

## 専門分野「計算固体力学(Computational Solid Mechanics)」

材料と構造のマルチフィールド・マルチスケール力学問題を対象として、有限要素法などの数値シミュレーション手法の開発と工業設計解析および先端テクノロジーへの応用に関する研究を行なってきた。

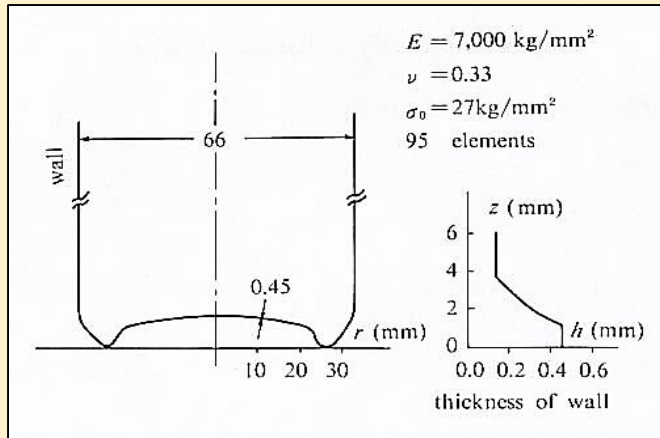
### (1)計算構造工学:非線形・マルチフィールド構造解析法の開発

- ①計算不連続体力学モデルによる鋼構造の離散化極限解析法の開発と体系化
- ②代表的な強非線形問題である鋼構造要素の有限要素クラッシュ解析と実験的検証
- ③最高度の計算効率・精度を有する順応型Shifted Integration法による骨組崩壊解析法
- ④電磁気・熱・相変態・電気化学・力学など連成場構造解析法の構築と工学的応用

### (2)計算損傷力学:材料損傷・構造寿命のメソ力学評価法の開発

### (3)計算機能材料工学:先端機能材料とアクチュエータ/センサの計算モデリング

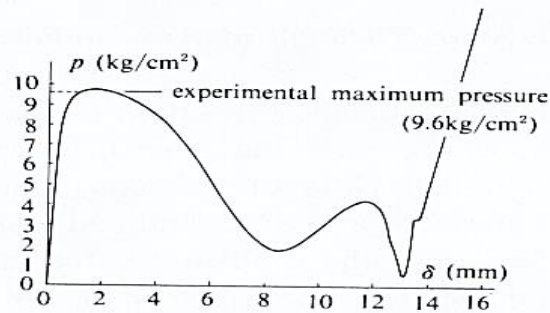
# 回転対称シェルの弾塑性飛移り挙動の一離散化解析 [1.都井・川井・石鍋1981]



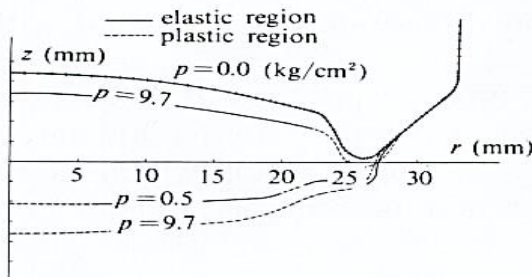
Aluminum can bottom profile



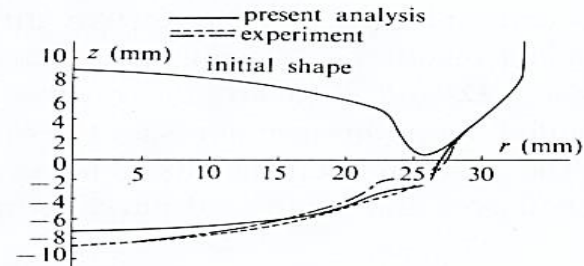
Collapsed can bottom



(a) pressure-central deflection curve

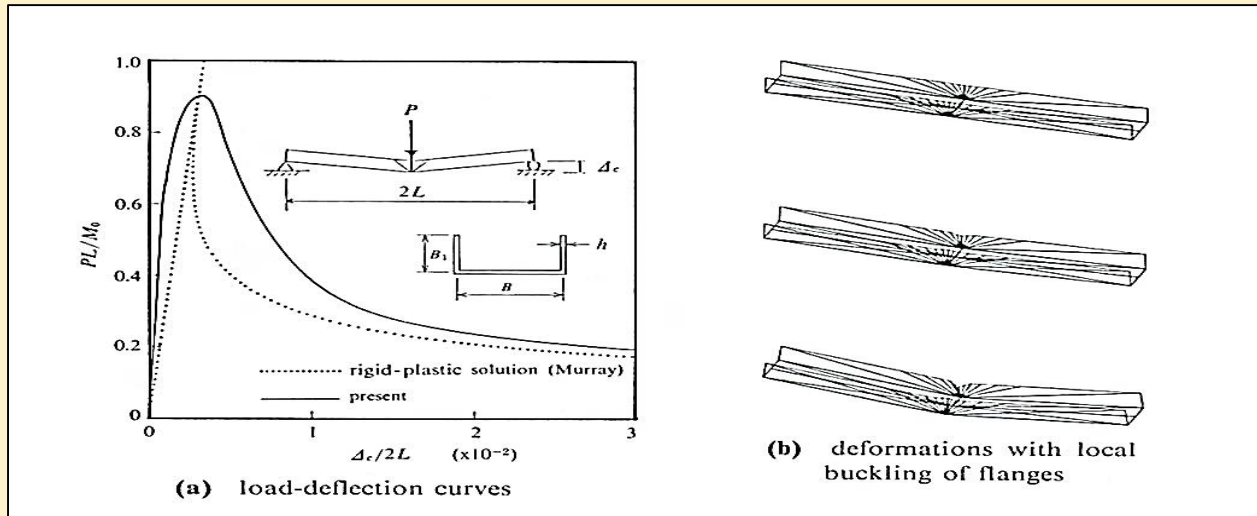


(b) deformation process

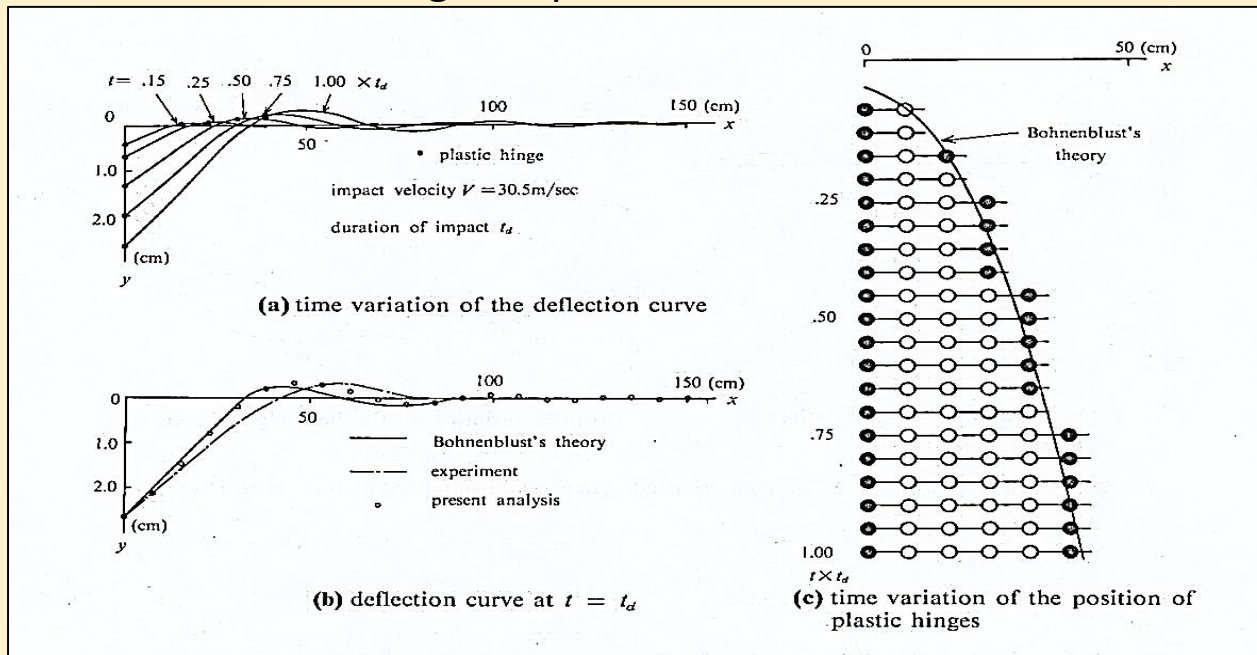


(c) permanently deformed profiles

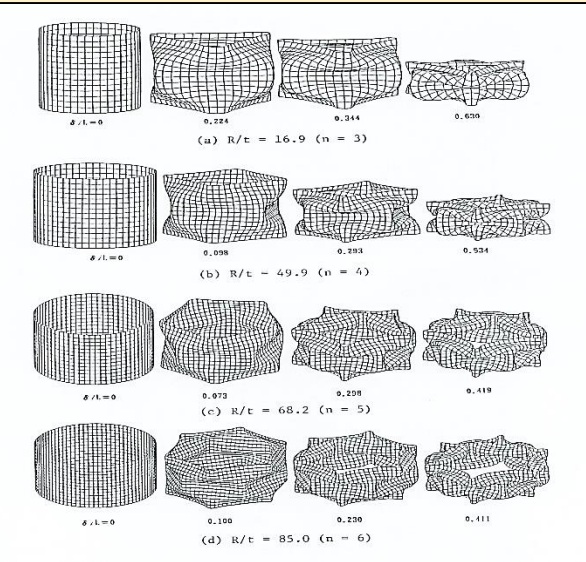
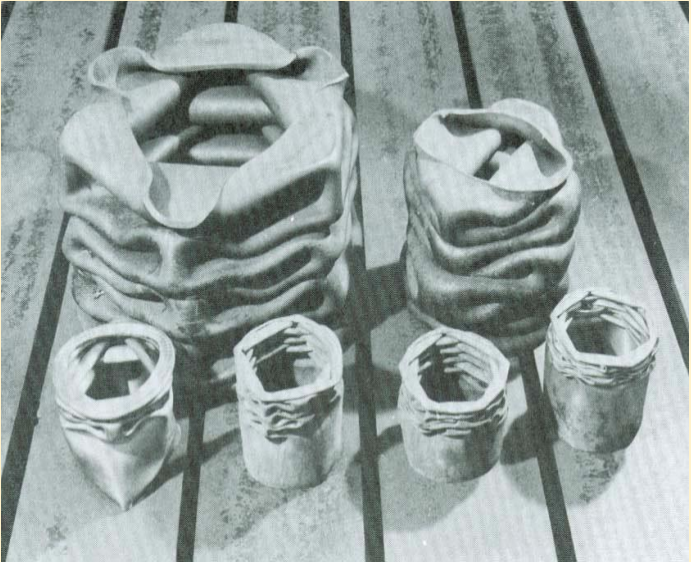
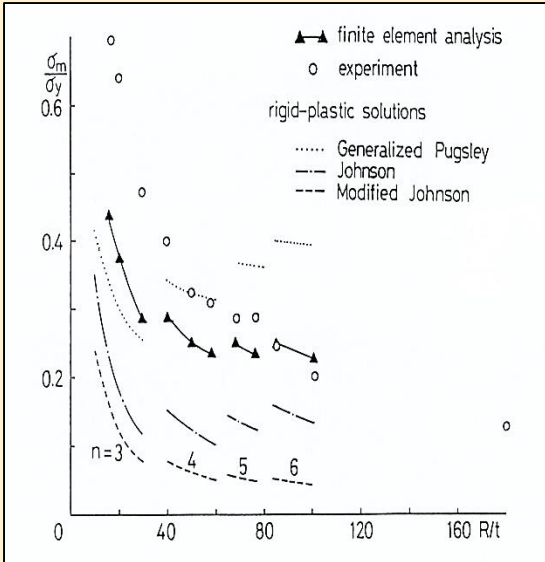
Snap-through collapse



### Bending collapse of a channel beam



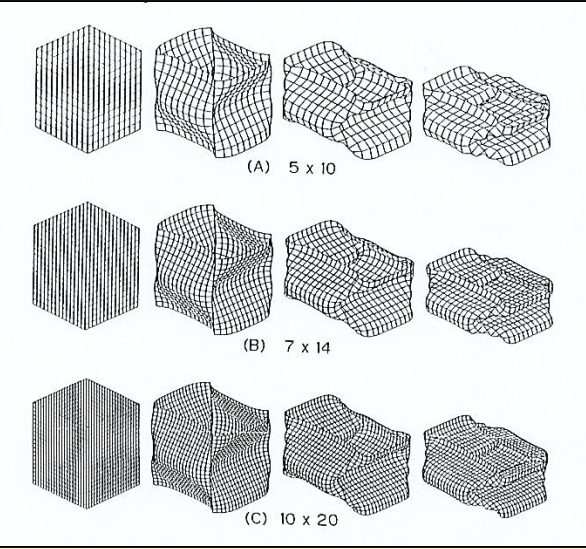
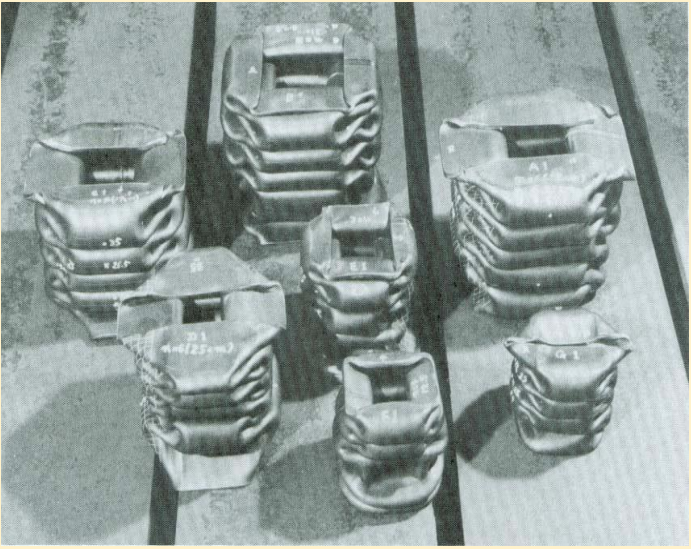
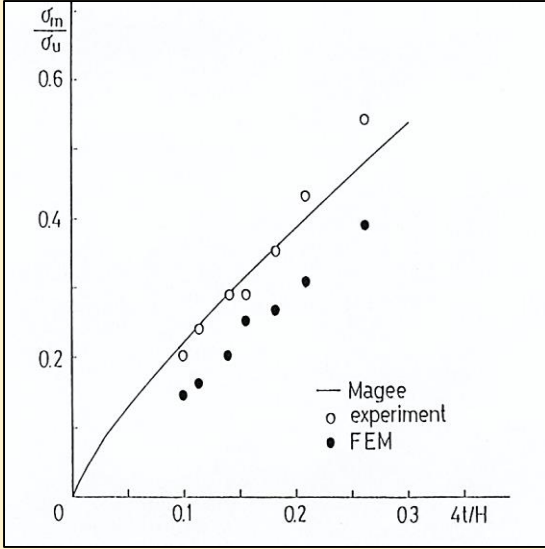
構造要素のクラッシュ強度に関する数値的・実験的研究① [4.都井・弓削・小畑1986, 5.同1987]



Mean crushing stresses for axially compressed circular tubes

Axially crushed circular tubes

Crushing deformations of axially compressed circular tubes

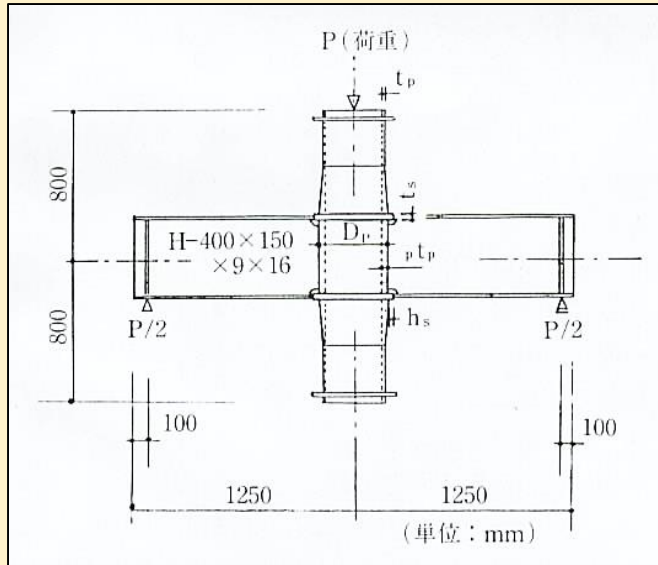


Mean crushing stresses for axially compressed square tubes

Axially crushed square tubes

Crushing deformations of axially compressed square tubes

# 鋼管柱・H形はり接合部の終局強度解析 [6.弓削・都井・寺岡1989]



Analysis model

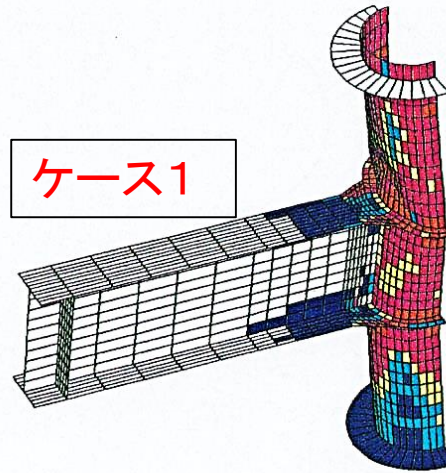
ケースNo.	本解析値 $eP_{max}$	実験値 $eP_{max}$	実験式値 $ceP_{max}$	梁全塑性 曲げ耐力 $eP_{BU}$	崩壊モード
ケース1	37.38	—	34.42	96.56	接合部鋼管 局部圧壊
ケース2	47.40	—	47.92	96.56	接合部鋼管 局部圧壊
ケース3	98.66	103.3*	—**	96.56	接合部鋼管 局部圧壊
ケース4	129.14	—	—**	96.56	はり局部 座屈

注1)  $eP_{max}$ ,  $eP_{max}$ ,  $ceP_{max}$ ,  $eP_{BU}$ の単位は (tonf)

$$\text{実験式}^{\text{①}}: ceP_{max} = (4.53B_f/D_p + 2.05) (r_p t_p / R)^{0.782} \times (t_s / R)^{0.564} ((r_p t_p + h_s) / R)^{0.380} \cdot \sigma_v \cdot R^2 \times h_0 / (L - D_p - 2h_s)$$

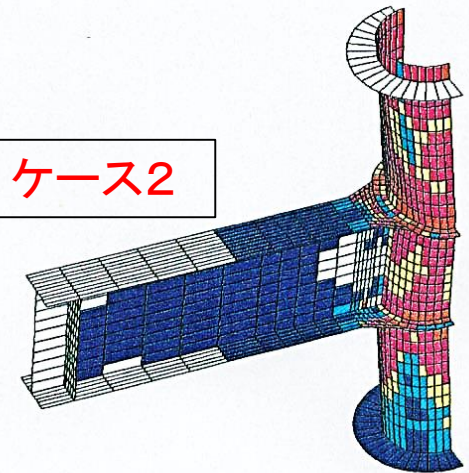
\* : 文献3) , \*\* : 適用範囲外

ケース1



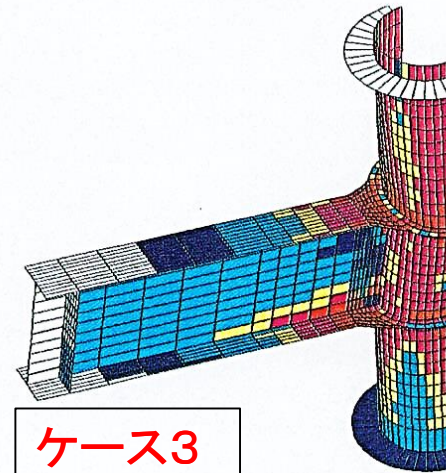
(a) ケース 1 ( $D_p/r_p t_p = 53.1$ ,  $\delta = 135.6\text{mm}$ )

ケース2



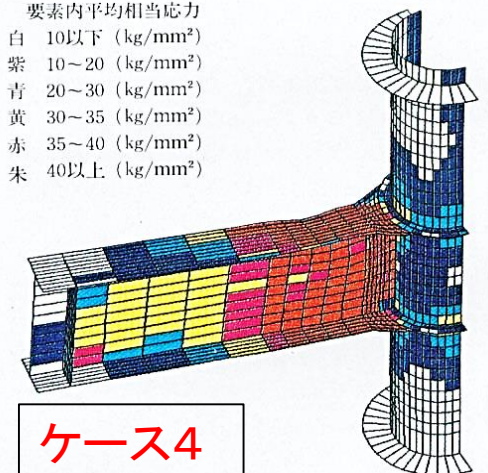
(b) ケース 2 ( $D_p/r_p t_p = 41.9$ ,  $\delta = 119.0\text{mm}$ )

ケース3



(c) ケース 3 ( $D_p/r_p t_p = 20.8$ ,  $\delta = 135.3\text{mm}$ )

ケース4



(d) ケース 4 ( $D_p/r_p t_p = 10.6$ ,  $\delta = 89.74\text{mm}$ )

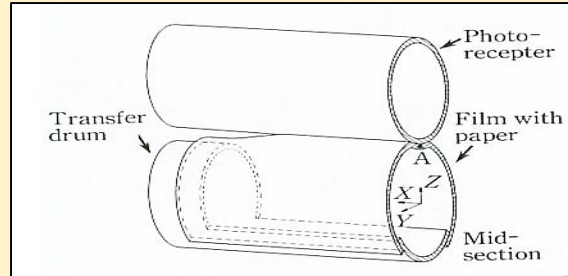
要素内平均相当応力

- 白 10以下 (kg/mm<sup>2</sup>)
- 紫 10~20 (kg/mm<sup>2</sup>)
- 青 20~30 (kg/mm<sup>2</sup>)
- 黄 30~35 (kg/mm<sup>2</sup>)
- 赤 35~40 (kg/mm<sup>2</sup>)
- 朱 40以上 (kg/mm<sup>2</sup>)

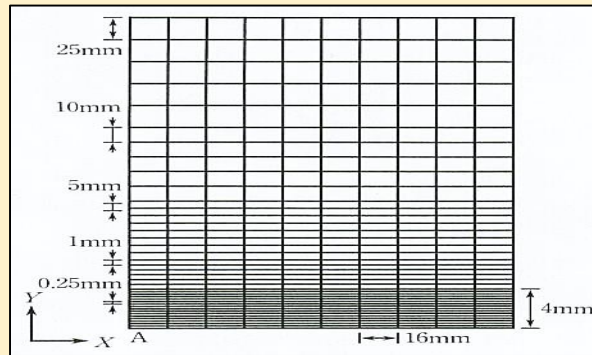
# 電界下における帯電した誘電体フィルムの変形解析 [7.中山・都井・弓削1990]



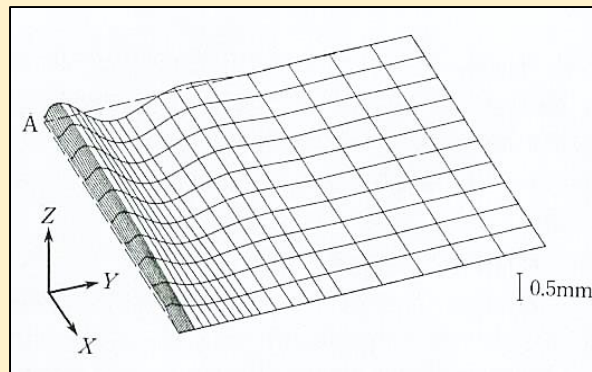
Color copying machine



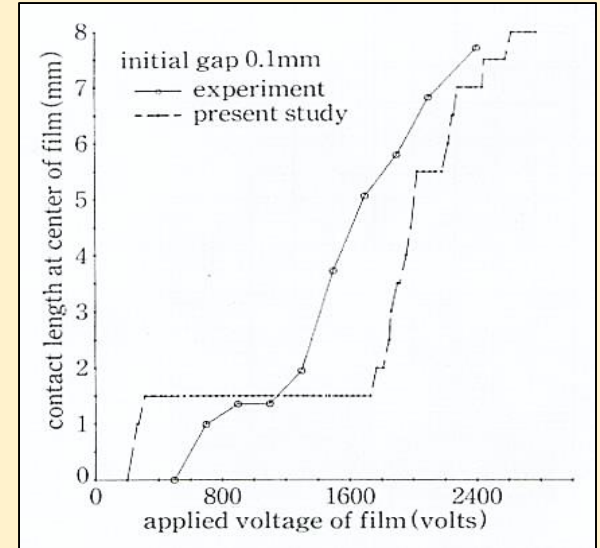
Schematic diagram of deformed film



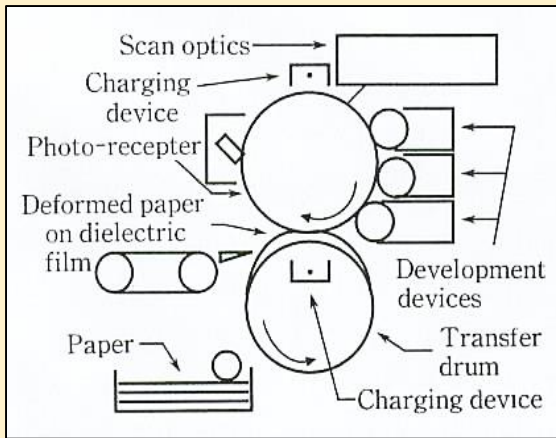
Mesh subdivision



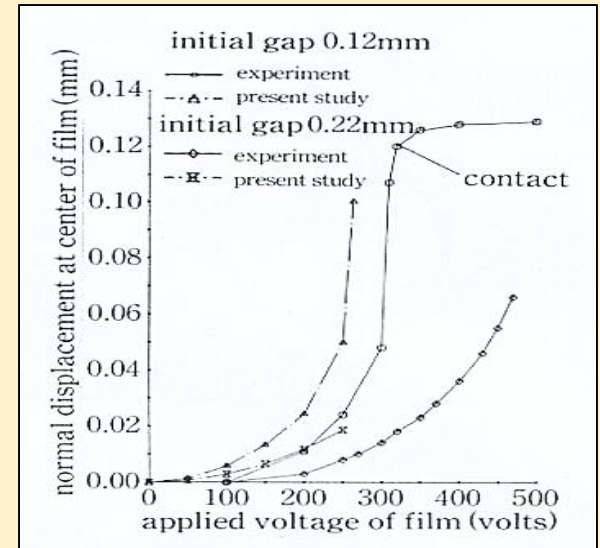
Calculated deformation of film



Variation of contact length with voltage

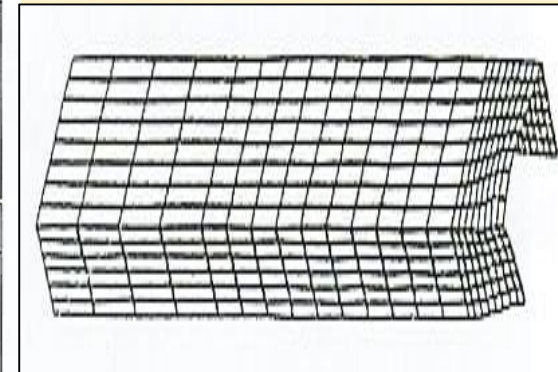
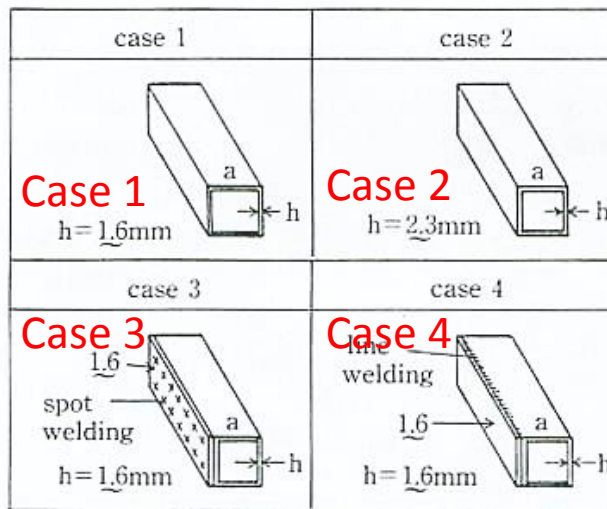
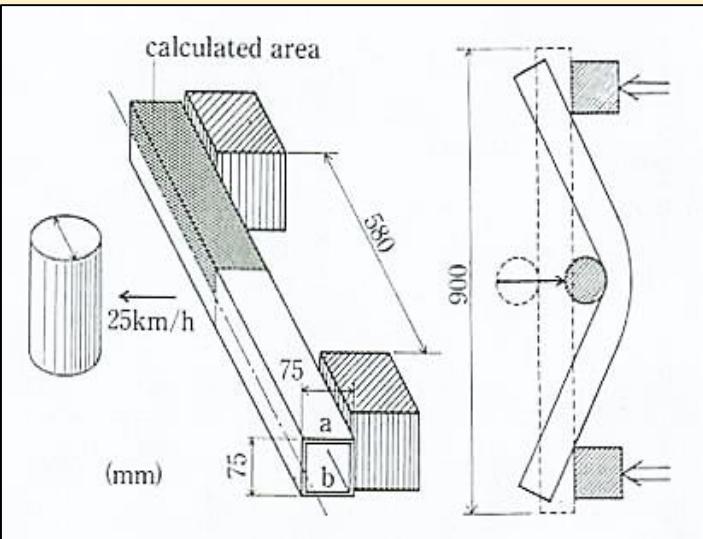


Process for color imaging



Normal displacement of film before contact

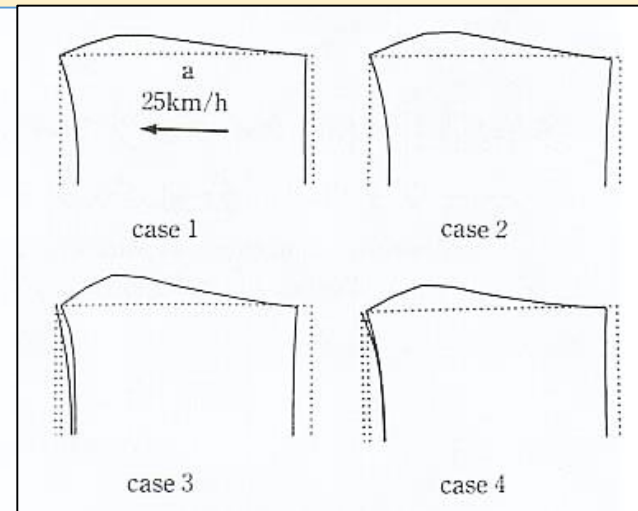
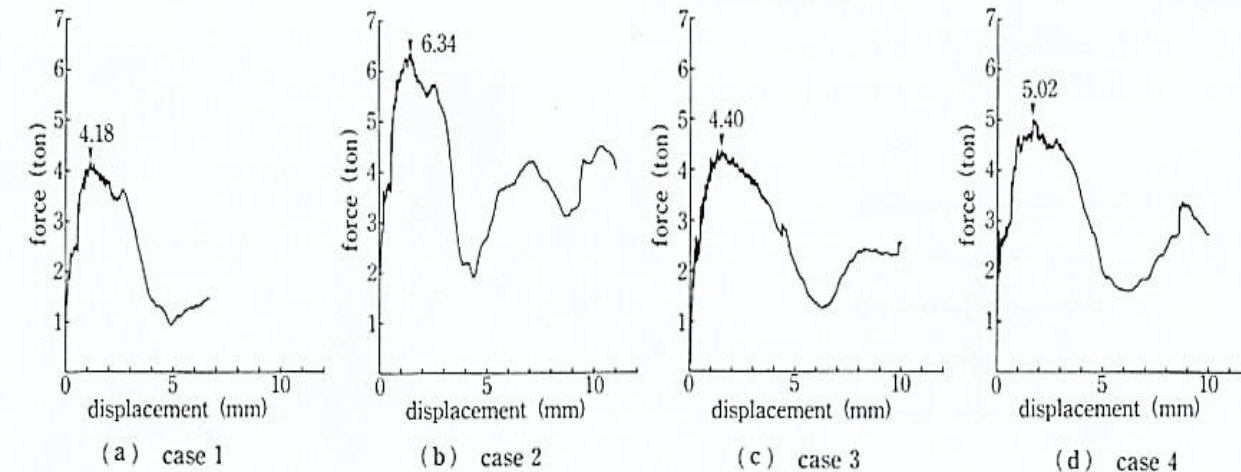
# 補強箱型はりの横衝突崩壊挙動の弾/粘塑性解析 [8.弓削・都井1990]



Overview of deformed configuration

Transverse collision of a box beam

Analysis models



Case 1

Case 2

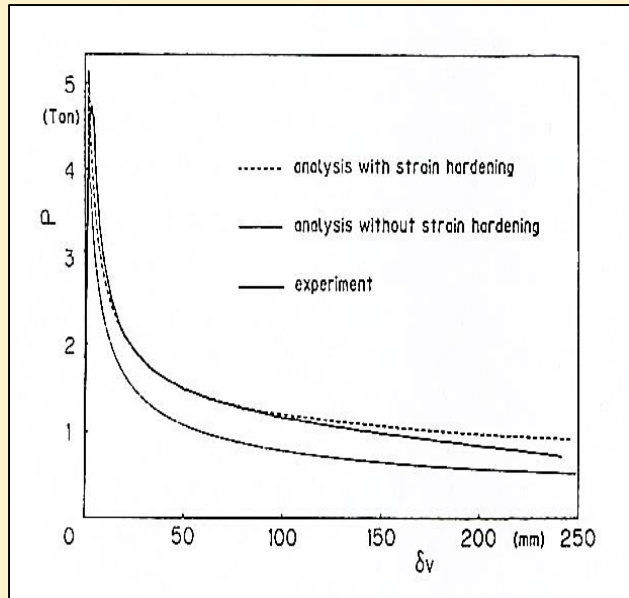
Case 3

Case 4

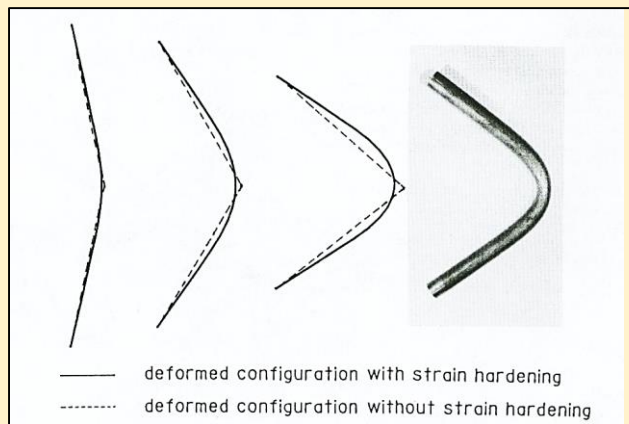
Force-displacement curves

Central cross section

# 骨組構造の崩壊シミュレーション [9.都井・梁・小畑1990]

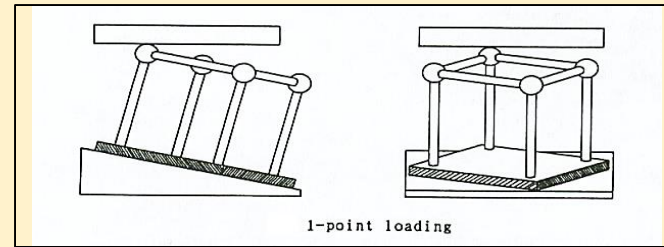


Load-shortening curves

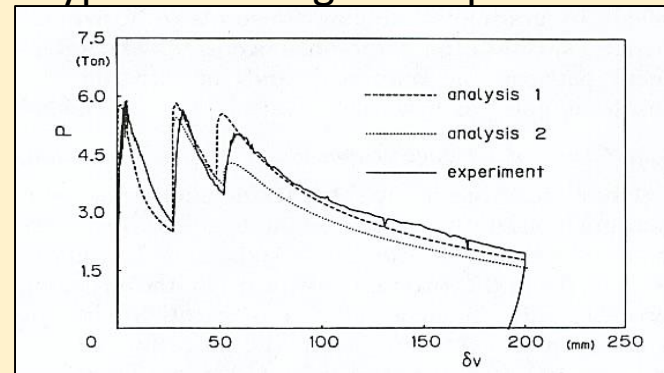


Deformed configurations

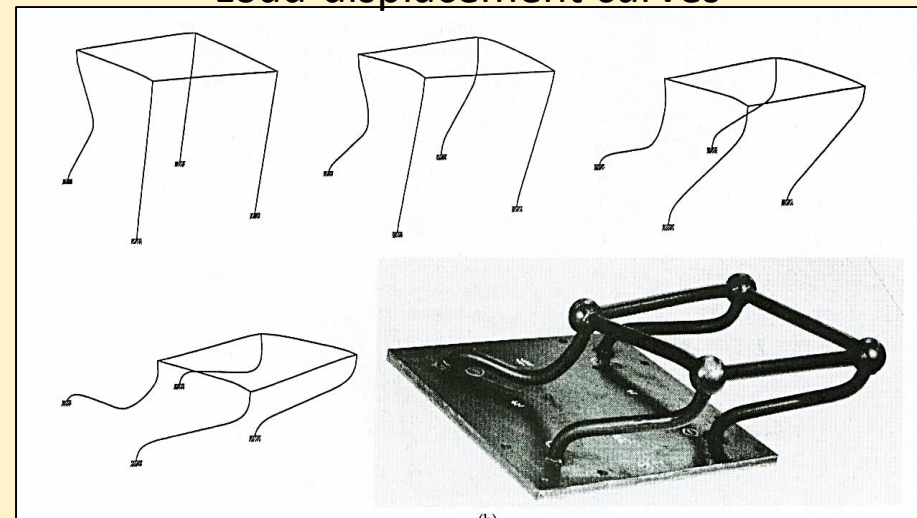
Simply supported column under eccentrically compressive loading



Type of loading for a space frame



Load-displacement curves



Deformed configurations  
Space frame under one-point loading



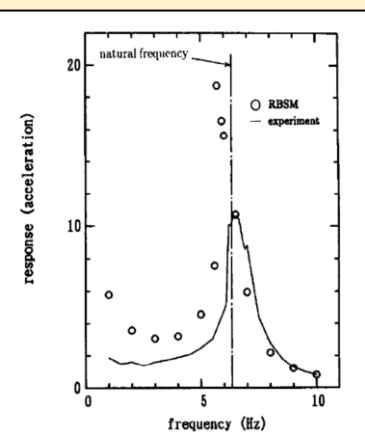
発泡スチロールブロック集合体の動的安定性に関する基礎的研究  
 [10.都井・吉田1991, 11.都井・芝野・田村・小長井1989]



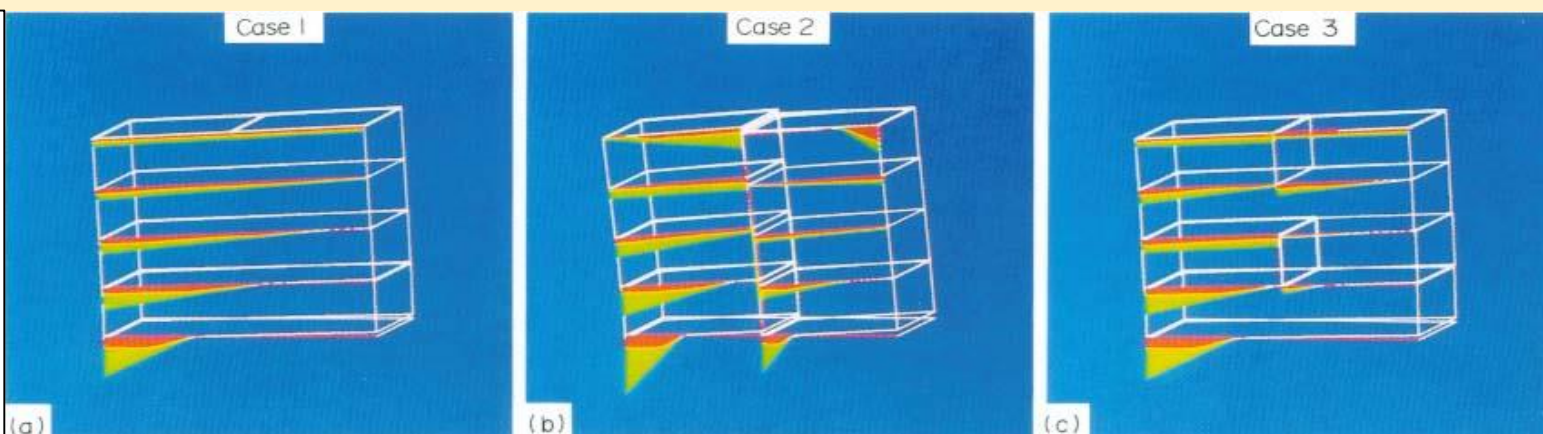
Under construction



Prof. Toi with EPS block

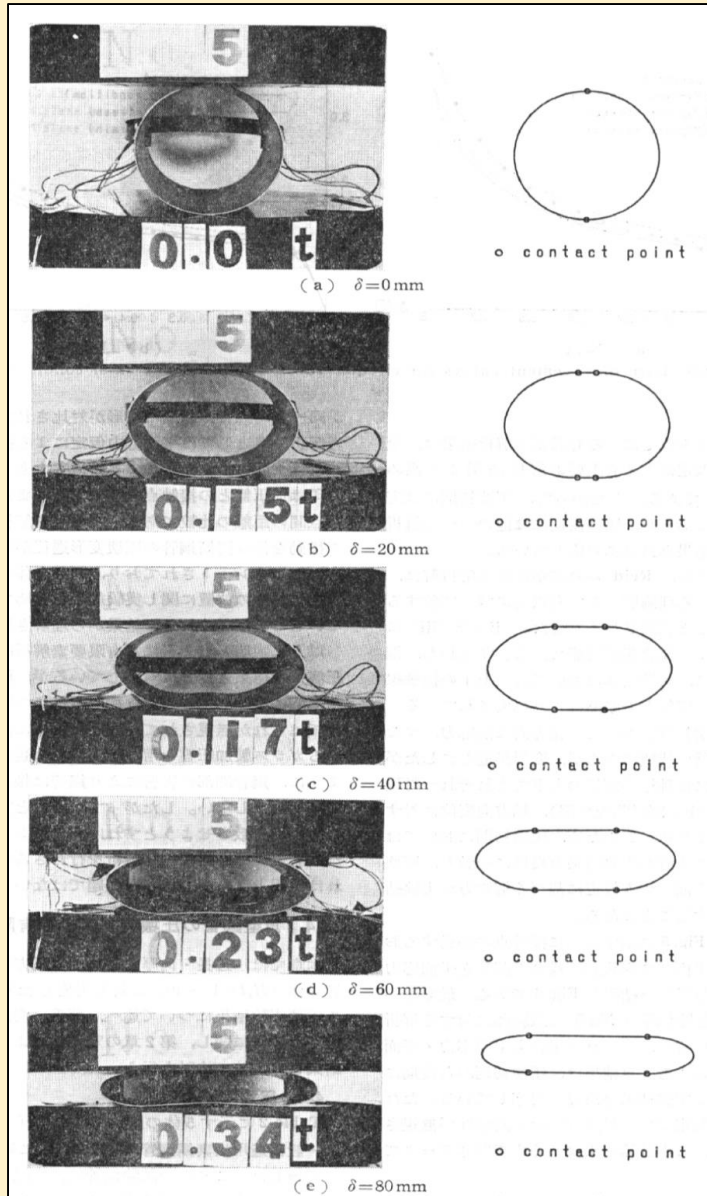


Frequency response

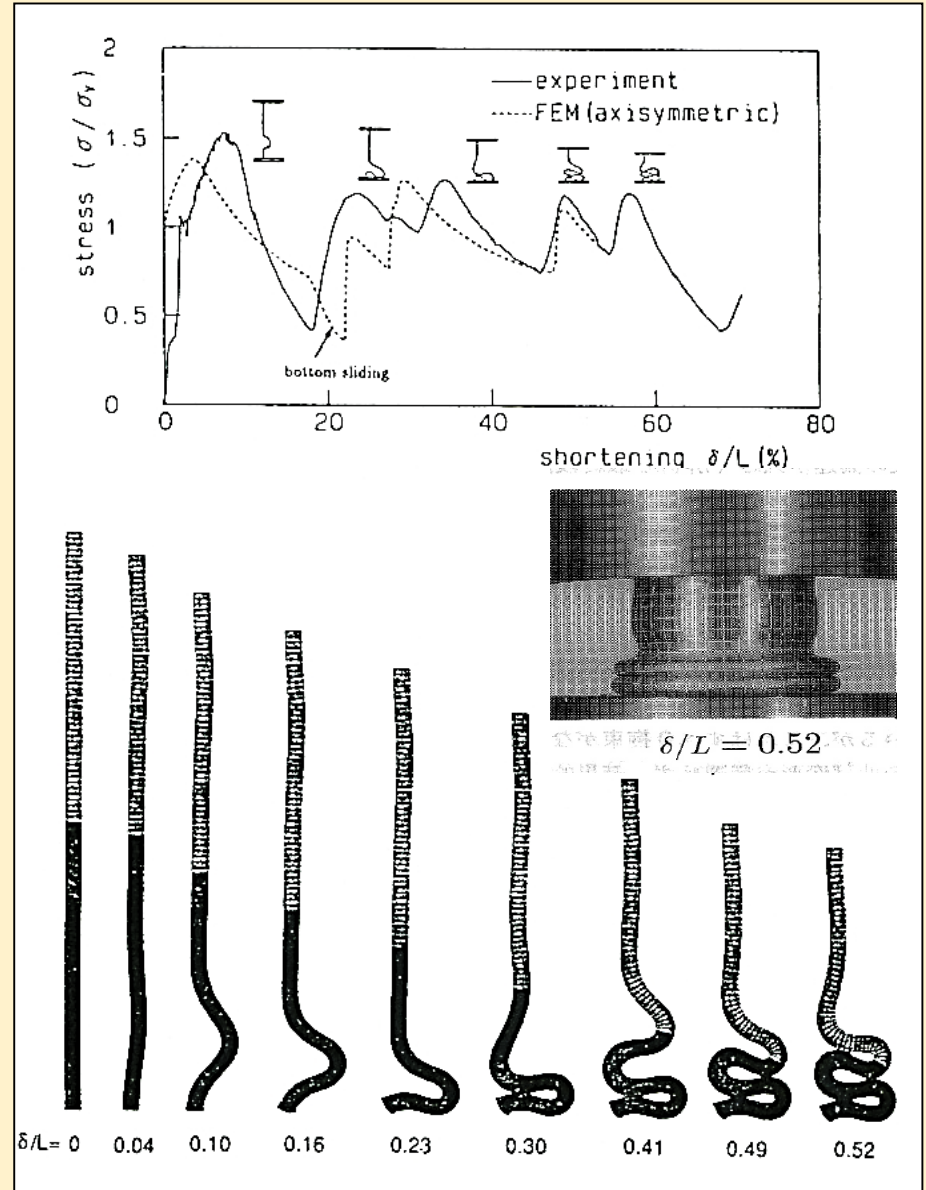


Vibration modes of EPS block structures

構造要素のクラッシュ強度に関する数值的・実験的研究②  
 [12.井根・都井1991, 13.都井・永山1987]

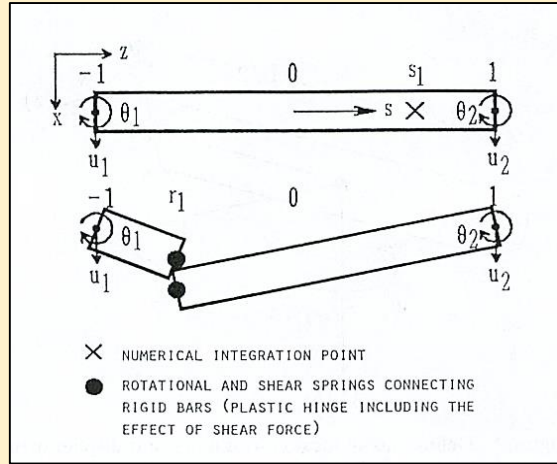


Flattening of circular tubes

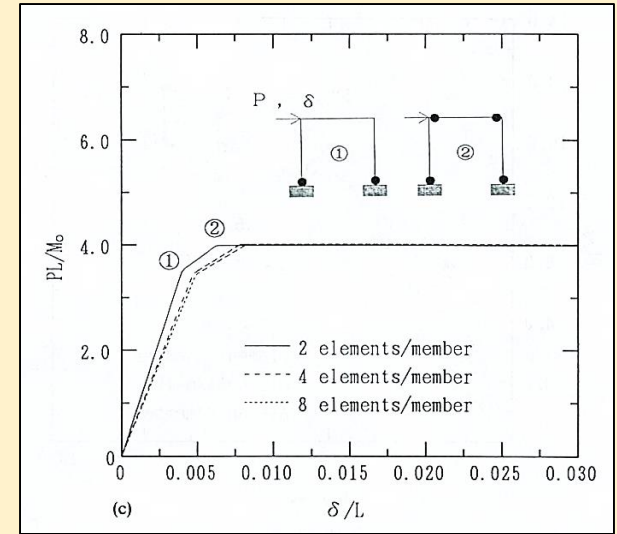
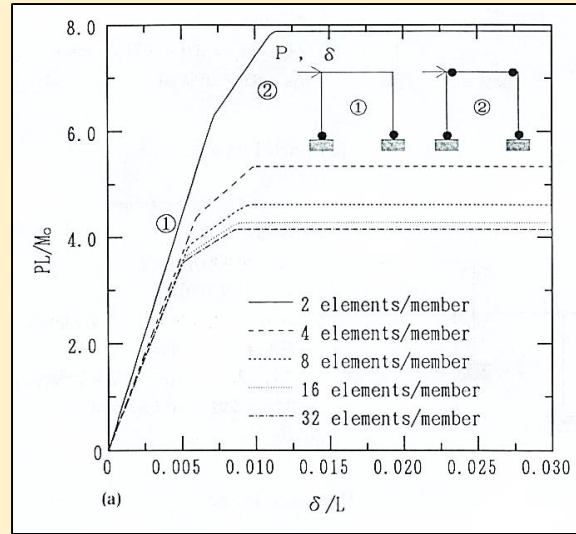


Axisymmetric crush of circular tubes

# 骨組構造の有限要素崩壊解析における順応型Shifted Integration法 [14.都井・磯部1992]



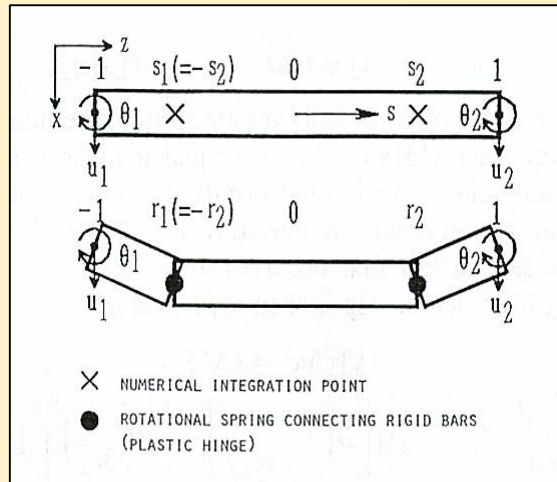
$$s_1 = -r_1 \quad \text{OR} \quad r_1 = -s_1$$



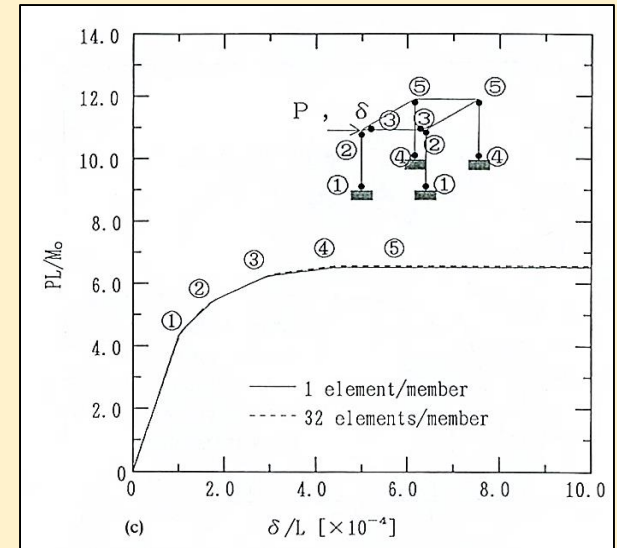
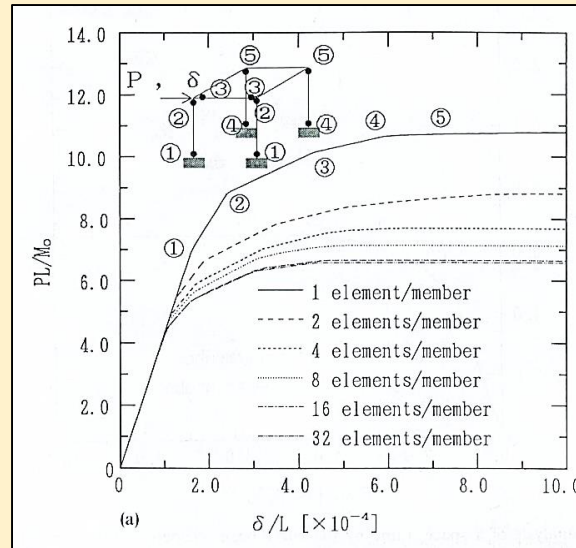
Linear Timoshenko beam element and its physical equivalent

Conventional method ( $s_1=0$ )

Adaptively shifted integration technique



$$r_i = \mp \frac{1}{3s_2} \quad (i = 1, 2)$$



Cubic beam element and its physical equivalent

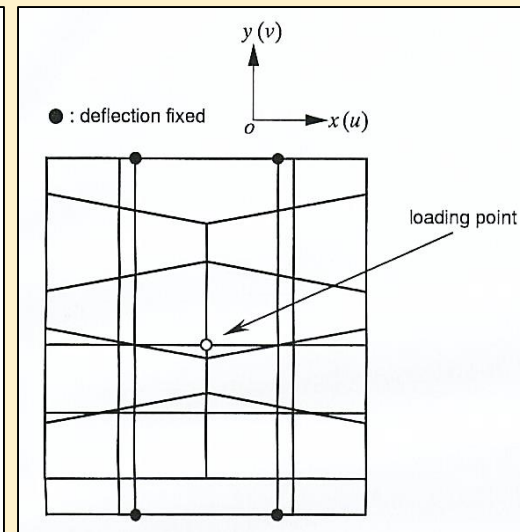
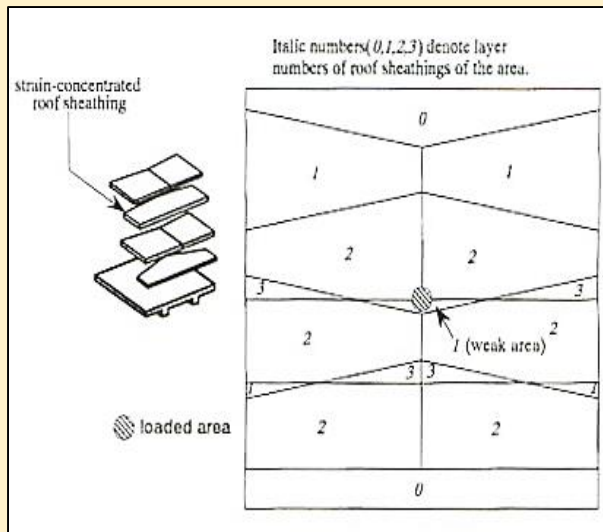
Conventional method (Gaussian integration)

Adaptively shifted integration technique

# ひずみ仮定・補強板有限要素による住宅屋根材解析 [15.小橋・都井・佐藤・西平1994]

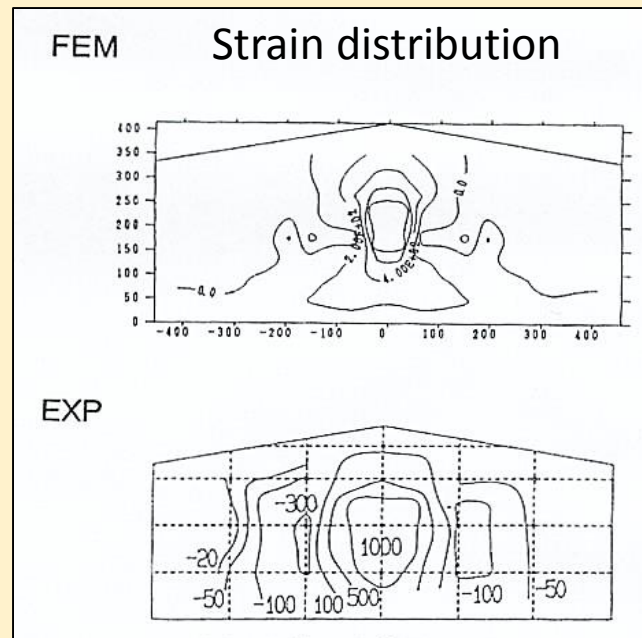
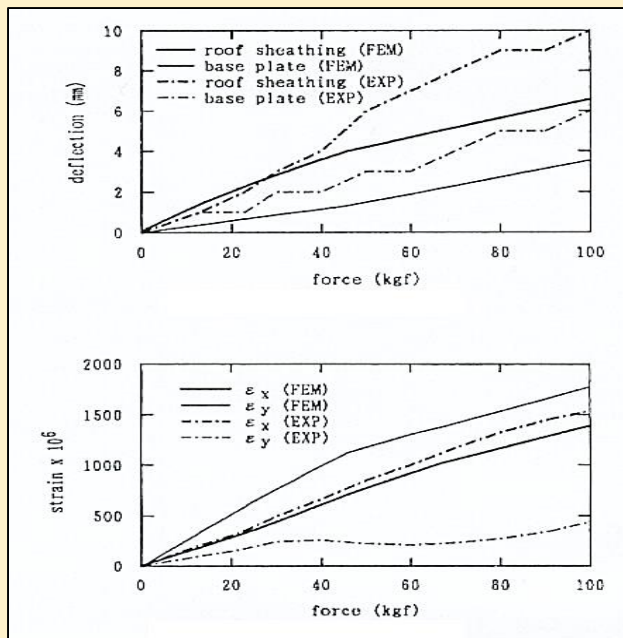


'Colonial'

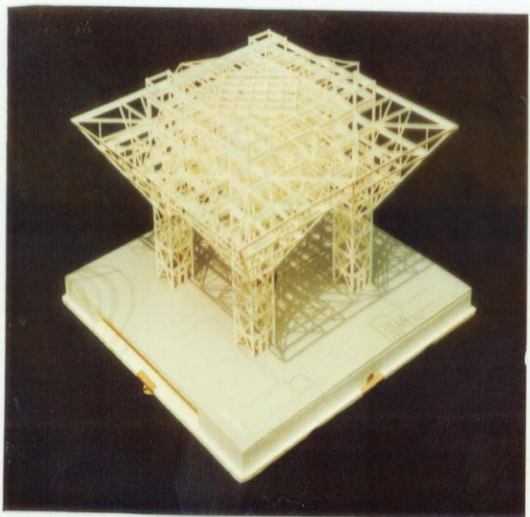
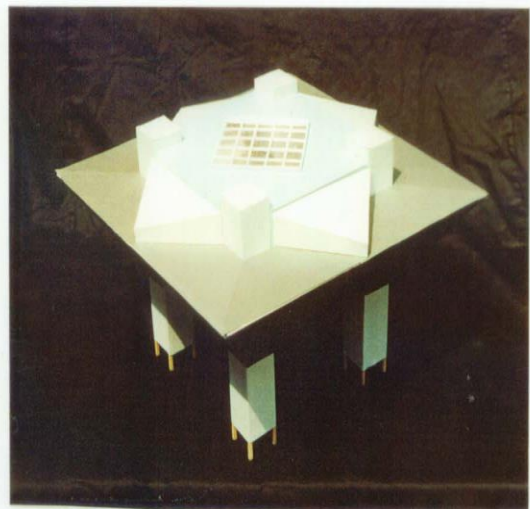


Roof-structure

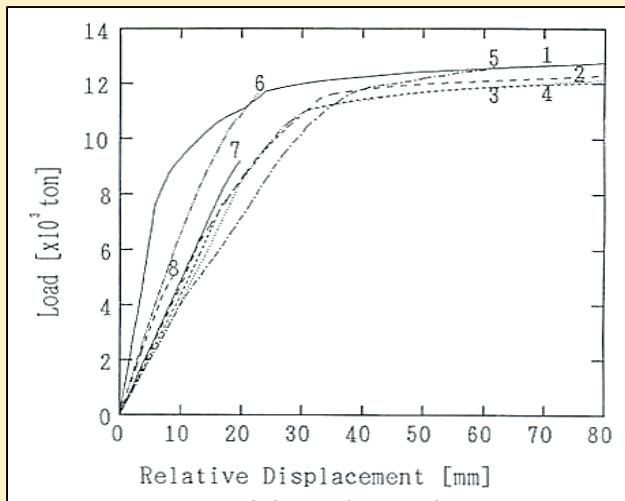
Calculation model



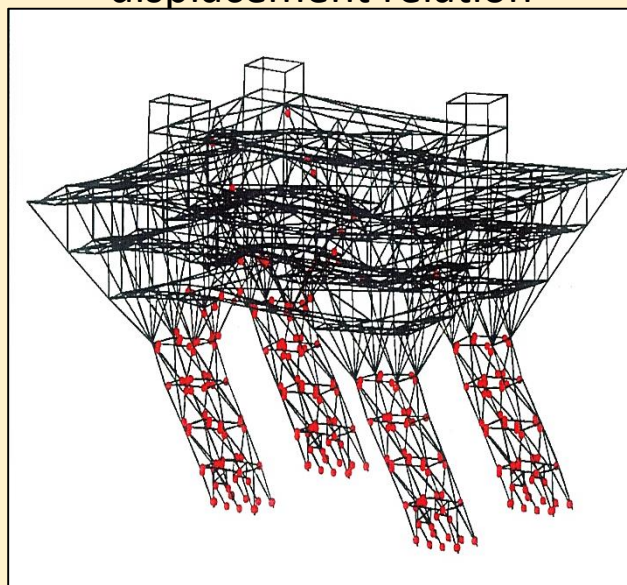
Finite element results (FEM) and experimental results (EXP)



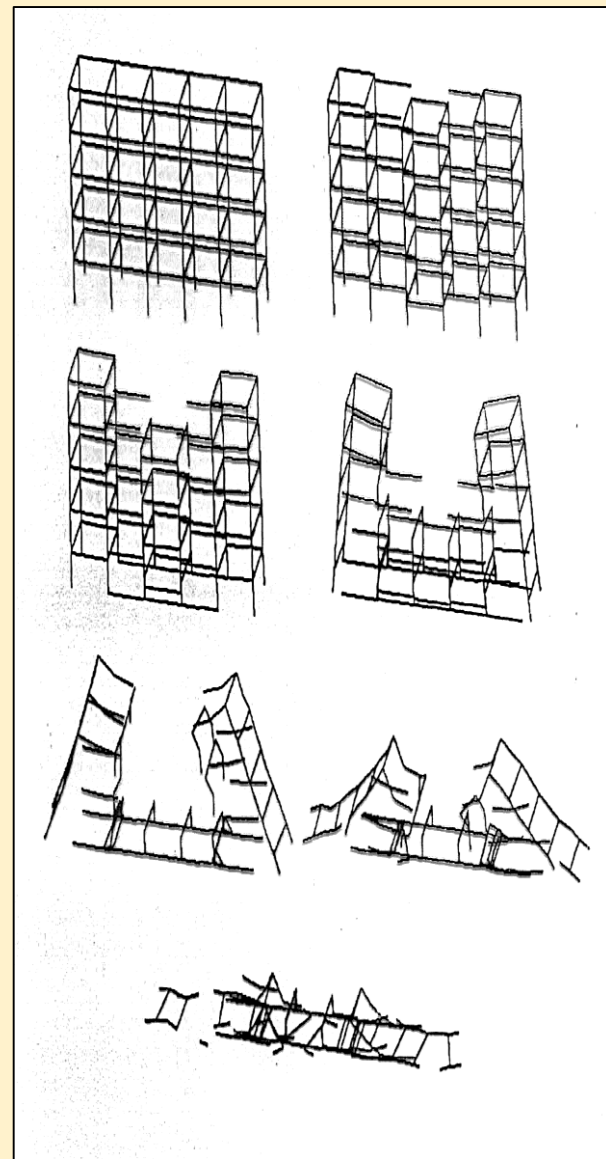
Tokyo Big Sight



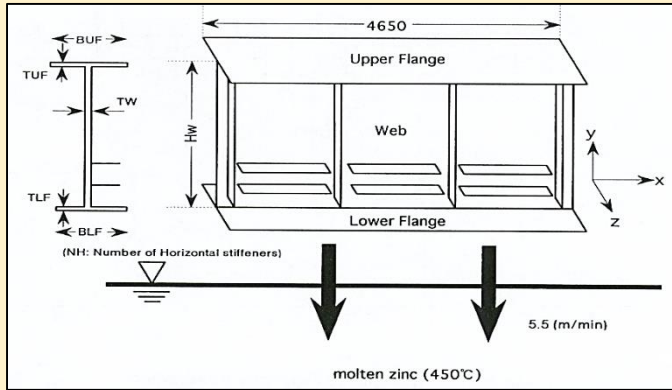
Lateral load - relative displacement relation



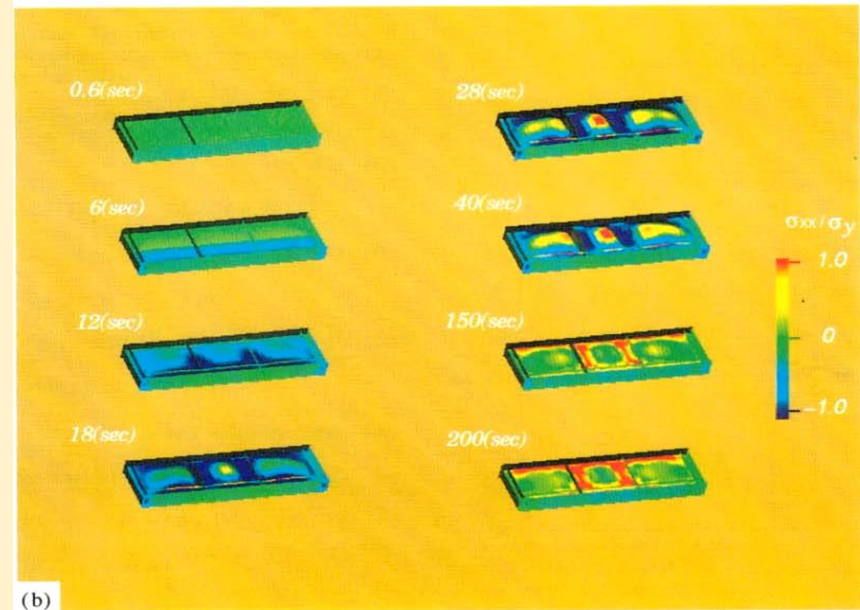
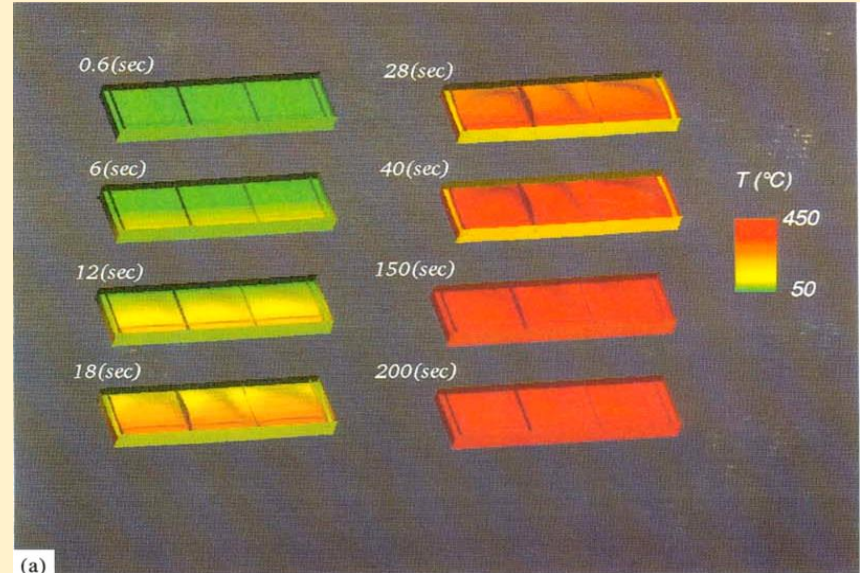
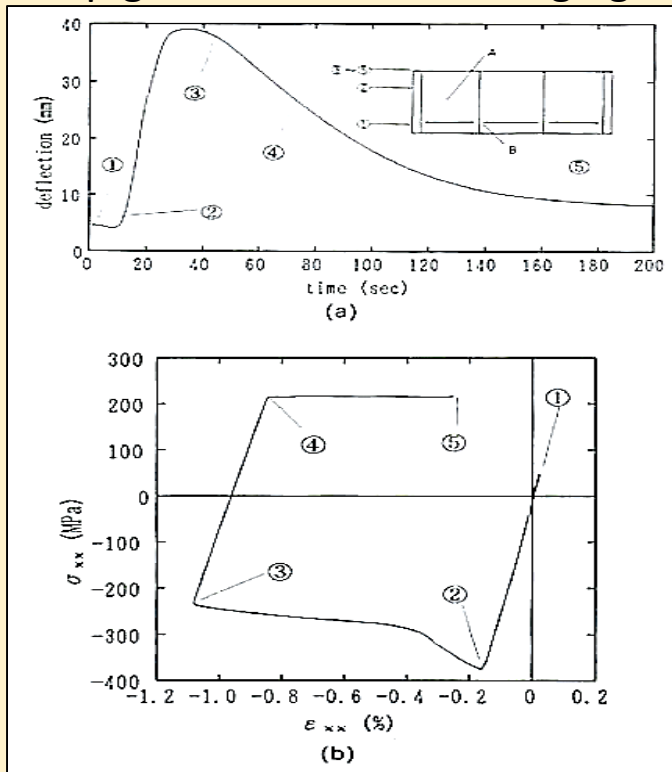
Deformed configuration and plastic hinges (load factor=2.46)



Blast demolition analysis



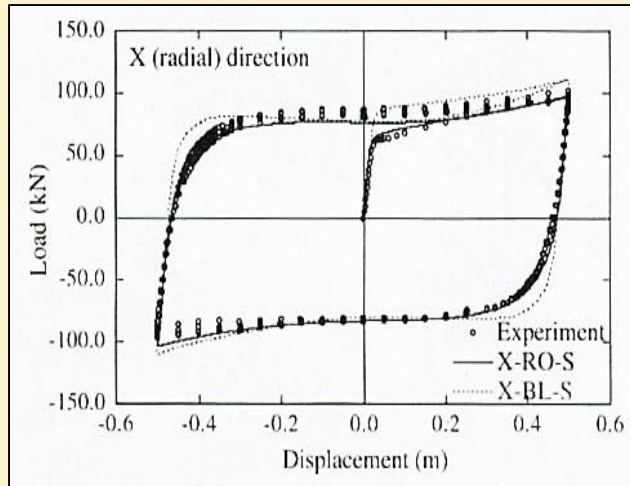
Hot-dip galvanization of a bridge girder



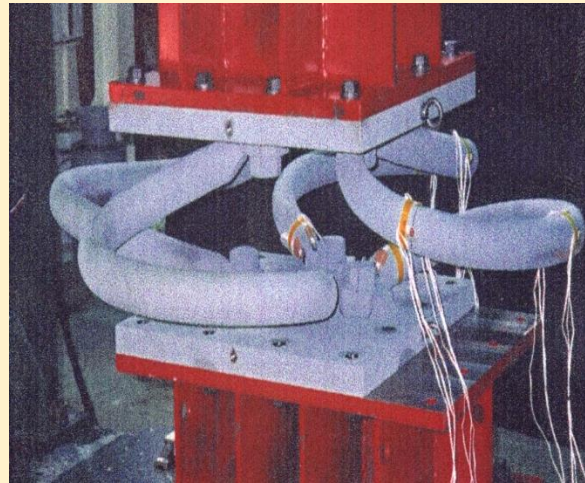
(a) Time history of lateral deformation (point A)  
 (b) Stress-strain curve (point B)

(a) Temperature distribution and deformation  
 (b) Stress distribution and deformation

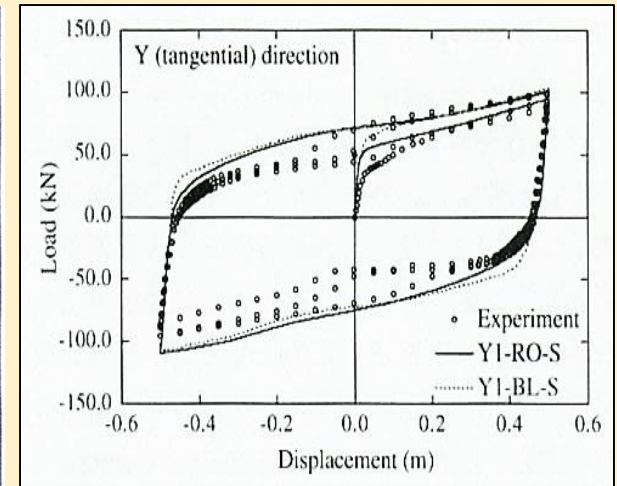
# 繰返し荷重を受ける免震鋼棒ダンパーの大変形弾塑性解析 [19.宮村・都井・土師1998]



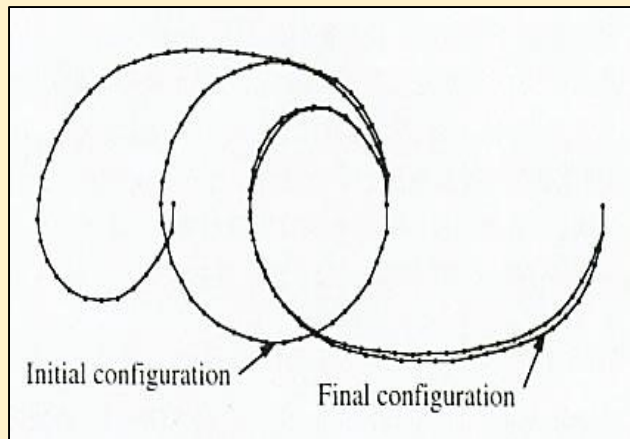
Load versus displacement loaded in X direction



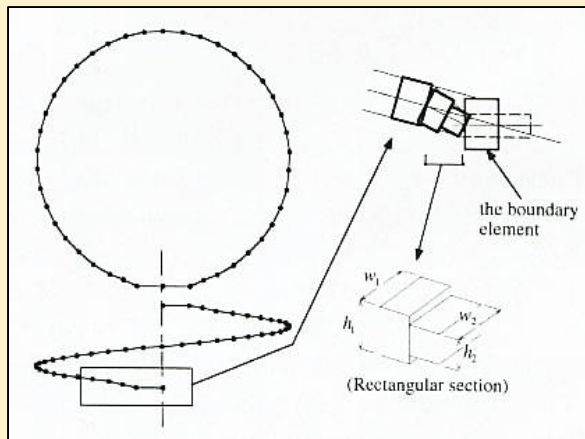
Overview of a steel damper



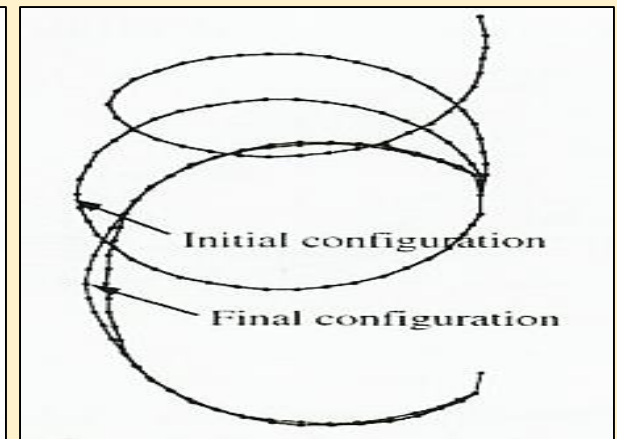
Load versus displacement loaded in Y1 direction



Deformed configuration loaded in X direction

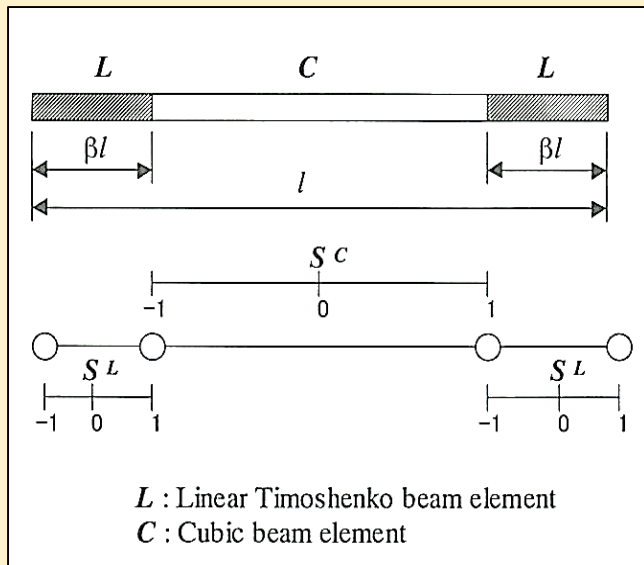


Subdivision of analysis model

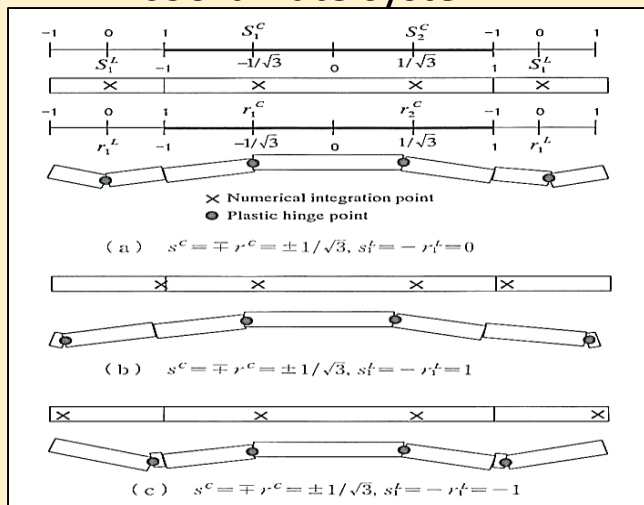


Deformed configuration loaded in Y1 direction

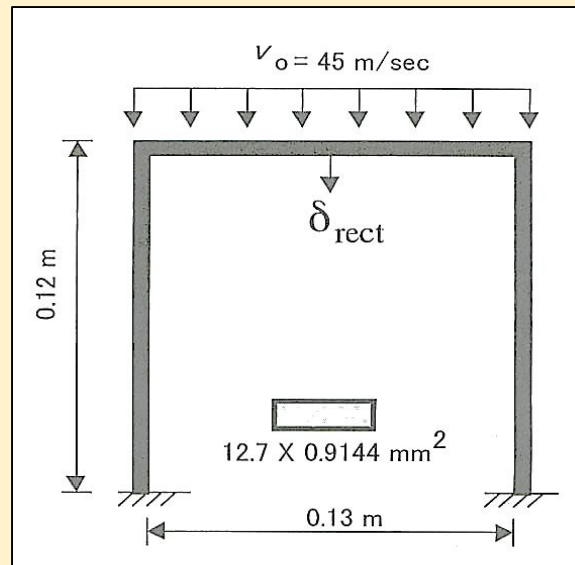
# ASI法による骨組構造体の有限要素クラッシュ解析 [20.都井・李廷権1999]



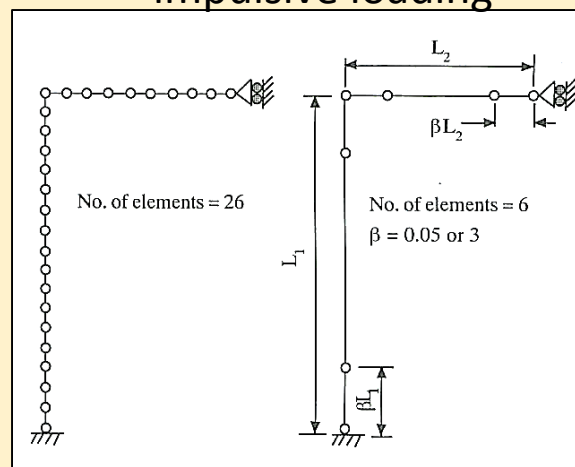
LCL model and nondimensional coordinate system



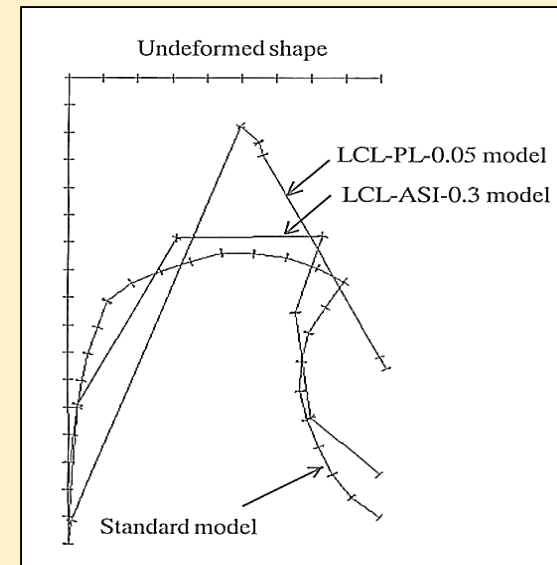
Relation between locations of integration points and plastic hinges



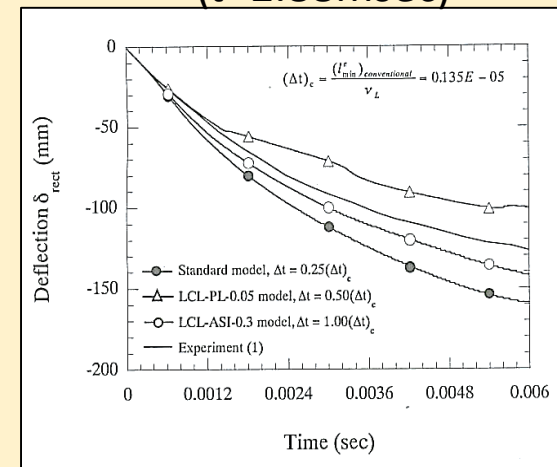
Schematic diagram of a rectangular frame under uniformly distributed impulsive loading



Mesh of conventional method and LCL model for a rectangular frame



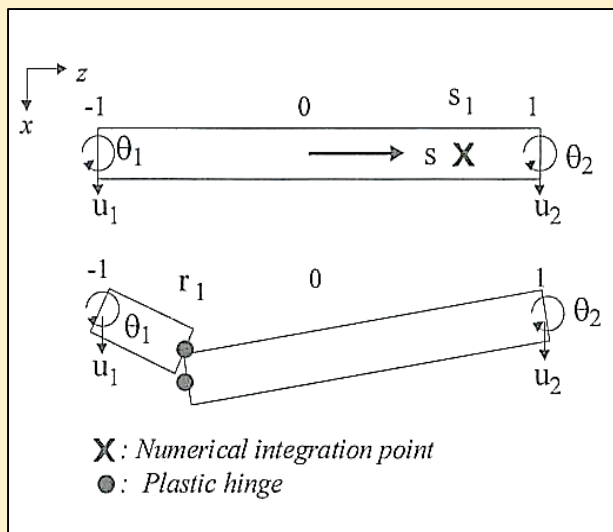
Deformed shapes of a rectangular frame ( $t=2.88\text{msec}$ )



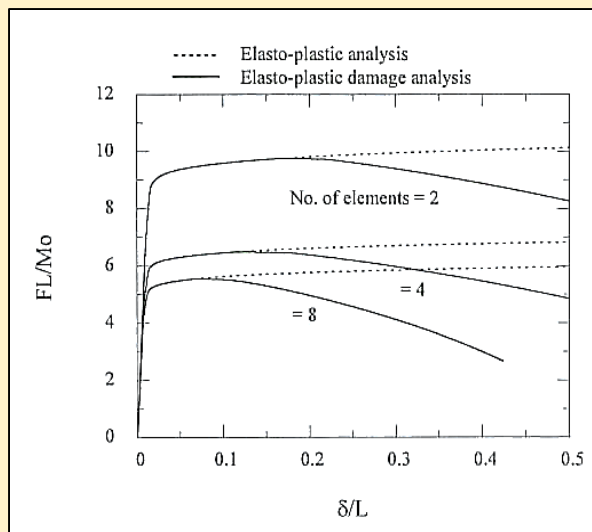
Time history of deflection of a rectangular frame



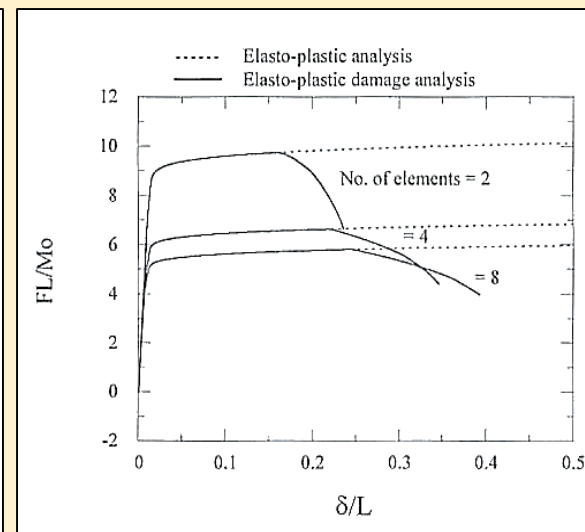
# 要素寸法に依存しない骨組構造体の弾塑性損傷解析 [21.都井・李廷権・井奥2001]



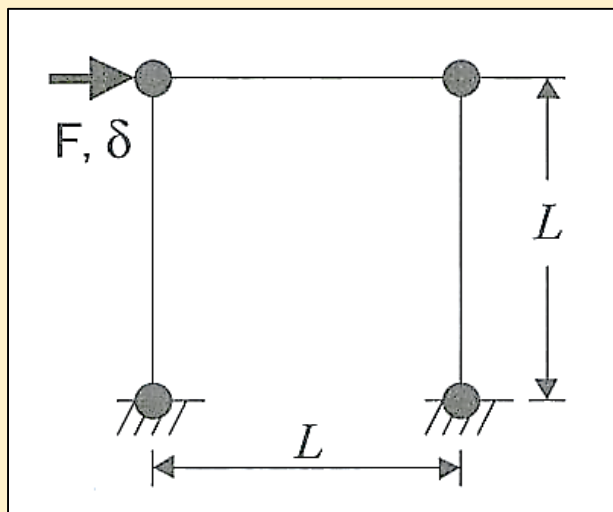
Relations between locations of integration points and plastic hinges



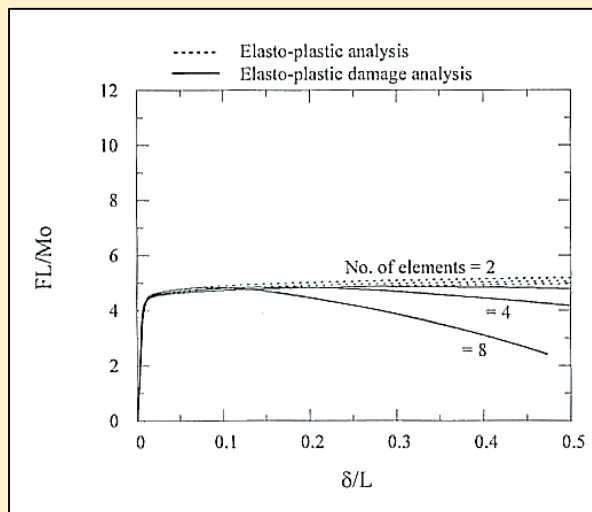
Load-deflection curves by the conventional method with damage parameter  $\rho$



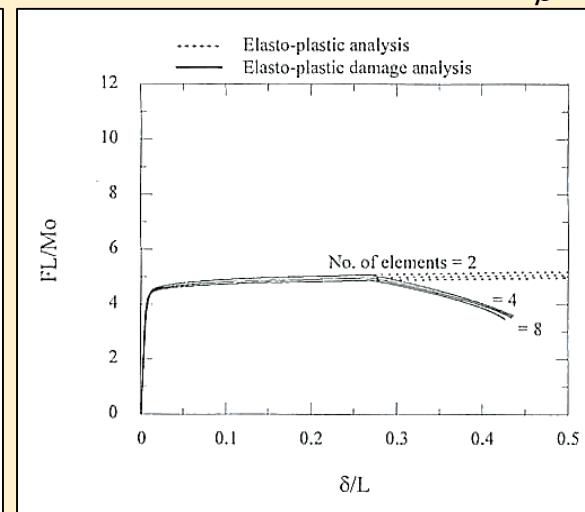
Load-deflection curves by the conventional method with damage parameter  $\vartheta_\rho$



Portal frame under lateral loading



Load-deflection curves by the ASI technique with damage parameter  $\rho$

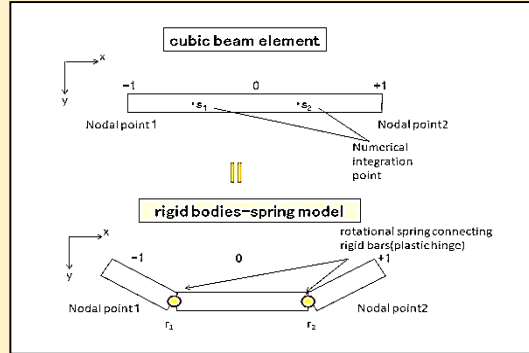


Load-deflection curves by the ASI technique with damage parameter  $\vartheta_\rho$

# マクロ損傷を考慮した骨組構造のメッシュ非依存弾塑性損傷解析 [22.村上・都井2014, 23.都井・長谷川2011]



Framed structure  
(Tokyo Big Sight)



$$s_i = \mp \frac{1}{3r_2} \quad (i = 1, 2; r_1 = -r_2)$$

Adaptively Shifted  
Integration Technique  
(concept)

