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# **ROLE OF DISSIPATIVE CONNECTIONS ON THE SEISMIC RESPONSES OF ONE-STOREY INDUSTRIAL BUILDINGS**

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- alternative design solutions for one storey-precast industrial buildings, which allow to locate the dissipation capacity of the structure in the mechanical connections preserving the integrity of the structural elements.

- Two design approaches:

partial isolation of the floor/roof system

total isolation of the roof-system

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- development of precast structures Since the 1970-80's
  - more than 80% of the category in Italy and in South Europe.
  - during the South-European earthquakes of the last decade, significant damage has been registered in the structural elements of one-storey precast industrial building designed according to the current codes
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- In the previous editions of Eurocode 8, this type of structure was particularly penalised with a lower behaviour factor
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- Recent research investigations are now focused on the experimental characterization of the cyclic behavior of the traditional connections between the structural elements, i.e. roof-to-beam and beam-to-column.
  
  - The intent is to reduce the structural damage in the columns due to the formation of plastic hinges in proximity of the column-to-foundation region, by introducing slight modifications to the typical adopted commercial connections
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## □ CONNECTIONS BETWEEN STRUCTURAL MEMBERS

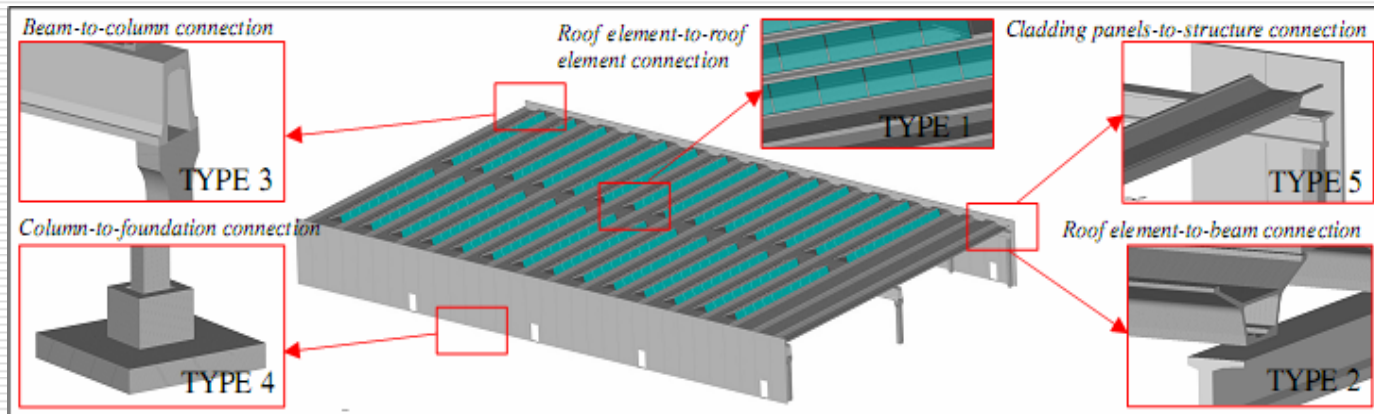


Figure 1 - Different typologies of connections between structural members

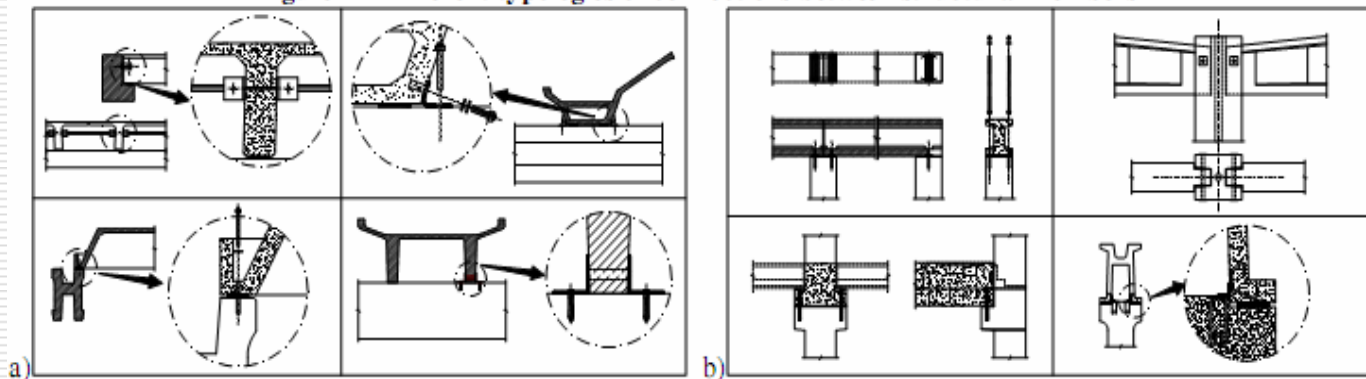


Figure 2 - a) Roof element-to-beam connections; b) Beam-to-column connections

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- (Type 1) connections between roof elements
  - (Type 2) roof element-to-beam connections
    - (Type 3) beam-to-column connections
    - (Type 4) column-to-foundation connection
  - (Type 5) connection of horizontal or vertical cladding panels to the structure
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# STRUCTURAL BEHAVIOUR WITH DISSIPATIVE OR NON-DISSIPATIVE CONNECTIONS

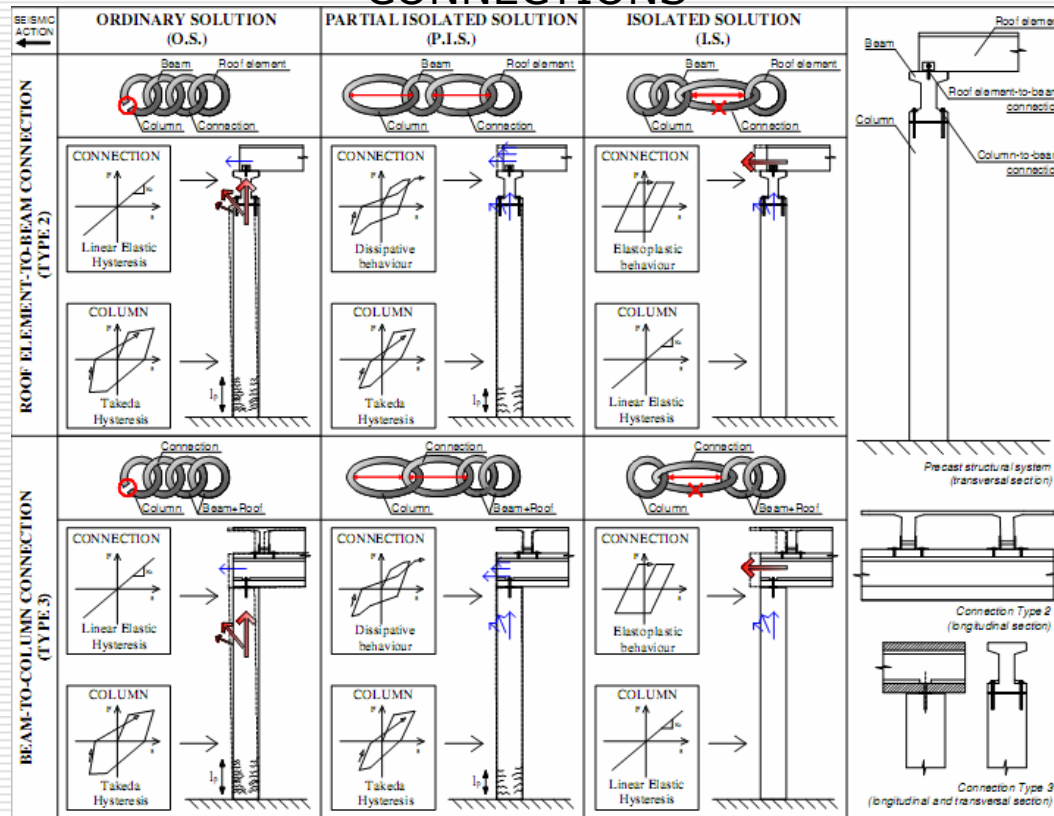


Figure 3 - Different solutions of roof element-to-beam connections and beam-to-column connections

## □ Experimental Tests on Roof Element-to-Beam Connection

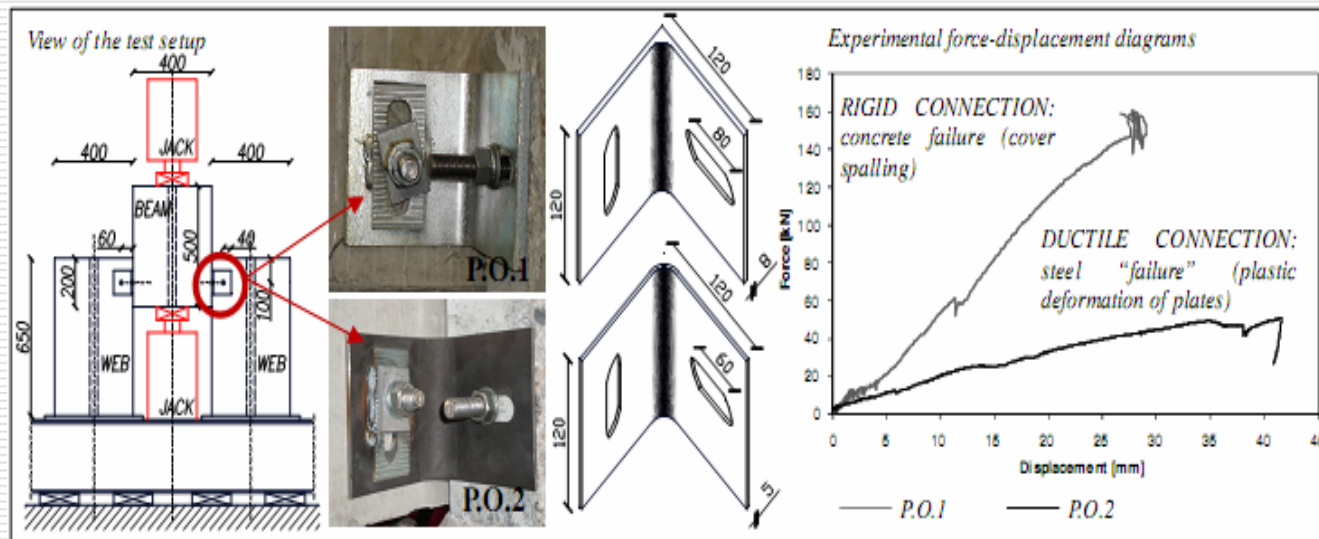


Figure 4 – Push-over test: comparison of two different connections' behaviour

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□ two pushover tests  
(P.O.1) typical commercial roof-to-beam connection  
(P.O.2) thinner plate (5mm instead of 8 mm) with rounded angles

□ 60% increment of maximum displacement respect to (P.O.1), with a significant distortion of the steel plate preventing spalling failure of "beam" concrete edges

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- The cyclic behaviour of (P.O.2) connection:

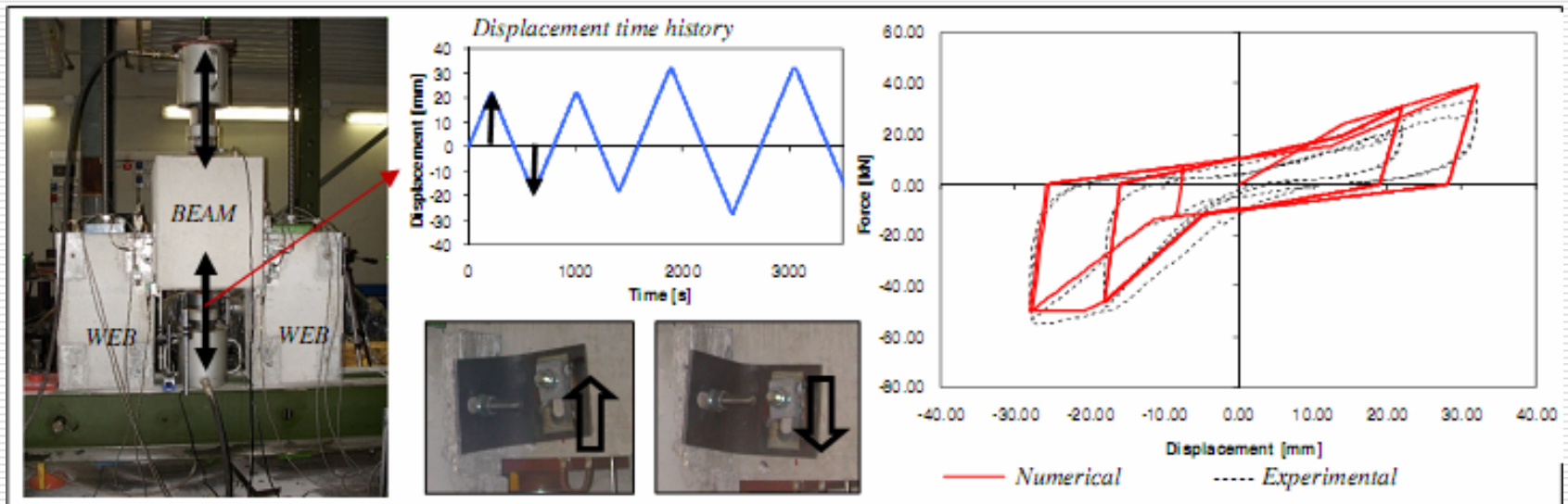


Figure 5 – Cyclic test: experimental-numerical comparison of force-displacement diagrams

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## NUMERICAL ANALYSIS

- pseudo-dynamic and quasi-static cyclic tests
    - one-storey precast industrial building
  
  - Quasi-static push-pull and time history analyses have been carried out with RUAUMOKO 2D
  
  - ordinary solution (O.S.), Linear Elastic rule is adopted since connections remain in the elastic field; the partial isolated solution (P.I.S.) is modelled with a Wayne-Steward hysteresis rule, while for the isolated solution (I.S.) elasto-plastic and flag-shaped hysteresis rules have been adopted
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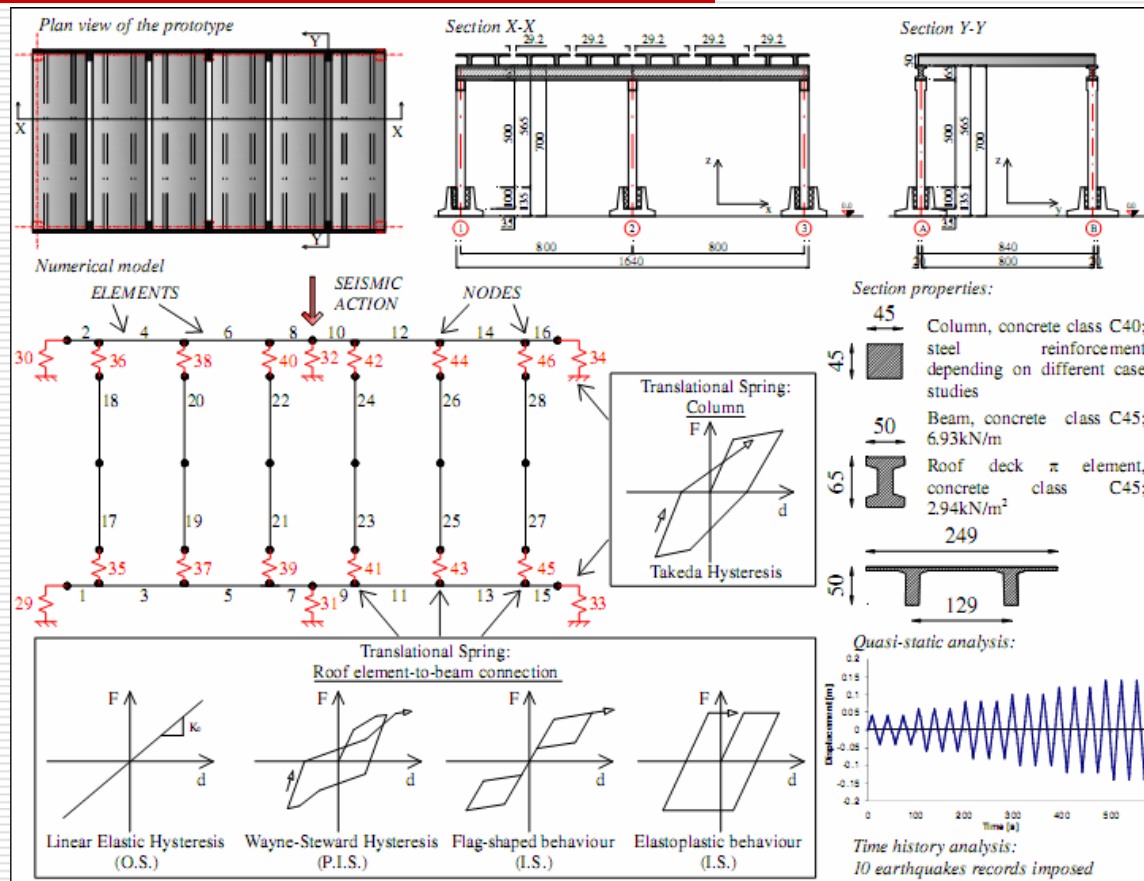


Figure 6 – Experimental prototype and numerical model

## □ Quasi-static cyclic push-pull analysis

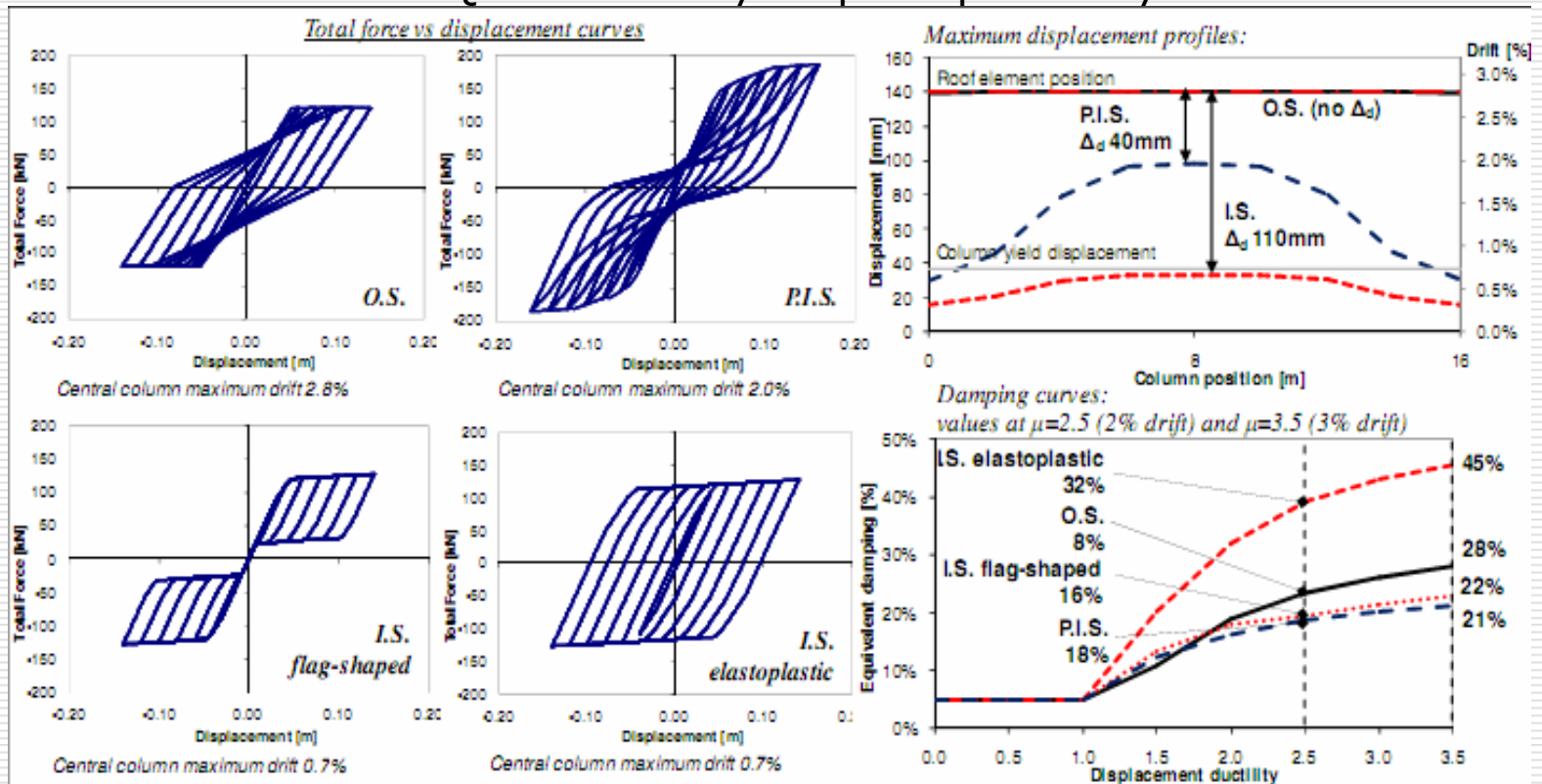


Figure 7 – Quasi-static analysis: total force vs displacement curves; displacement profiles; damping curves

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- high stiffness of connections
  - no relative displacement between roof elements and beams
  - central columns reach higher displacements/drift than the external ones
  
  - use of elastoplastic dissipative connections (I.S.) allows a greater dissipation capacity ( $\mu=3.5$ ,  $\xi_{equiv}=45\%$ ) compared to I.S. flag-shaped ( $\mu=3.5$ ,  $\xi_{equiv}=22\%$ ), O.S. ( $\mu=3.5$ ,  $\xi_{equiv}=28\%$ ) and P.I.S. ( $\mu=3.5$ ,  $\xi_{equiv}=21\%$ ).
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## □ Time history analysis

Time history analyses use an ensemble of ten Californian earthquake records scaled to match the EC-8 design response spectrum with an acceleration of 0.3.

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**Table 1 – Time history analysis: a) residual displacements; b) maximum displacements contributions**

| a) | Earthquake record        | Station                    | O.S.                |                          | P.I.S.              |                          | I.S. elastoplastic  |                          |
|----|--------------------------|----------------------------|---------------------|--------------------------|---------------------|--------------------------|---------------------|--------------------------|
|    |                          |                            | $\Delta_{res}$ [mm] | drift <sub>res/max</sub> | $\Delta_{res}$ [mm] | drift <sub>res/max</sub> | $\Delta_{res}$ [mm] | drift <sub>res/max</sub> |
|    | Cape Mendocino, 1992     | Rio Dell Overpass-FF       | 3.9                 | 0.02                     | 2.80                | 0.03                     | 8.33                | 0.07                     |
|    | Landers 1, 1992          | Desert Hot Springs         | 23.0                | 0.13                     | 1.55                | 0.01                     | 1.48                | 0.01                     |
|    | Landers 2, 1992          | Yermo Fire Station         | 27.4                | 0.15                     | 1.43                | 0.01                     | 3.75                | 0.02                     |
|    | Loma Prieta 1, 1989      | Hollister Diff. Array      | 2.9                 | 0.03                     | 0.29                | 0.00                     | 8.56                | 0.12                     |
|    | Loma Prieta 2, 1989      | Gilroy Array #7            | 3.5                 | 0.03                     | 3.09                | 0.03                     | 7.28                | 0.06                     |
|    | Northridge 2, 1994       | Canoga Park-Topanga Can    | 38.1                | 0.17                     | 20.59               | 0.10                     | 5.55                | 0.02                     |
|    | Northridge 3, 1994       | Beverly Hills 14145 Mulhol | 0.8                 | 0.01                     | 1.59                | 0.02                     | 3.44                | 0.03                     |
|    | Northridge 5, 1994       | N Holliwoood-Coldwater Can | 3.6                 | 0.03                     | 2.09                | 0.03                     | 5.35                | 0.05                     |
|    | Northridge 10, 1994      | Sunland-Mt. Gleason Ave    | 10.2                | 0.09                     | 7.40                | 0.06                     | 1.37                | 0.01                     |
|    | Superstition Hills, 1997 | Plaster City               | 5.7                 | 0.04                     | 3.95                | 0.06                     | 1.93                | 0.02                     |
|    | MEAN                     |                            | 11.9                | 0.07                     | 4.5                 | 0.04                     | 4.7                 | 0.04                     |
|    | STDV                     |                            | 12.9                | 0.06                     | 6.0                 | 0.03                     | 2.7                 | 0.04                     |


| b) | Earthquake record | O.S.      |            |                 | P.I.S.    |            |                 | I.S. elastoplastic |            |                 | I.S. flag-shaped |            |                 |
|----|-------------------|-----------|------------|-----------------|-----------|------------|-----------------|--------------------|------------|-----------------|------------------|------------|-----------------|
|    |                   | total [m] | column [m] | connection [mm] | total [m] | column [m] | connection [mm] | total [m]          | column [m] | connection [mm] | total [m]        | column [m] | connection [mm] |
|    | EQ1               | 0.162     | 0.162      | -               | 0.103     | 0.085      | 18.2            | 0.130              | 0.047      | 82.5            | 0.140            | 0.041      | 99.3            |
|    | EQ2               | 0.176     | 0.176      | -               | 0.181     | 0.058      | 122.6           | 0.197              | 0.022      | 174.9           | 0.209            | 0.037      | 171.4           |
|    | EQ3               | 0.186     | 0.186      | -               | 0.102     | 0.081      | 21.0            | 0.169              | 0.085      | 84.6            | 0.184            | 0.034      | 150.5           |
|    | EQ4               | 0.086     | 0.086      | -               | 0.066     | 0.038      | 28.7            | 0.066              | 0.029      | 37.0            | 0.065            | 0.029      | 35.5            |
|    | EQ5               | 0.115     | 0.115      | -               | 0.115     | 0.061      | 53.7            | 0.109              | 0.071      | 37.3            | 0.109            | 0.066      | 43.5            |
|    | EQ6               | 0.220     | 0.220      | -               | 0.198     | 0.113      | 84.6            | 0.218              | 0.007      | 210.5           | 0.202            | 0.051      | 151.0           |
|    | EQ7               | 0.099     | 0.099      | -               | 0.095     | 0.079      | 15.9            | 0.091              | 0.067      | 23.6            | 0.102            | 0.051      | 51.2            |
|    | EQ8               | 0.137     | 0.137      | -               | 0.073     | 0.051      | 22.2            | 0.102              | 0.036      | 66.1            | 0.102            | 0.018      | 84.2            |
|    | EQ9               | 0.117     | 0.117      | -               | 0.119     | 0.076      | 42.6            | 0.128              | 0.079      | 49.8            | 0.140            | 0.054      | 85.3            |
|    | EQ10              | 0.140     | 0.140      | -               | 0.066     | 0.047      | 18.7            | 0.083              | 0.030      | 53.7            | 0.069            | 0.032      | 36.4            |
|    | MEAN              | 0.144     | 0.144      | -               | 0.112     | 0.069      | 42.8            | 0.129              | 0.047      | 82.0            | 0.132            | 0.041      | 90.8            |
|    | STDV              | 0.042     | 0.042      | -               | 0.045     | 0.022      | 35.3            | 0.050              | 0.027      | 62.1            | 0.052            | 0.014      | 51.3            |

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## □ Results

use of totally isolated floor solution, allow to drastically reduce column displacements limiting the cost of repair to the substitution of the mechanical devices

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Thank you for your attention

