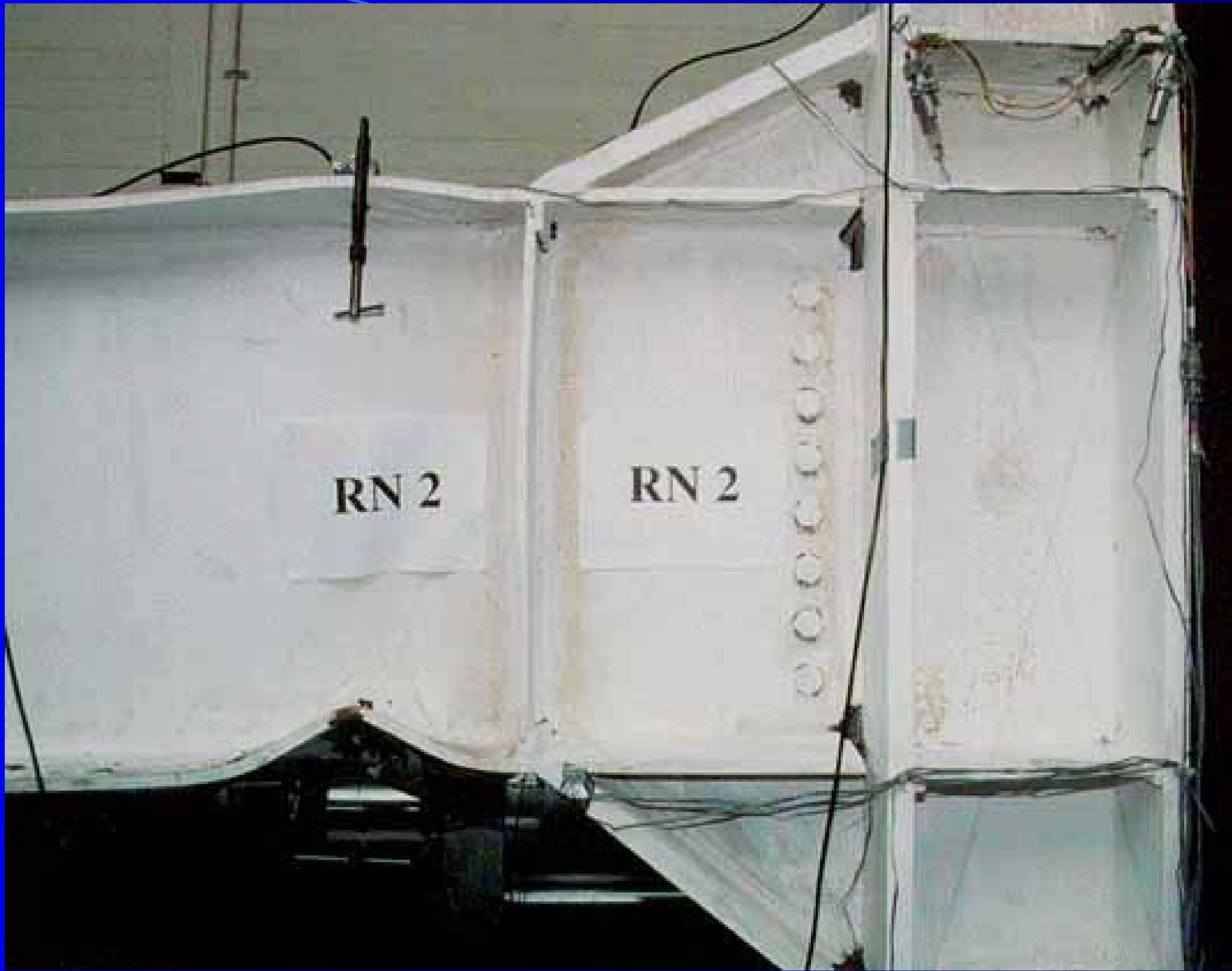
Formation of plastic hinge at some distance from the column face. Buckling of the beam flanges and severe yielding of beam’s web



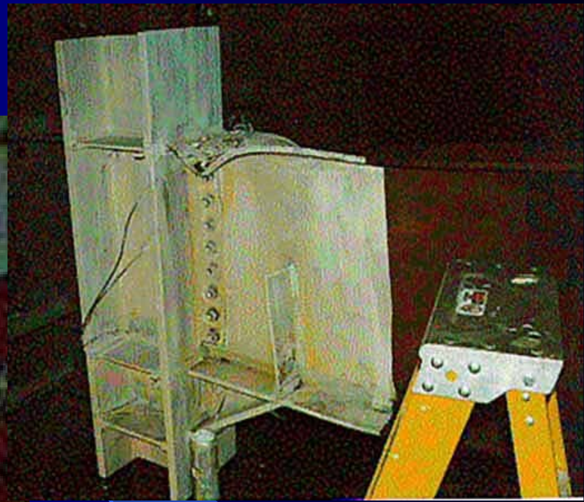
Formation of plastic mechanism composed from buckled flanges and yielding of the web



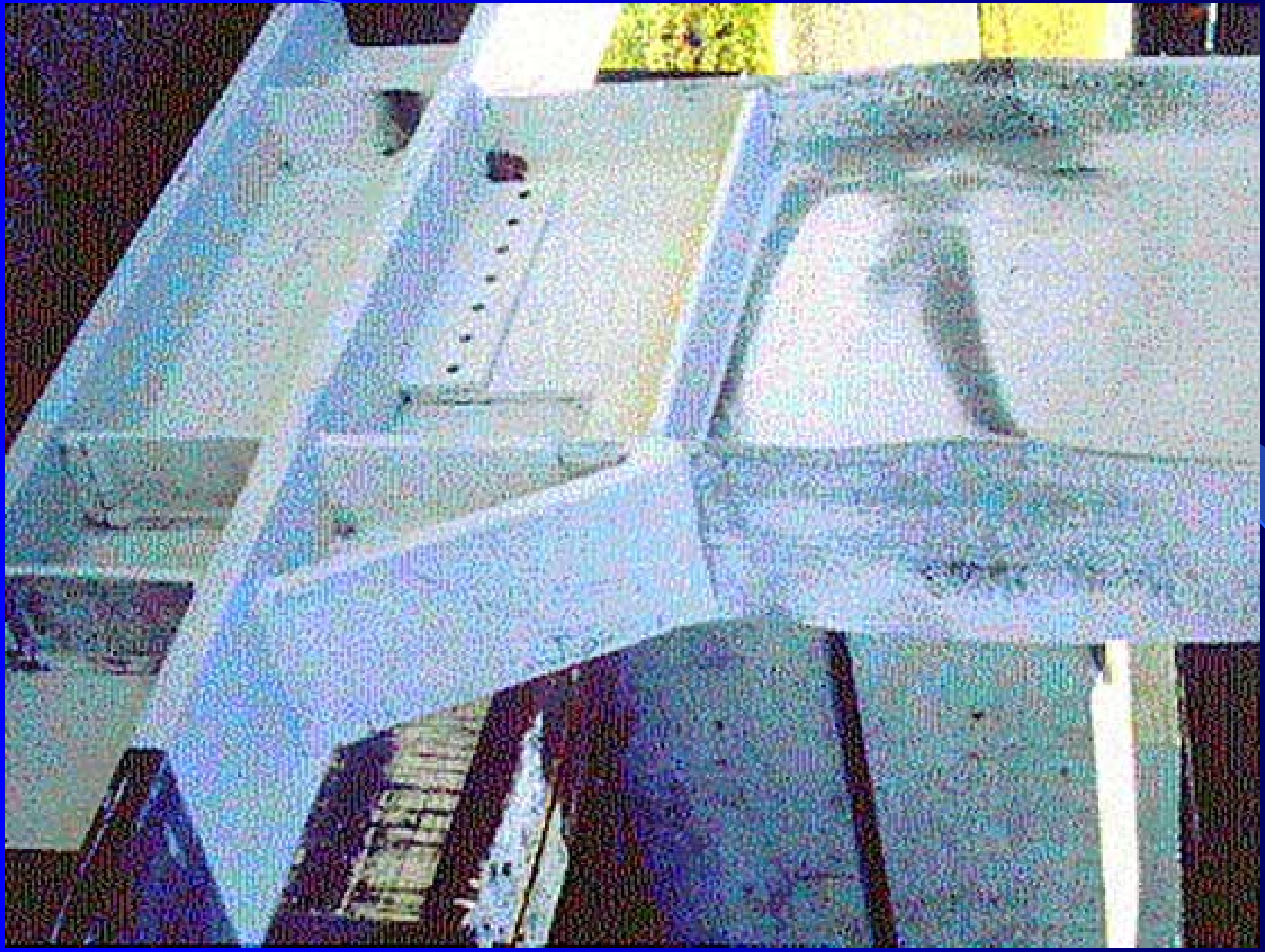
Formation of plastic mechanism composed from buckled flanges and yielding of the web and panel zone yielding



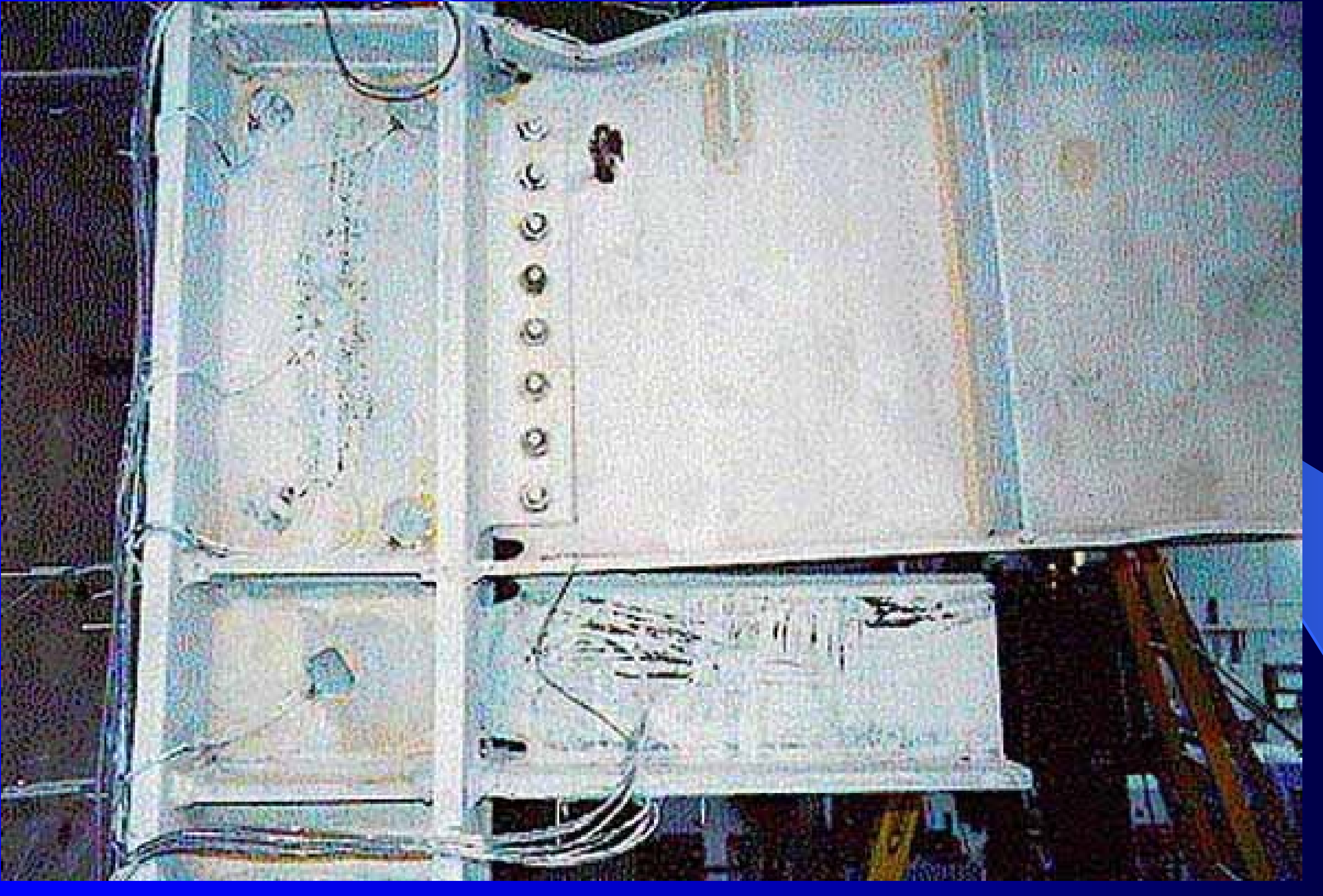
Local buckling of flanges



a)Strengthening using only a rib, at the bottom, and stiffeners



b)Strengthening using only a rib, at the bottom, and stiffeners



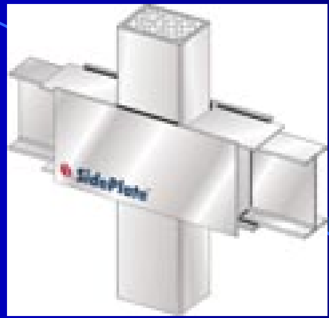
b)Strengthening using a T rib, at the bottom, and stiffeners

Strengthening using

cover plates

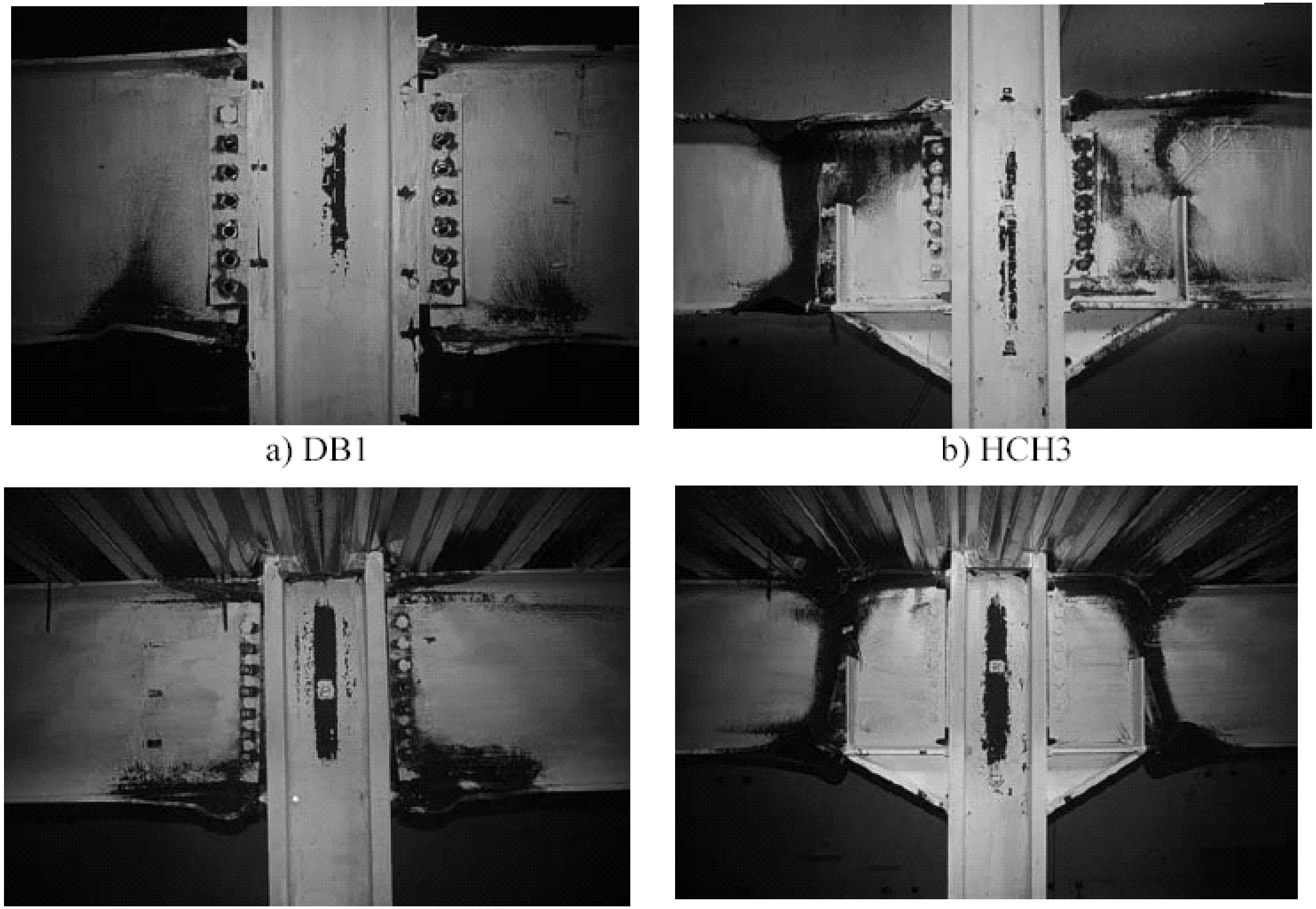
Strengthening using

side plates



Strengthening using

side plates

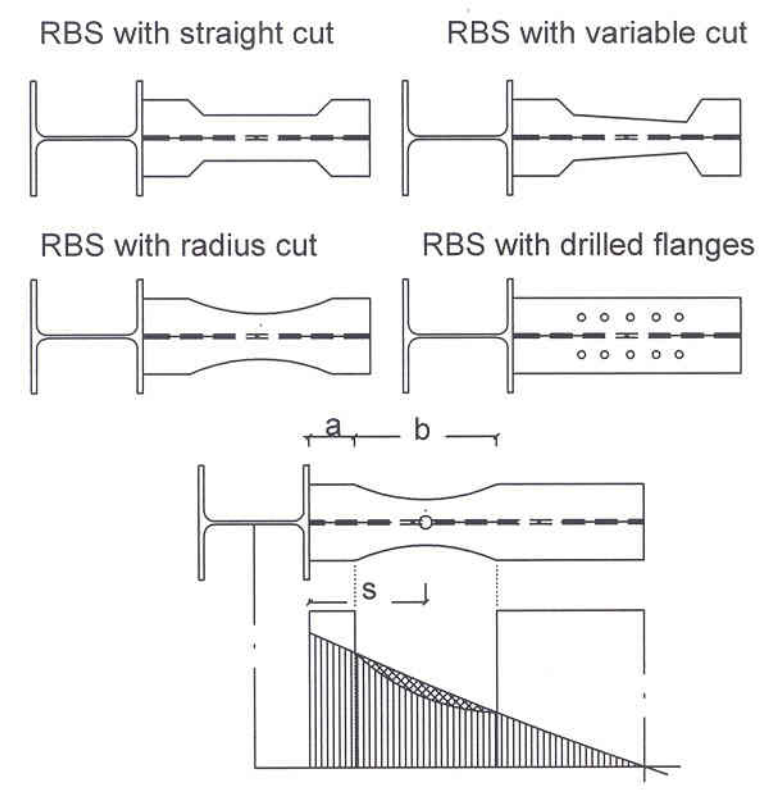


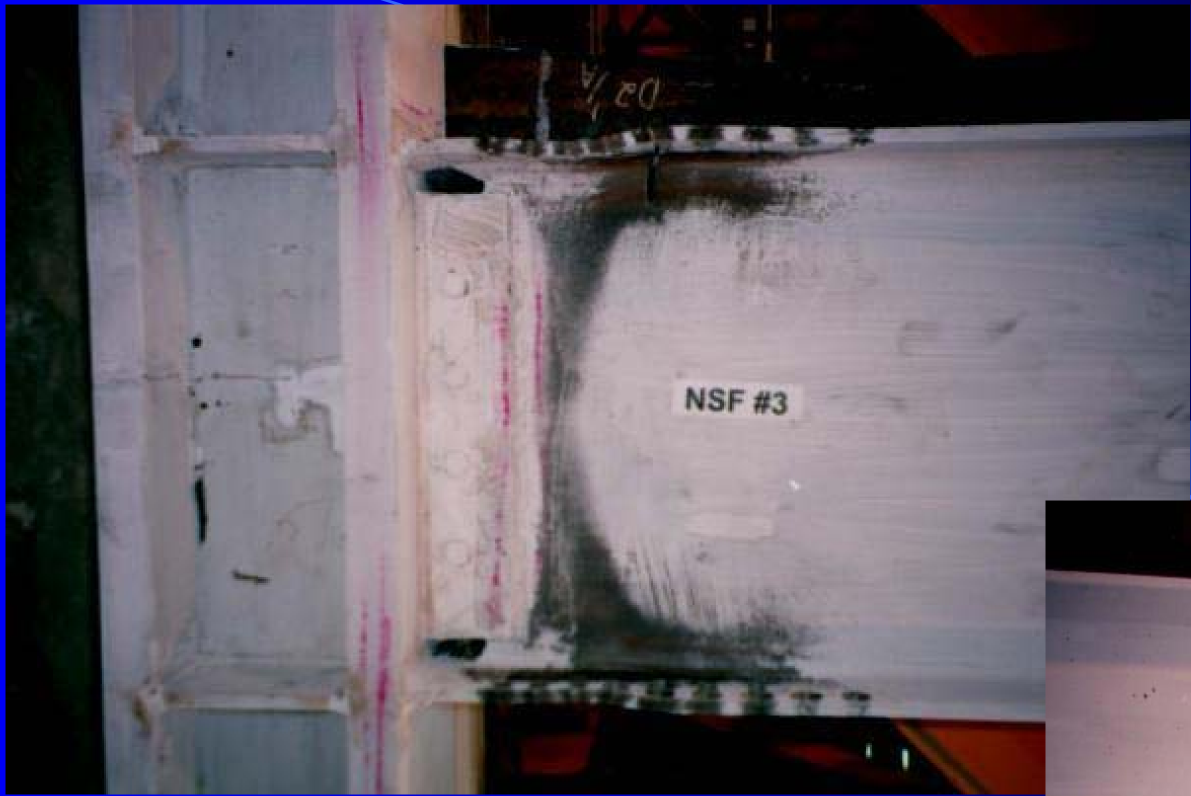
Influence of the r/c slab (Civijan & Enghelhard)

THE WEAKING SOLUTION

The aformentioned solution moves the formation of the plastic hinge at some distance from the highly stressed zone (interface of beam to column connection)

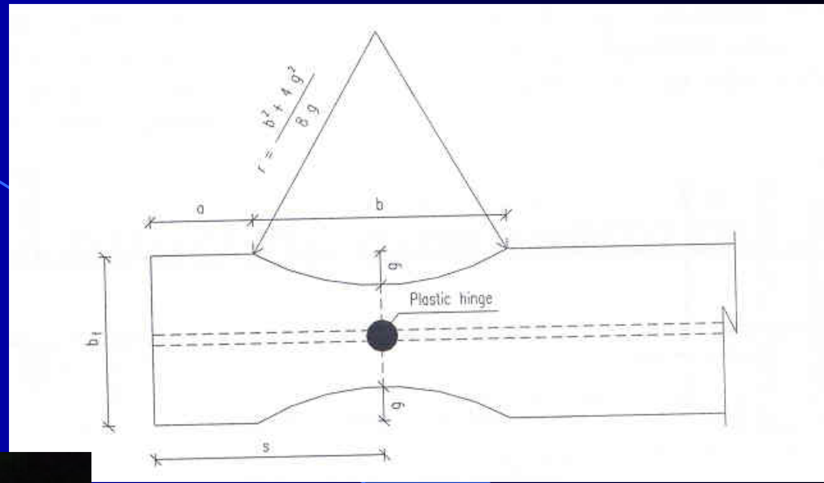
Due to weaking has the advandage to reduce the composite action with the r/c slab. Special details should be considered.

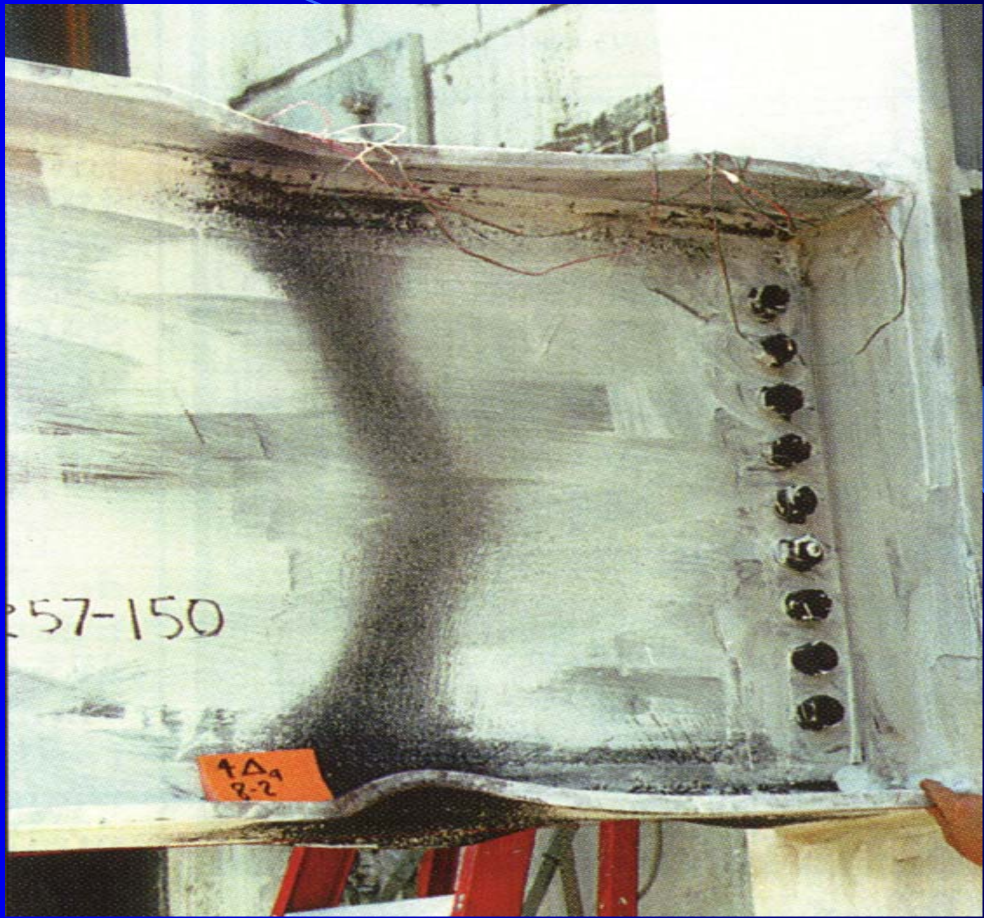




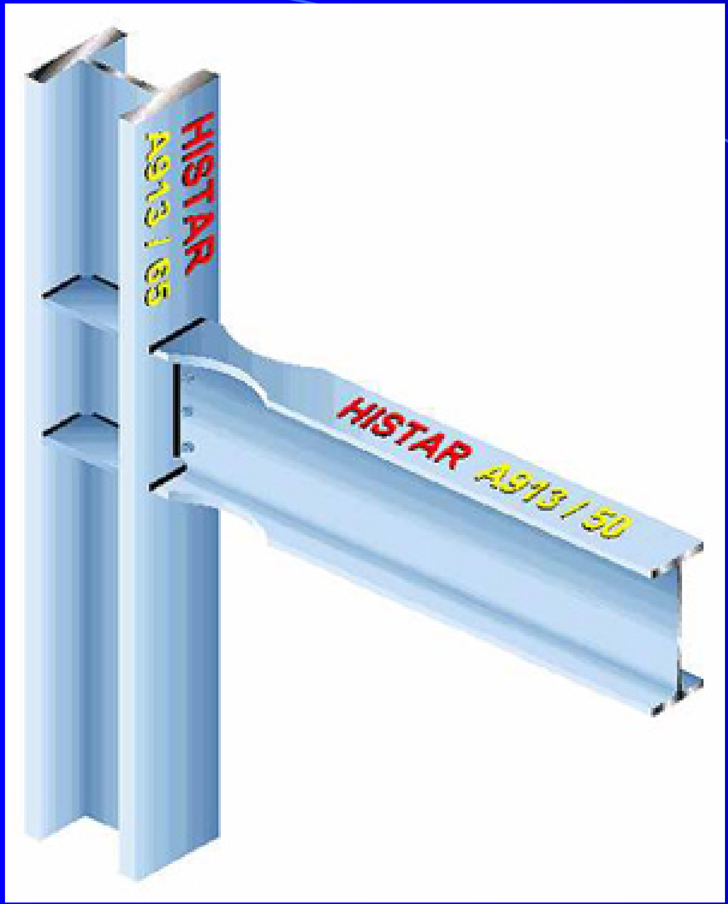
RBS with drilled flanges. Move the formation of the plastic hinge at the drilled zone protecting the connection

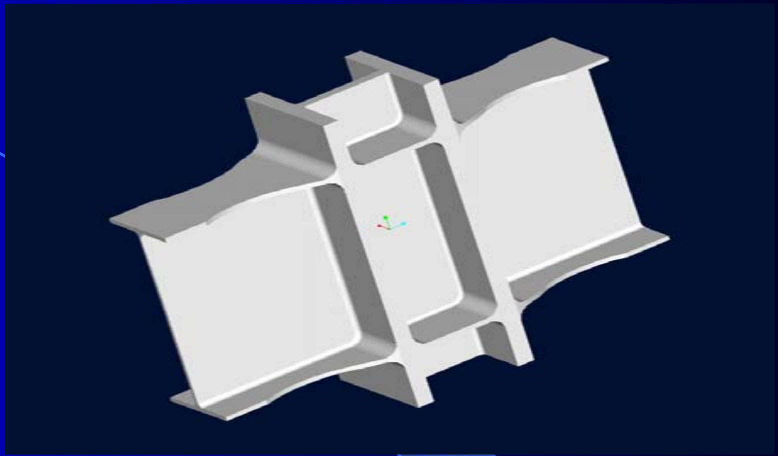
RBS with radius cut of beam flanges.

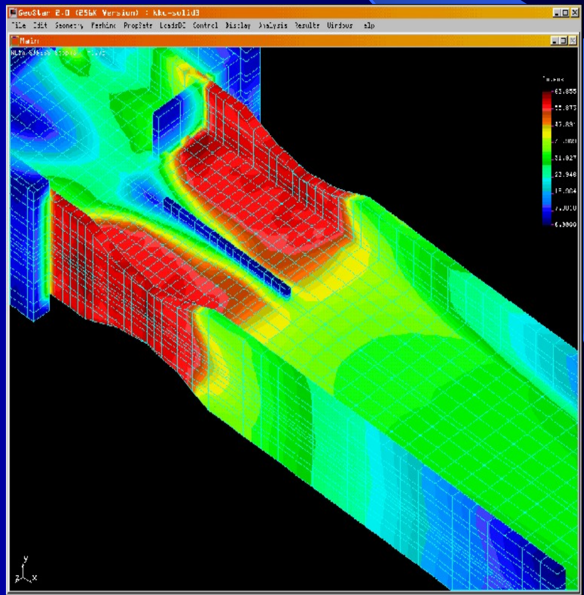




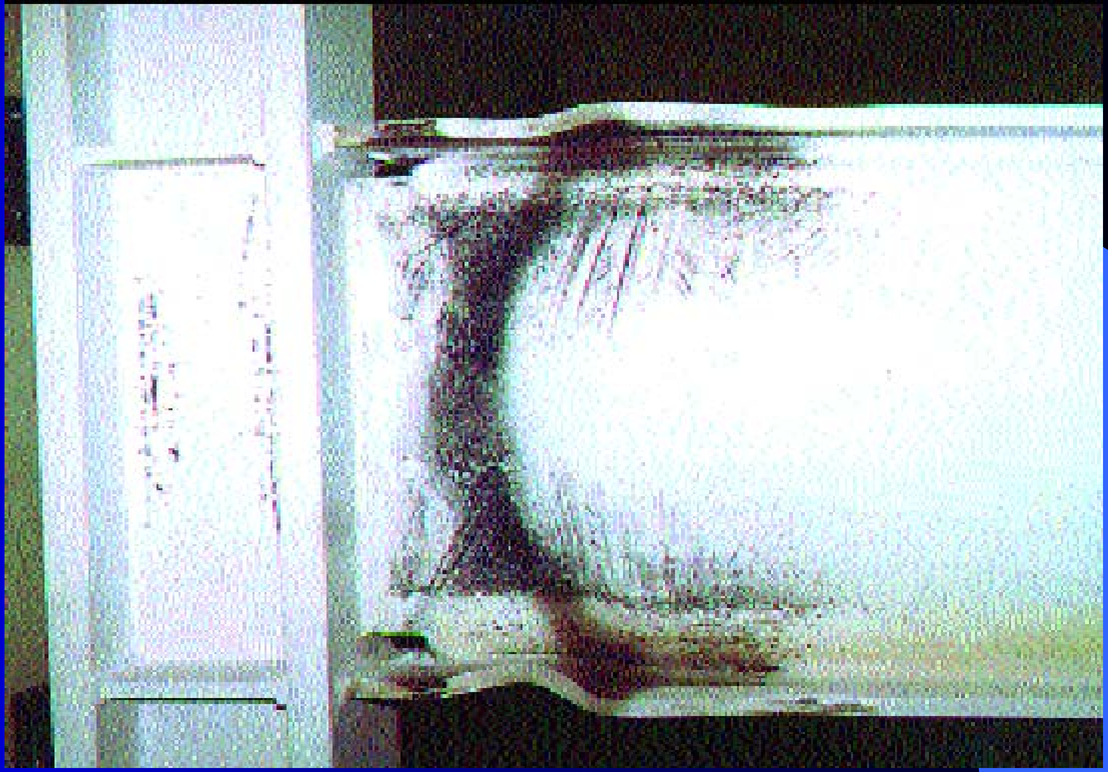
Move the formation of the plastic hinge at the reduced zone protecting the connection



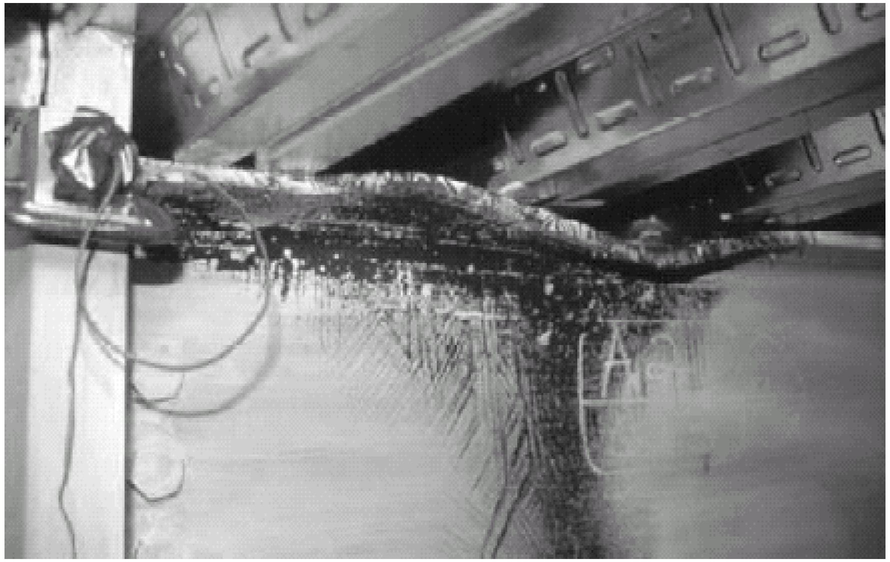




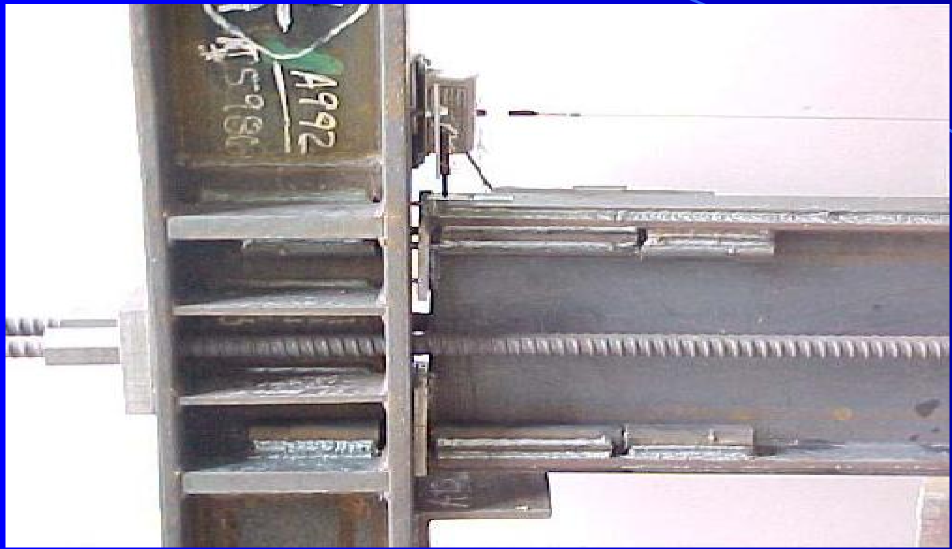
It is evidenced that the highly stressed zone is the reduced zone



Formation of plastic mechanism



Influence of slab on the plastic behaviour of the beam



Pretensioned connections

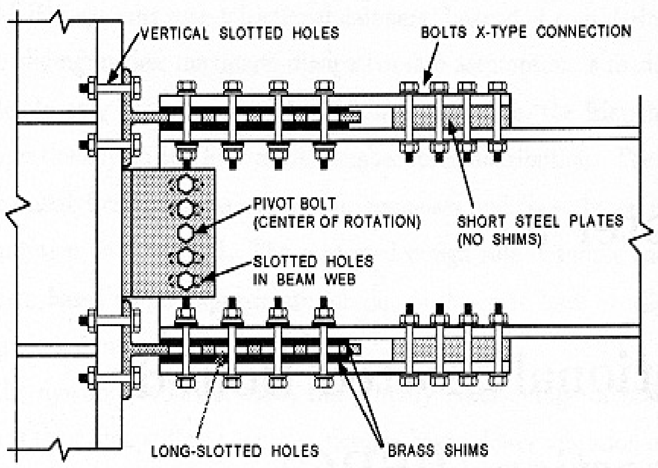
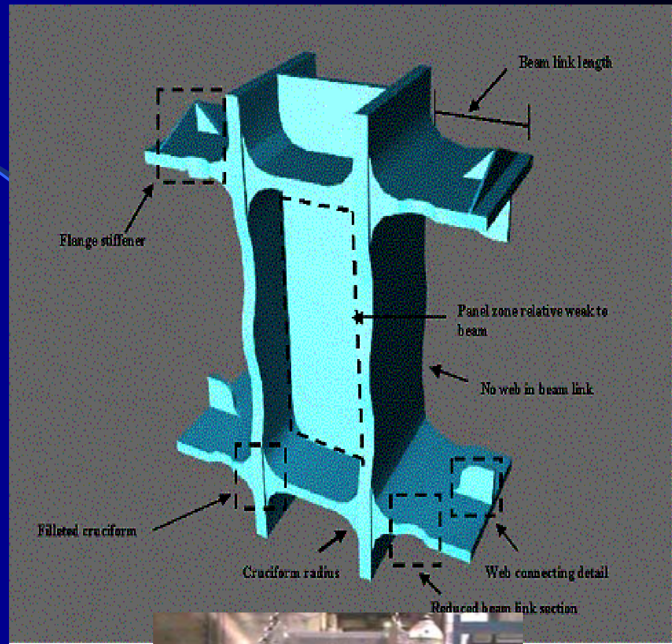
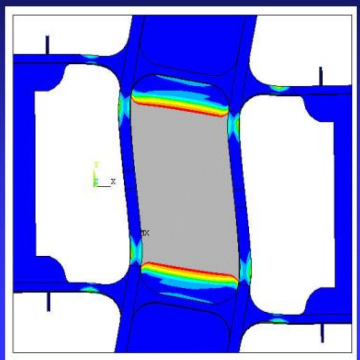


Fig. 5.1: RSBC for Moment Resisting Connections.

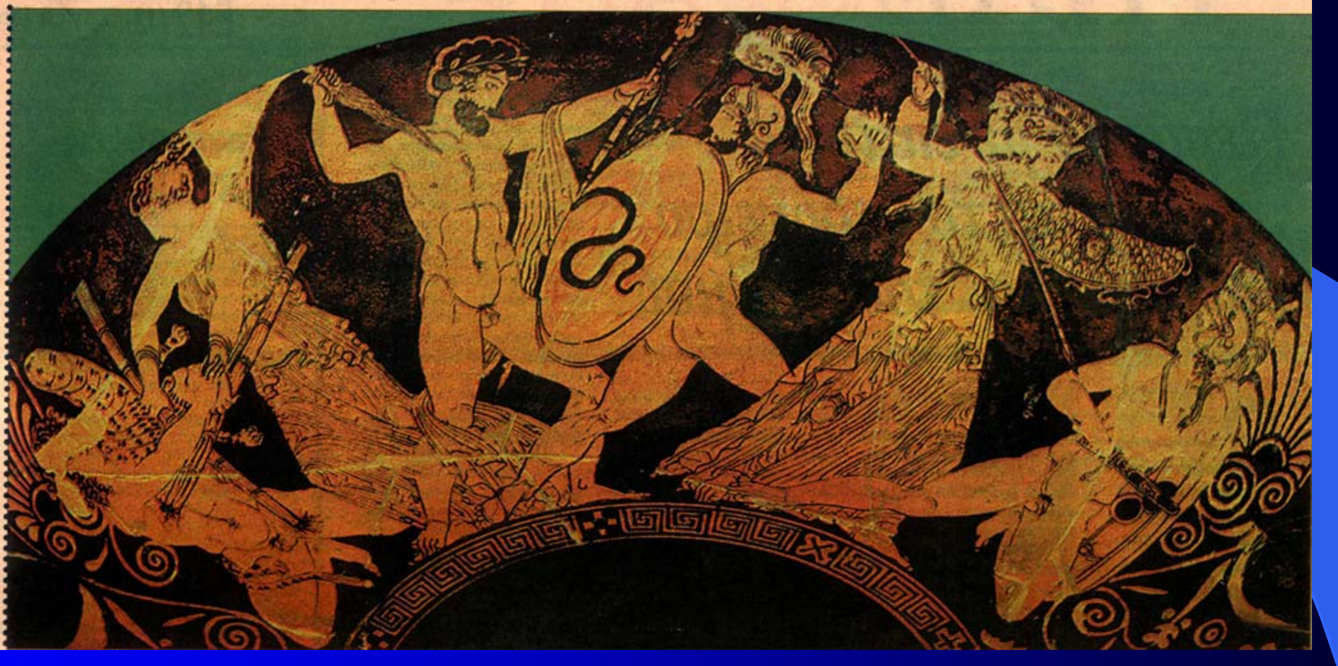
Moment connection with long slotted holes and brass shims





Modular connections

Thank you for your attention



From ancient times was known that only with science people could protect our lives against earthquake forces