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Esercizi di
Scienza delle Costruzioni
svolti con l'utilizzo di Sap2000®
(Versione 8)

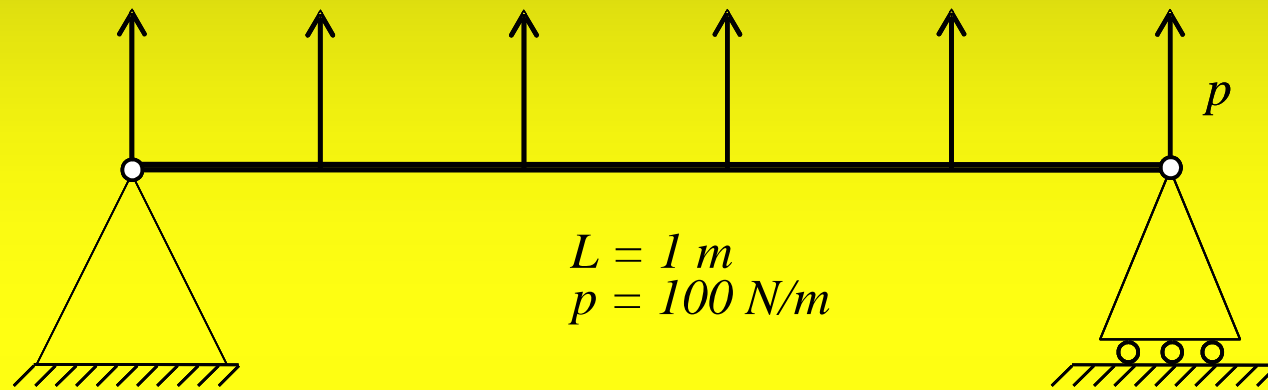


Figura 1.1: Ideogramma del modello.

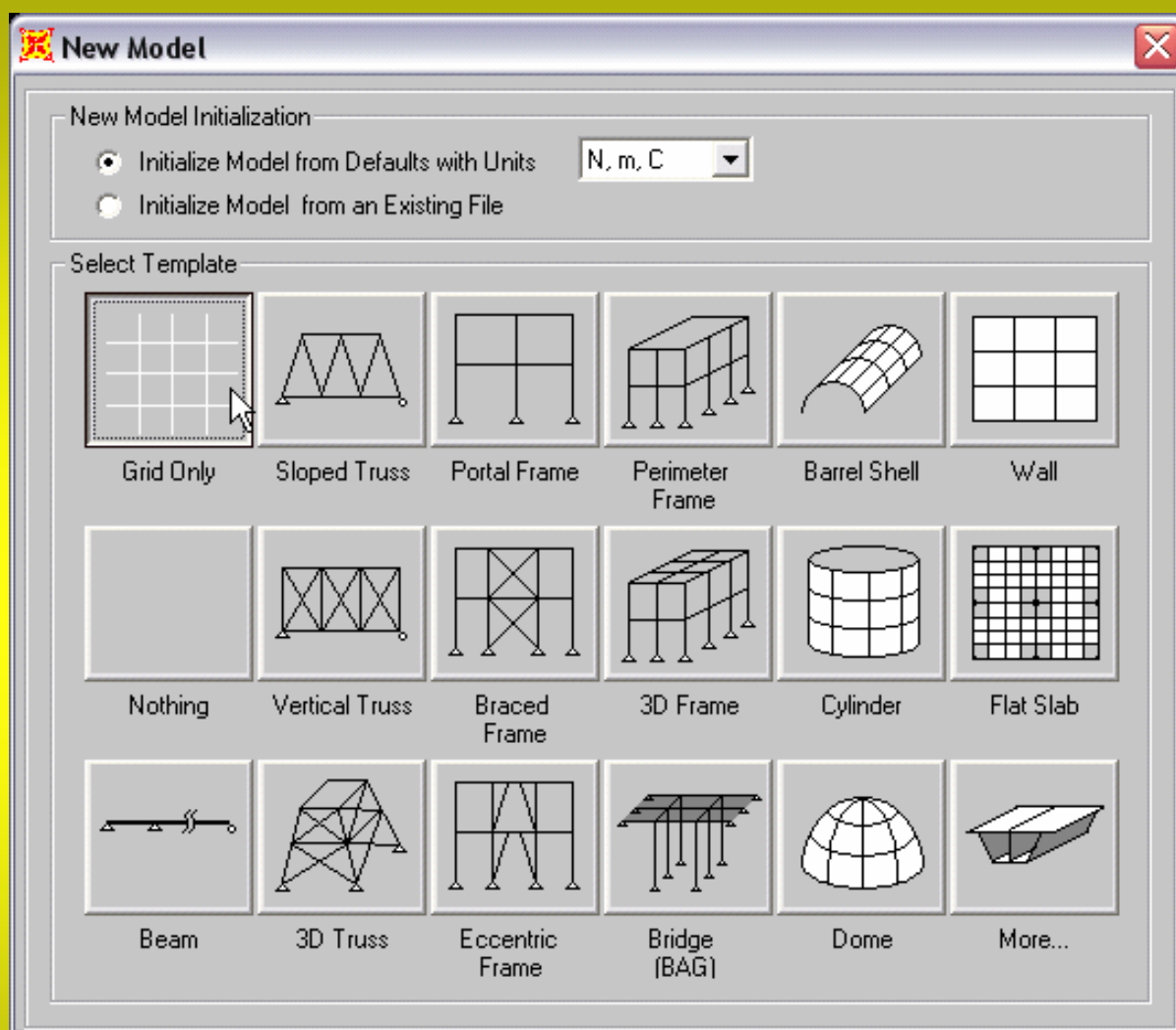


Figura 1.2: Templates predefiniti.

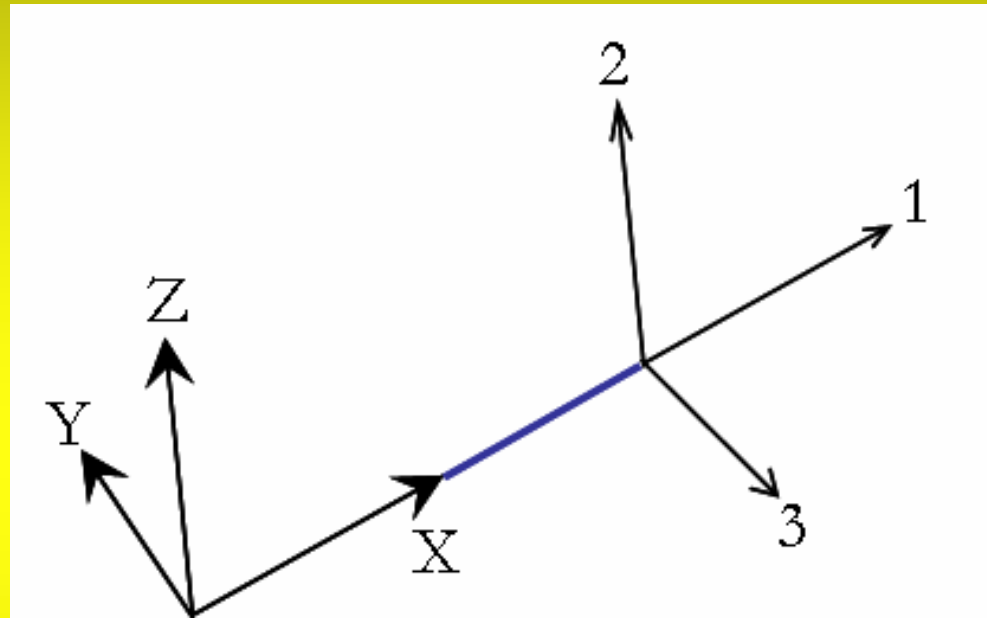


Figura 1.3: Sistemi di riferimento globale e locale per un **Frame**.

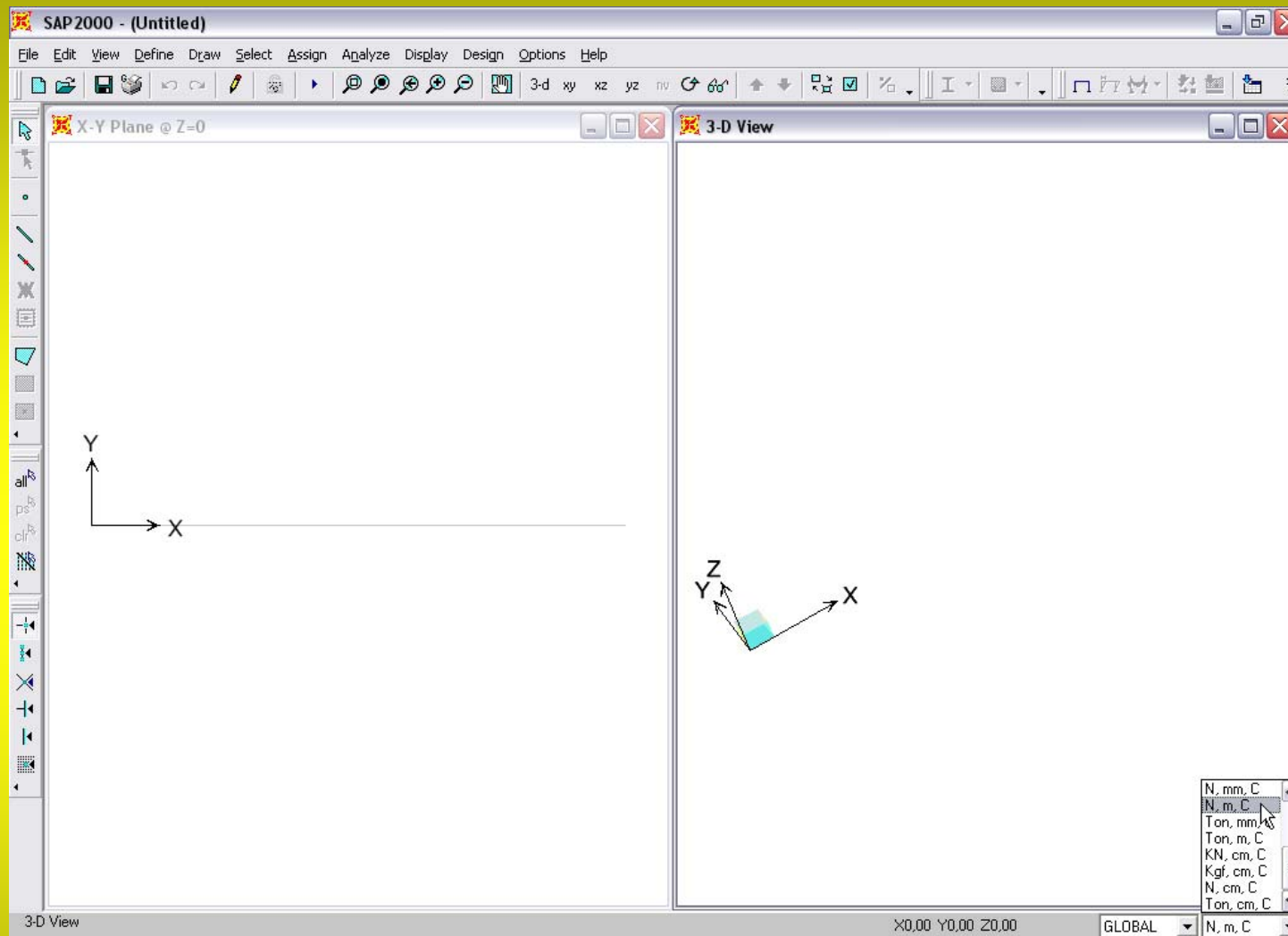


Figura 1.4: Scelta dell'unità di misura.

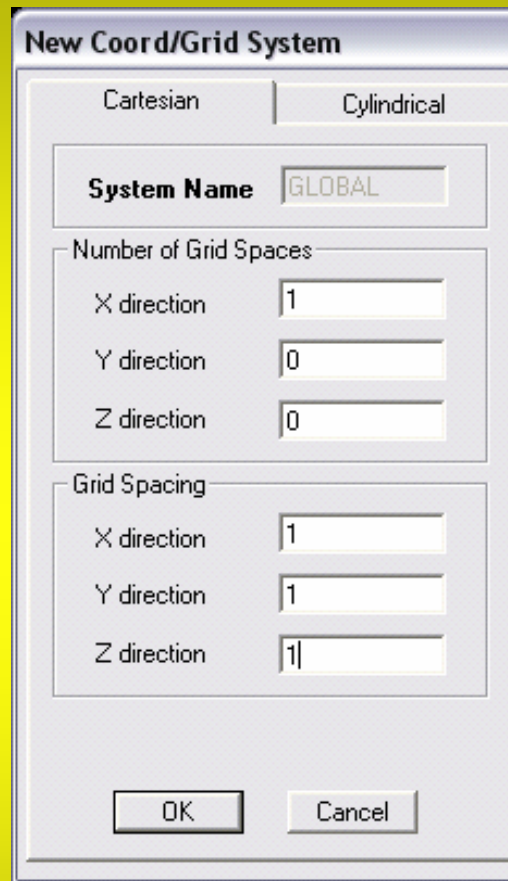


Figura 1.5: Specifica delle **Grid Lines**.

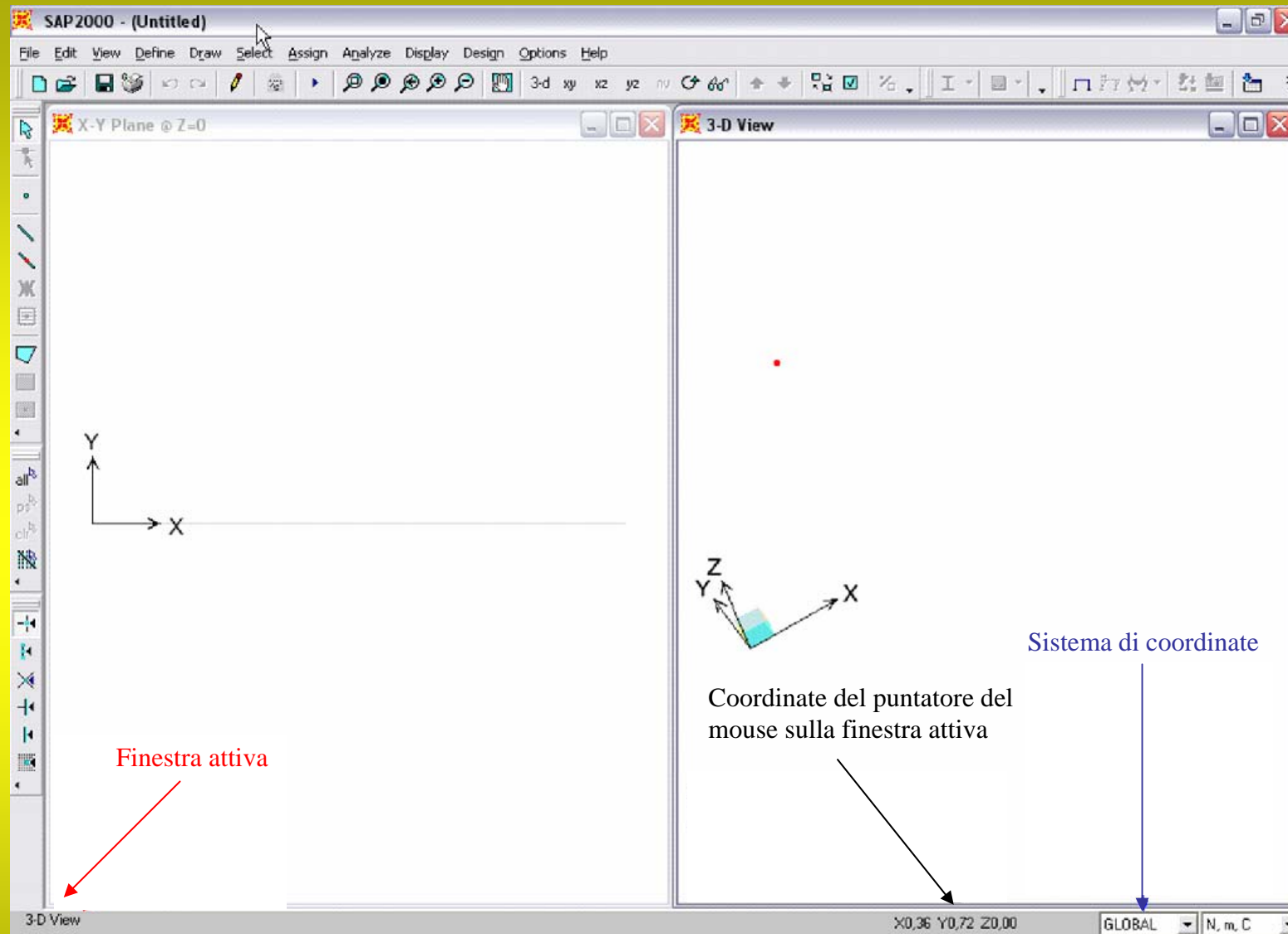


Figura 1.6: Finestre di lavoro.

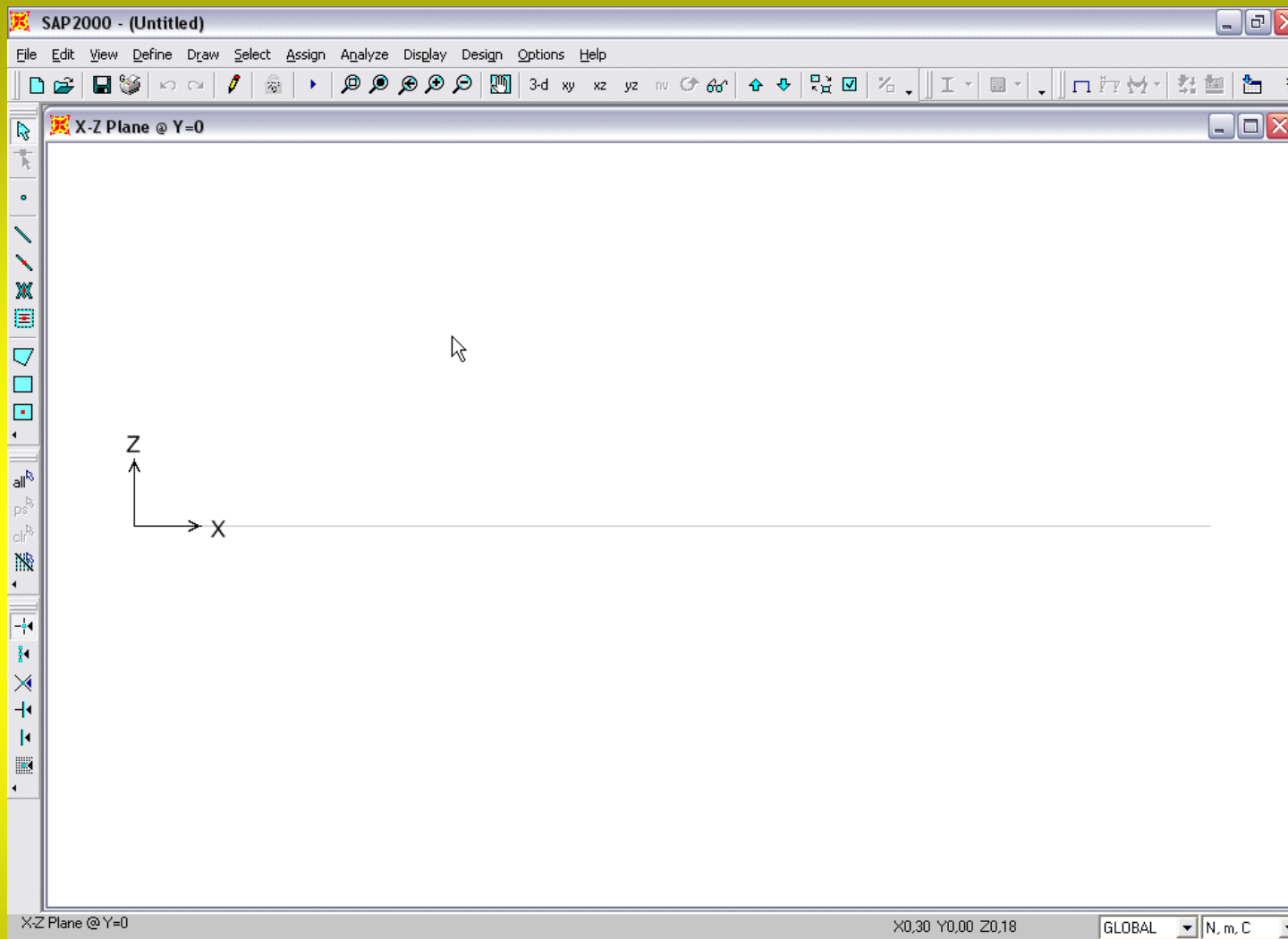


Figura 1.7: Piano X-Z.

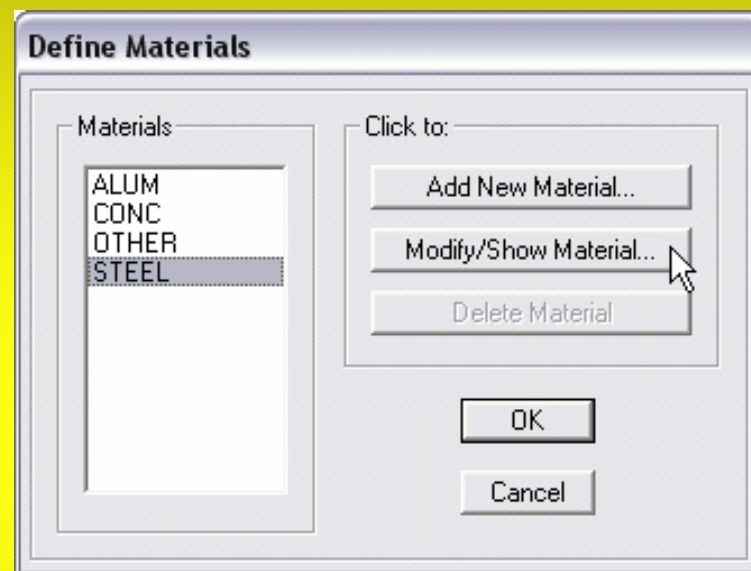
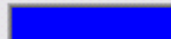


Figura 1.8: Definizione del materiale.

Material Property Data

Material Name	STEEL	Display Color	
Type of Material	<input checked="" type="radio"/> Isotropic <input type="radio"/> Orthotropic <input type="radio"/> Anisotropic	Type of Design	Design: Steel
Analysis Property Data		Design Property Data	
Mass per unit Volume	7849,0474	Minimum Yield Stress, Fy	2,482E+08
Weight per unit Volume	76972,86	Minimum Tensile Stress, Fu	3,999E+08
Modulus of Elasticity	1,999E+11		
Poisson's Ratio	0,3		
Coeff of Thermal Expansion	1,170E-05		
Shear Modulus	7,688E+10		

Material Damping - Advanced...

OK Cancel

Figura 1.9: Proprietà del materiale.

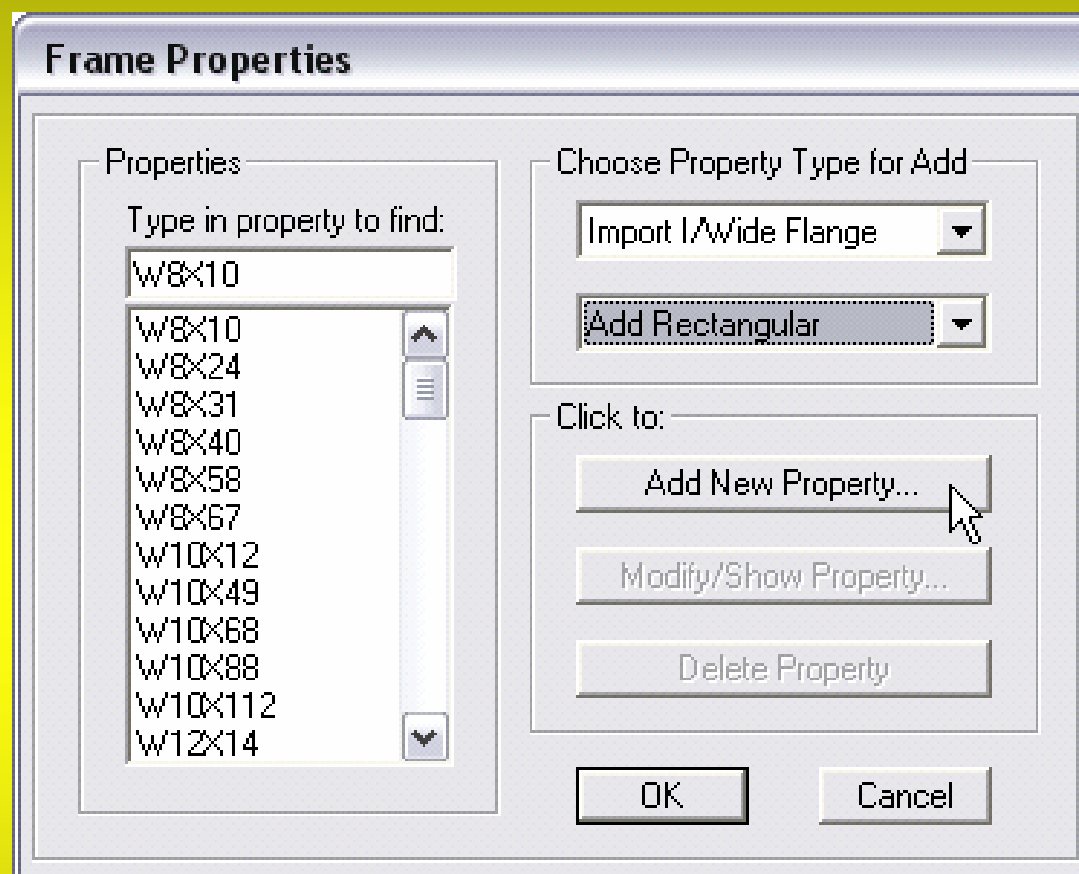


Figura 1.10: Proprietà del **Frame**.

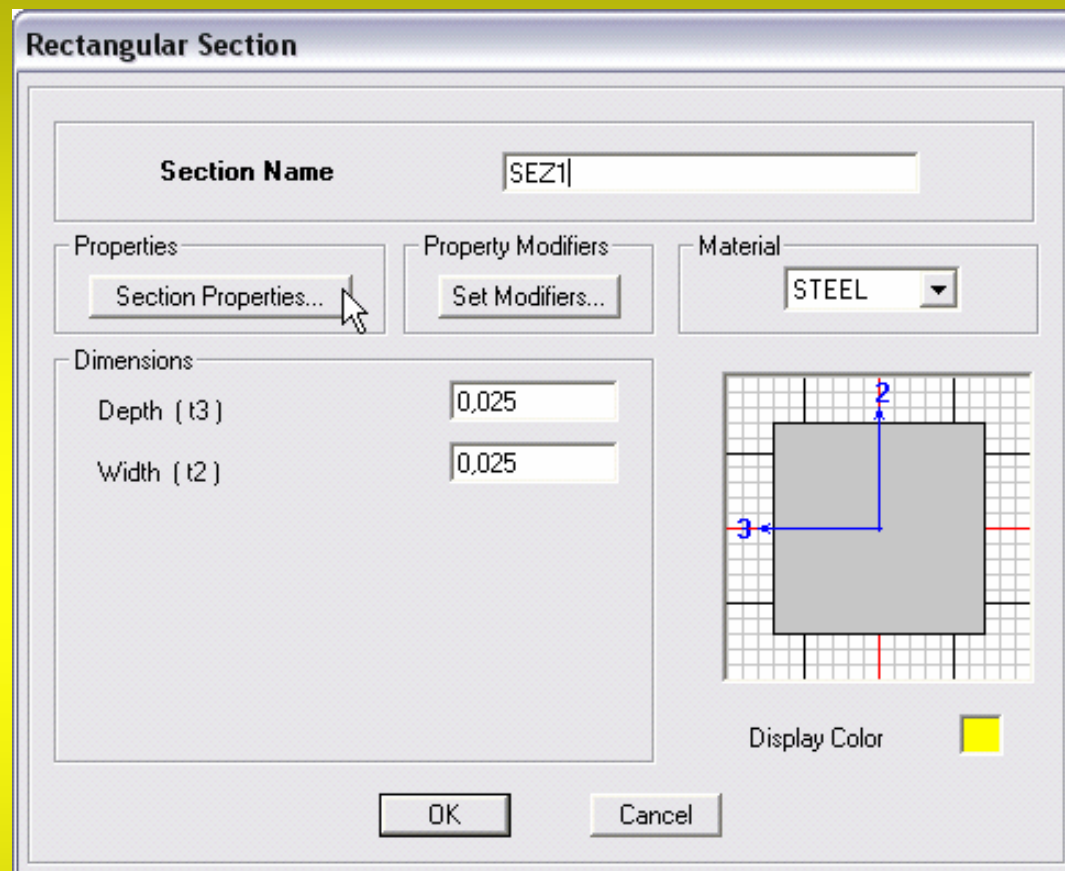


Figura 1.11: Specifica di una sezione rettangolare.

Property Data

Section Name

Properties

Cross-section (axial) area	<input type="text" value="6,250E-04"/>	Section modulus about 3 axis	<input type="text" value="2,604E-06"/>
Torsional constant	<input type="text" value="5,501E-08"/>	Section modulus about 2 axis	<input type="text" value="2,604E-06"/>
Moment of Inertia about 3 axis	<input type="text" value="3,255E-08"/>	Plastic modulus about 3 axis	<input type="text" value="3,906E-06"/>
Moment of Inertia about 2 axis	<input type="text" value="3,255E-08"/>	Plastic modulus about 2 axis	<input type="text" value="3,906E-06"/>
Shear area in 2 direction	<input type="text" value="5,208E-04"/>	Radius of Gyration about 3 axis	<input type="text" value="7,217E-03"/>
Shear area in 3 direction	<input type="text" value="5,208E-04"/>	Radius of Gyration about 2 axis	<input type="text" value="7,217E-03"/>

Figura 1.12: Proprietà geometriche della sezione rettangolare.

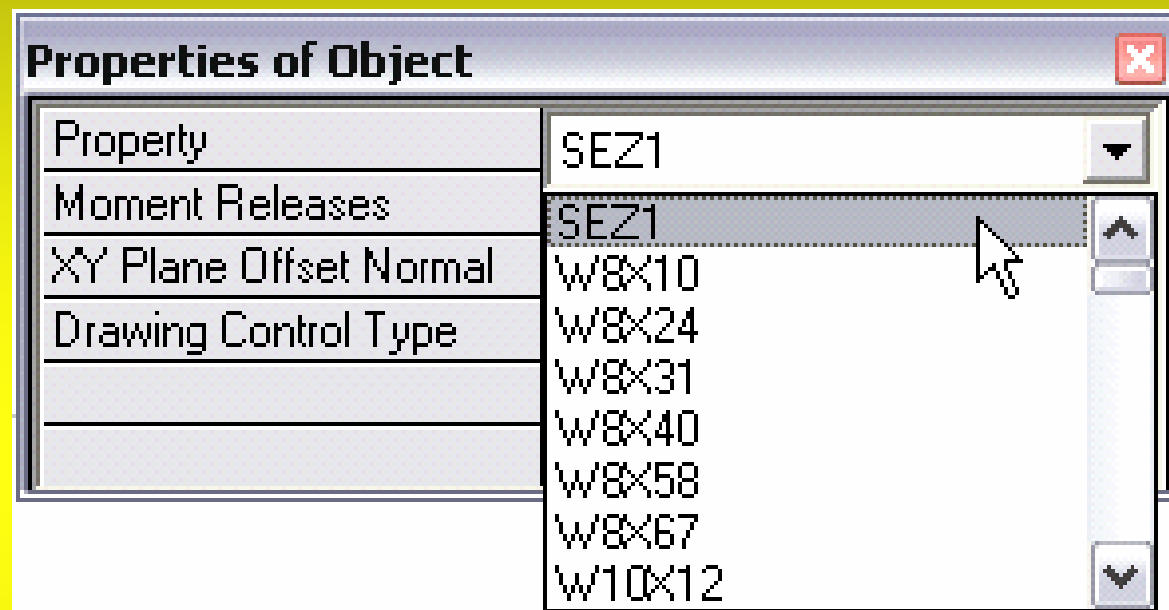


Figura 1.13: Proprietà dell'oggetto (nel caso di un **Frame**).

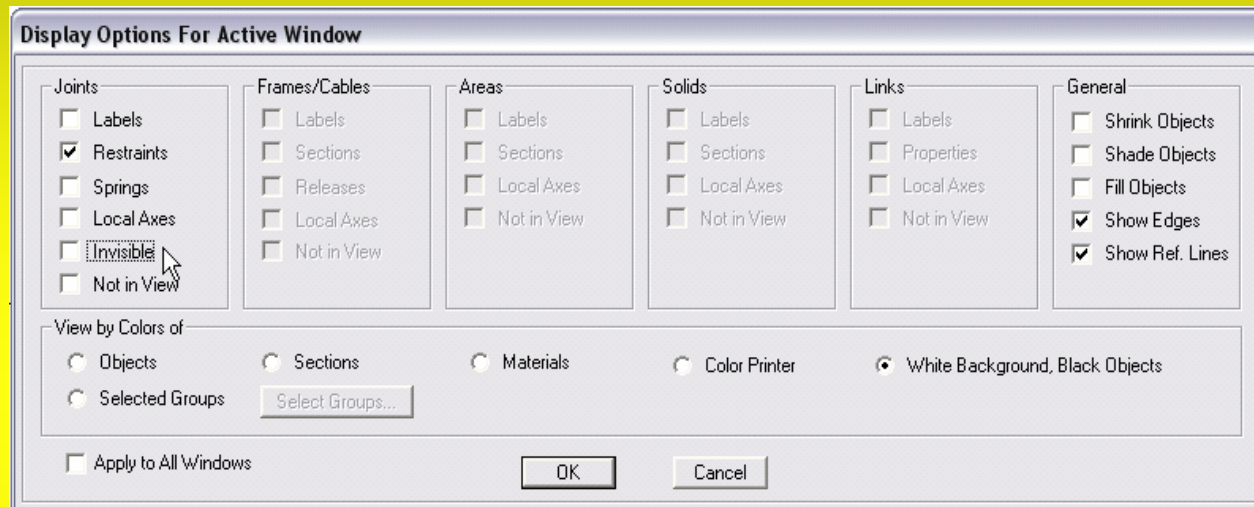


Figura 1.14: Opzioni di visualizzazione per gli oggetti nella finestra attiva.

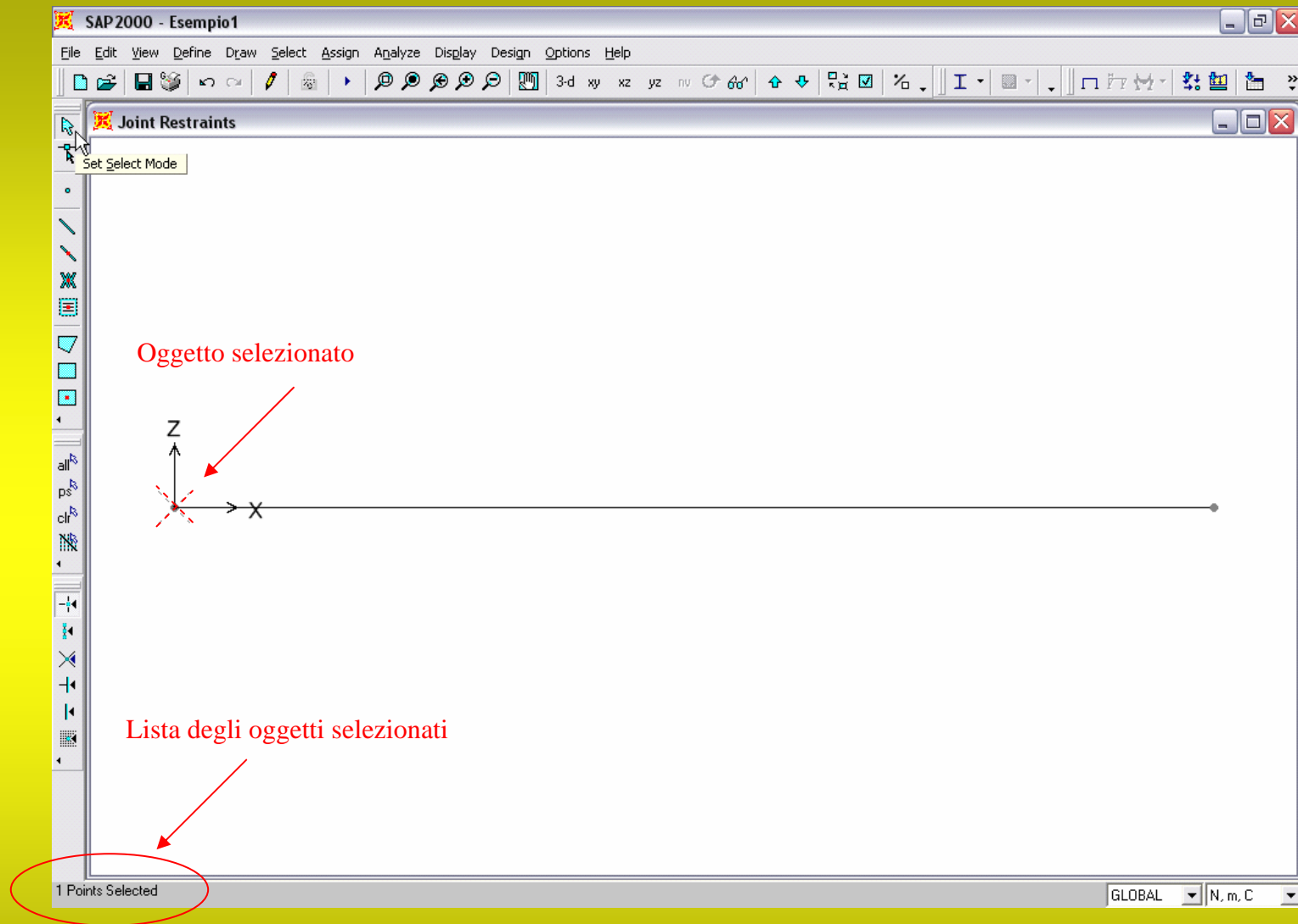


Figura 1.15: Selezione di un oggetto.

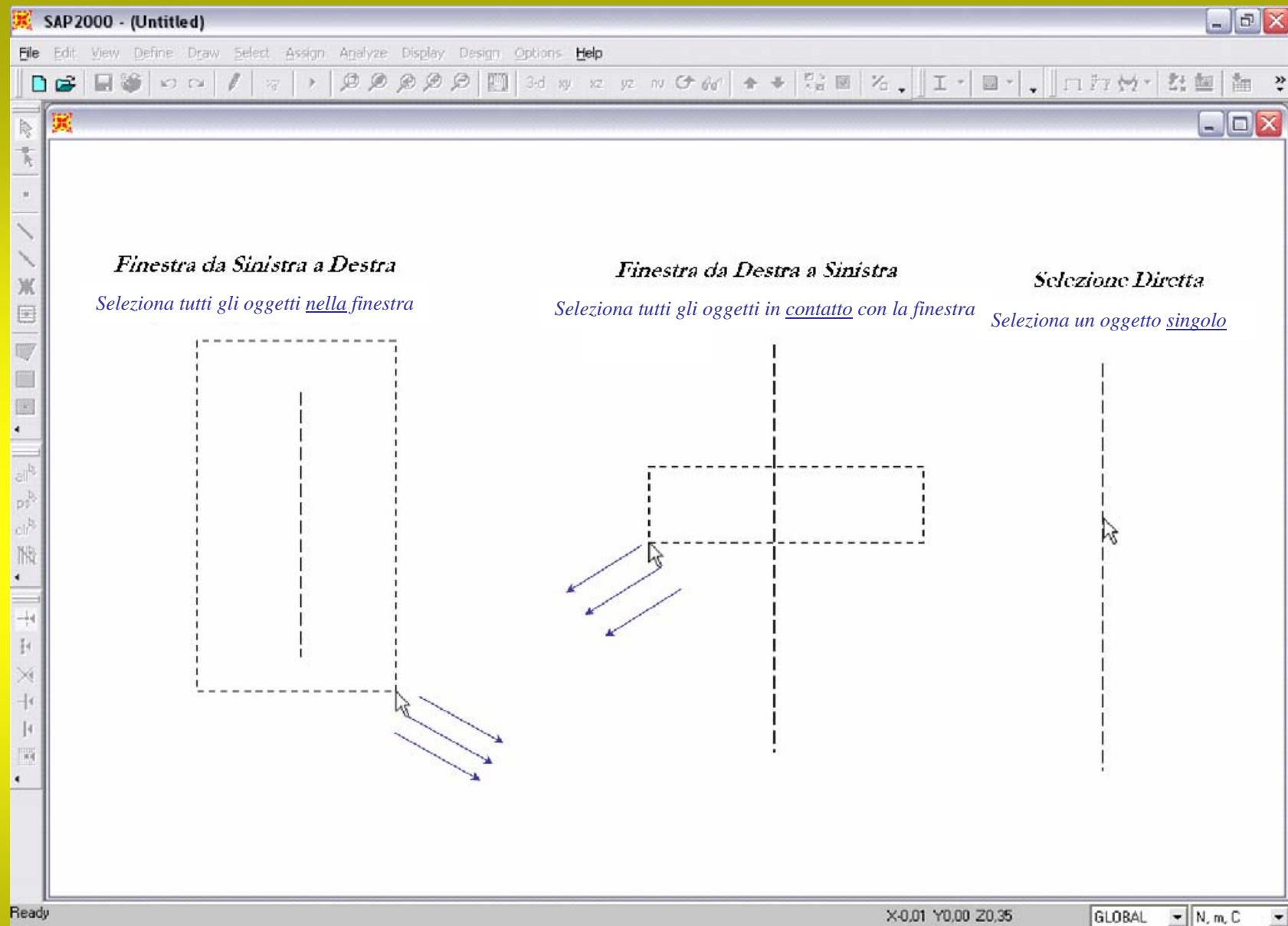


Figura 1.16: Modalità di selezione con il mouse.

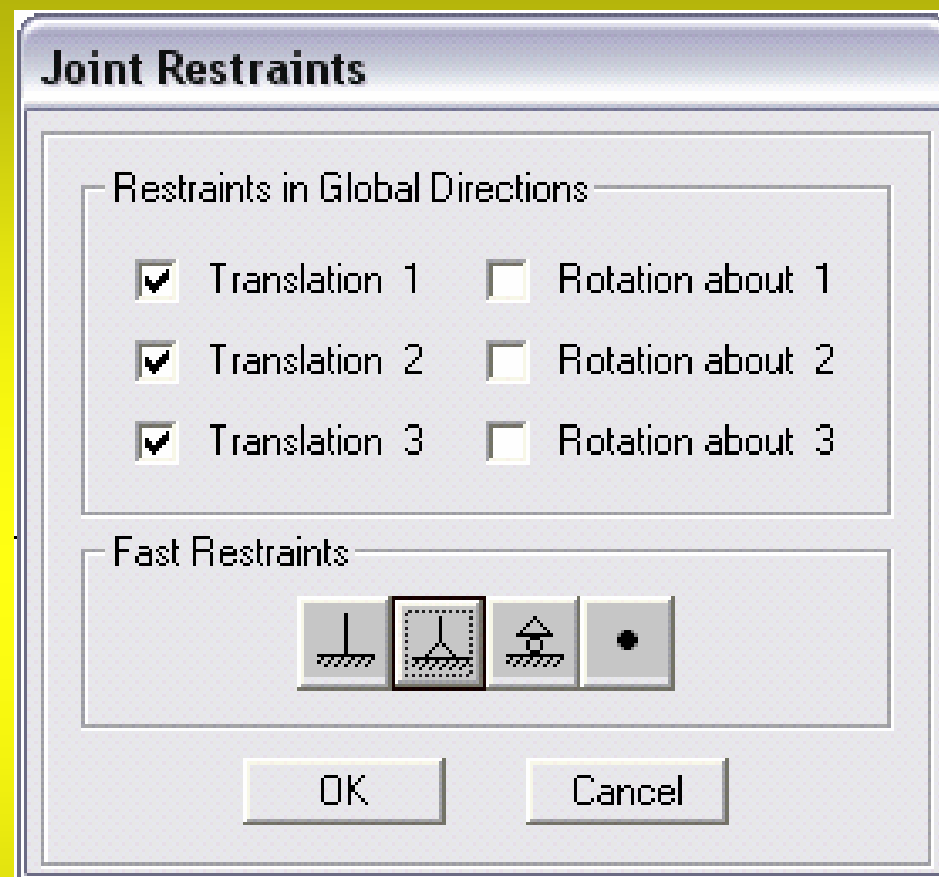


Figura 1.17: Assegnazione di un vincolo esterno.

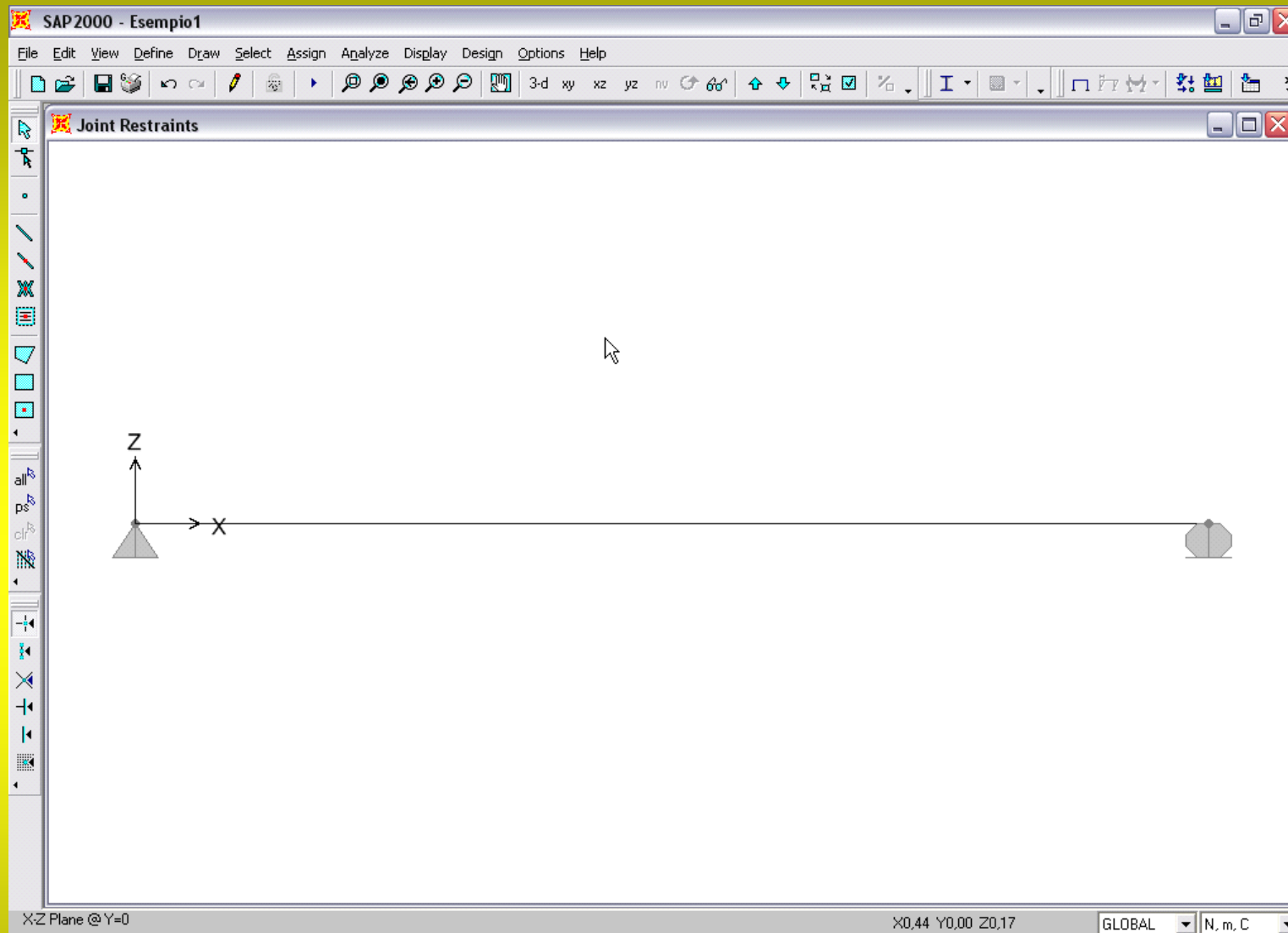


Figura 1.18: Trave vincolata.

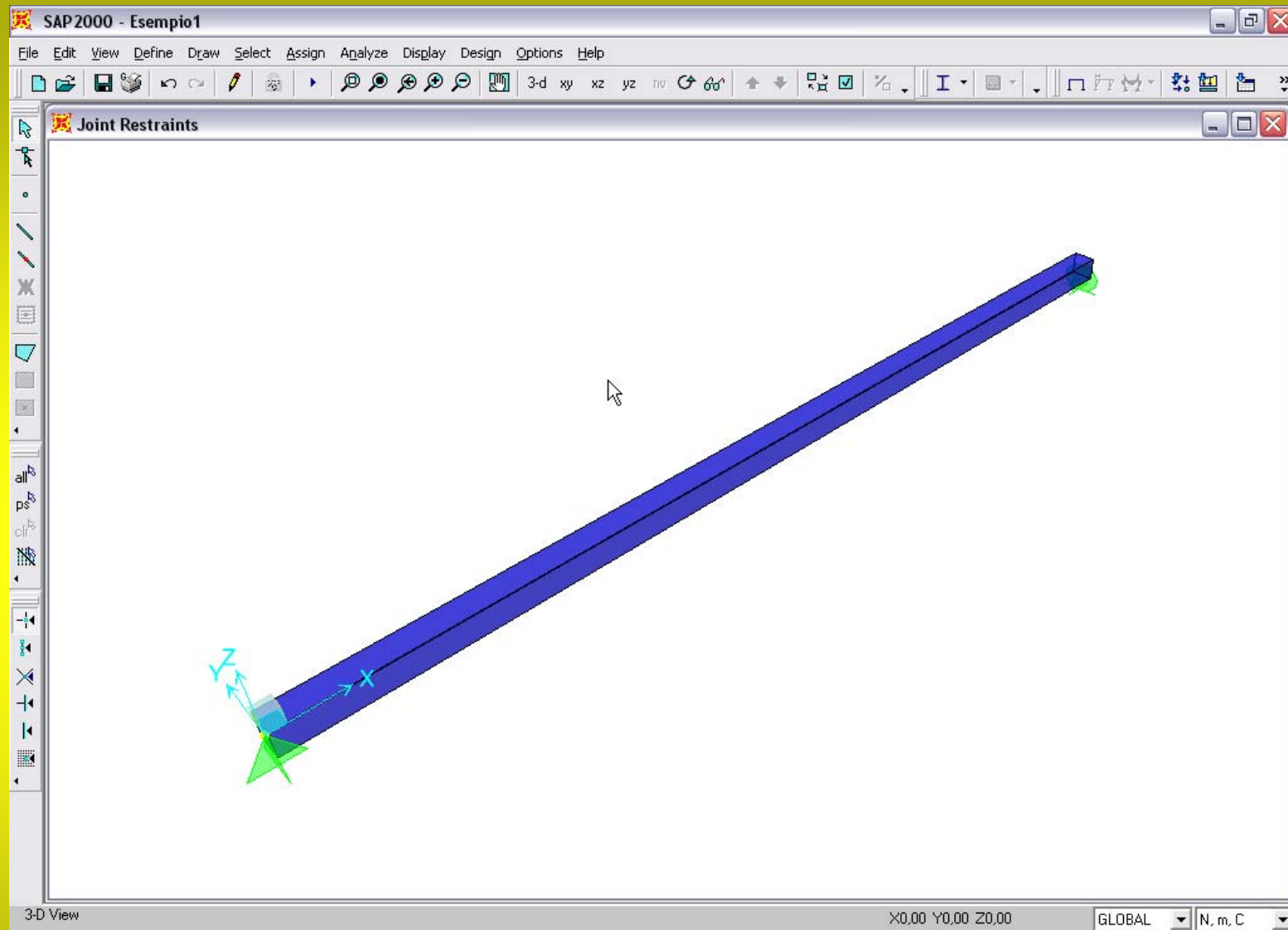


Figura 1.19: Visione in **3D** con sezione in evidenza.

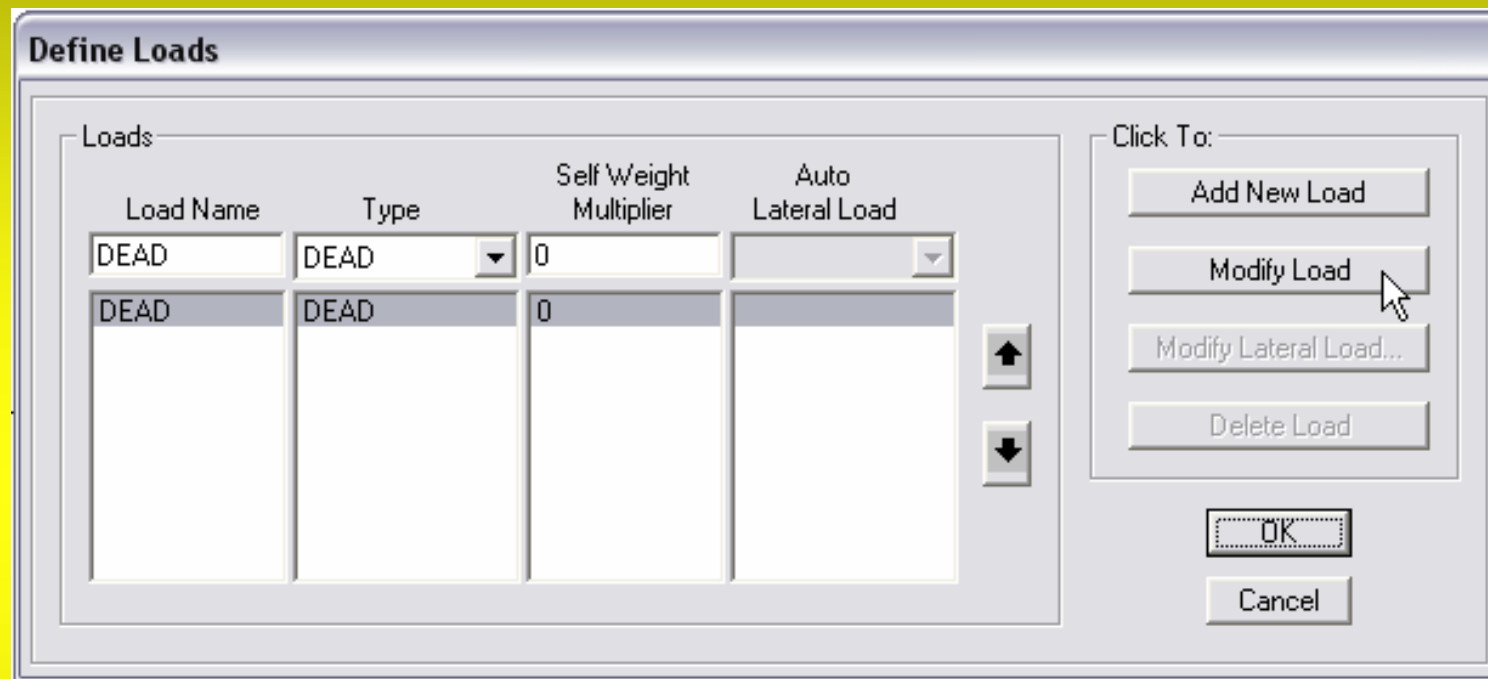


Figura 1.20: Definizione dei tipi di carico.

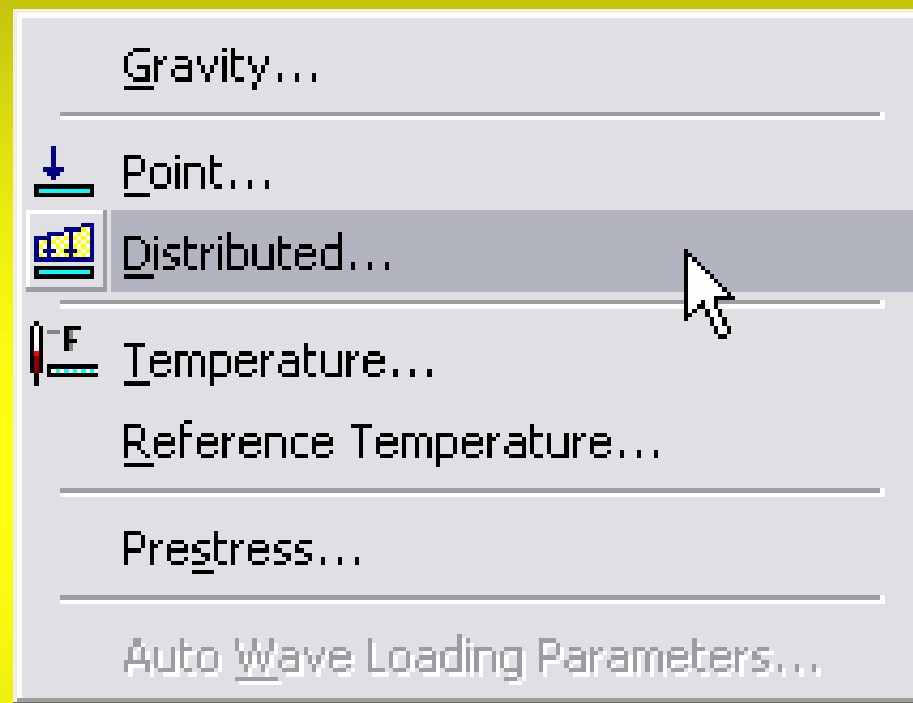


Figura 1.21: Carichi applicabili ad un **Frame**.

Frame Distributed Loads

Load Case Name: DEAD Units: N, m, C

Load Type and Direction:
 Forces Moments
Coord Sys: GLOBAL
Direction: Z

Options:
 Add to Existing Loads
 Replace Existing Loads
 Delete Existing Loads

Trapezoidal Loads

	1.	2.	3.	4.
Distance	0.	0,25	0,75	1.
Load	0.	0.	0.	0.

Relative Distance from End-I Absolute Distance from End-I

Uniform Load
Load: 100

OK Cancel

Figura 1.22: Specifica di un carico a distribuzione uniforme per un **Frame**.

Frame Point Loads

Load Case Name: DEAD Units: N, m, C

Load Type and Direction: Forces Moments
Coord Sys: GLOBAL Direction: Gravity

Options: Add to Existing Loads Replace Existing Loads Delete Existing Loads

Point Loads:

	1.	2.	3.	4.
Distance	0.	0,25	0,75	1.
Load	0.	0.	0.	0.

Relative Distance from End-I Absolute Distance from End-I

OK Cancel

Figura 1.23: Specifica di un carico concentrato per un **Frame**.

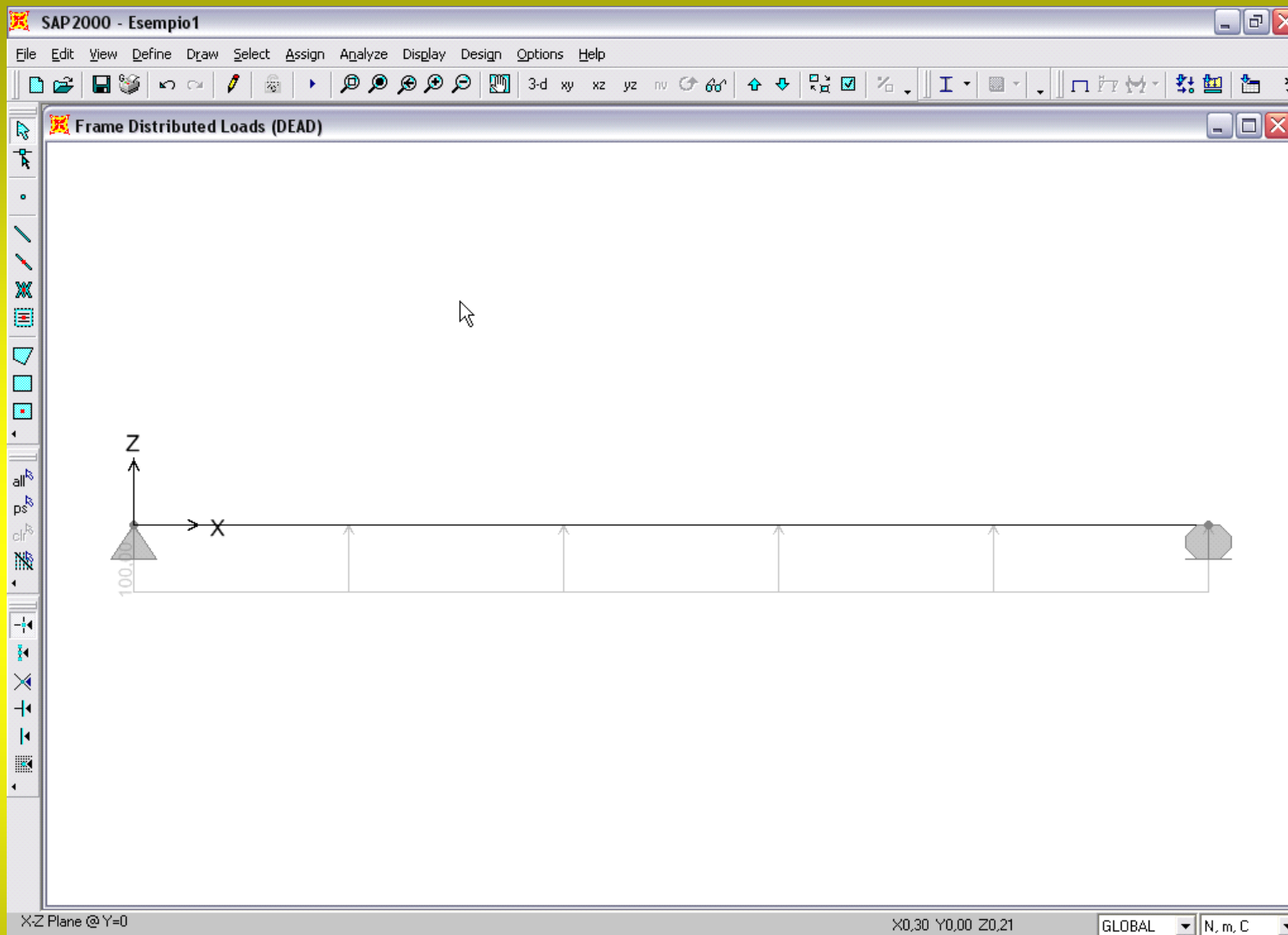


Figura 1.24: Visualizzazione del carico applicato.

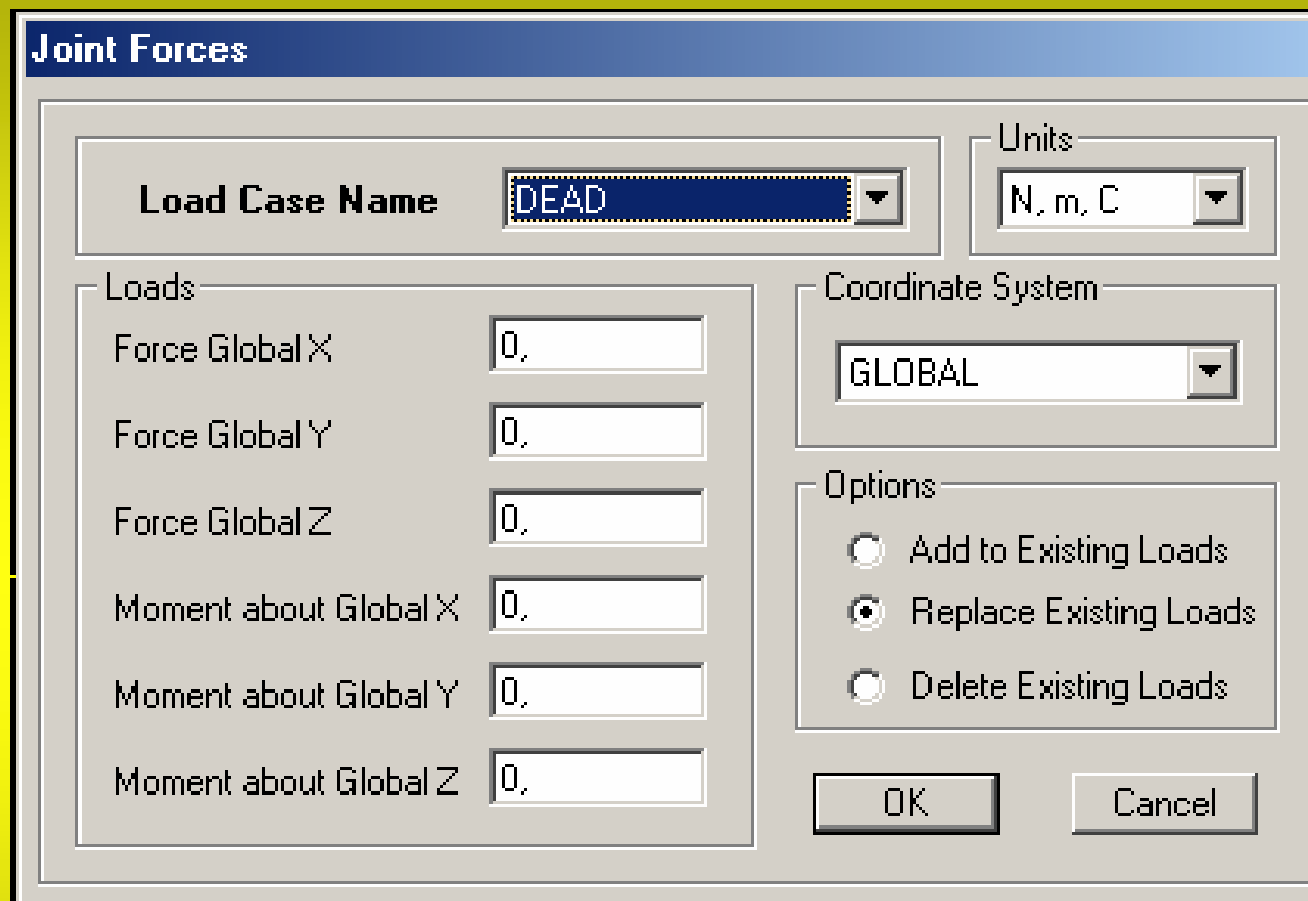


Figura 1.25: Carichi applicati su un **Joint**

Ground Displacements

Load Case Name DEAD **Units** N, m, C

Displacements

Translation Global X	0,
Translation Global Y	0,
Translation Global Z	0,
Rotation about Global X	0,
Rotation about Global Y	0,
Rotation about Global Z	0,

Coordinate System GLOBAL

Options

- Add to Existing Loads
- Replace Existing Loads
- Delete Existing Loads

OK Cancel

Figura 1.26: Spostamenti e rotazioni assegnati ad un **Joint**

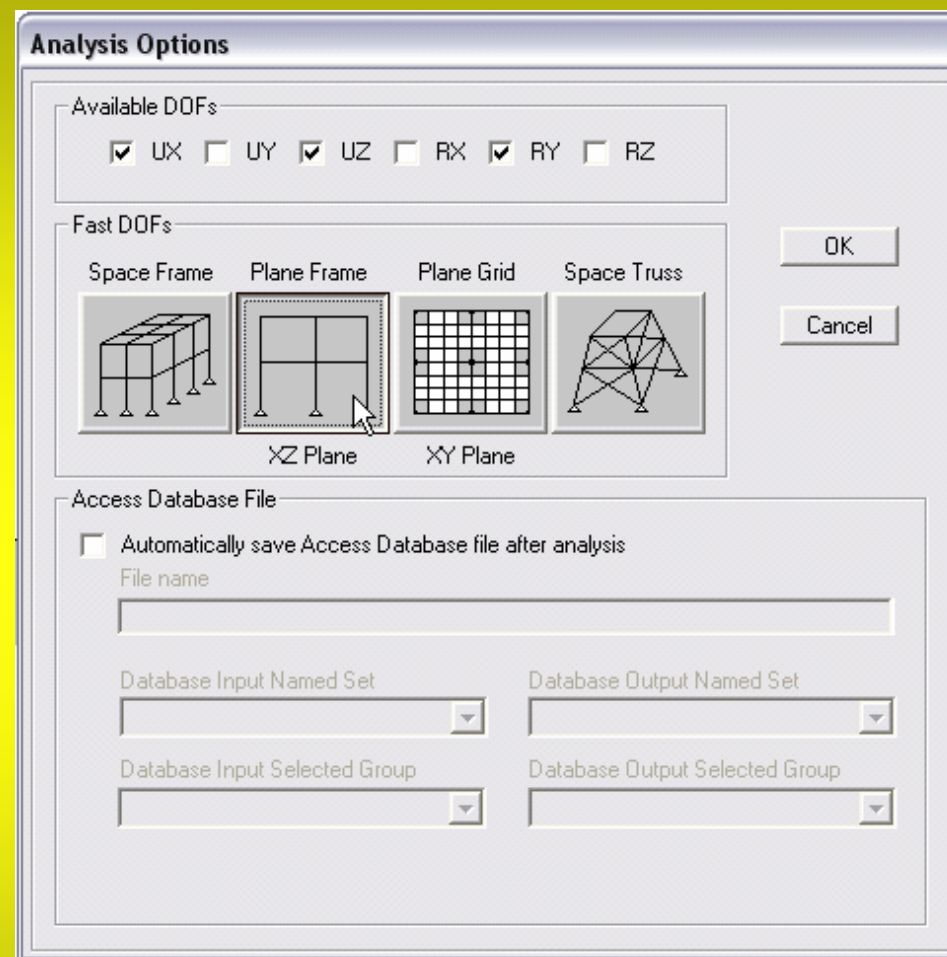


Figura 1.27: Opzioni di analisi.

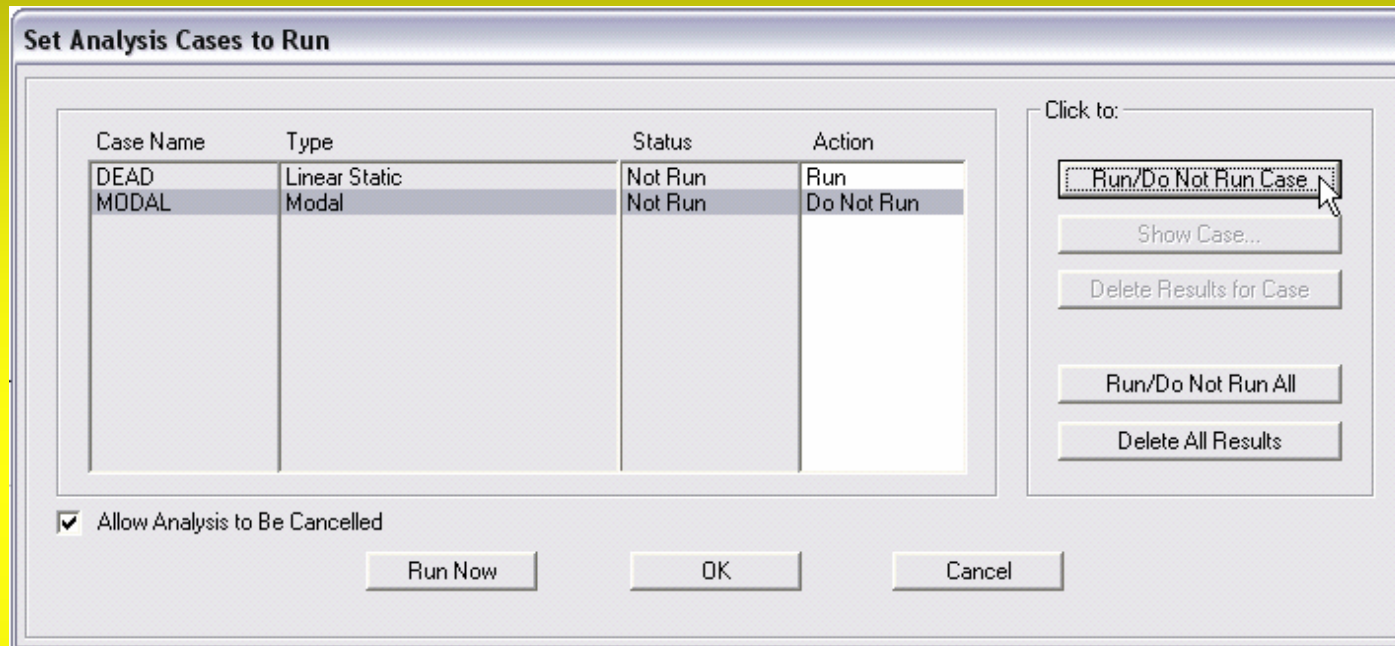


Figura 1.28: Specifica dei tipi di analisi.

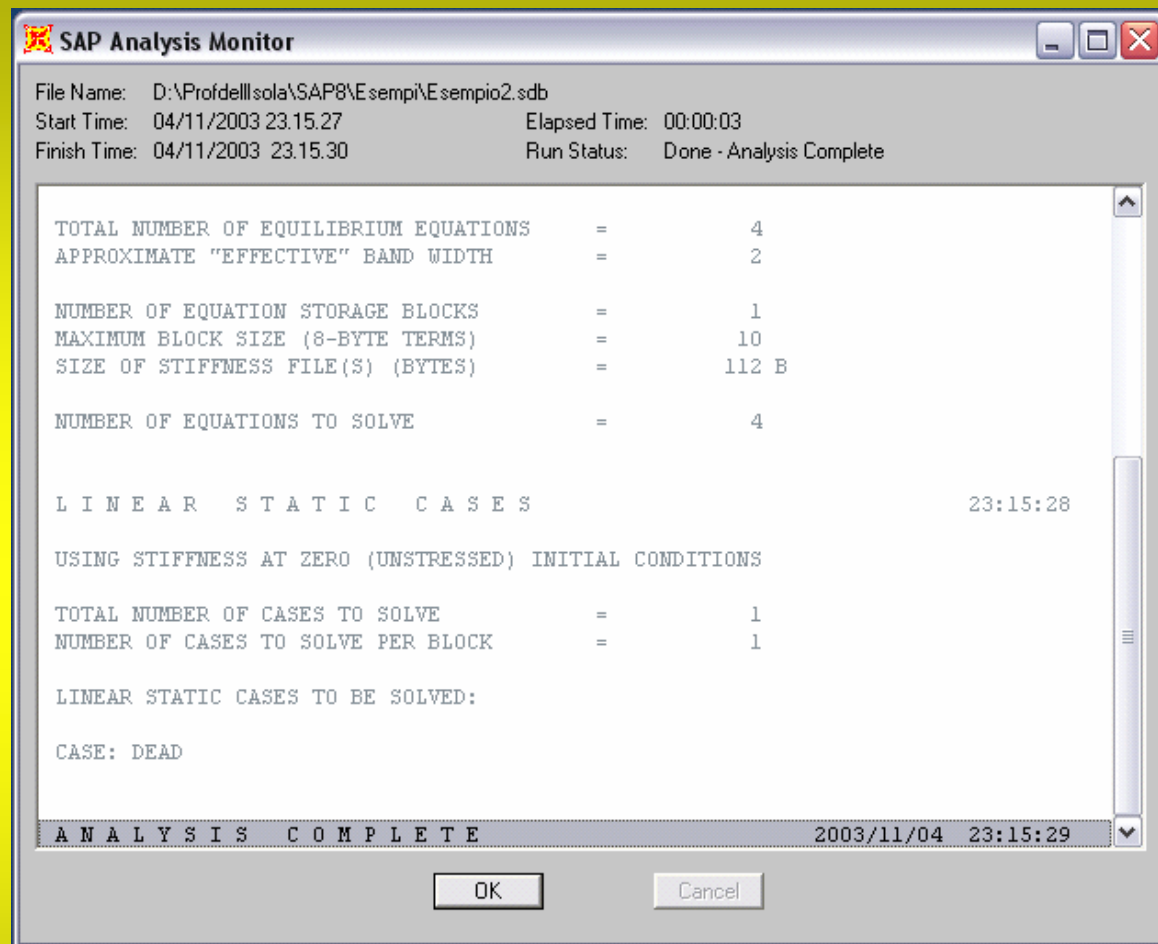


Figura 1.29: Finestra di dialogo ad analisi completata.

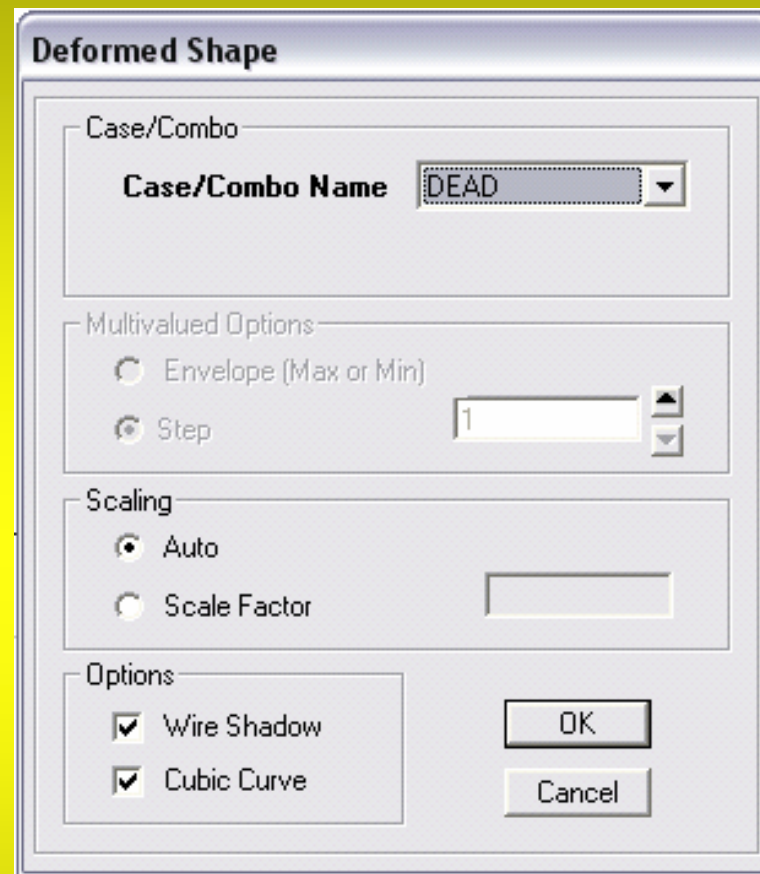


Figura 1.30: Impostazioni per la visualizzazione della deformatata.

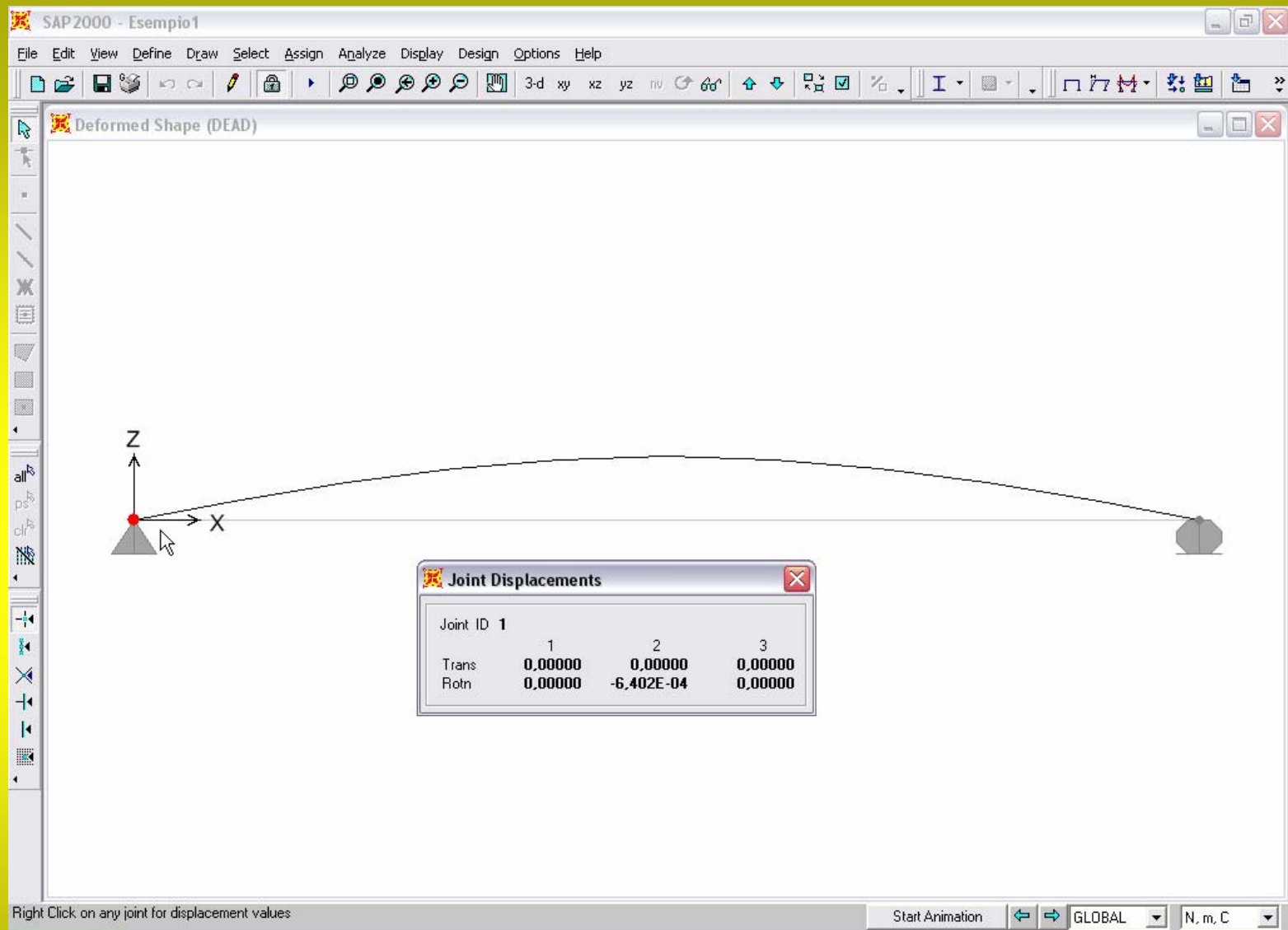


Figura 1.31: Configurazione deformata

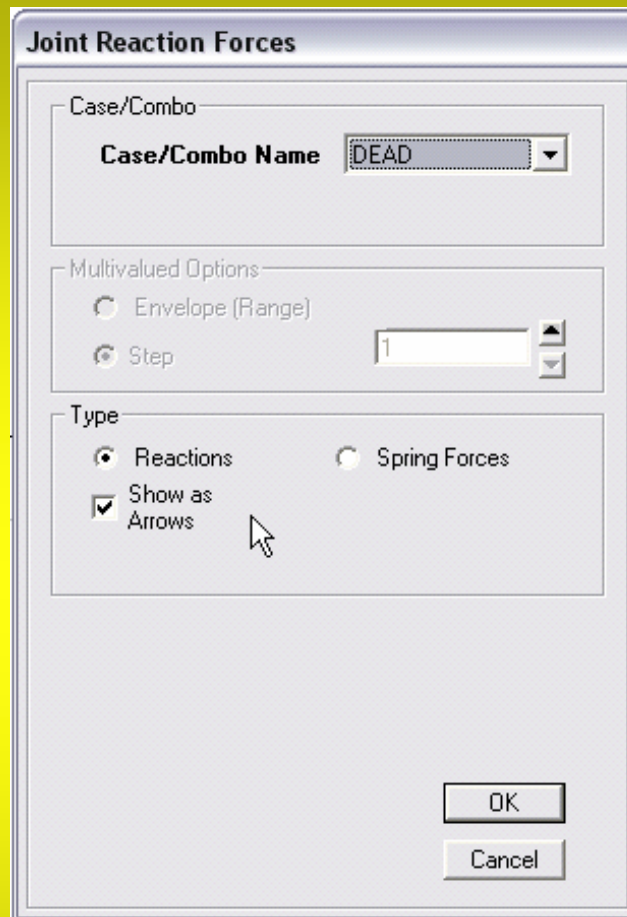


Figura 1.32: Impostazioni per la visualizzazione delle componenti di reazione vincolare.

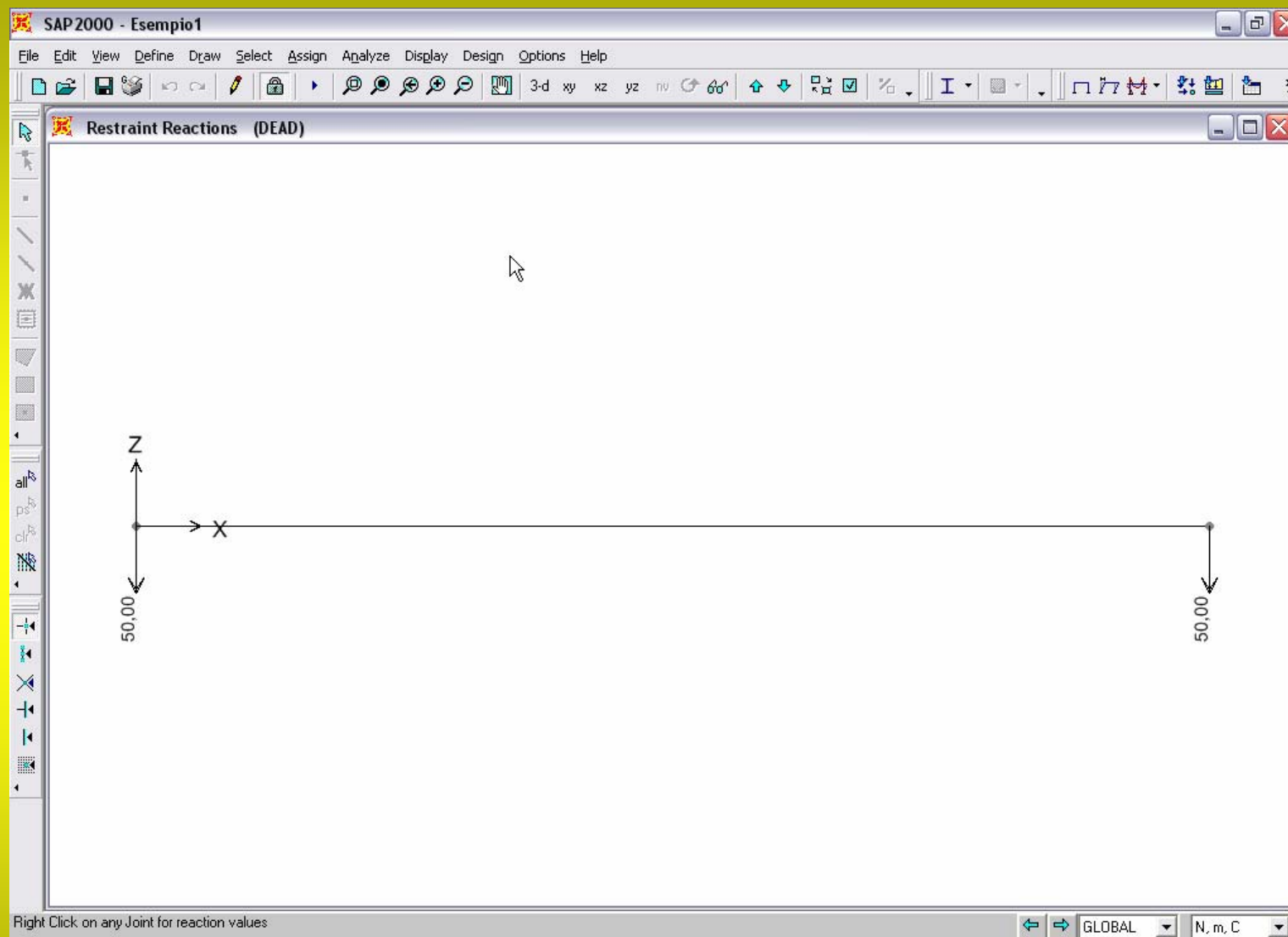


Figura 1.33: Componenti di reazione vincolare.

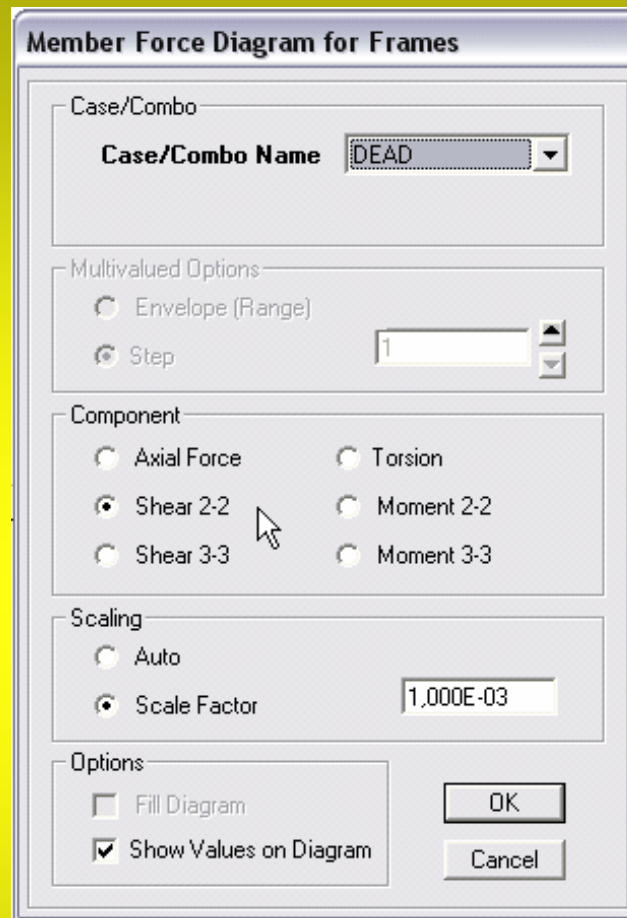


Figura 1.34: Impostazioni per la visualizzazione delle caratteristiche di sollecitazione.

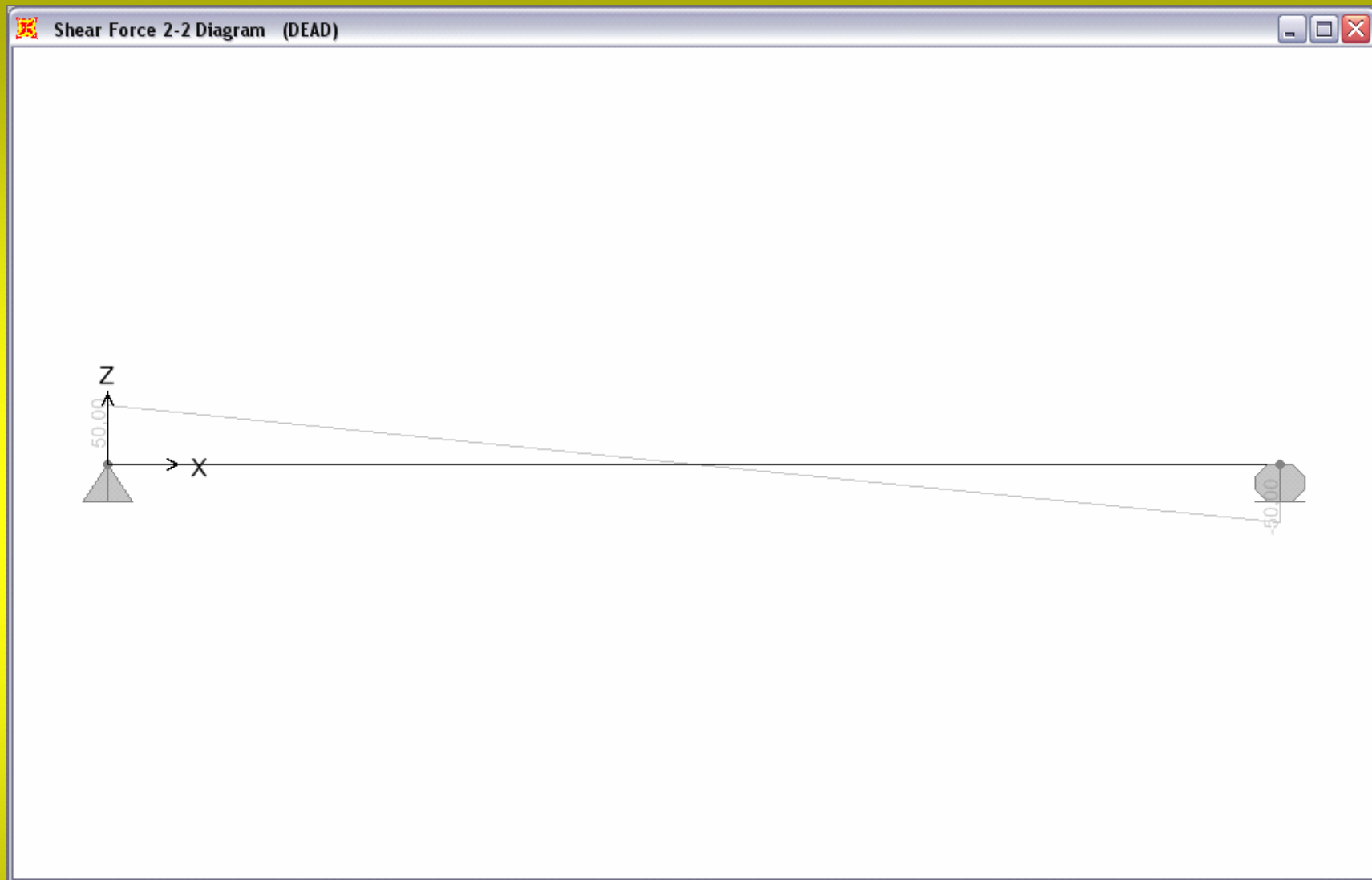
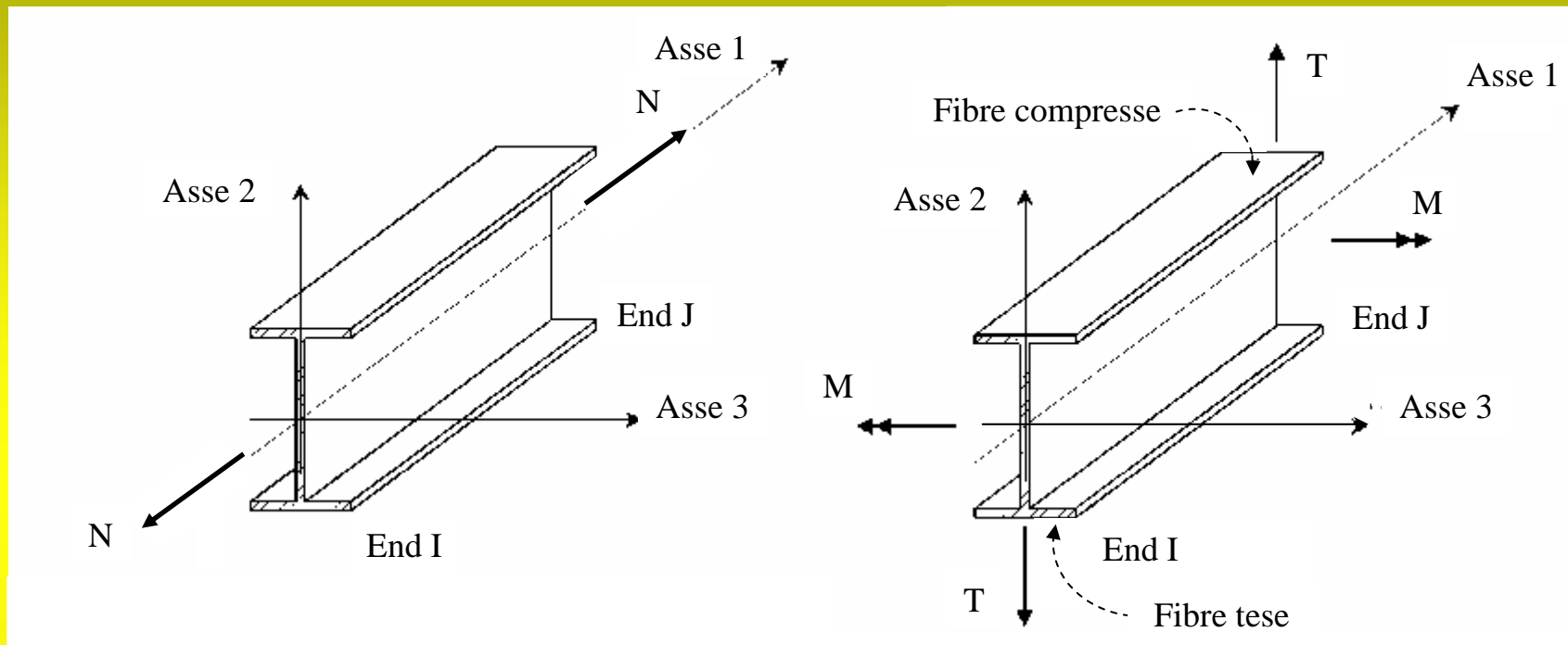


Figura 1.35: Forza trasversale.



(a)

(b)

Figura 1.36:

(a) Convenzione sui segni: forza assiale positiva.

(b) Convenzione sui segni: forza trasversale e momento flettente positivi.

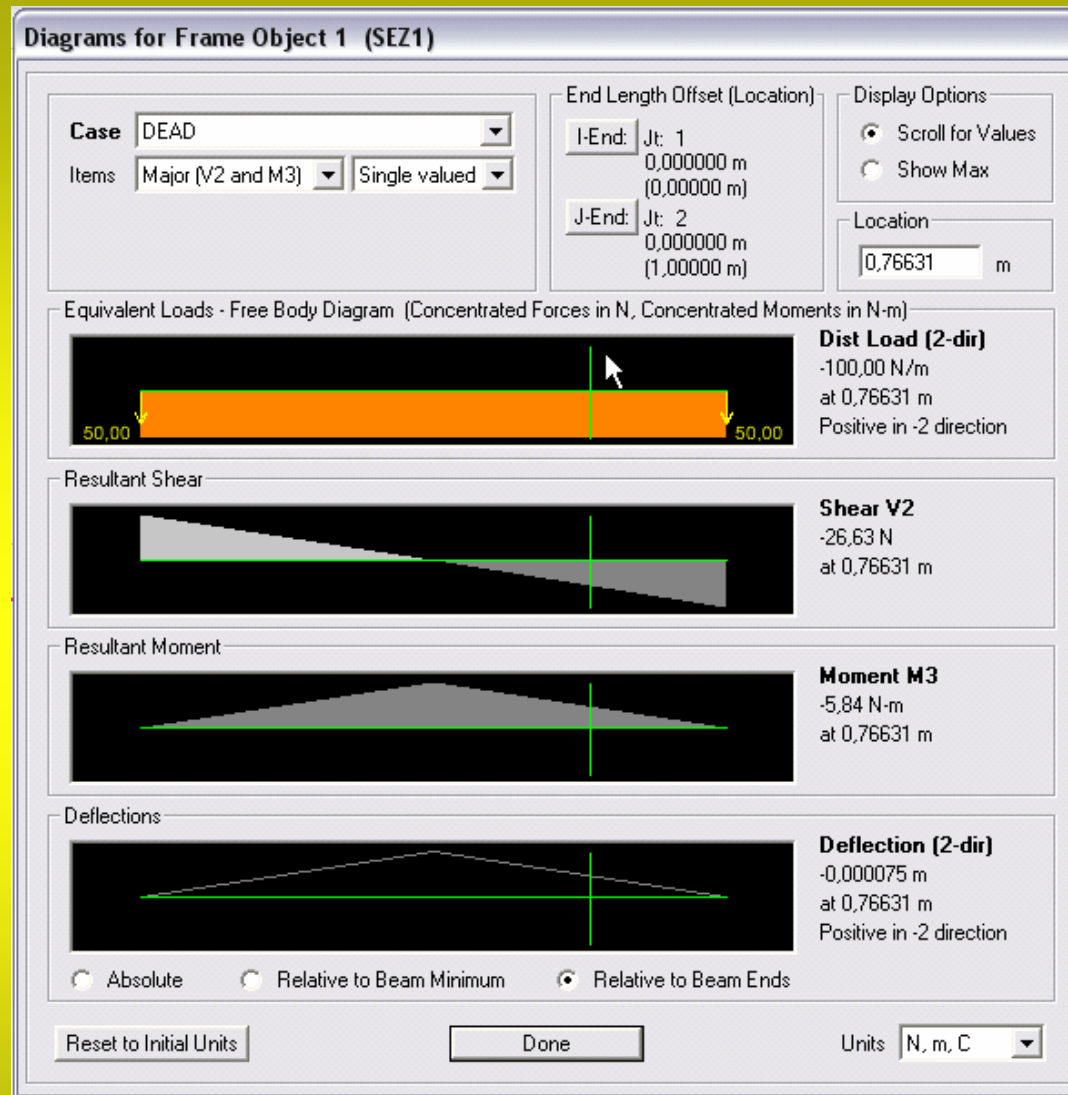


Figura 1.37: Diagrammi per un **Frame**.

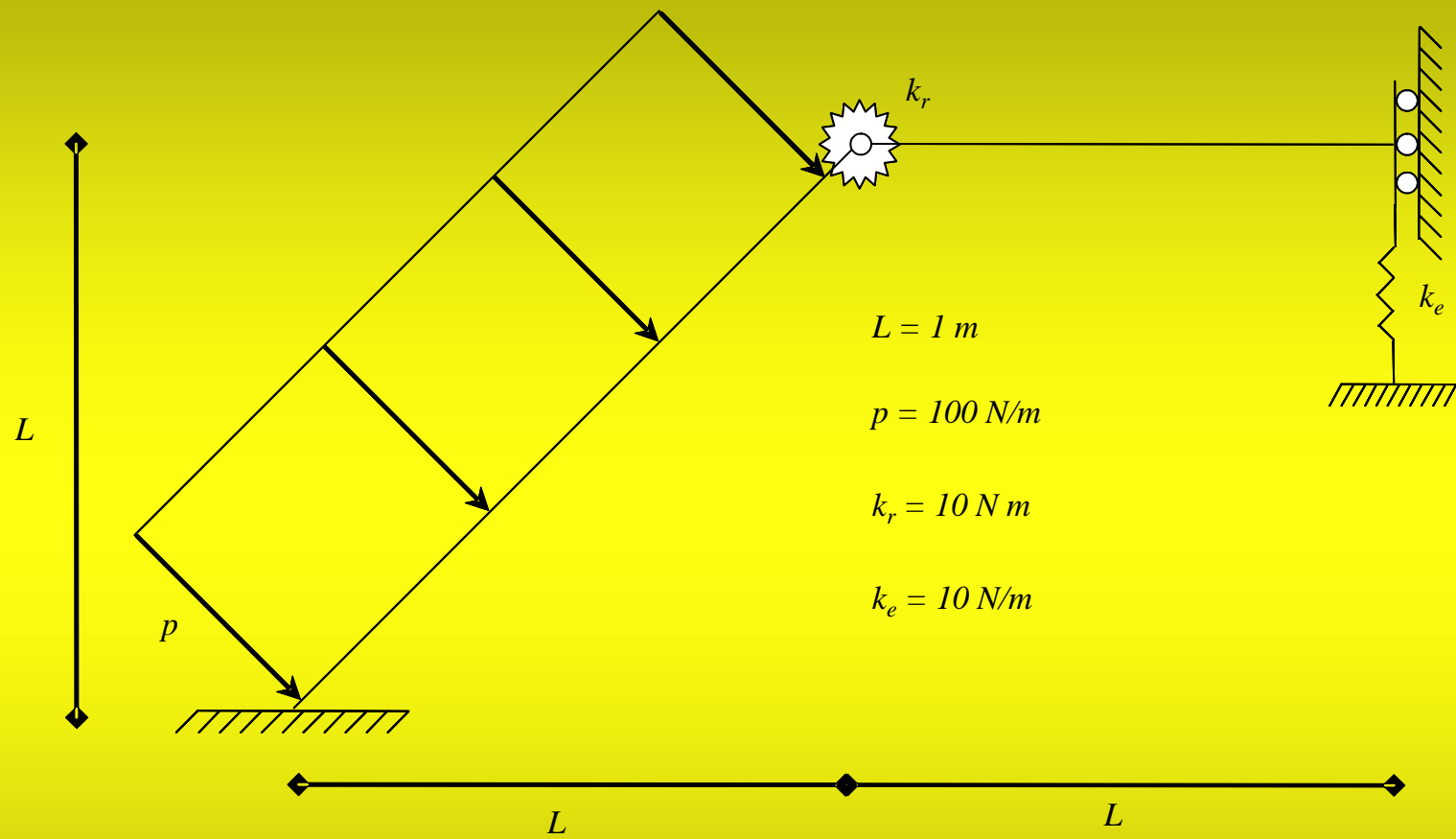


Figura 2.1: Ideogramma del modello.

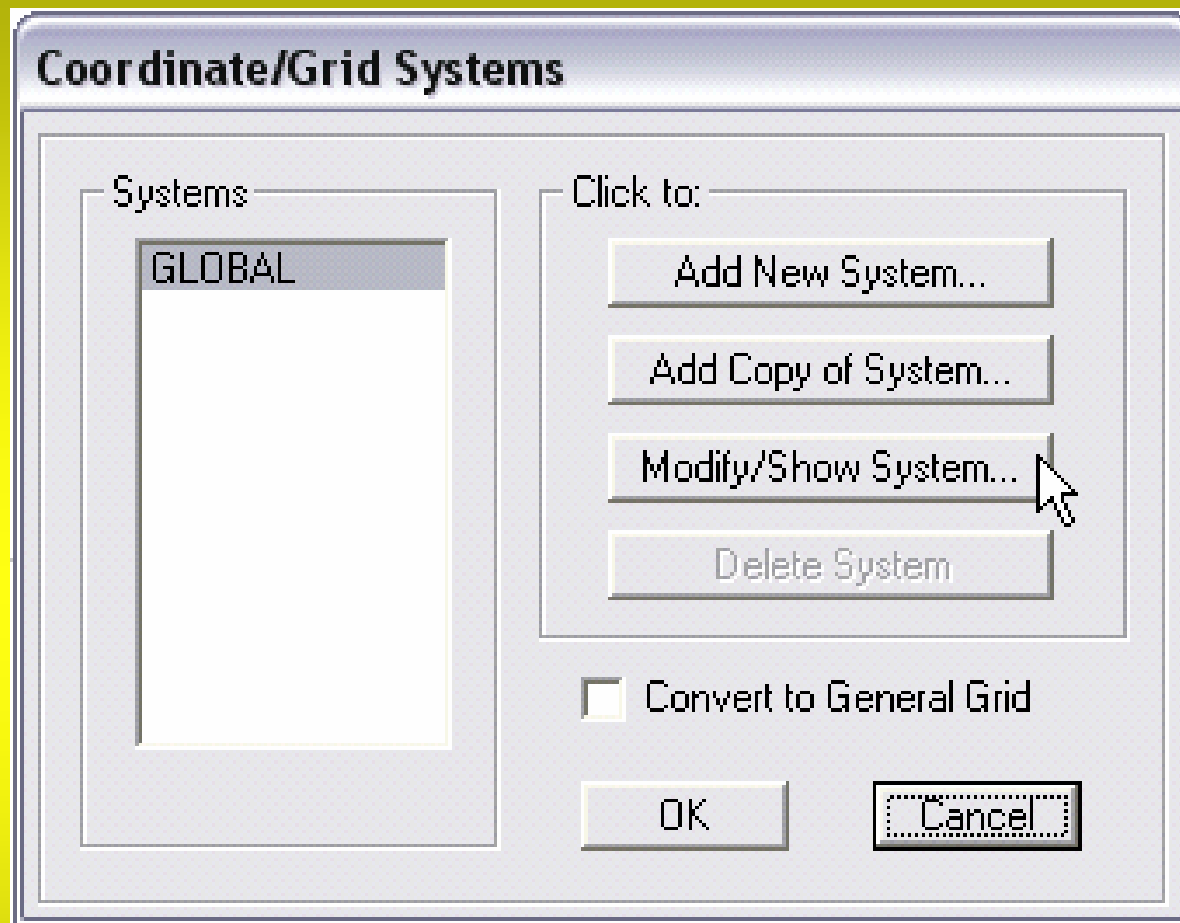


Figura 2.2: Gestione dei sistemi di coordinate.

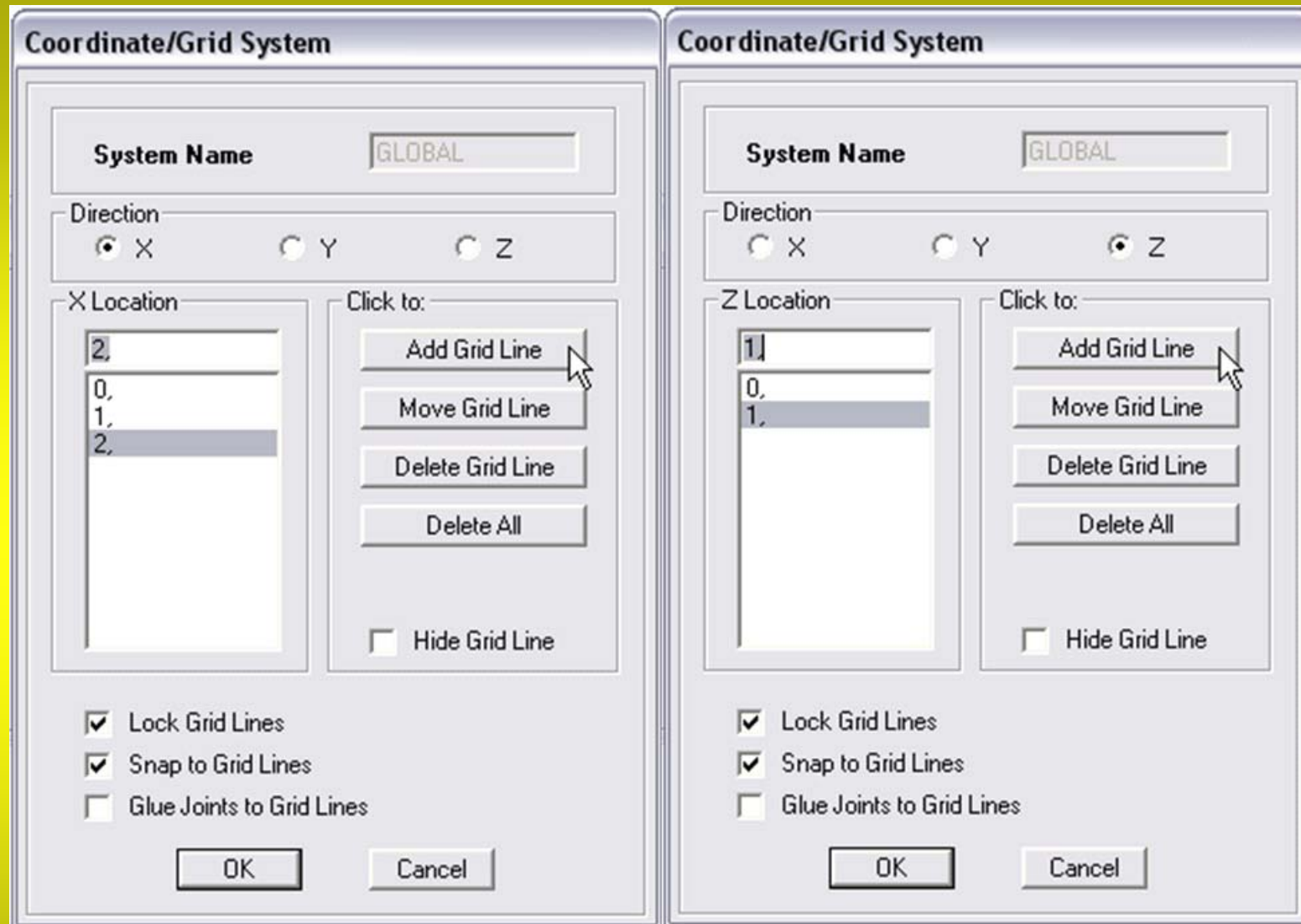


Figura 2.3: Gestione della griglia.

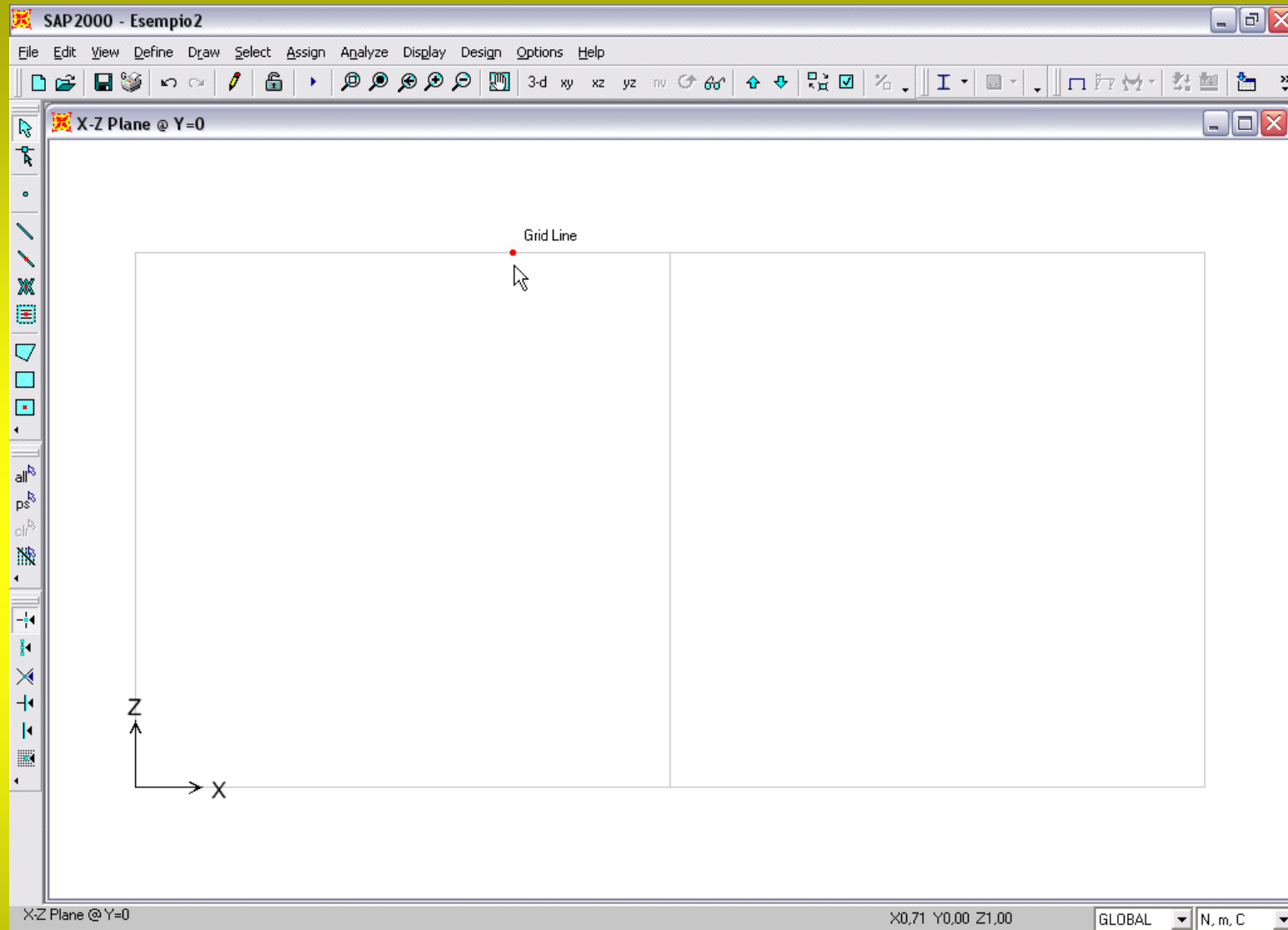


Figura 2.4: Nuova griglia di riferimento.

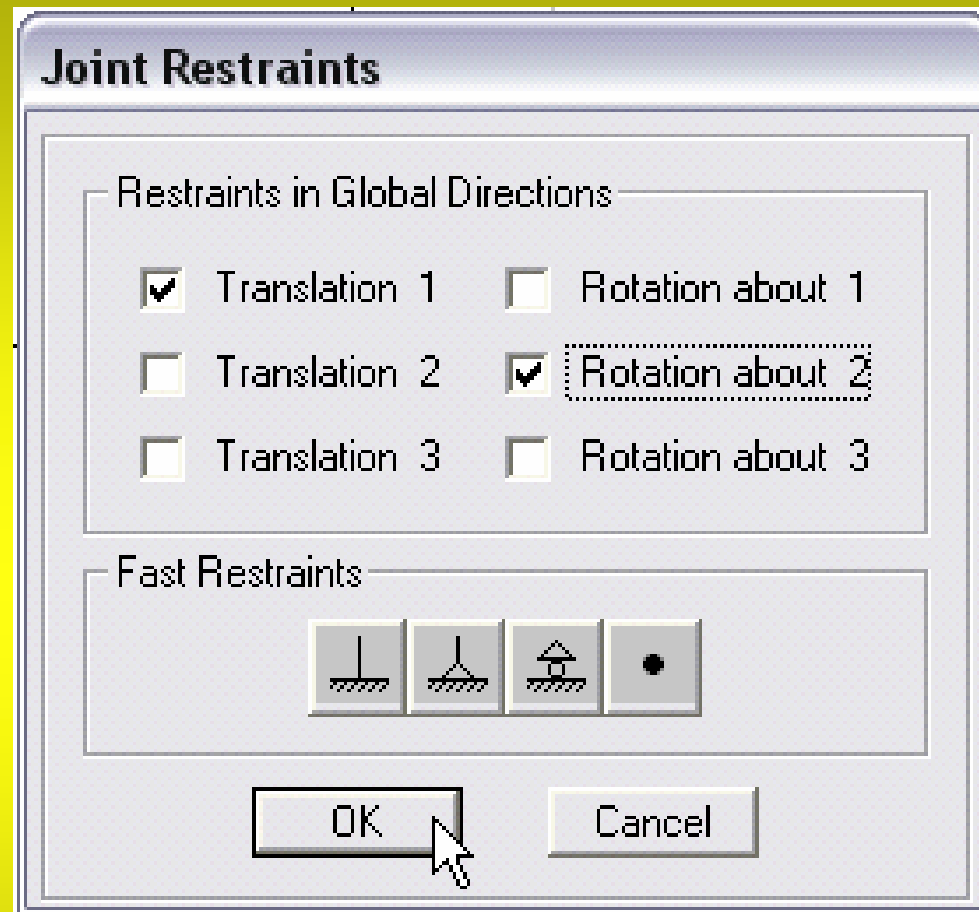


Figura 2.5: Assegnazione del glifo esterno.

Assign Frame Releases

Frame Releases

	Release		Frame Partial Fixity Springs	
	Start	End	Start	End
Axial Load	<input type="checkbox"/>	<input type="checkbox"/>		
Shear Force 2 (Major)	<input type="checkbox"/>	<input type="checkbox"/>		
Shear Force 3 (Minor)	<input type="checkbox"/>	<input type="checkbox"/>		
Torsion	<input type="checkbox"/>	<input type="checkbox"/>		
Moment 22 (Minor)	<input type="checkbox"/>	<input type="checkbox"/>		
Moment 33 (Major)	<input type="checkbox"/>	<input checked="" type="checkbox"/>		10.

No Releases

OK Cancel

Figura 2.6: Assegnazione dei rilasci per un **Frame**.

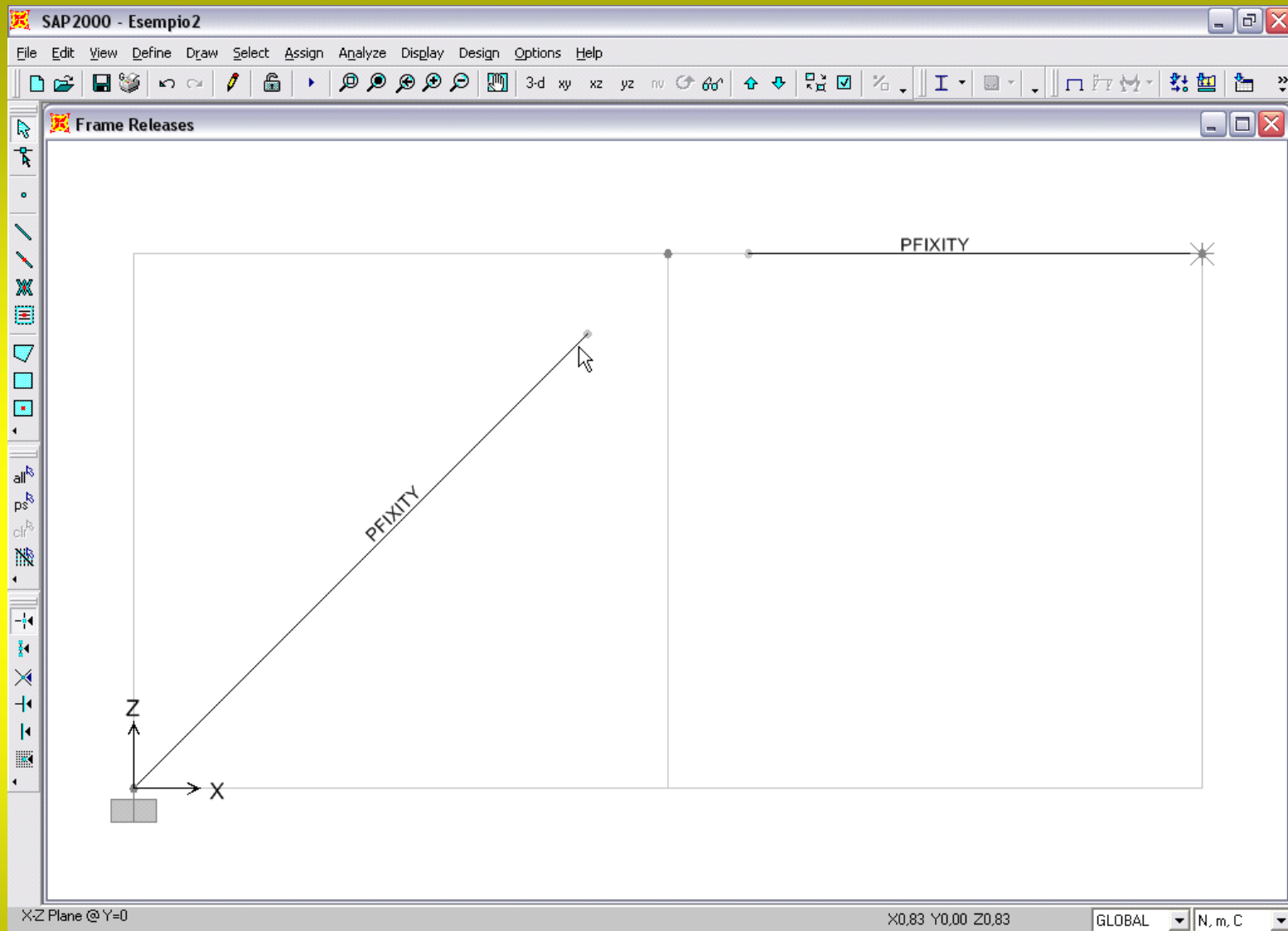


Figura 2.7: Visualizzazione dei rilasci per un **Frame**.

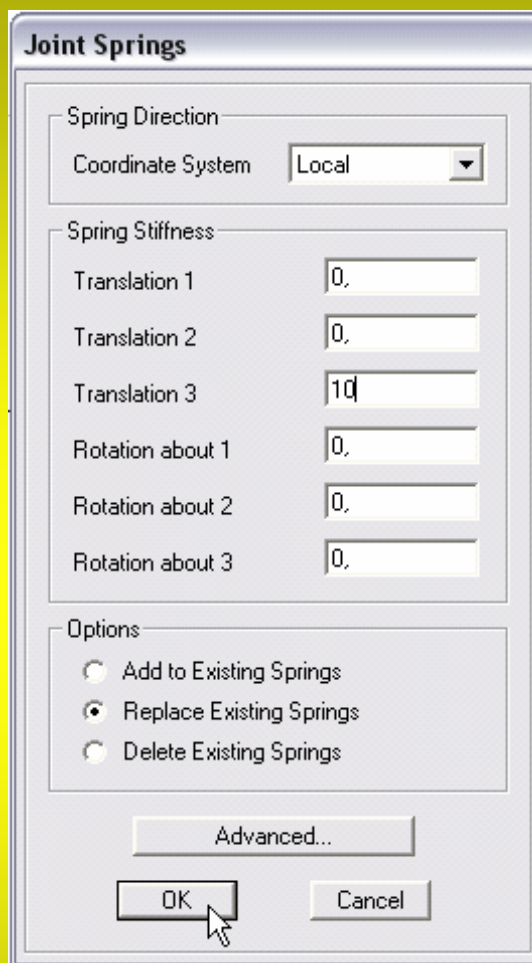


Figura 2.8: Assegnazione di una molla esterna.

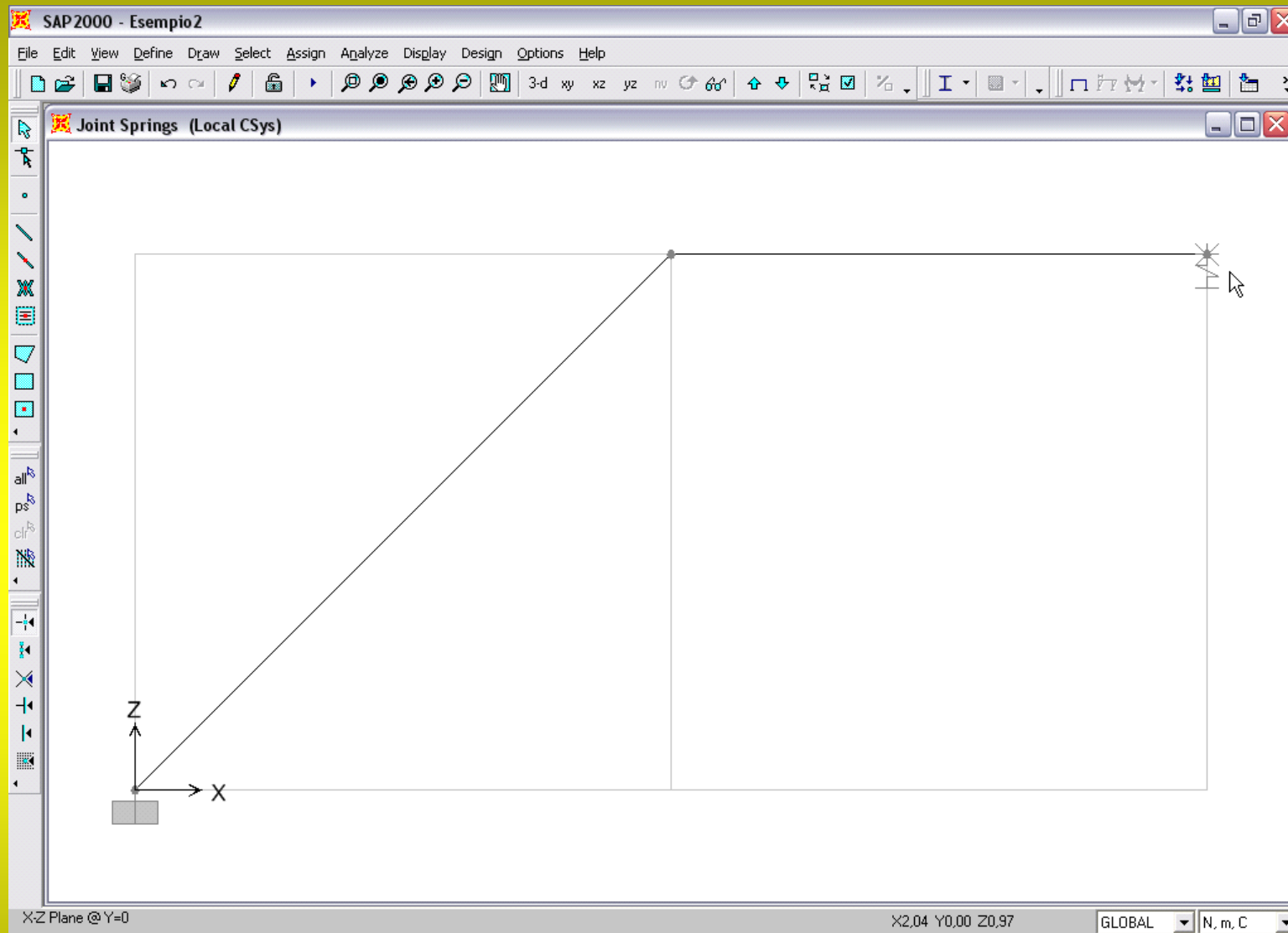


Figura 2.9: Struttura da analizzare.

Frame Distributed Loads

Load Case Name: DEAD Units: N, m, C

Load Type and Direction: Forces Moments
Coord Sys: Local Direction: 2

Options: Add to Existing Loads Replace Existing Loads Delete Existing Loads

Trapezoidal Loads:

	1.	2.	3.	4.
Distance	0.	0,25	0,75	1.
Load	0.	0.	0.	0.

Relative Distance from End-I Absolute Distance from End-I

Uniform Load: Load: -100

OK Cancel

Figura 2.10: Assegnazione del carico distribuito uniformemente

Line Information

Location **Assignments** Loads

Identification

Label Design Procedure

Section Property	SEZ1
Property Modifiers	None
Material Overwrite	None
Releases End-J	M3
Partial Fixity Springs	
End-J Spring M3	10,
Local Axes	Default
Insertion Point	Default
End Length Offsets	None
Min. Number Stations	3
P-Delta Force	None
Prestress Patterns	None
Cable Parameters	None
T/C Limits	None
Nonlinear Hinges	None
Line Springs	None
Line Mass	None
Automatic Subdivide	
Subdivide Option	At Intermediate Joints
Material Temp	Default

Units

Figura 2.11: Informazioni sul **Frame**.

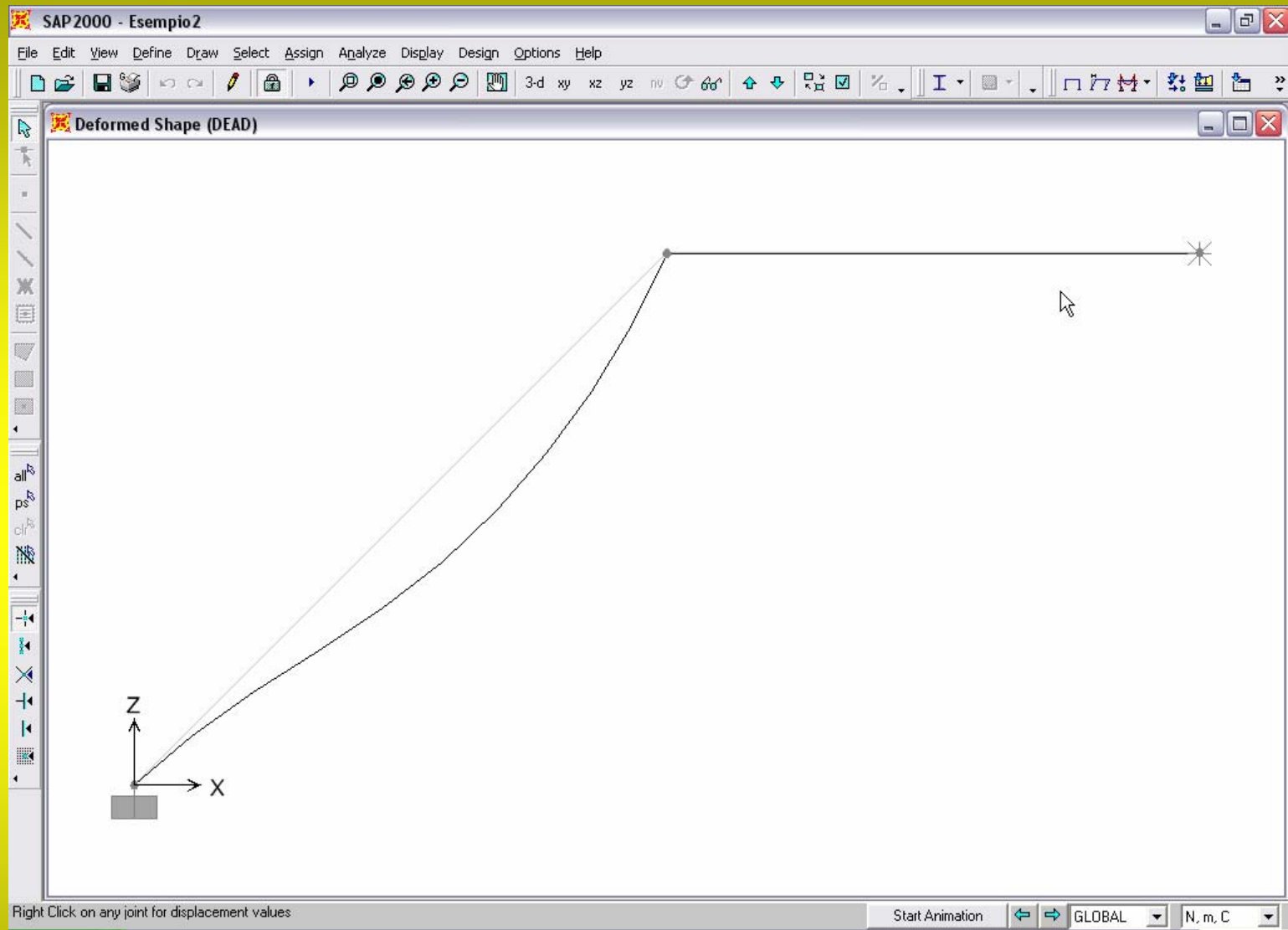


Figura 2.12: Configurazione deformata.

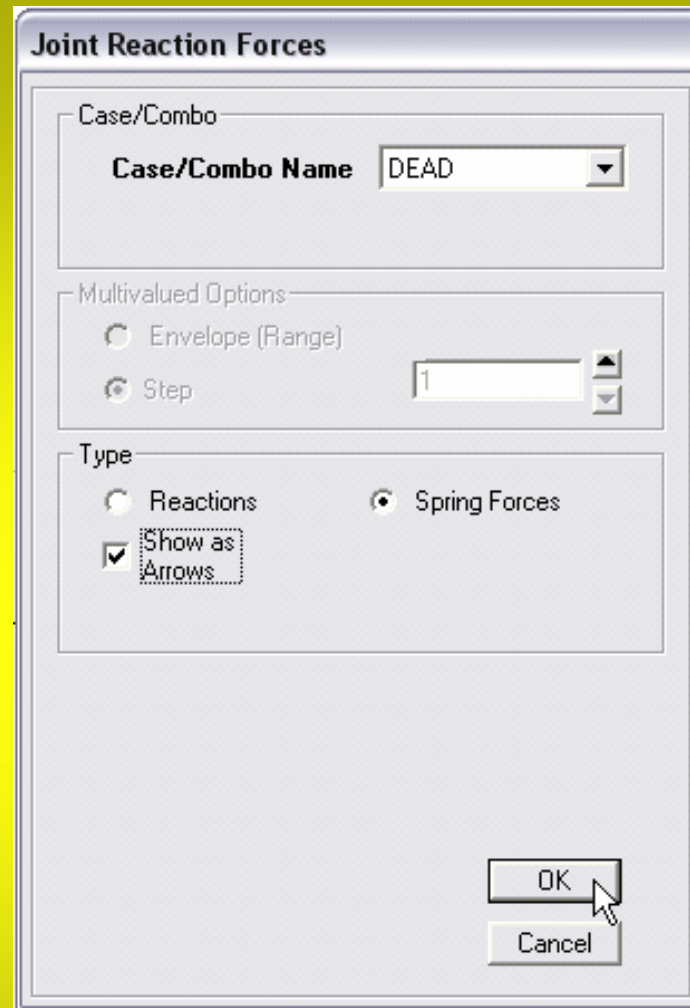


Figura 2.13: Impostazioni per la visualizzazione delle componenti di reazione vincolare.

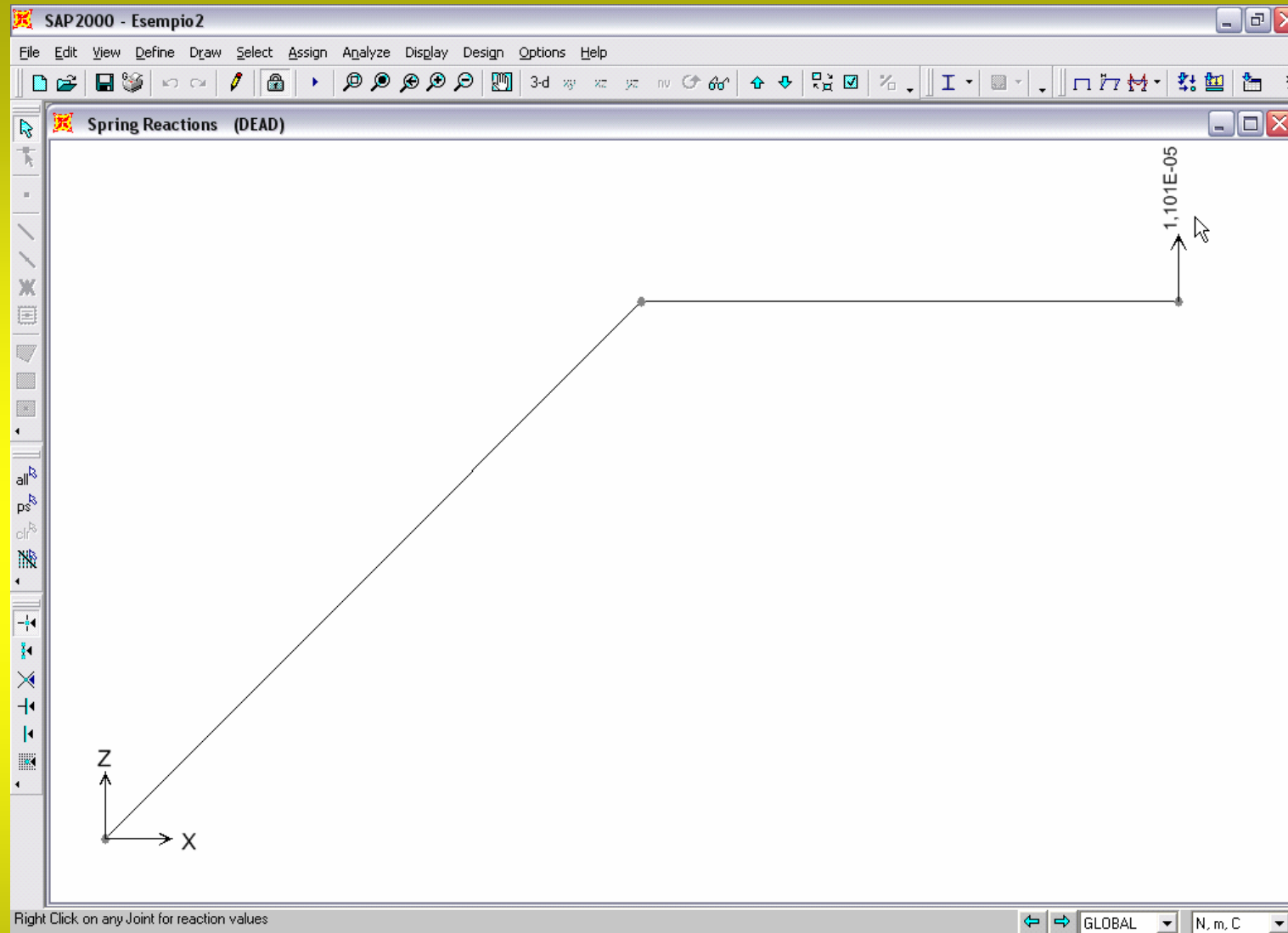


Figura 2.14: Reazione vincolare erogata dalla molla estensionale.

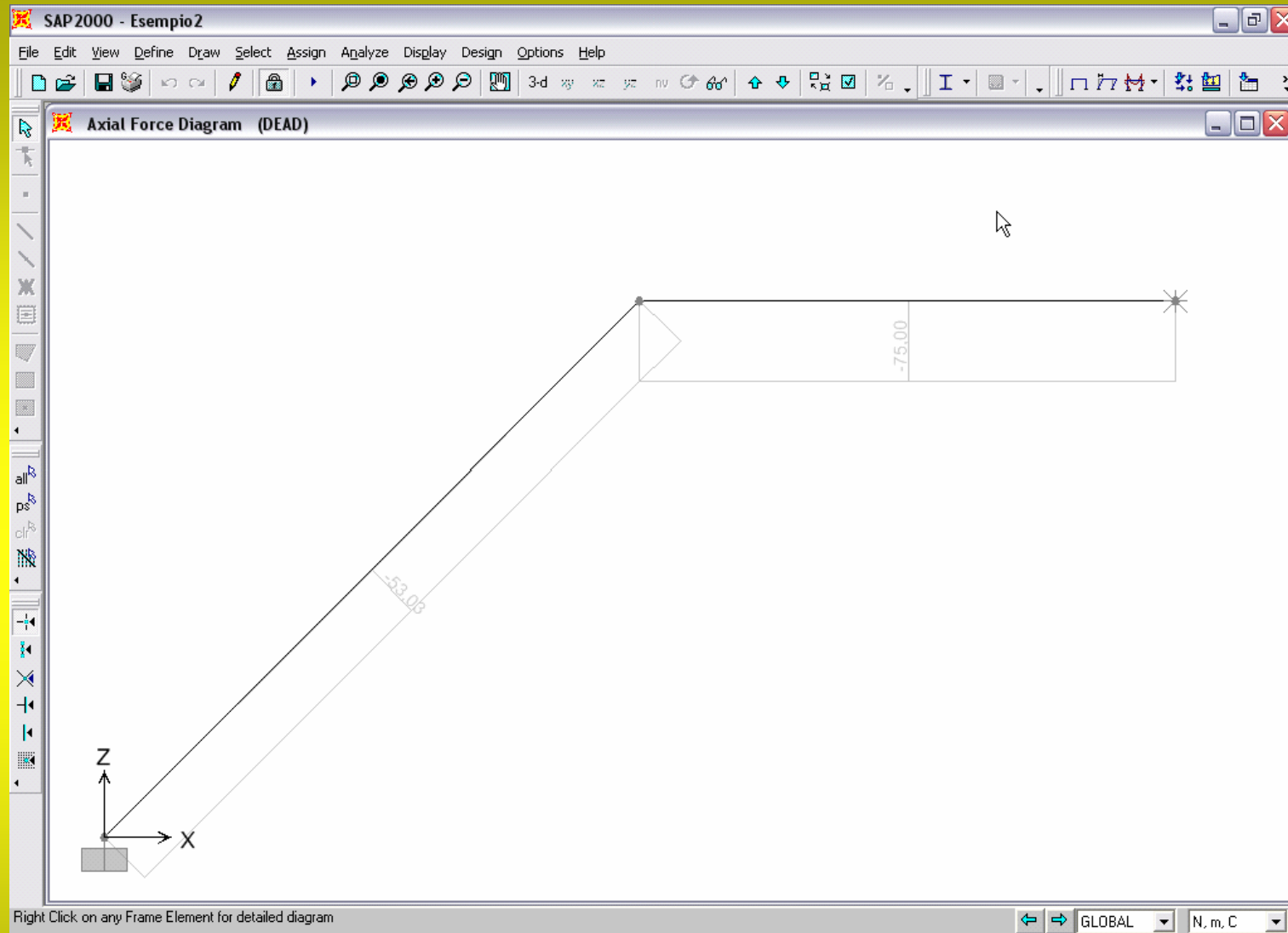


Figura 2.15: Forza assiale.

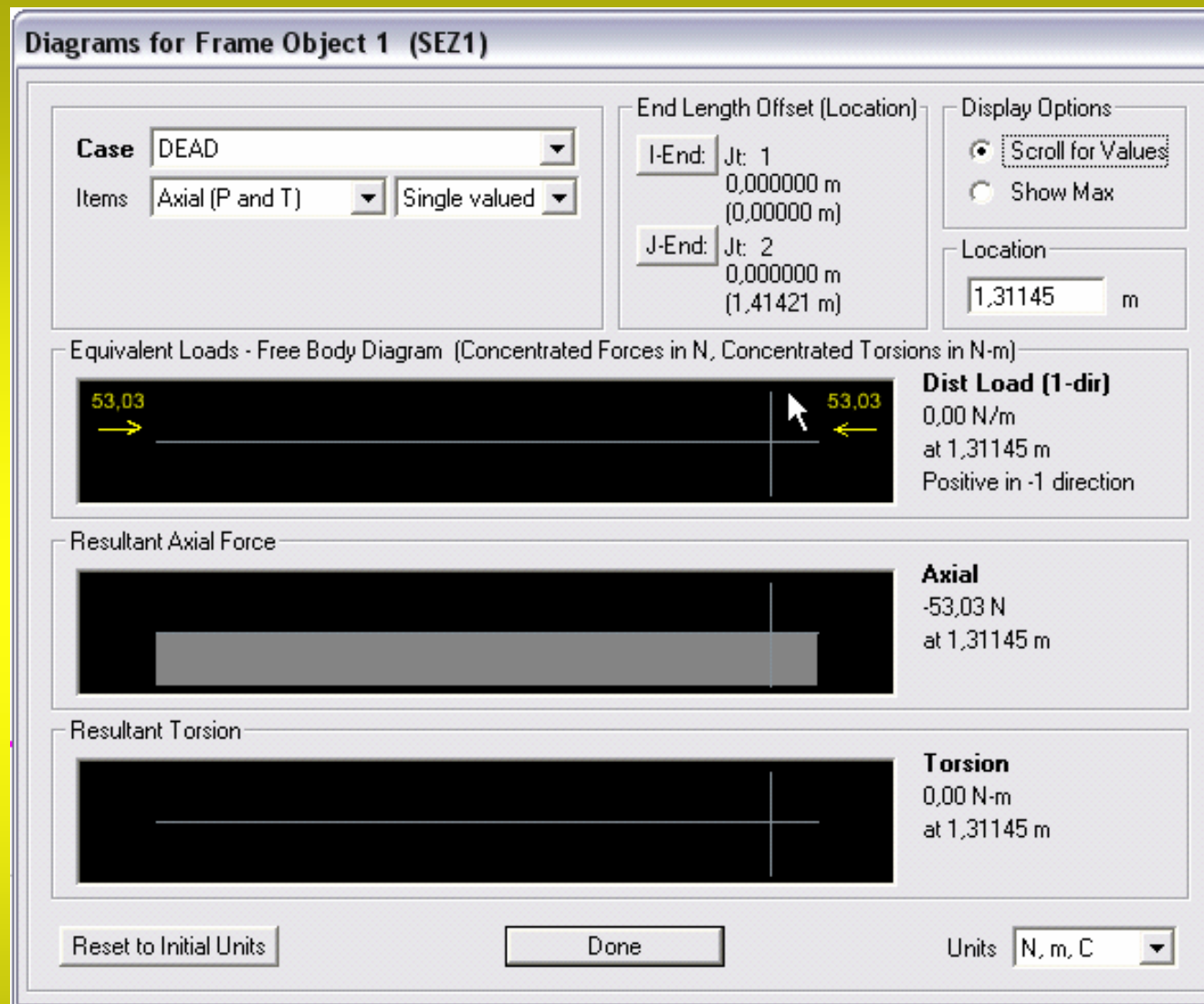


Figura 2.16: Diagrammi per un **Frame**.

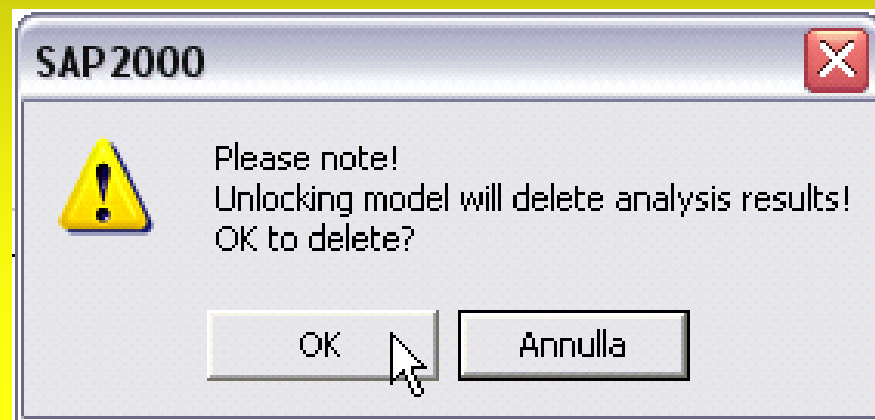


Figura 2.17: Messaggio di warning relativo alla richiesta di sblocco del modello.

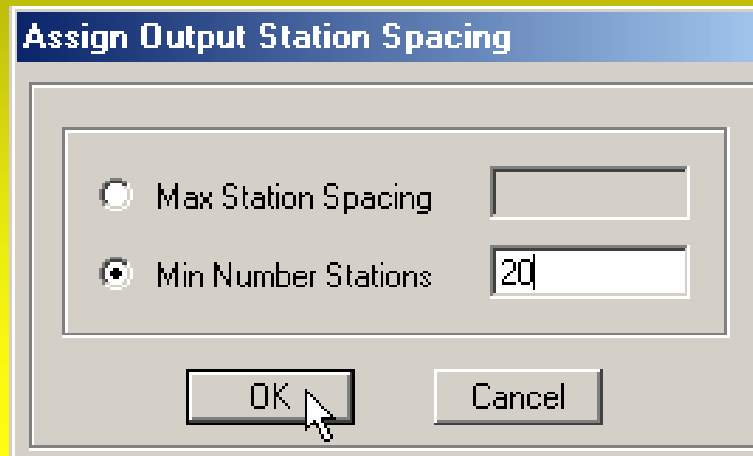
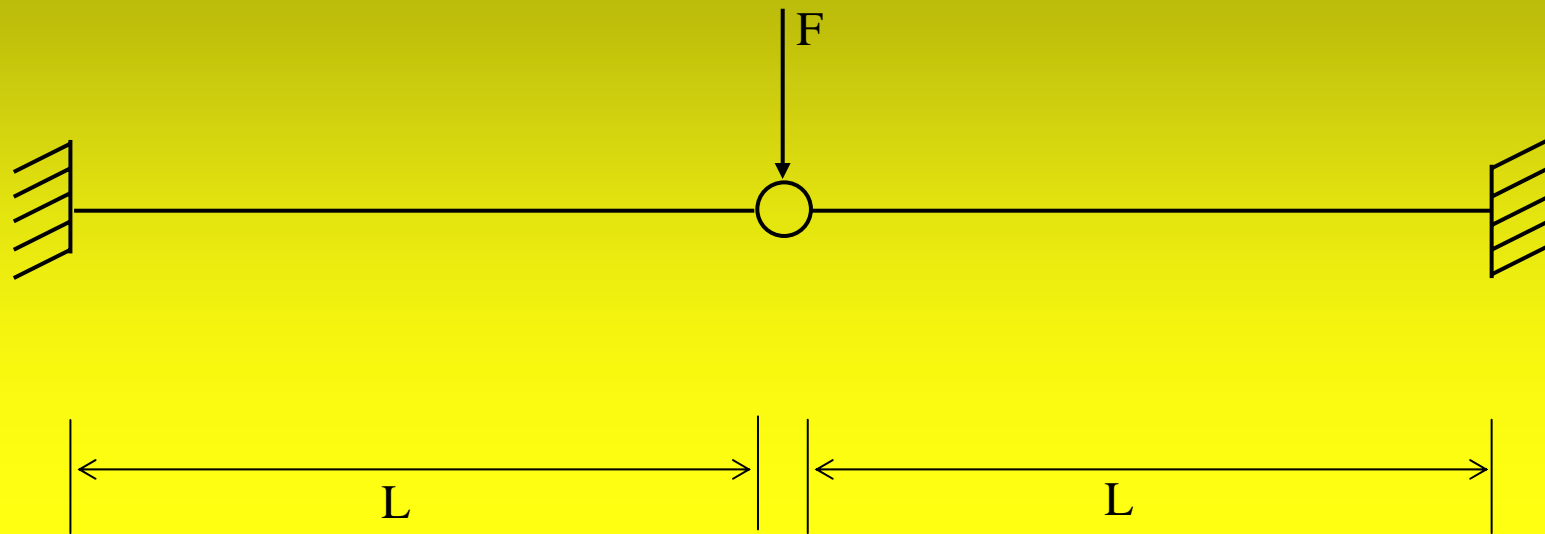


Figura 2.18: Assegnazione delle **Output Stations**.



$$L = 1 \text{ m}$$
$$F = 1000 \text{ N}$$

Figura 2.19: Ideogramma del modello.

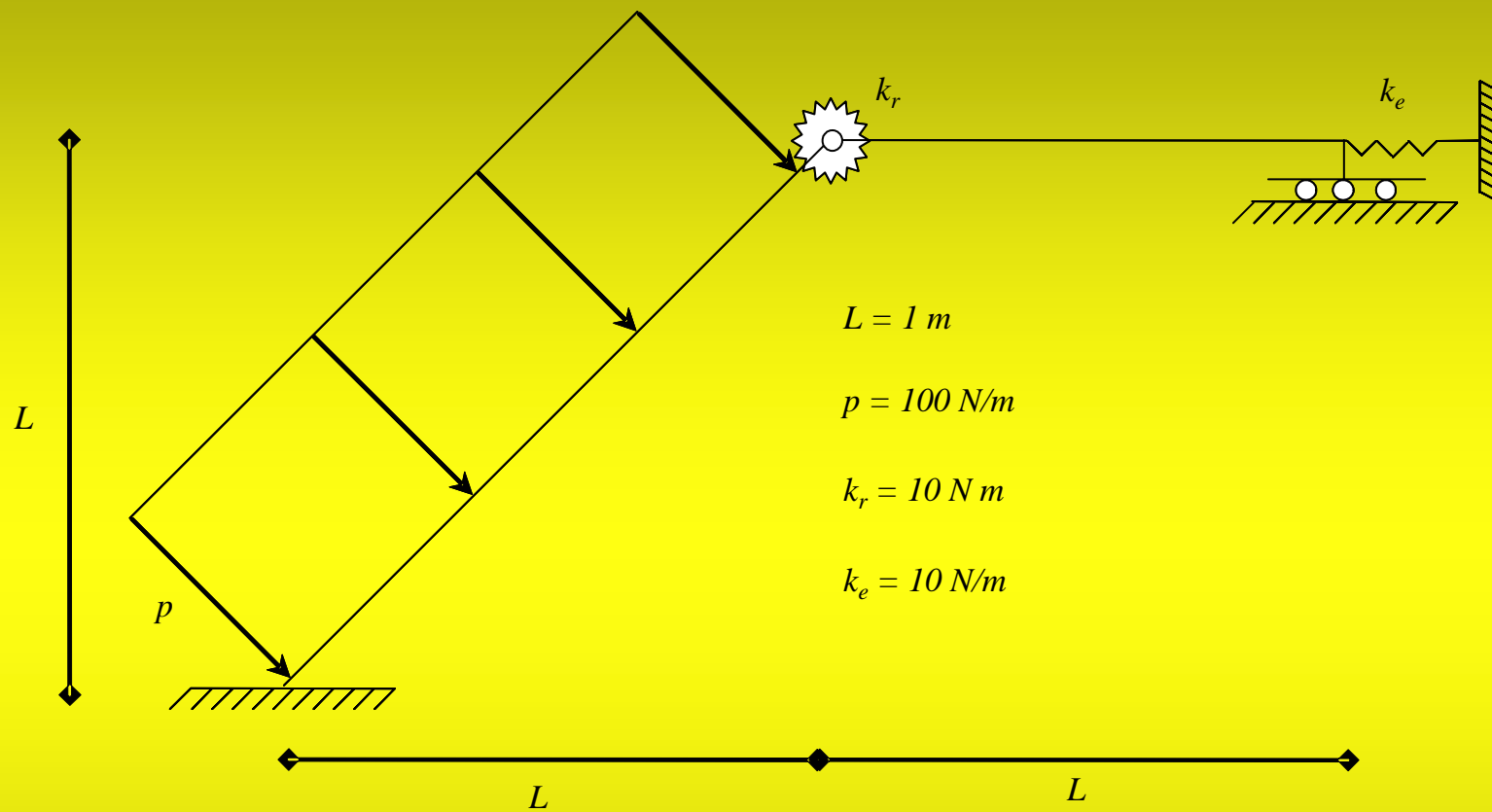


Figura 2.20: Ideogramma del modello per la struttura modificata.

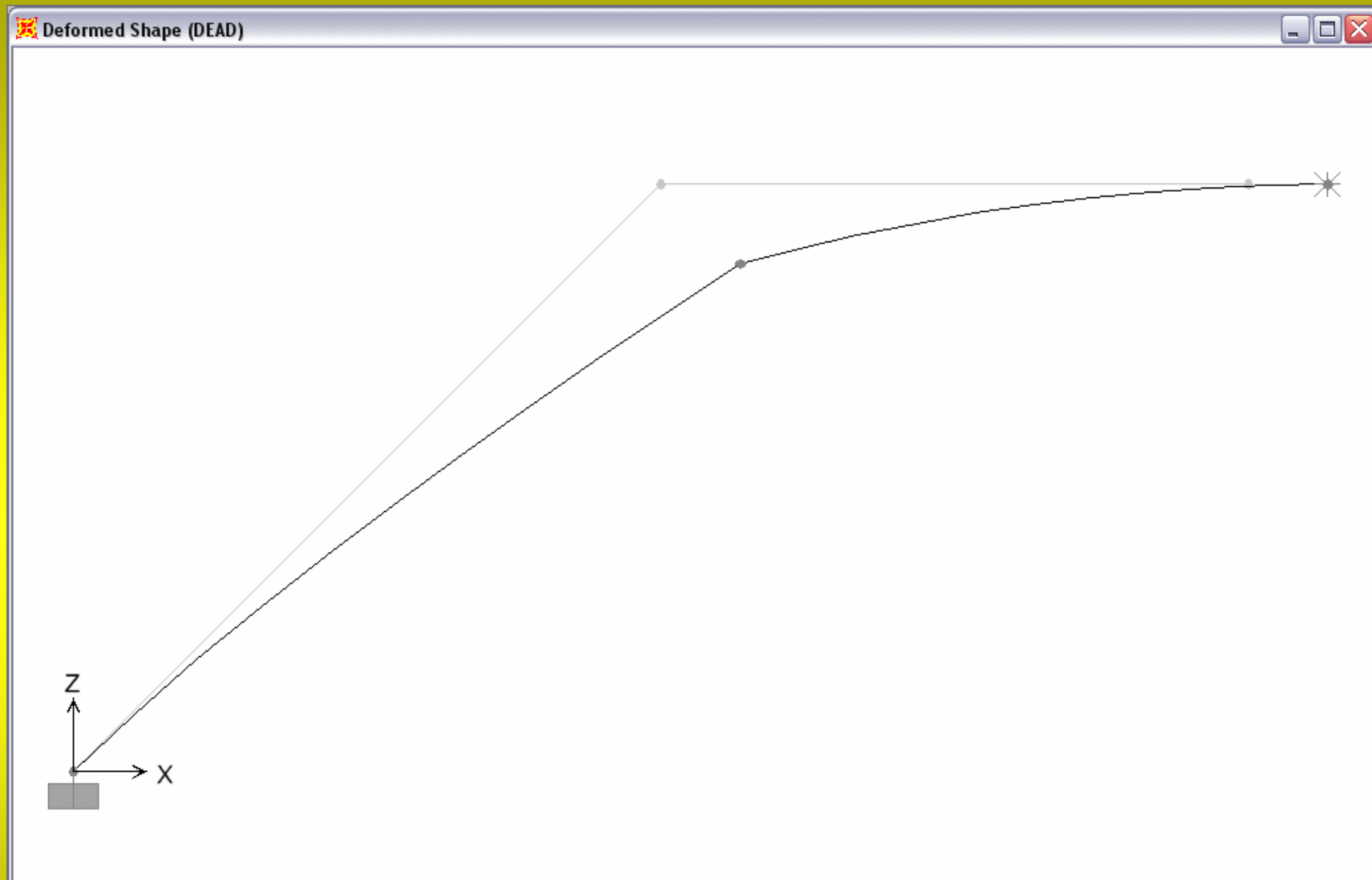


Figura 2.21: Configurazione deformata.

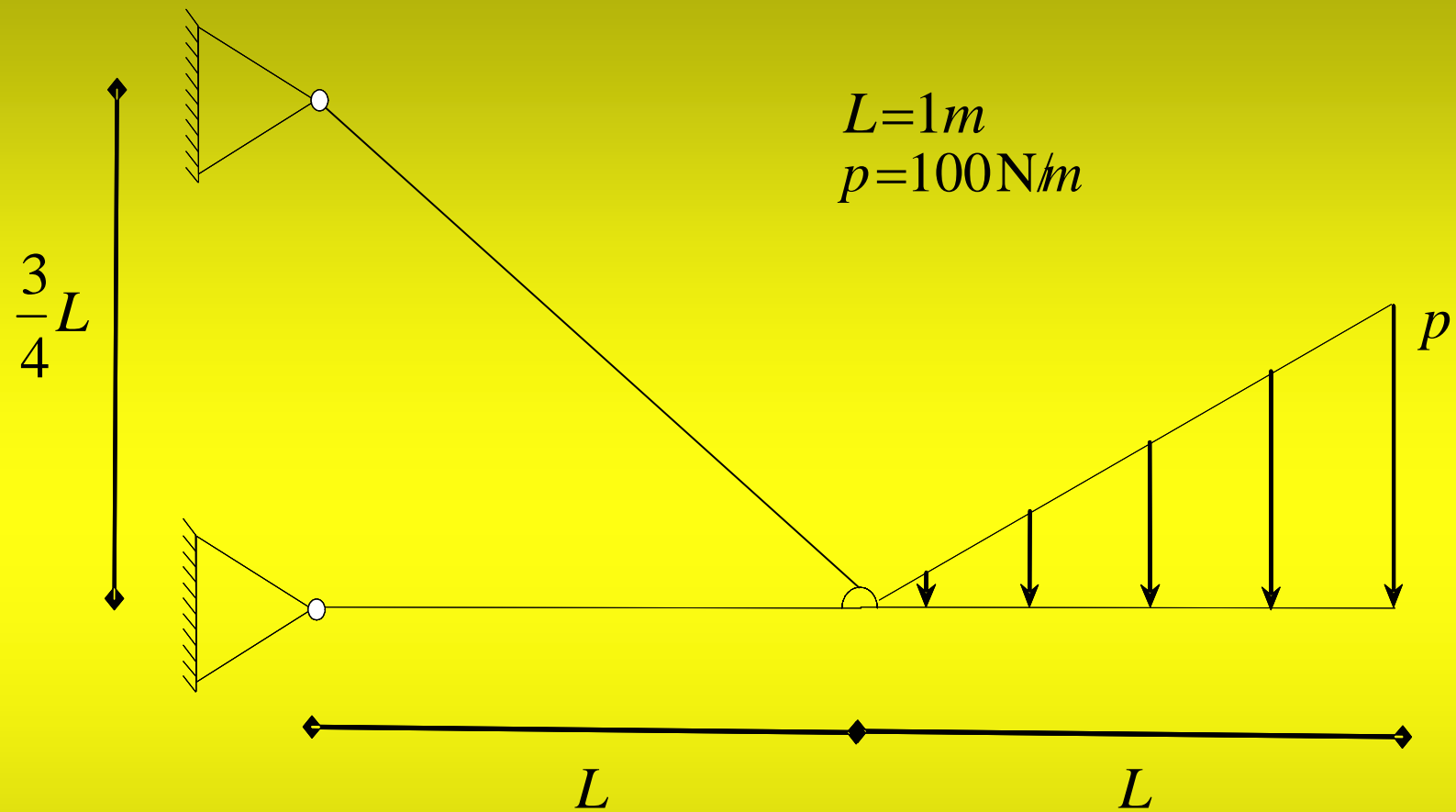


Figura 3.1: Ideogramma del modello.

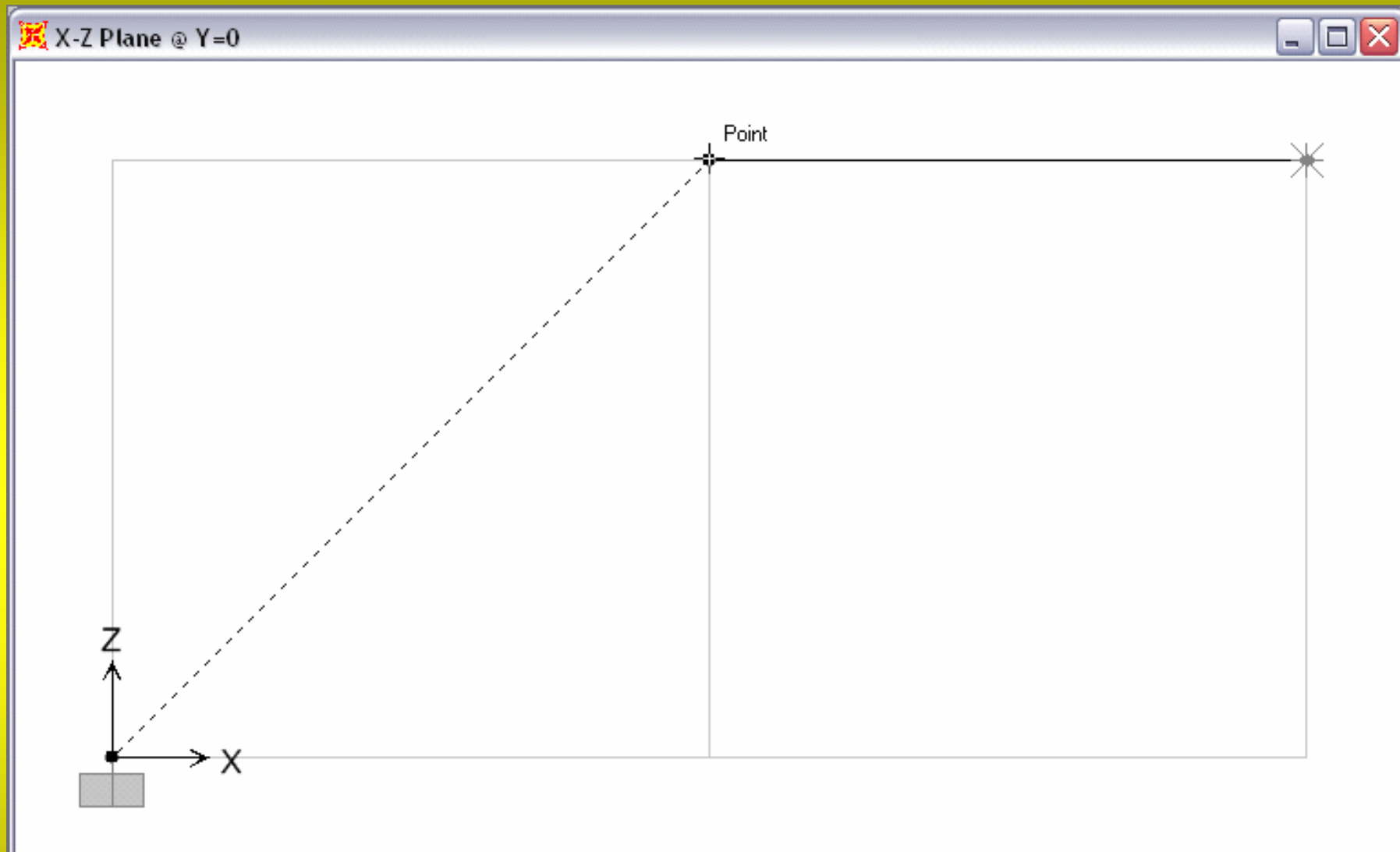


Figura 3.2: Utilizzo del comando **Reshape Element**.

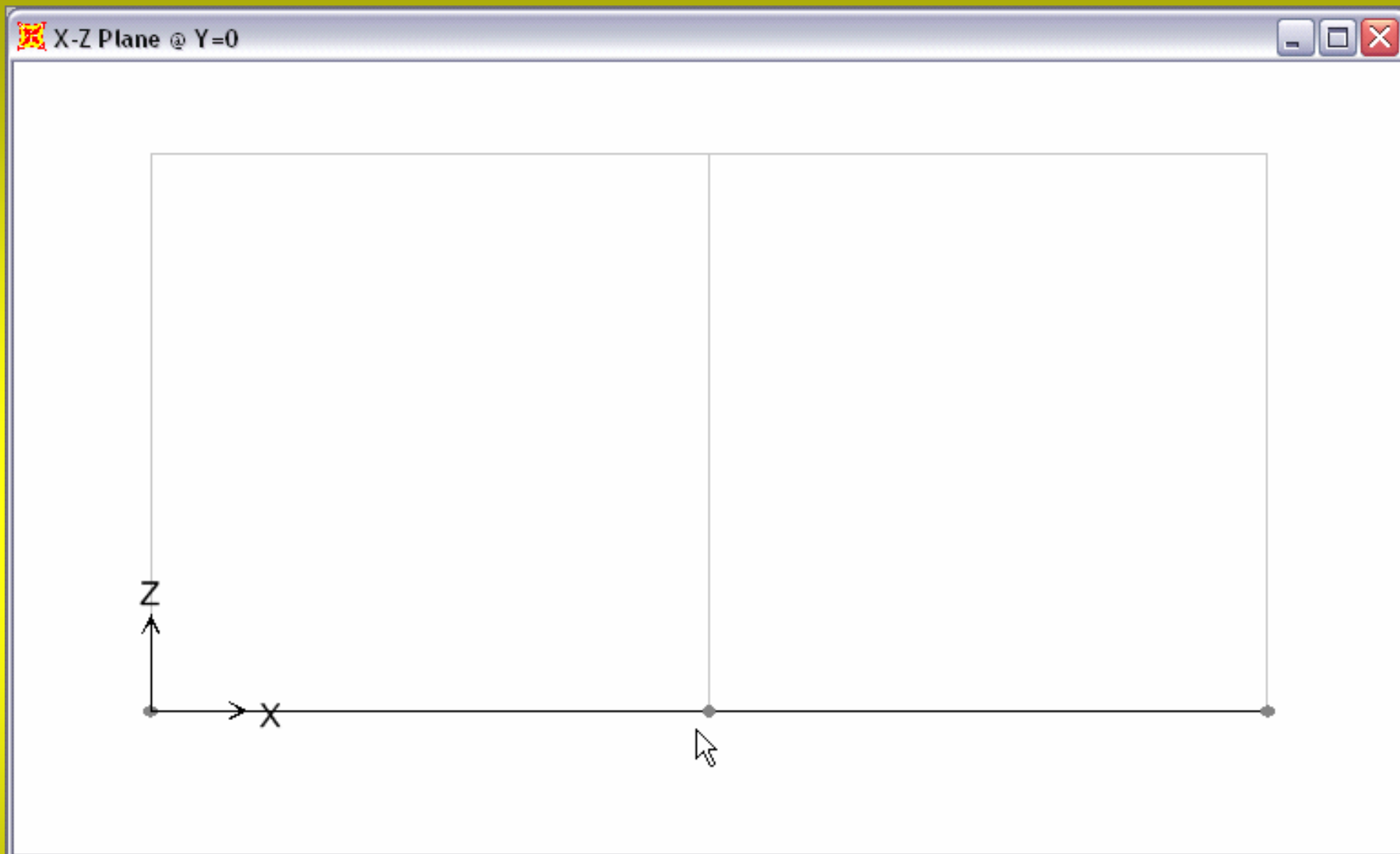


Figura 3.3: Modifica della geometria.

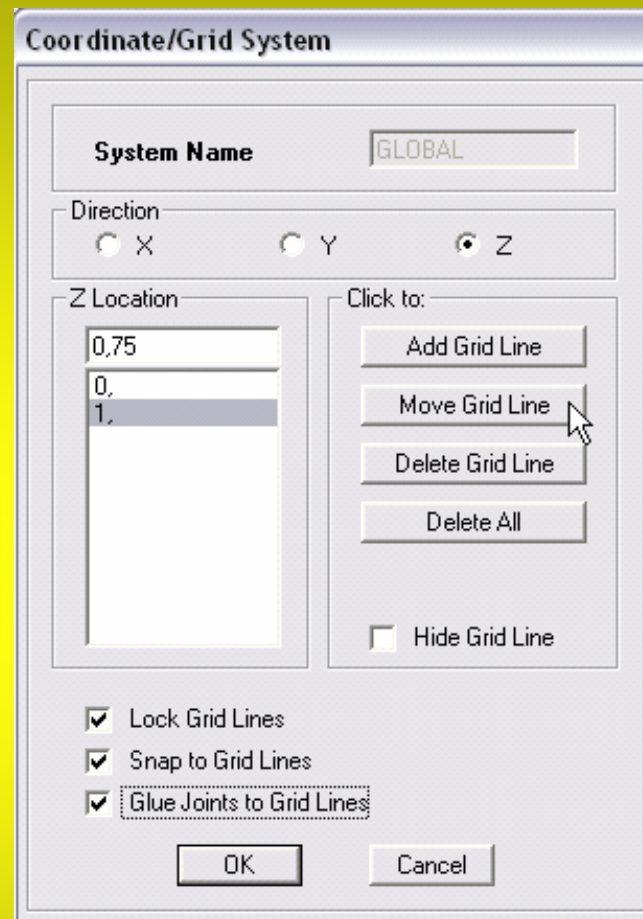


Figura 3.4: Modifica della **Grid Line** di equazione $Z=1$.

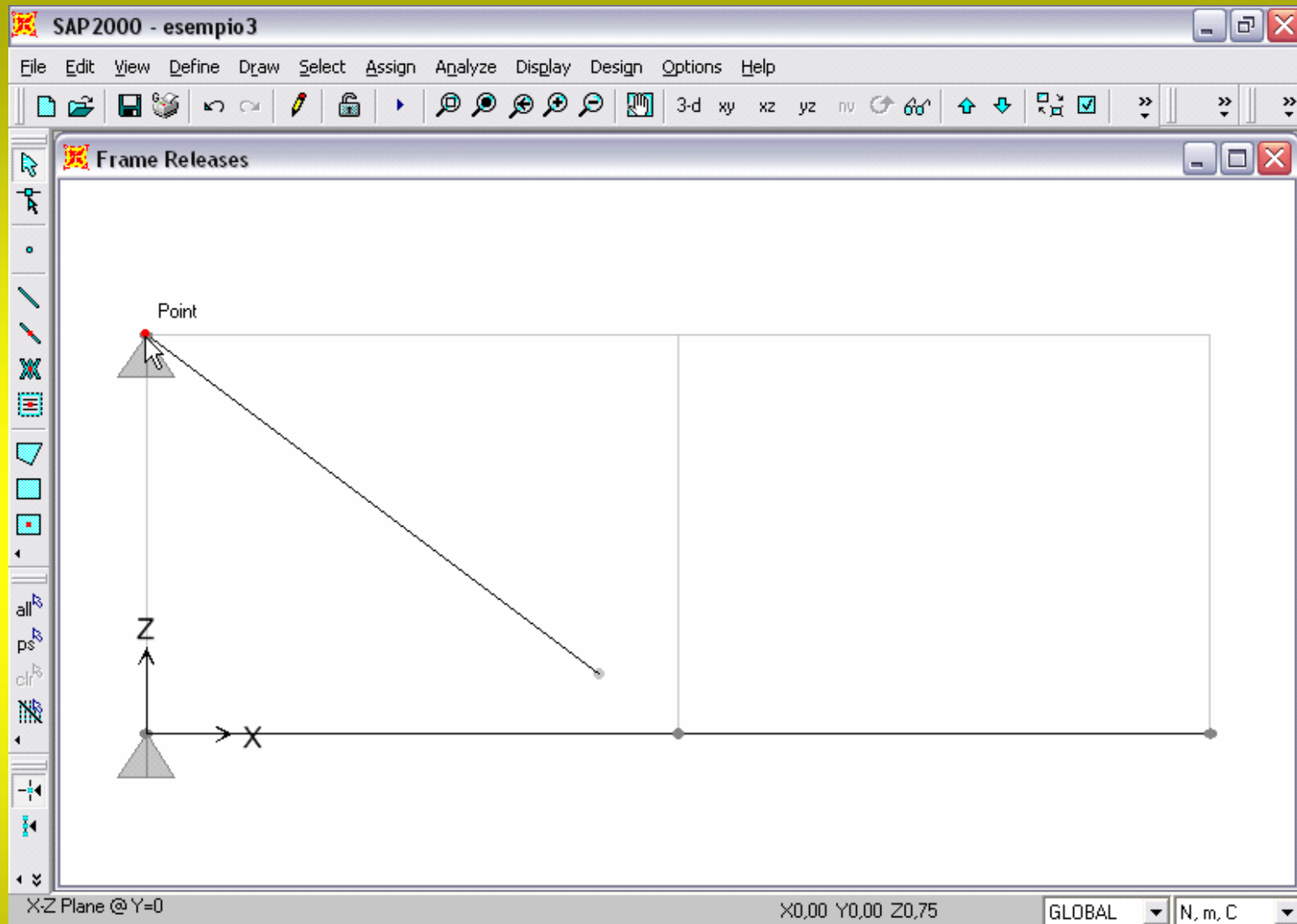


Figura 3.5: Assegnazione dei vincoli esterni.

Frame Distributed Loads

Load Case Name: DEAD Units: N, m, C

Load Type and Direction:

 Forces Moments

Coord Sys: GLOBAL

Direction: Gravity

Options:

 Add to Existing Loads

 Replace Existing Loads

 Delete Existing Loads

Trapezoidal Loads

	1.	2.	3.	4.
Distance	0.	0.	0.	1.
Load	0.	0.	0.	100.

Relative Distance from End-I Absolute Distance from End-I

Uniform Load: Load: 0.

OK Cancel

Figura 3.6: Assegnazione del carico esterno con distribuzione triangolare.

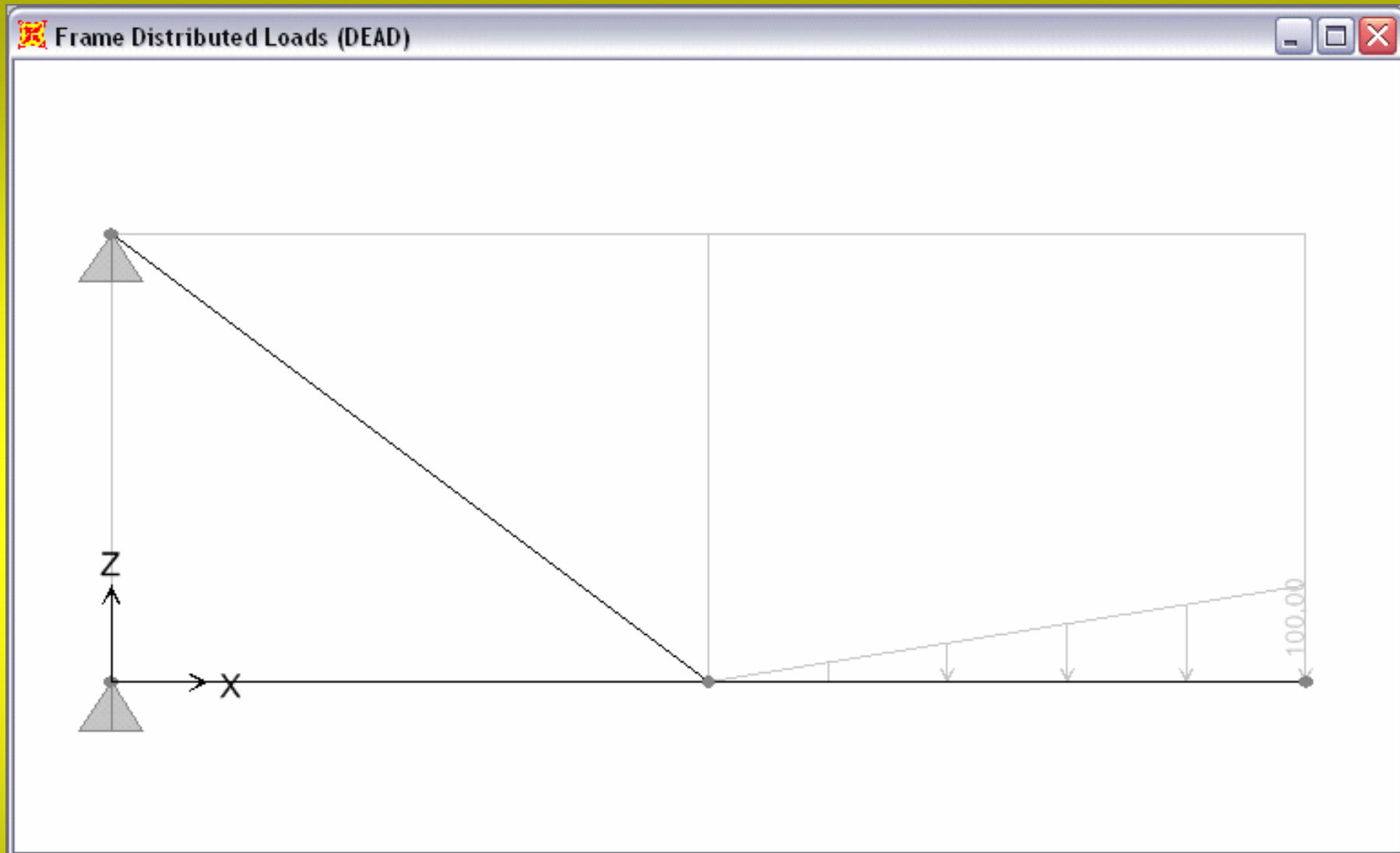


Figura 3.7: Modello completo.

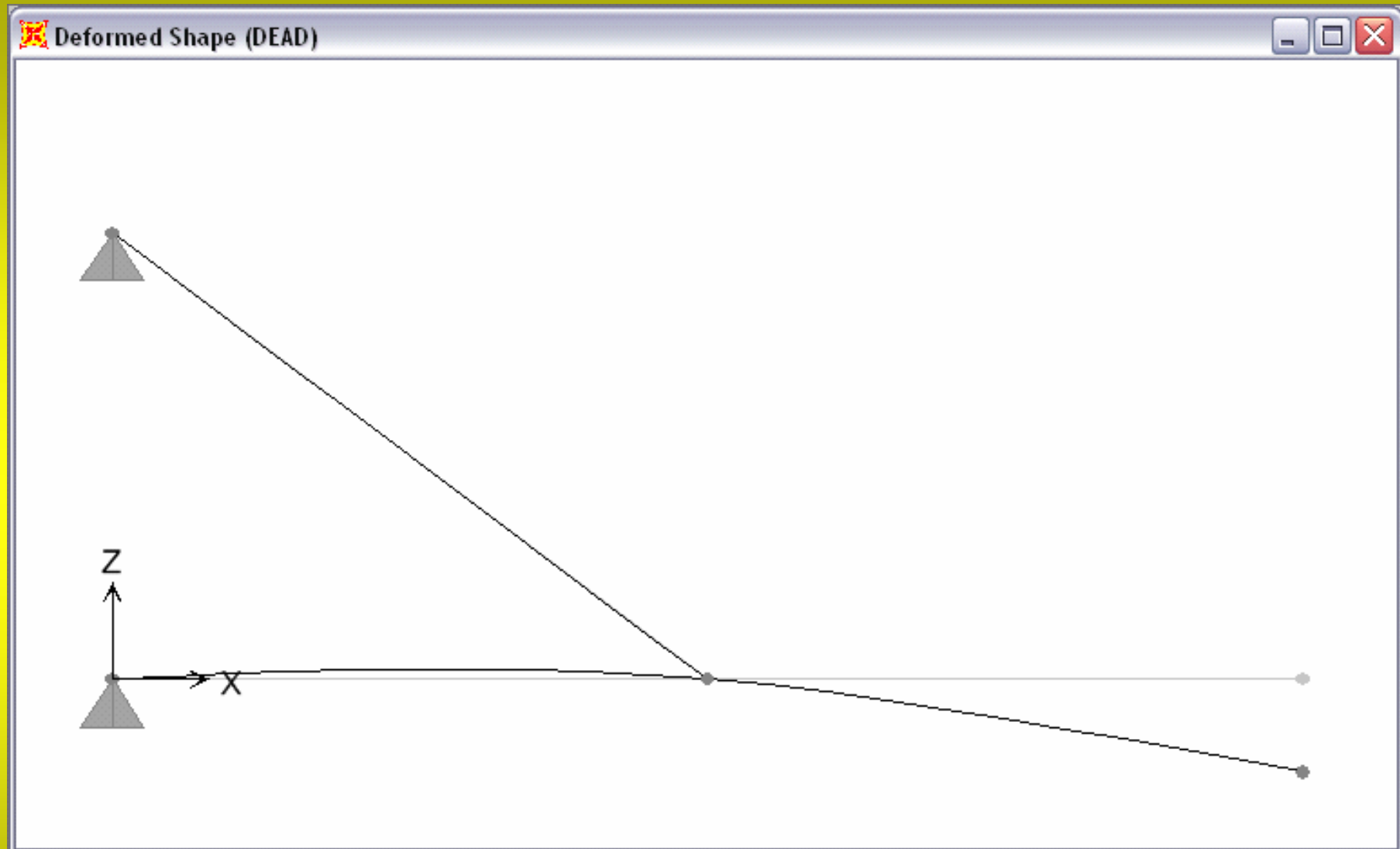


Figura 3.8: Configurazione deformata.

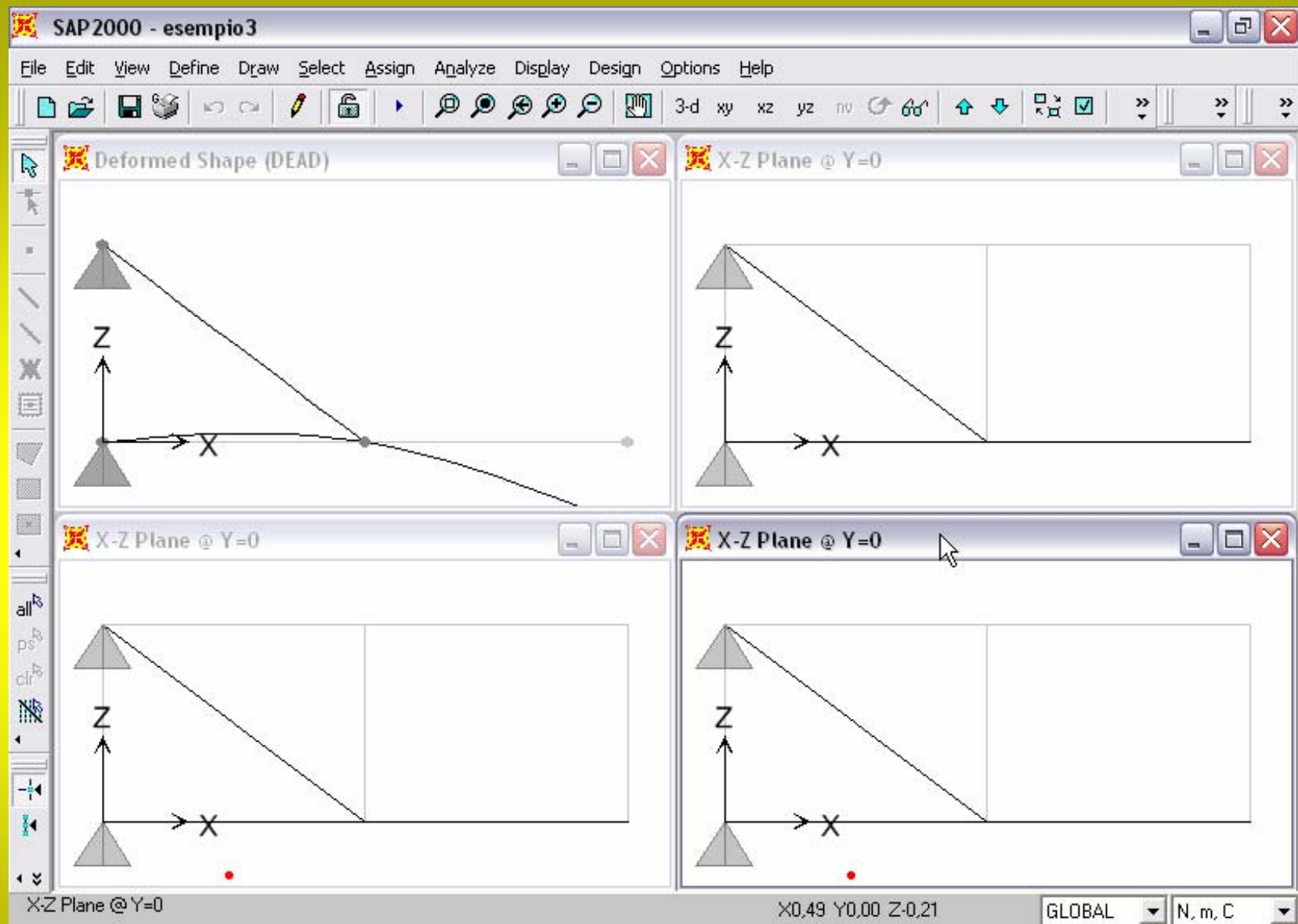


Figura 3.9: Visualizzazione della struttura attraverso quattro finestre.

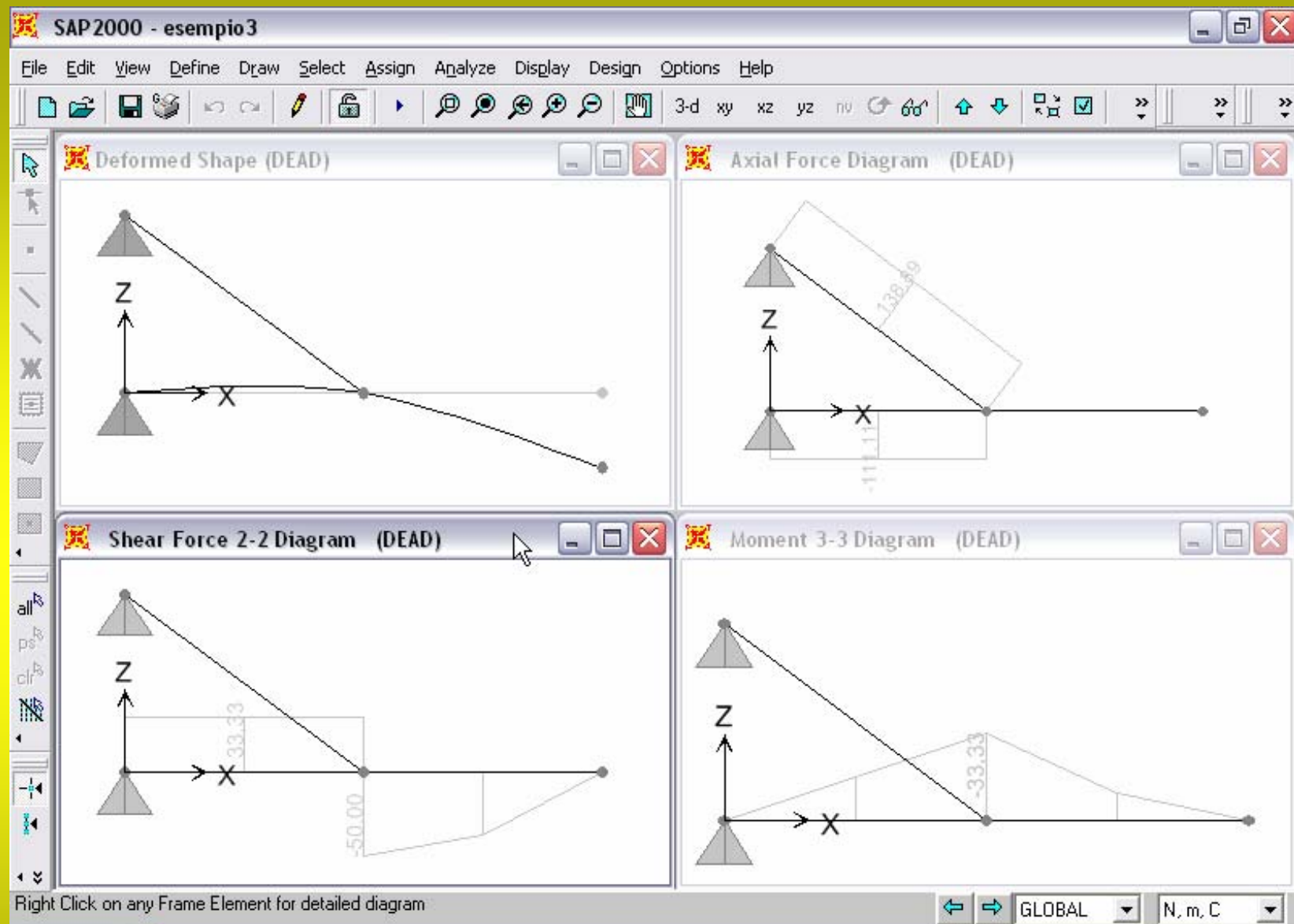


Figura 3.10: Configurazione deformata e caratteristiche di sollecitazione per la struttura sotto esame.

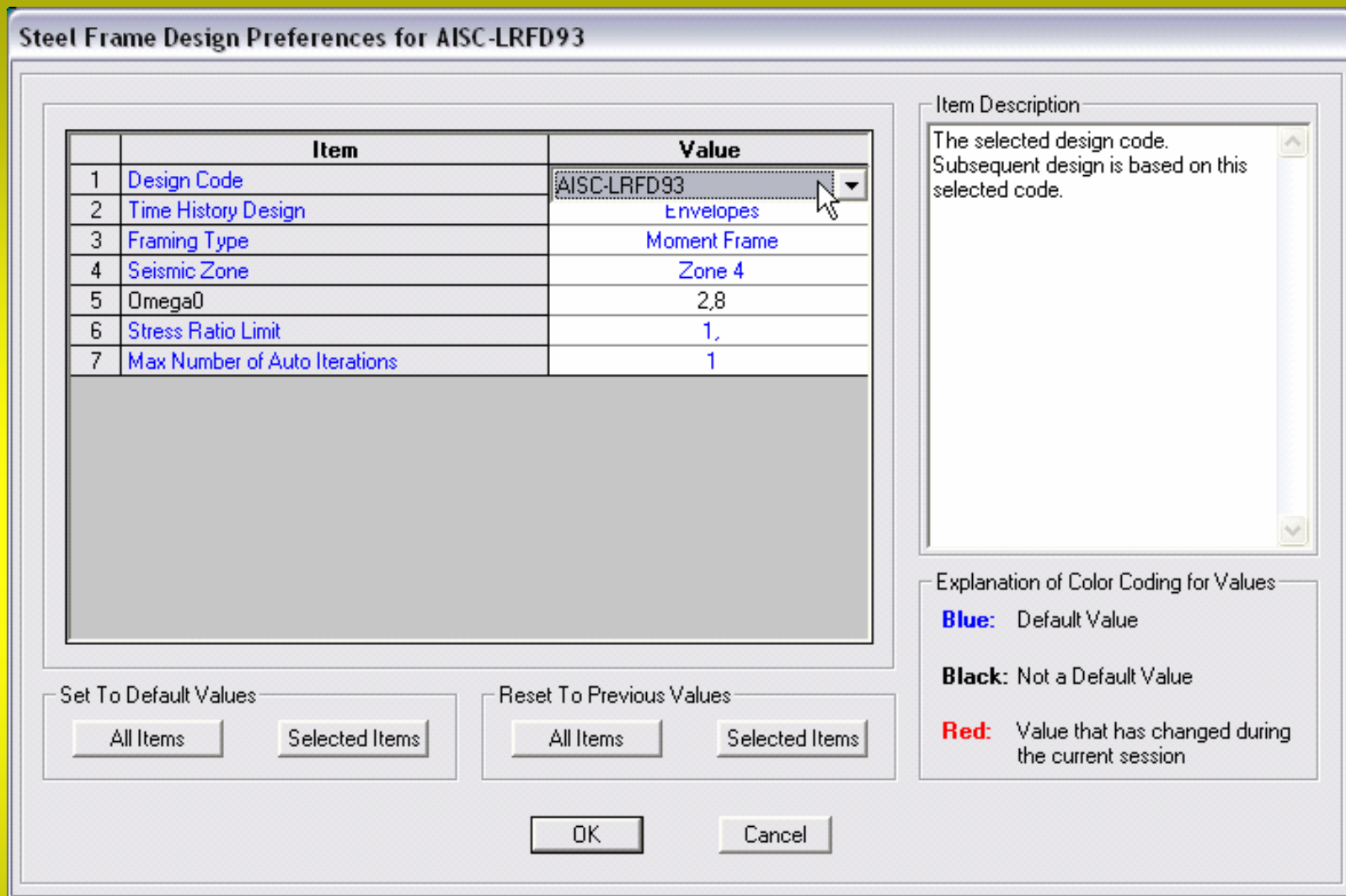


Figura 3.11: Scelta del codice per la verifica a rottura.

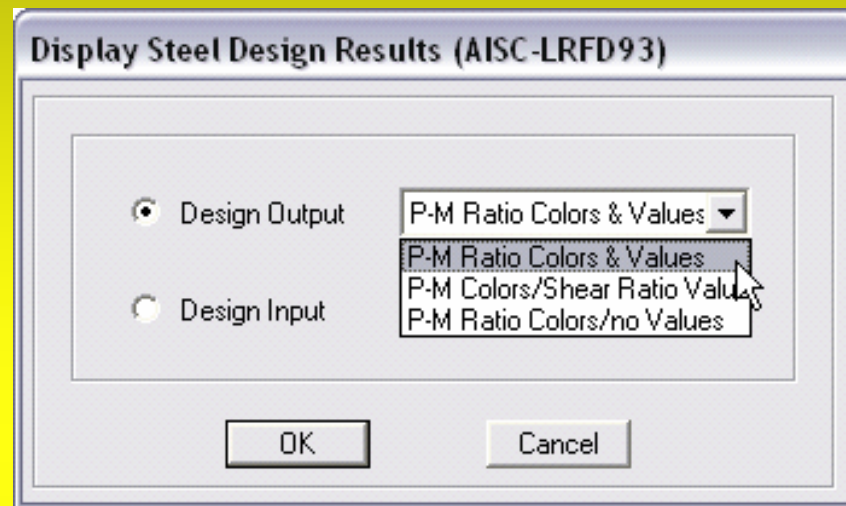


Figura 3.12: Scelta della modalità di visualizzazione dei risultati della verifica a rottura.

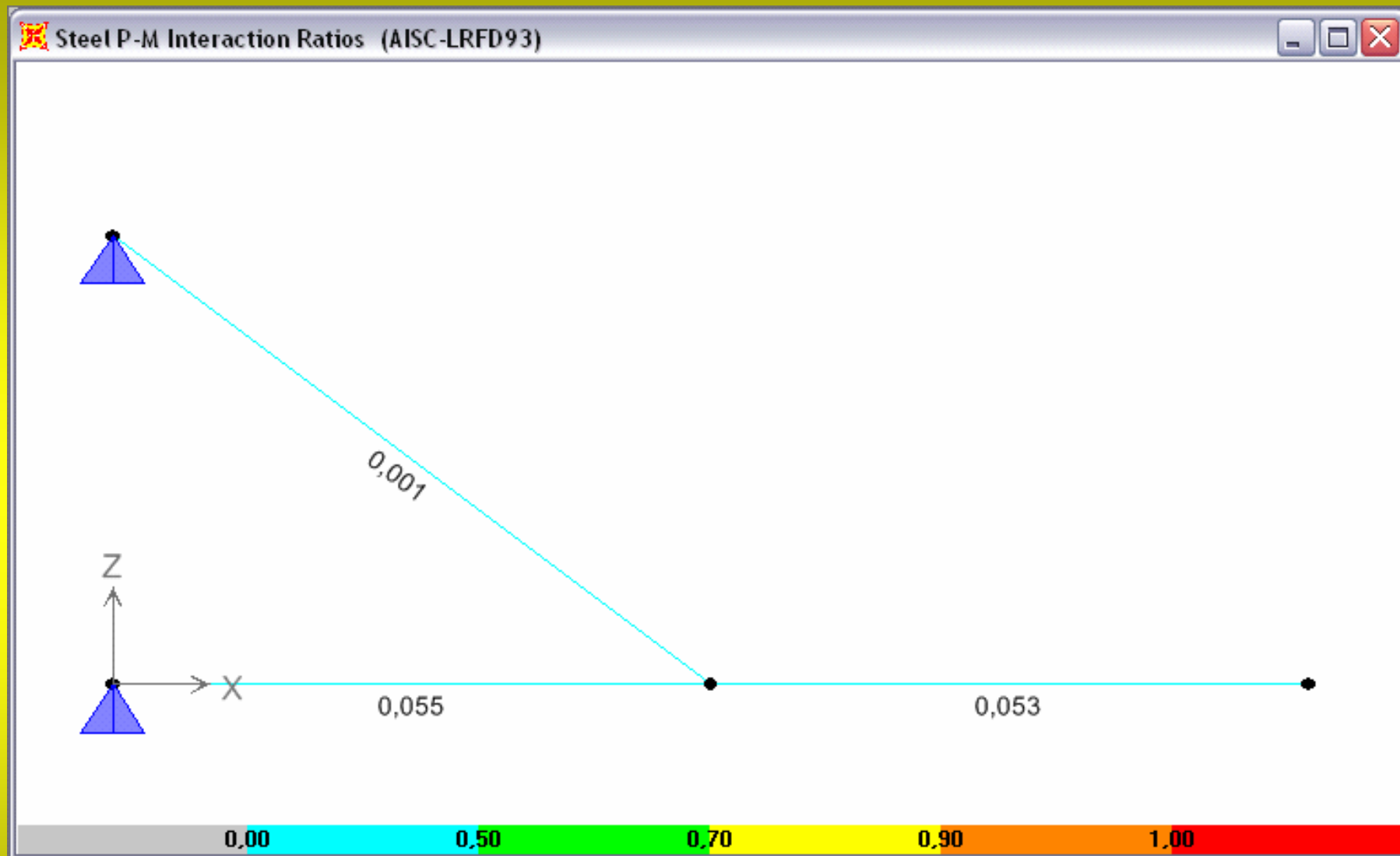


Figura 3.13: Risultati della verifica della sezione.

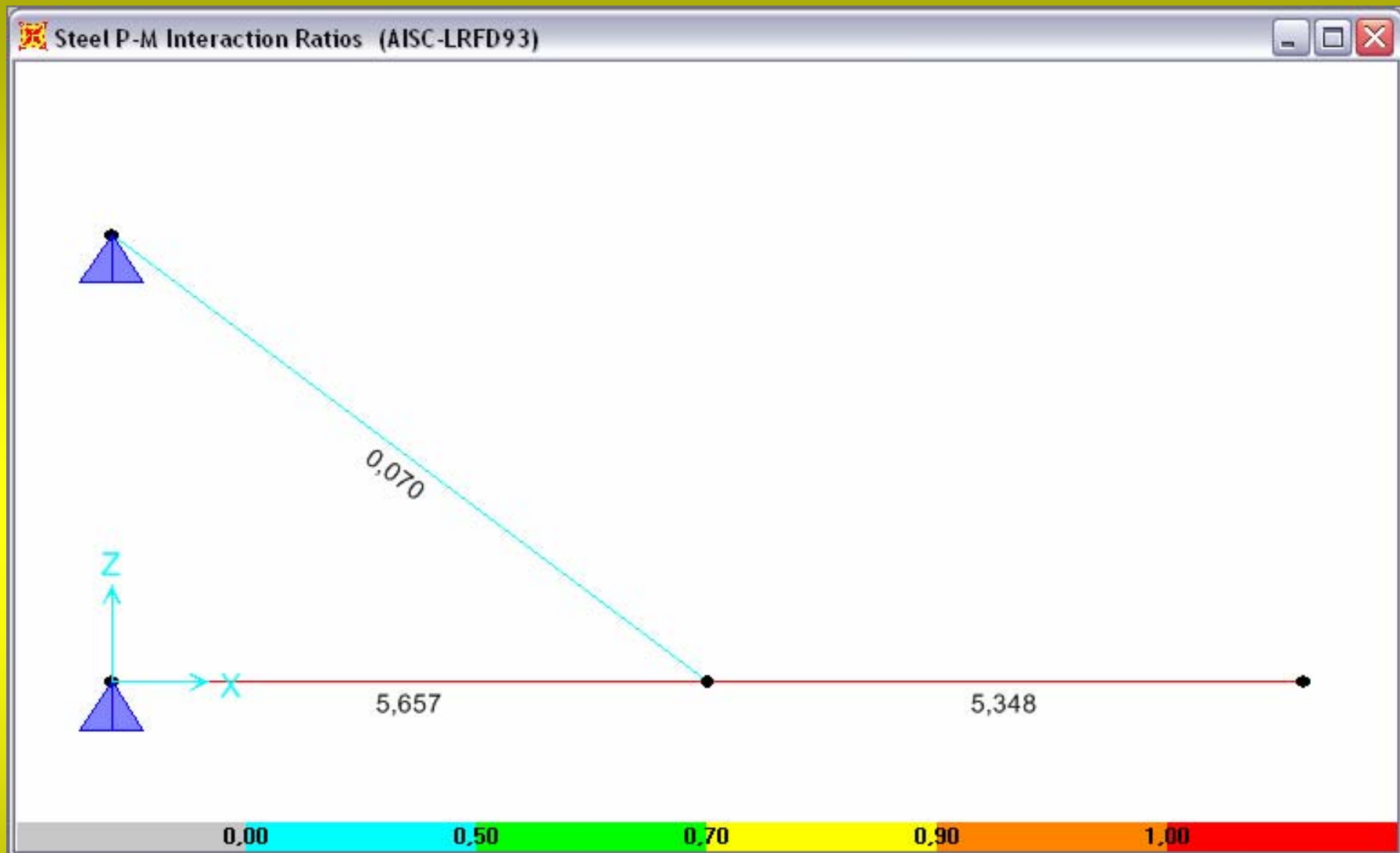


Figura 3.14: Risultati della verifica della sezione.

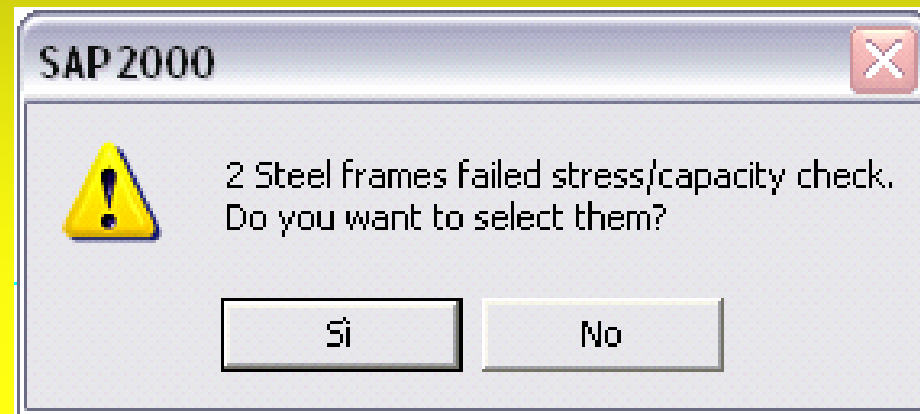


Figura 3.15: Messaggio di warning.

Steel Stress Check Information (AISC-LRFD93)

Frame ID: Analysis Section:
 Design Code: Design Section:

COMBO ID	STATION LOC	/---MOMENT INTERACTION CHECK---	//-MAJ-SHR---MIN-SHR-
		RATIO = AXL + B-MAJ + B-MIN	RATIO RATIO
DSTL1	0,00	5,348 (T) = 0,000 + 5,348 + 0,000	0,100 0,000
DSTL1	0,50	1,671 (T) = 0,000 + 1,671 + 0,000	0,075 0,000
DSTL1	1,00	0,000 (T) = 0,000 + 0,000 + 0,000	0,000 0,000
DSTL2	0,00	4,584 (T) = 0,000 + 4,584 + 0,000	0,086 0,000
DSTL2	0,50	1,432 (T) = 0,000 + 1,432 + 0,000	0,064 0,000
DSTL2	1,00	0,000 (T) = 0,000 + 0,000 + 0,000	0,000 0,000

Current Stylesheet: Program Default

Figura 3.16: Informazioni sulla verifica della sezione di un **Frame**.

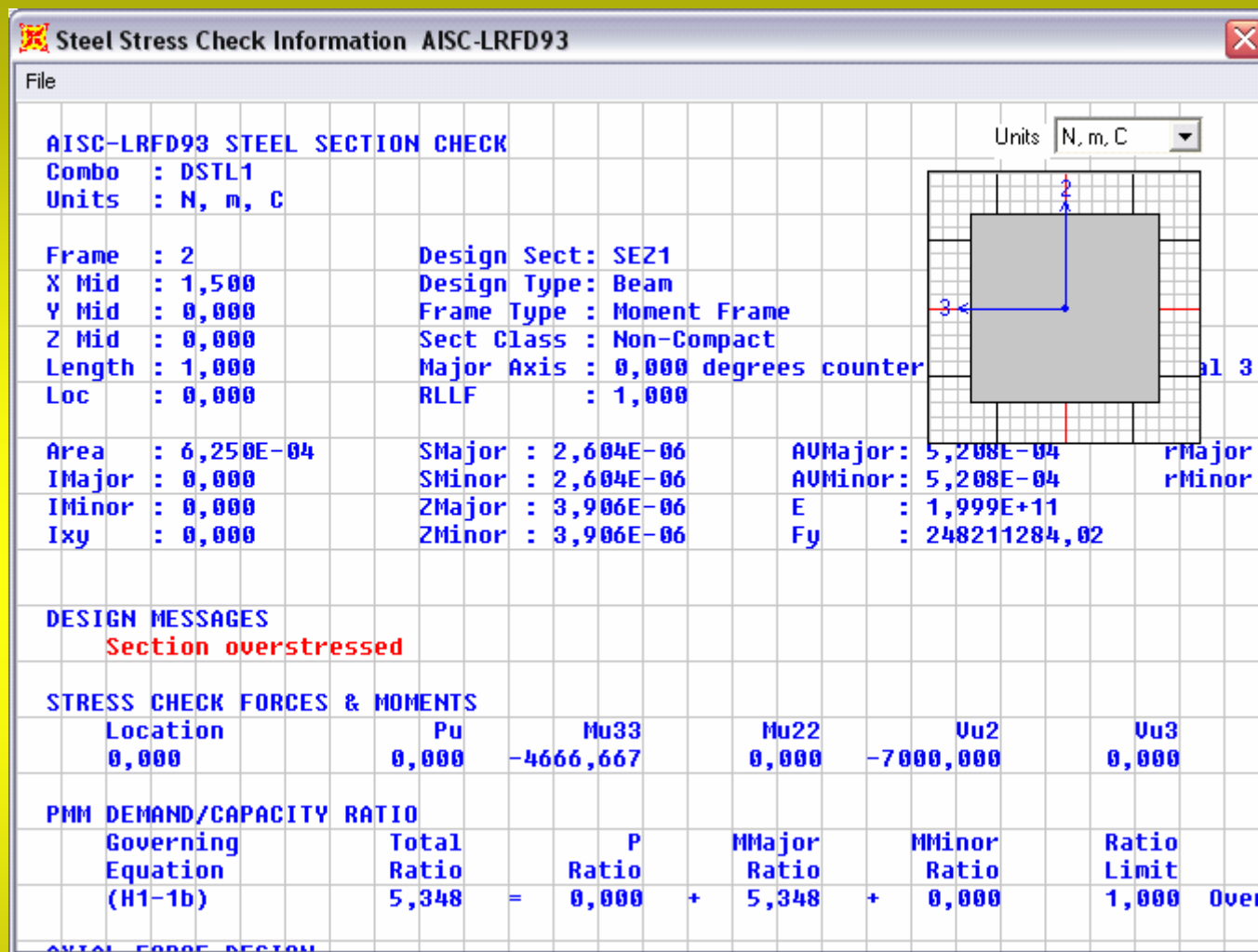


Figura 3.17: Informazioni dettagliate sulla verifica della sezione di un Frame.

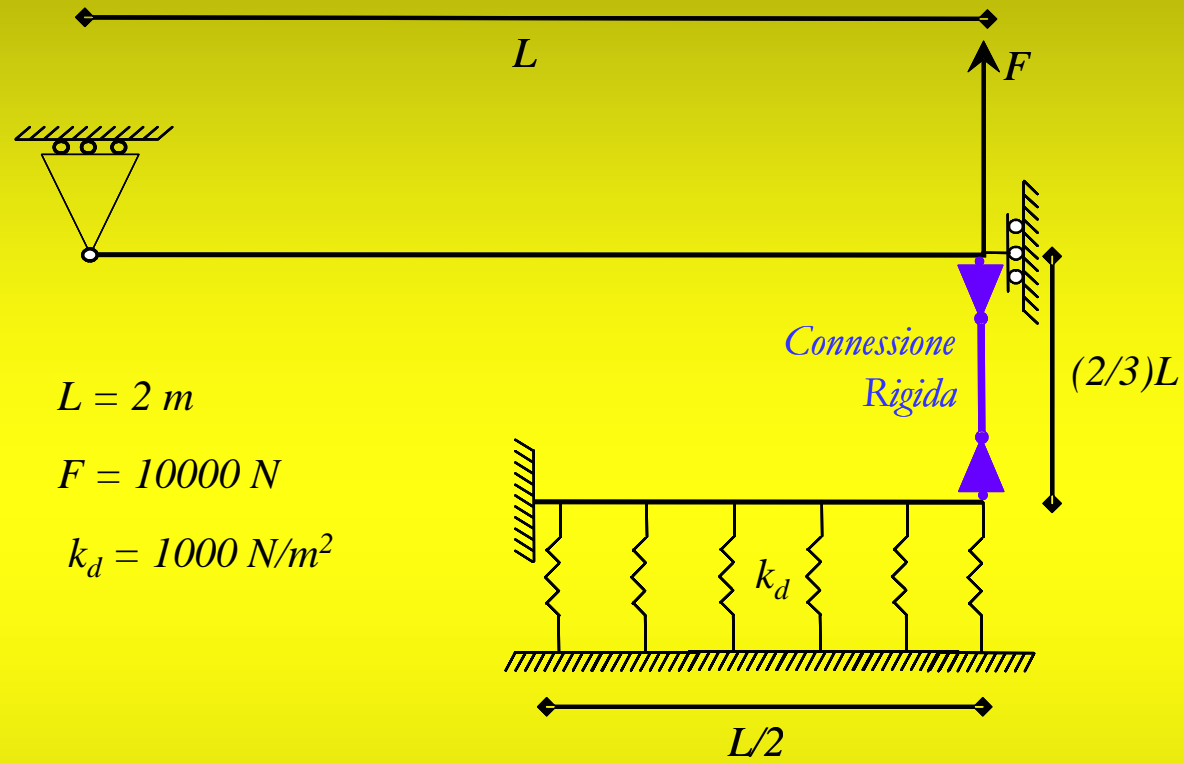


Figura 4.1: Ideogramma del modello.

New Coord/Grid System

Cartesian Cylindrical

System Name GLOBAL

Number of Grid Spaces

X direction 2

Y direction 0

Z direction 1

Grid Spacing

X direction 1

Y direction 1

Z direction 0,666

OK Cancel

Figura 4.2: Generatore di griglia.

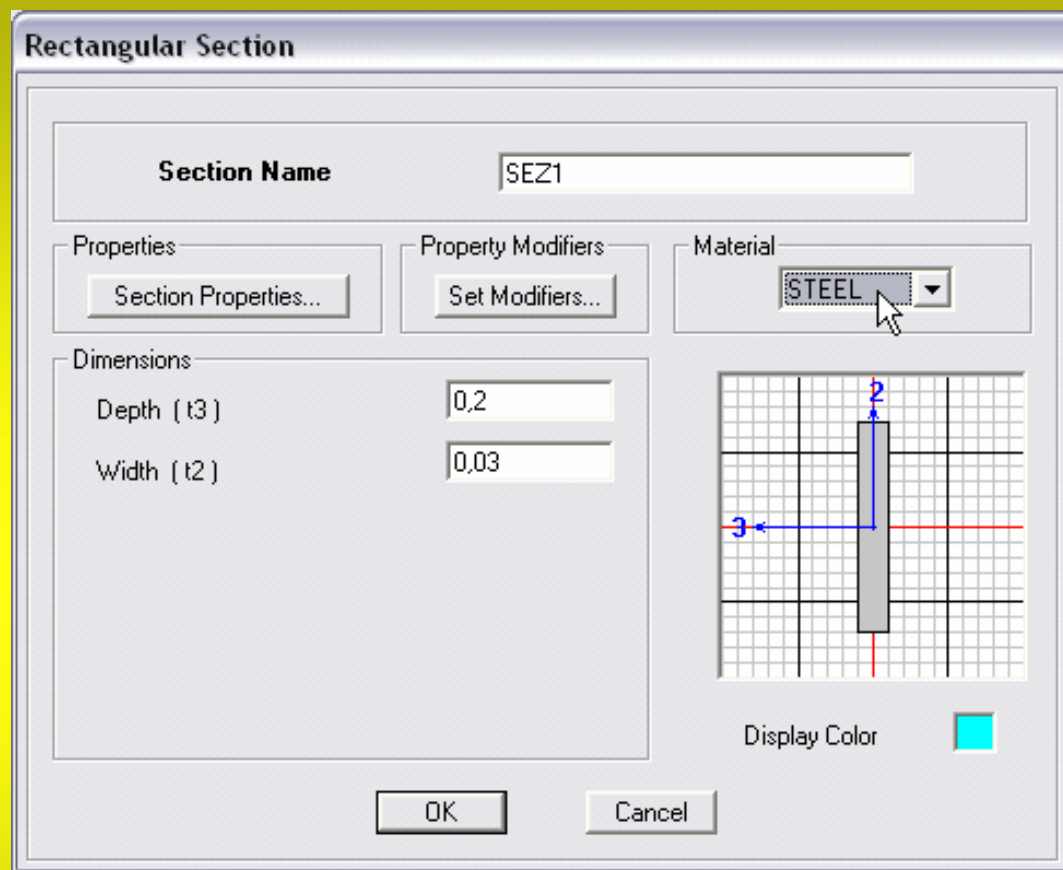


Figura 4.3: Geometria della sezione rettangolare.

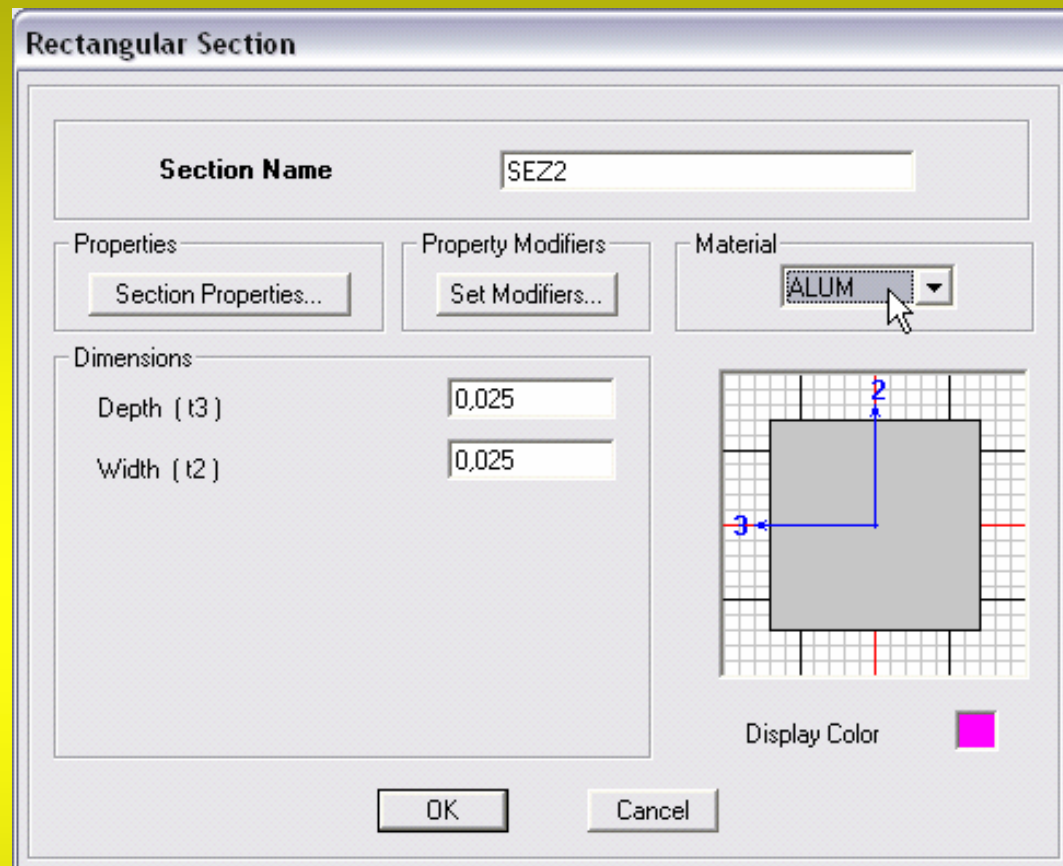


Figura 4.4: Geometria della sezione quadrata.

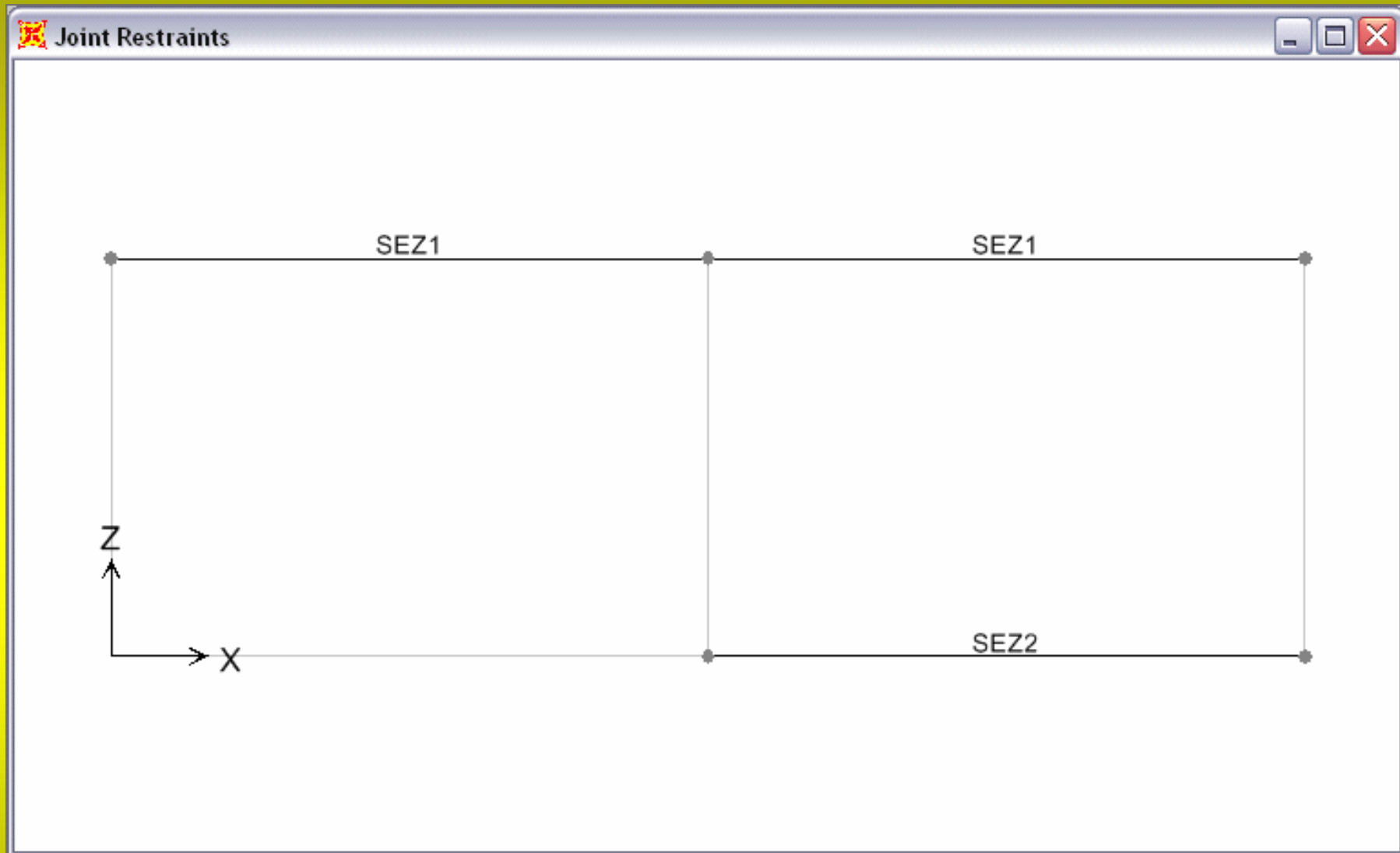


Figura 4.5: Geometria dei **Frames**, con sezioni in evidenza.

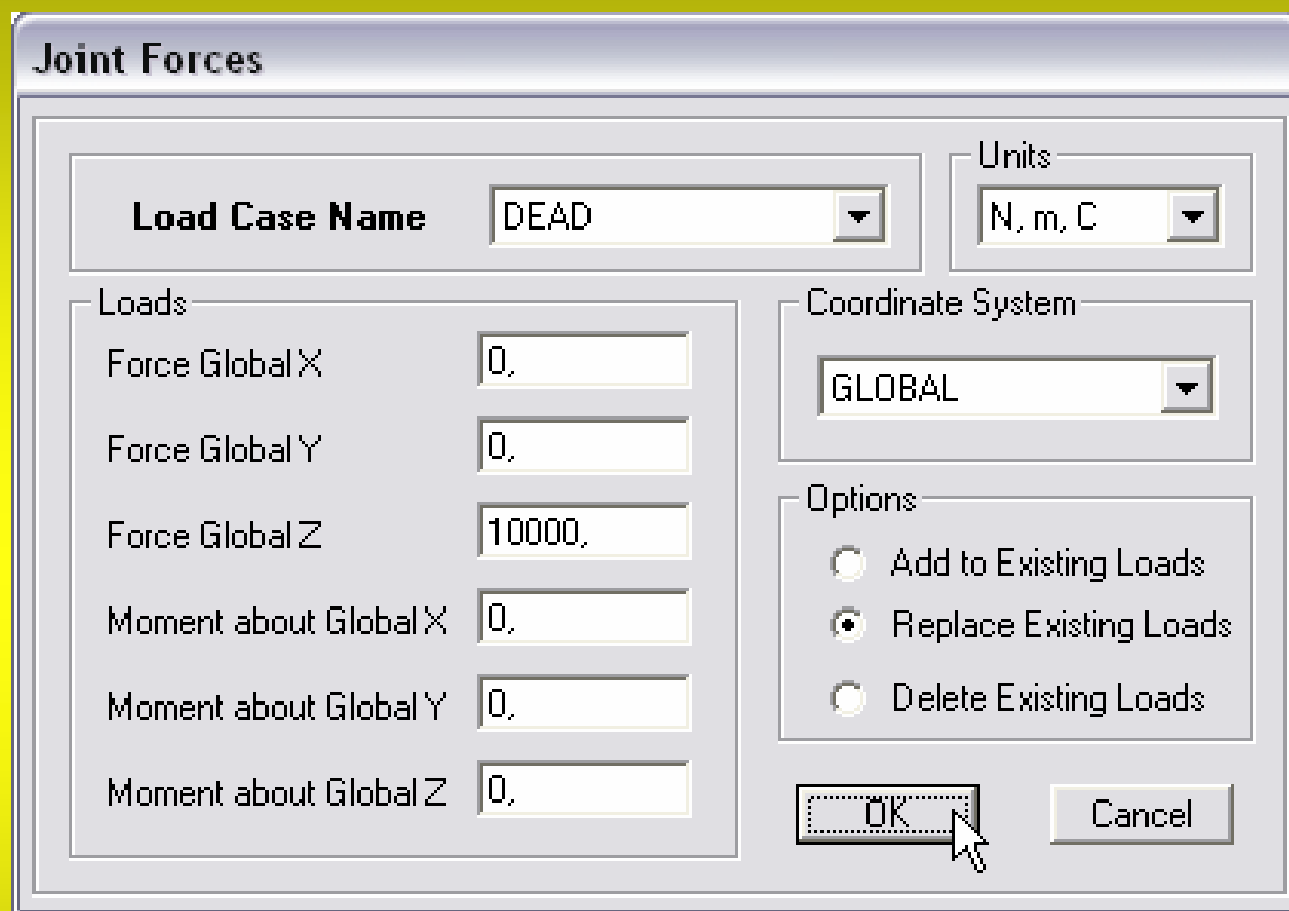


Figura 4.6: Assegnazione di carichi puntuali su un nodo.

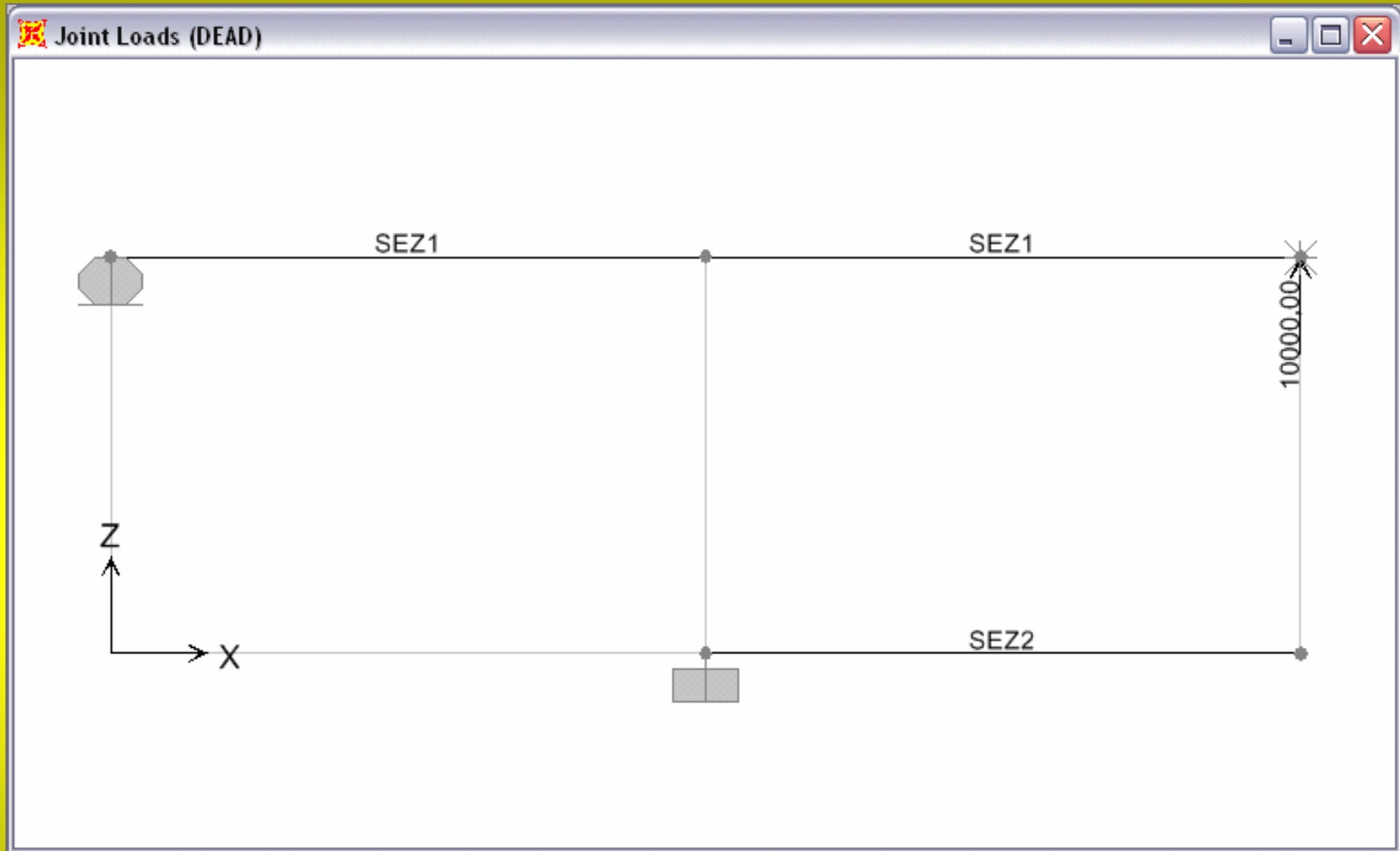


Figura 4.7: Struttura da analizzare.

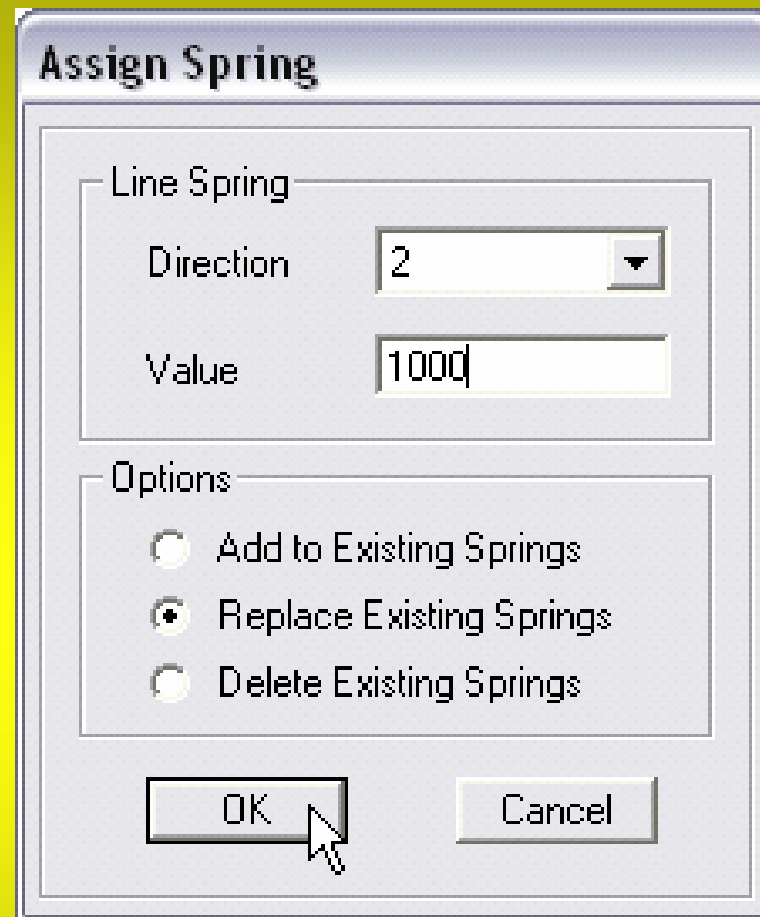


Figura 4.8: Assegnazione di una molla distribuita.

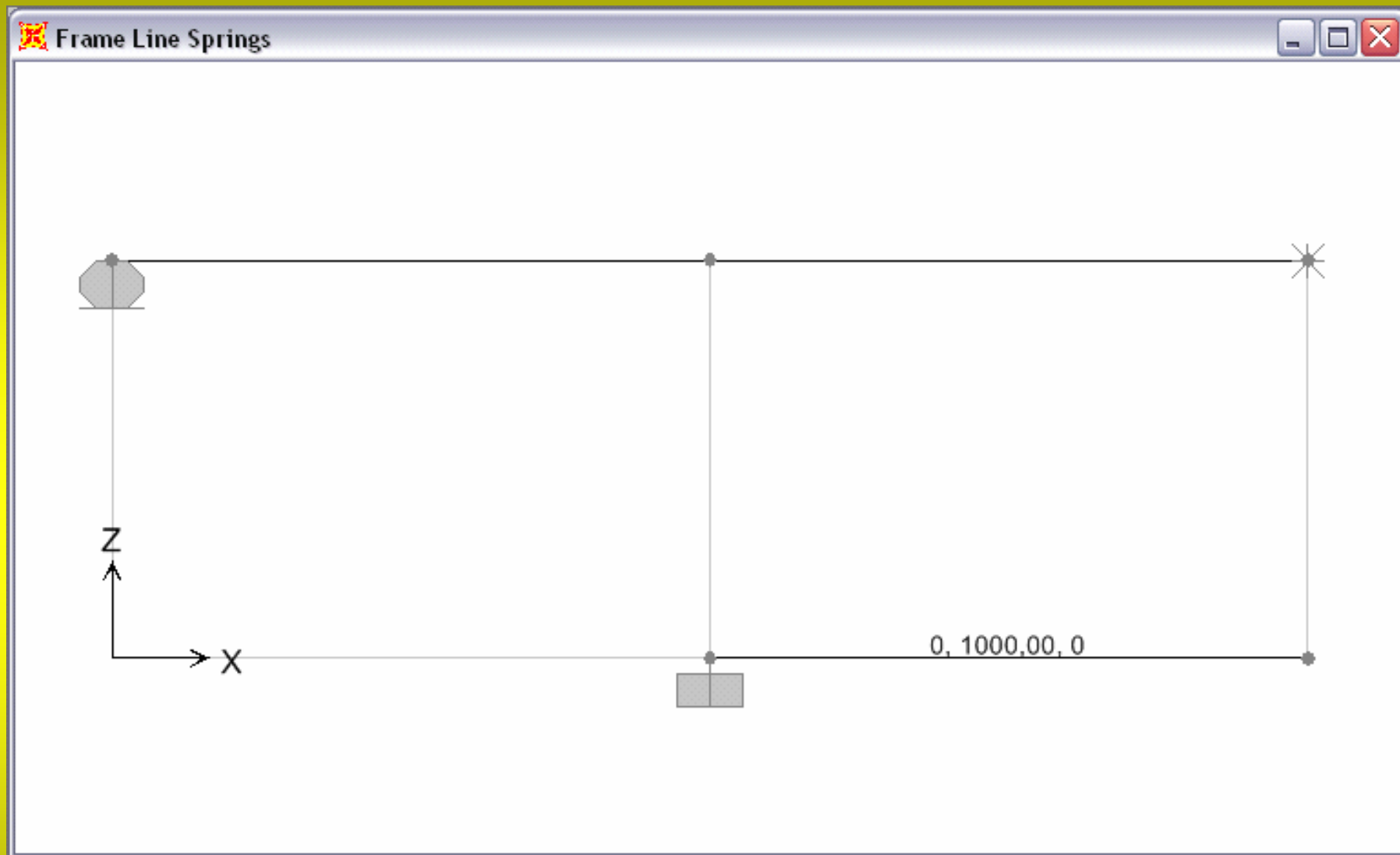


Figura 4.9: Struttura da analizzare.

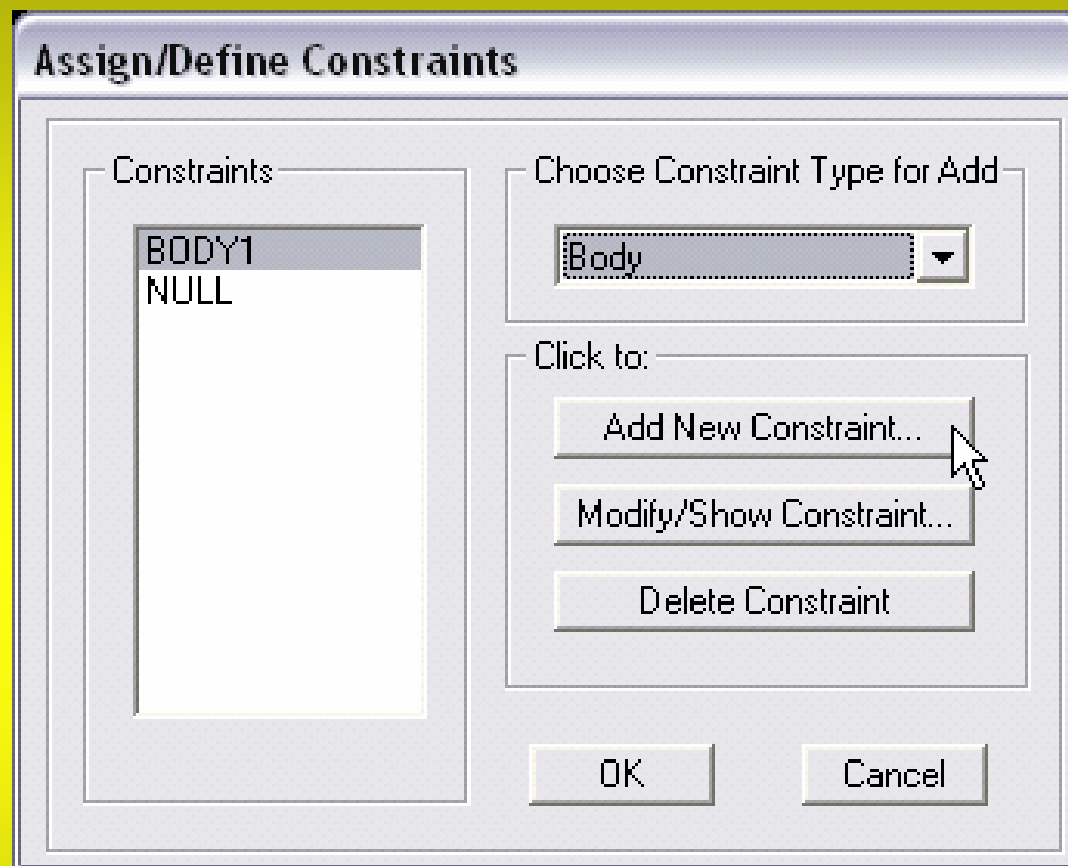


Figura 4.10: Definizione/assegnazione di un **Constraint**.

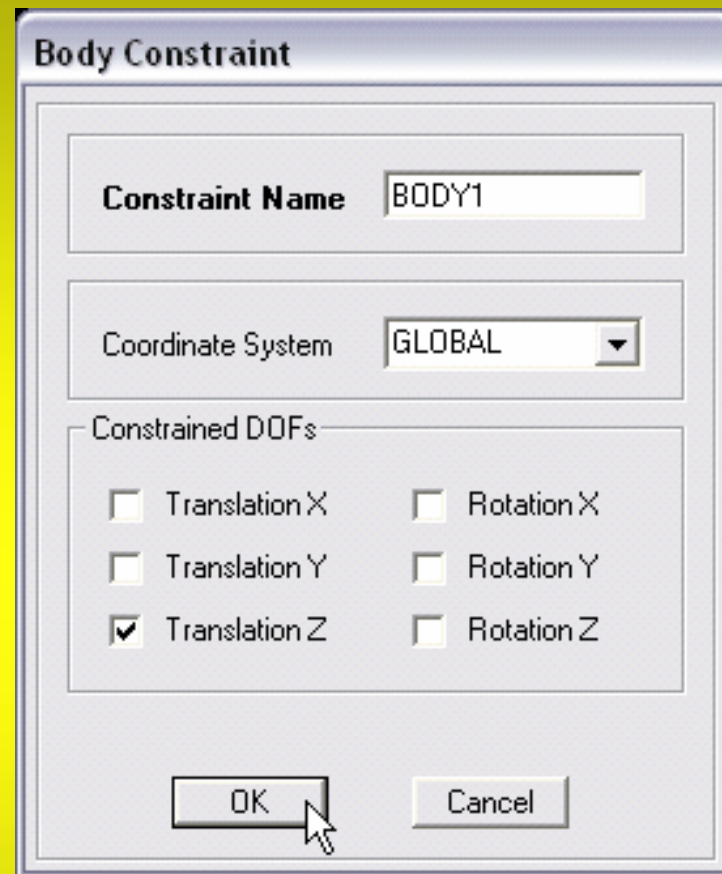


Figura 4.11: Specifica di un **Body Constraint**.

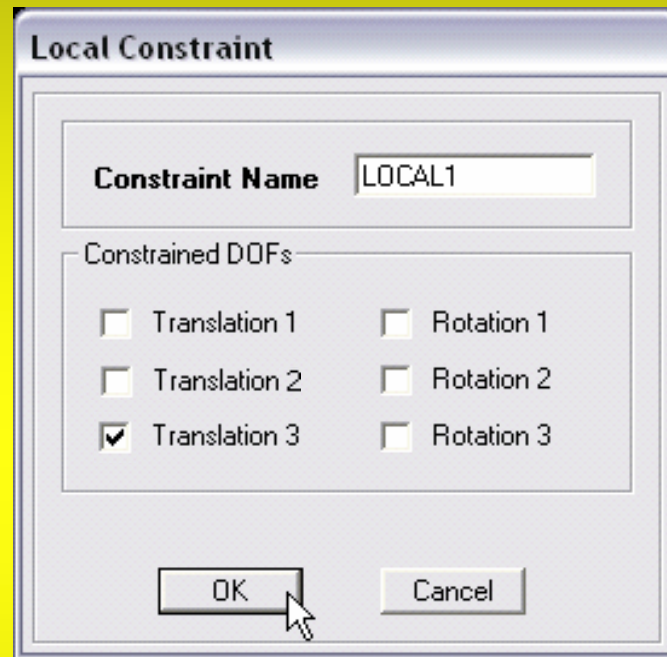


Figura 4.12: Specifica di un **Local Constraint**.

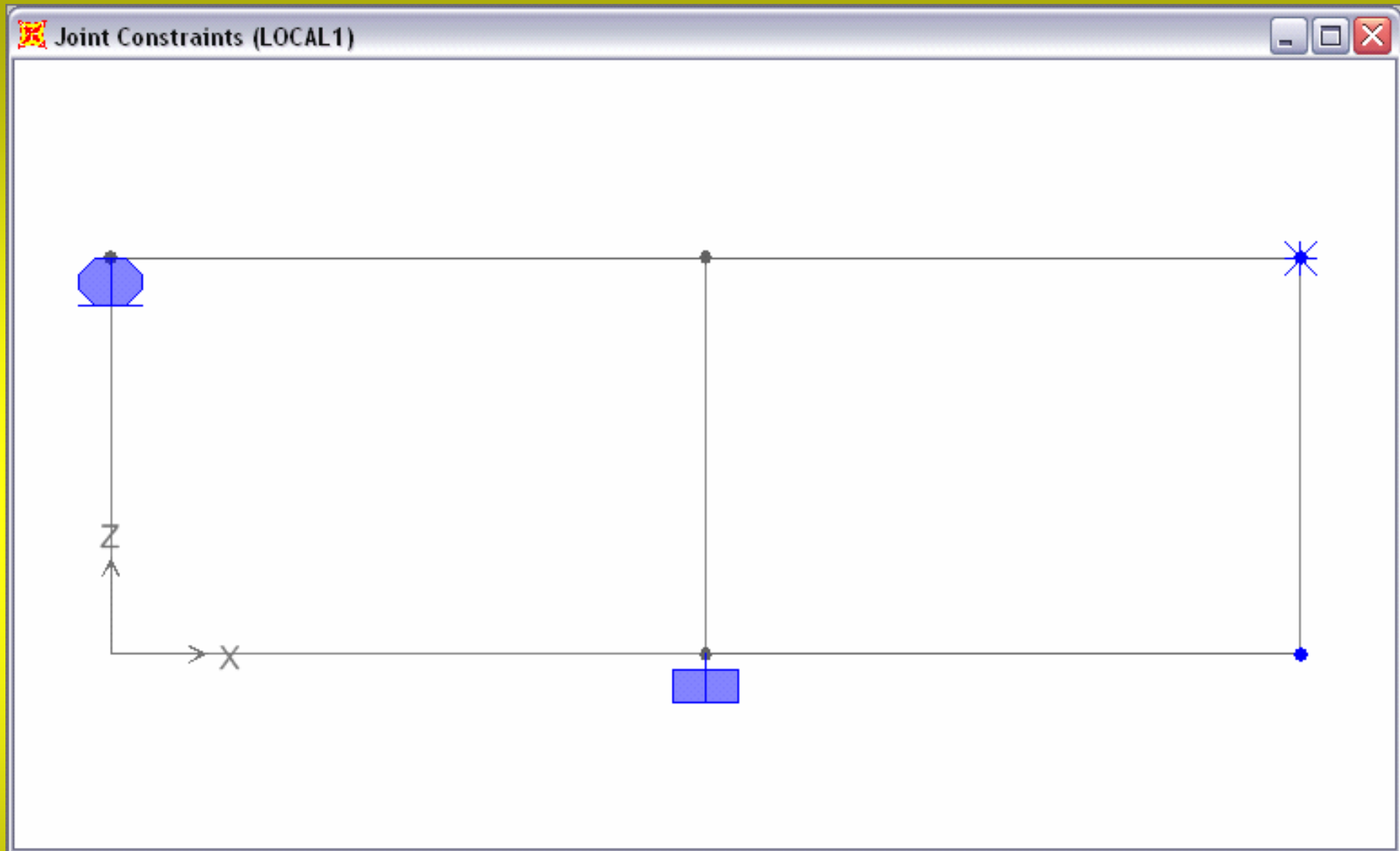


Figura 4.13: Visualizzazione del **Constraint**.

Joint Displacements			
Joint ID 3			
	1	2	3
Trans	0,00000	0,00000	0,00629
Rotn	0,00000	0,00000	0,00000

Joint Displacements			
Joint ID 5			
	1	2	3
Trans	0,00000	0,00000	0,00629
Rotn	0,00000	-0,00984	0,00000

Figura 4.14: Componenti di spostamento e di rotazione dei **Joints** di coordinate (2;0;0,67) e (2;0;0).

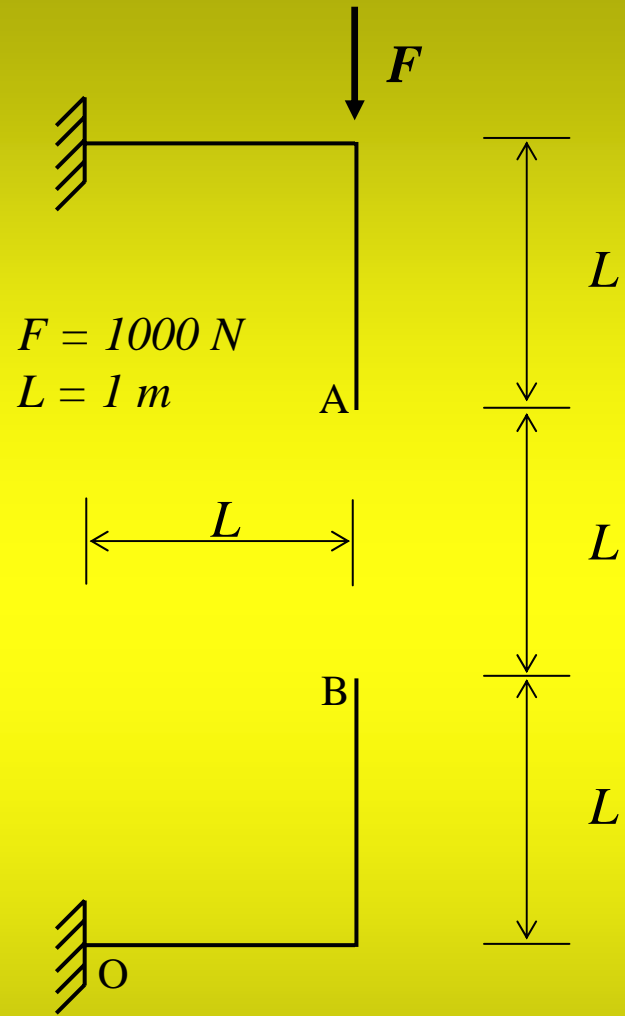
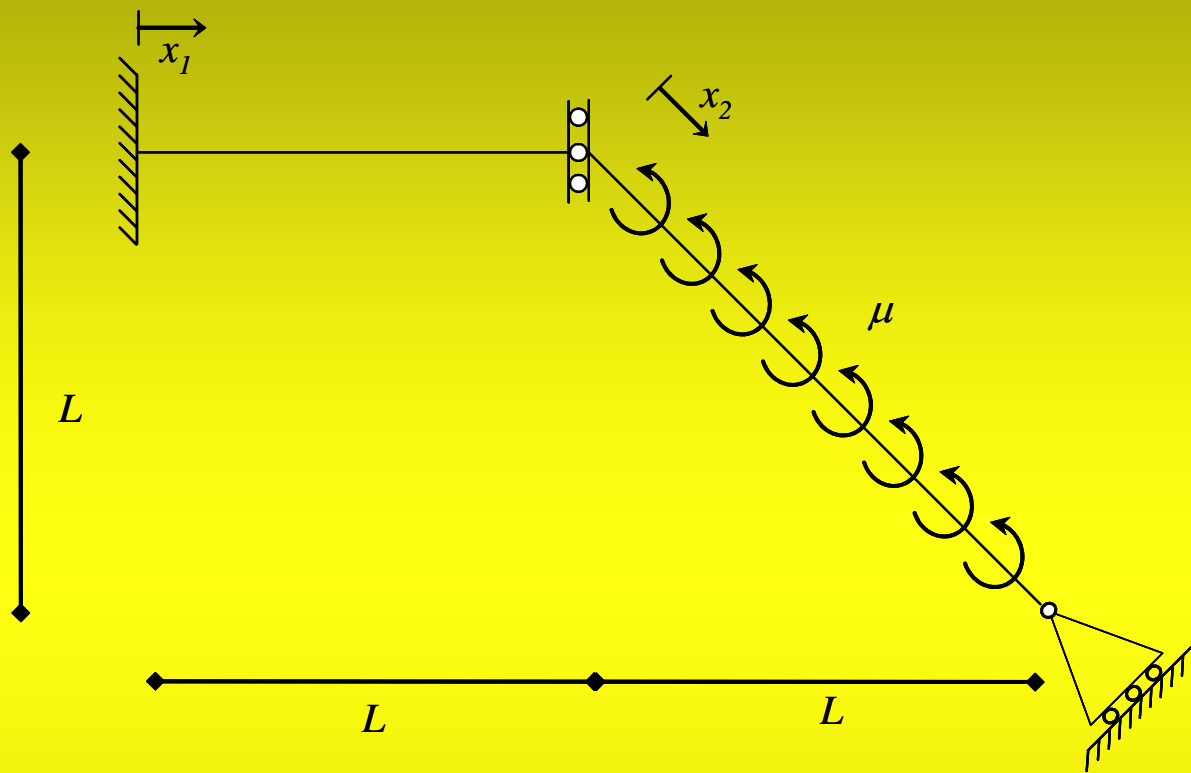
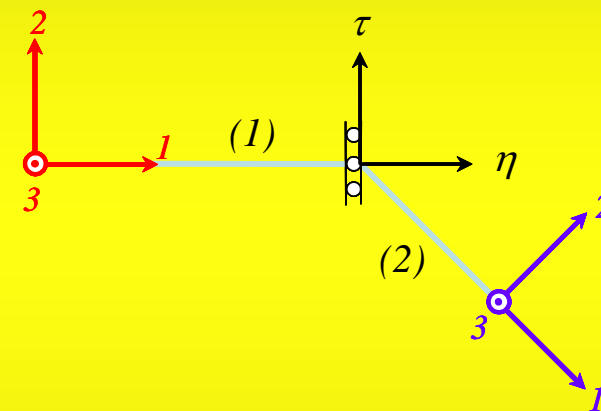


Figura 4.15: Ideogramma del modello per l'esercizio proposto.



(a)



(b)

Figura 5.1:

(a) Ideogramma del modello.

(b) Sistemi coordinati locali ai **Frames** e direzioni di azione del glifo.

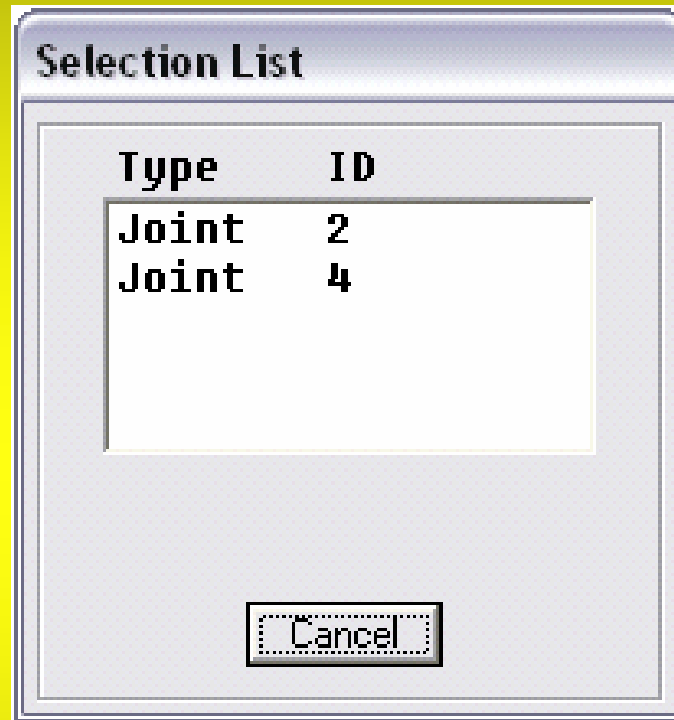


Figura 5.2: Finestra di selezione tra più **Joints**.

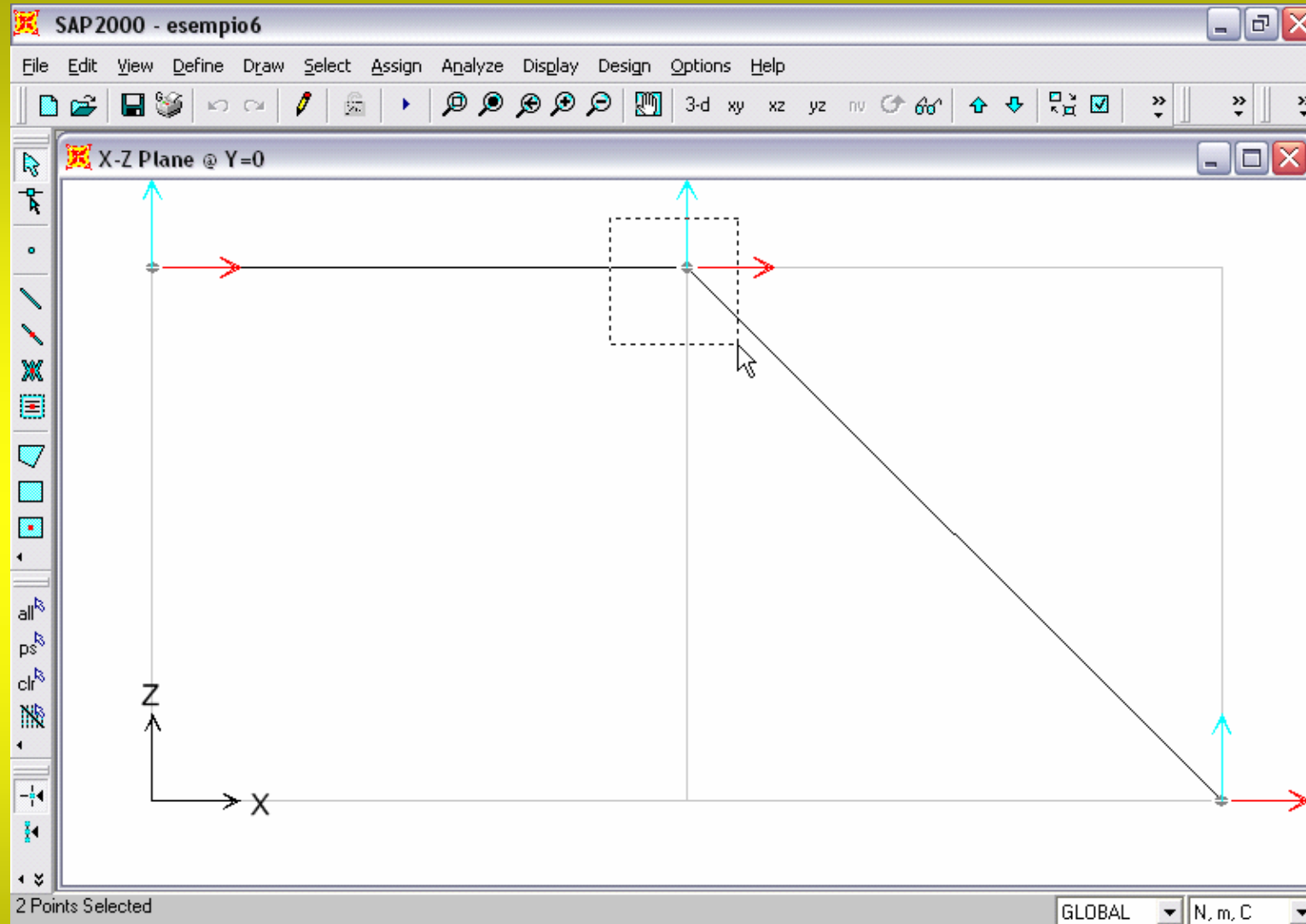


Figura 5.3: Modalità di selezione raccomandata.

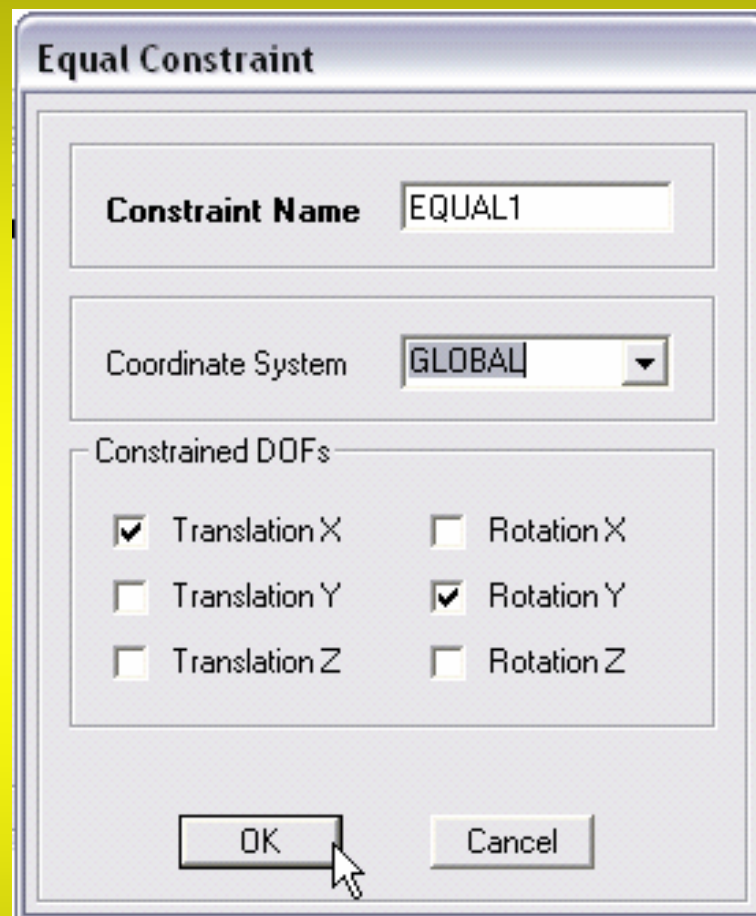


Figura 5.4: Specifica di un **Equal Constraint**.

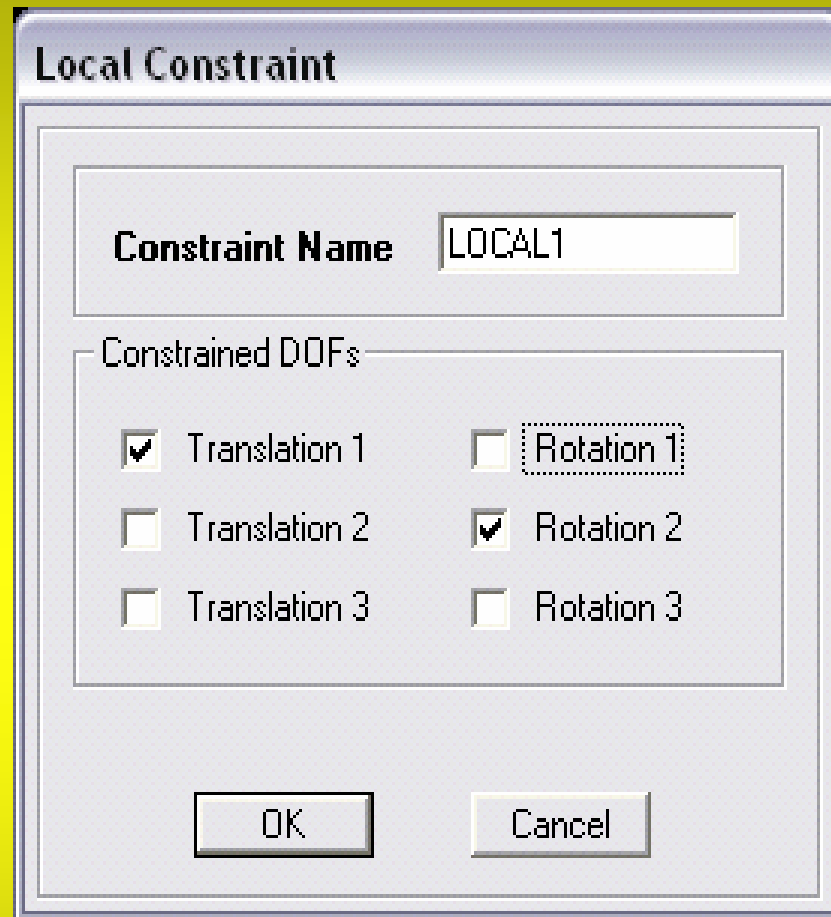


Figura 5.5: Specifica di un **Local Constraint**.

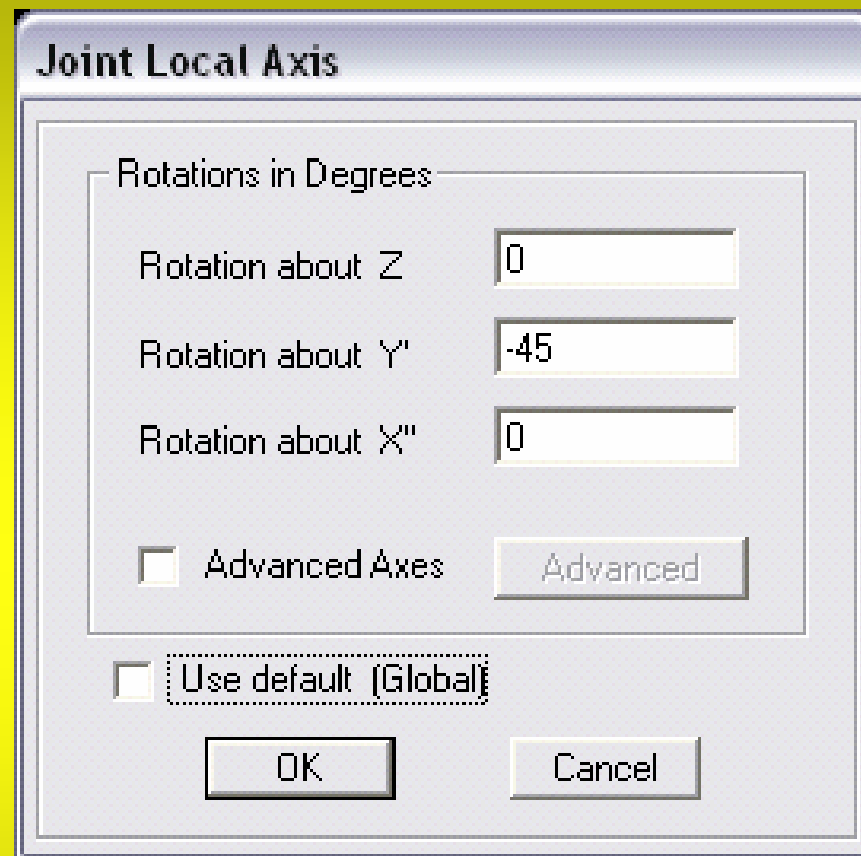


Figura 5.6: Finestra di modifica della terna di riferimento associata ad un **Joint**.

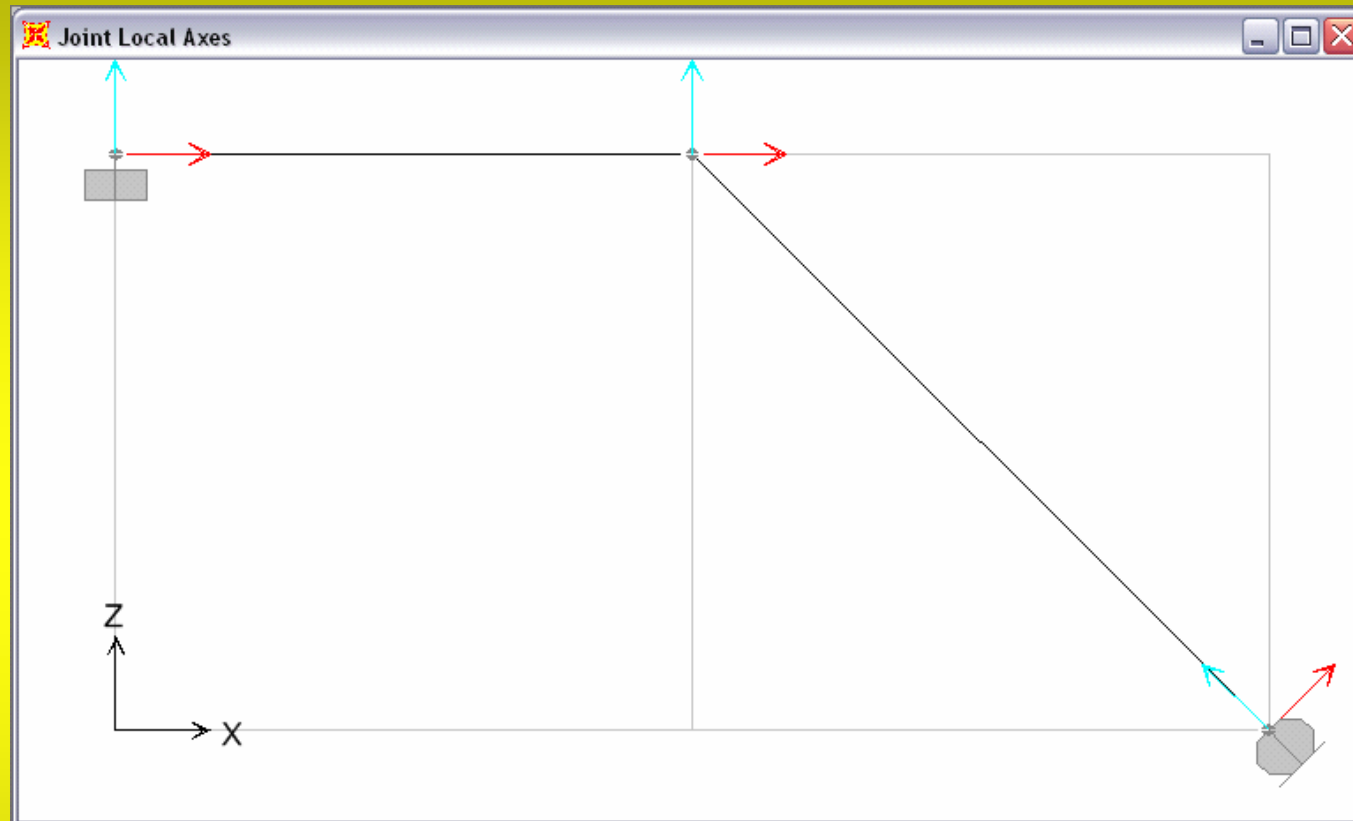


Figura 5.7: Visualizzazione degli assi locali associati ai **Joints** e dei vincoli esterni applicati.

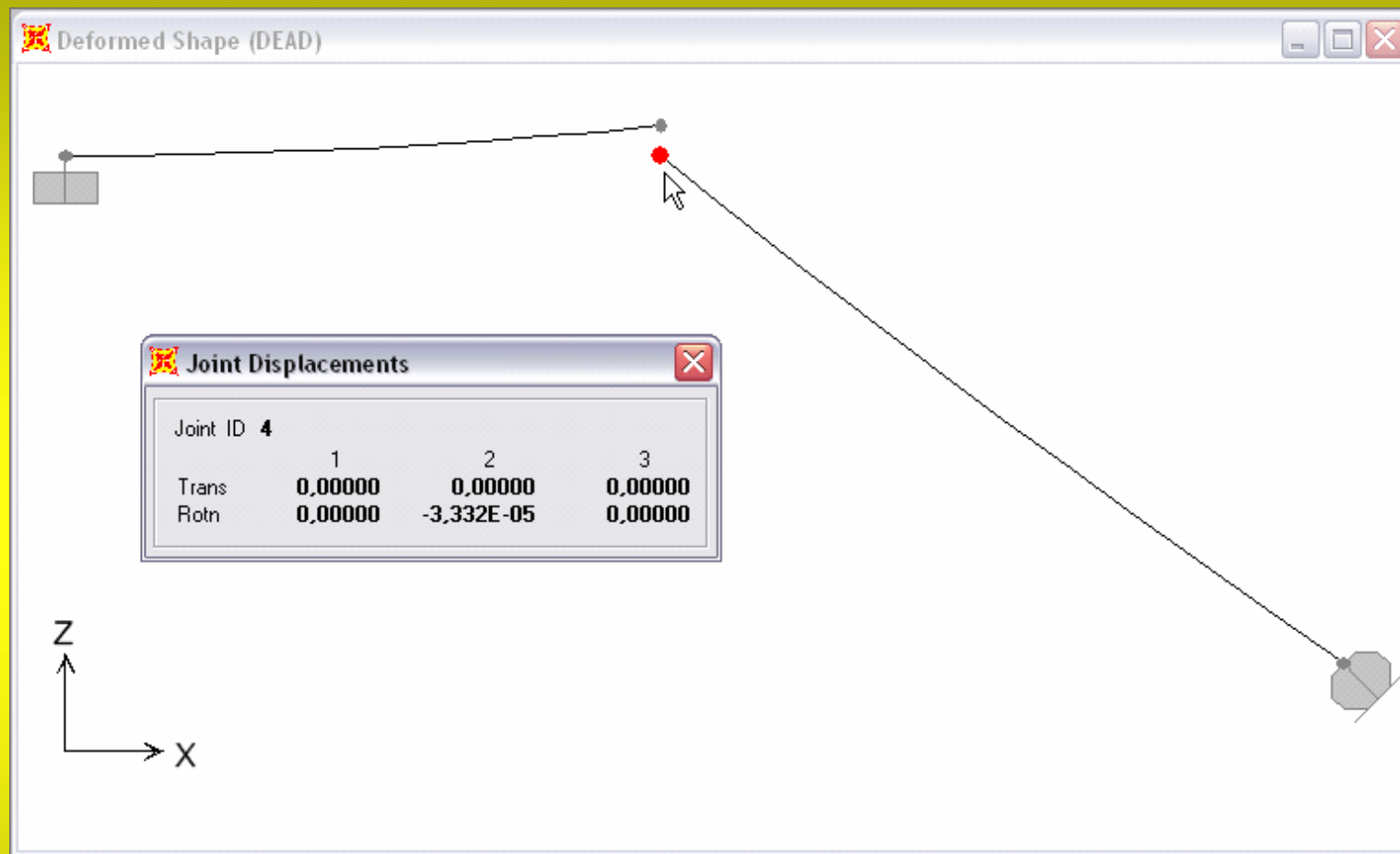


Figura 5.8: Configurazione deformata e componenti di spostamento e rotazione del punto in cui è applicato il glifo interno.

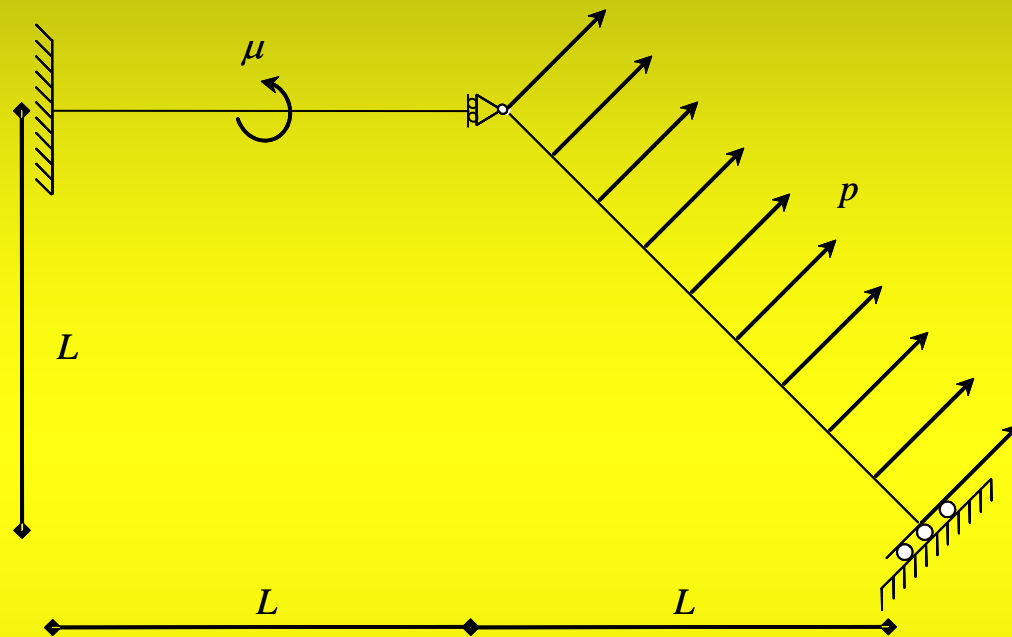


Figura 5.9: Ideogramma del modello (esercizio 1).

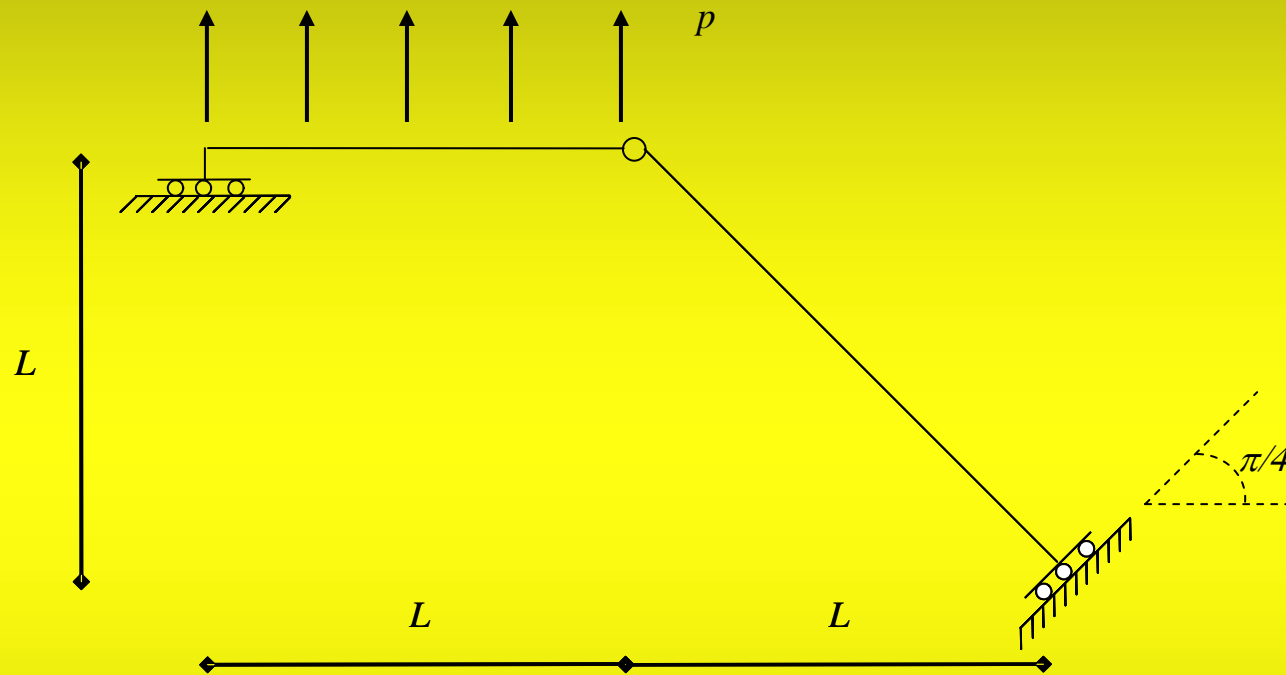


Figura 5.10: Ideogramma del modello (esercizio 2).

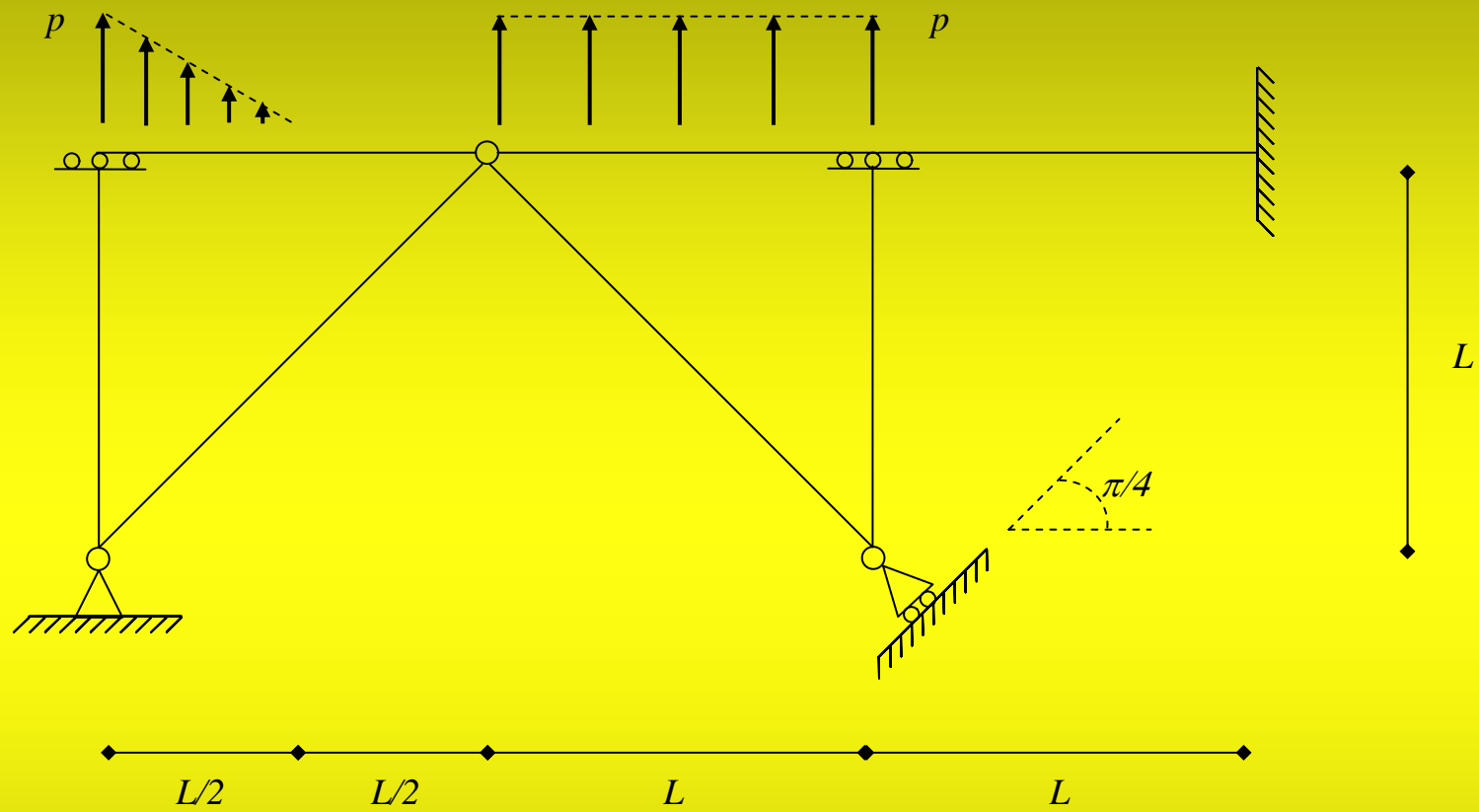


Figura 5.11: Ideogramma del modello (esercizio 3).

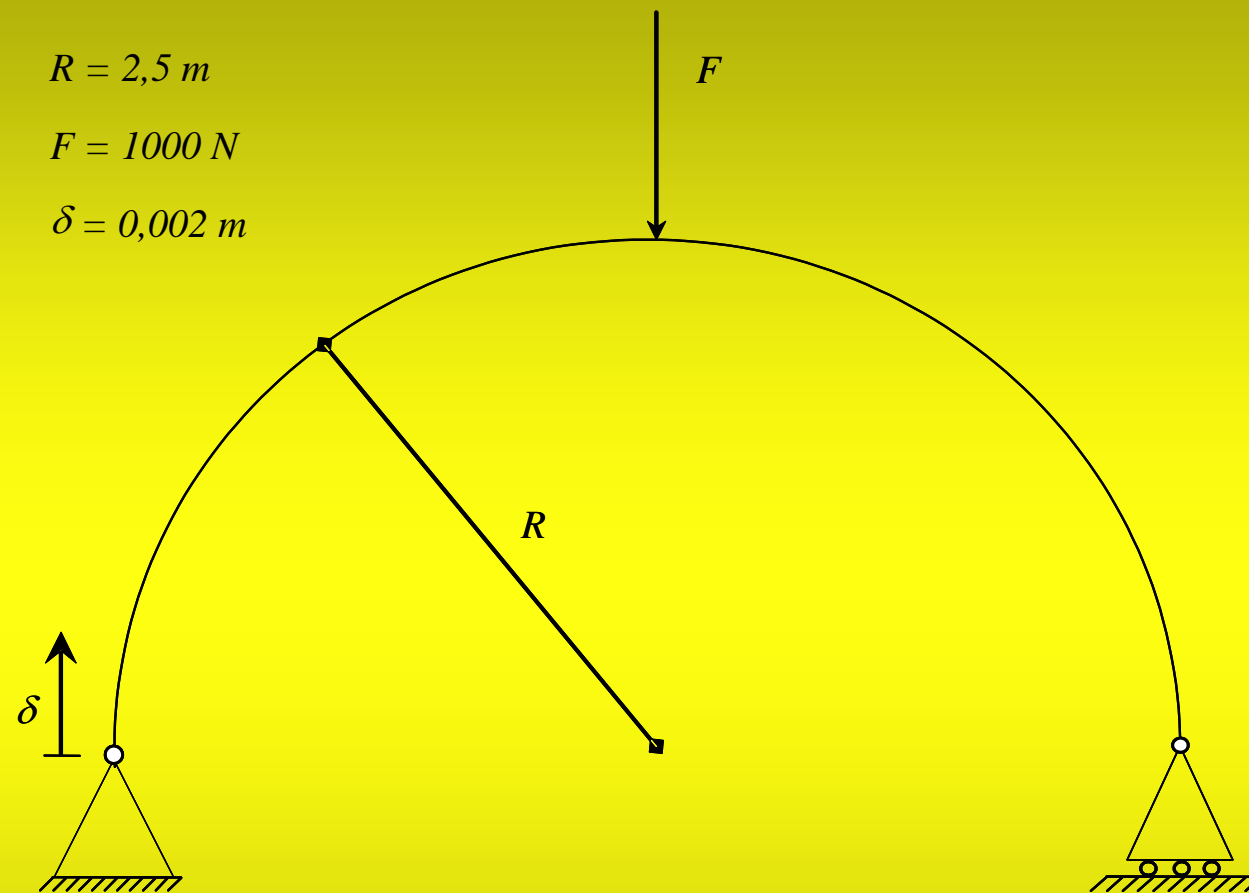


Figura 6.1: Ideogramma del modello.

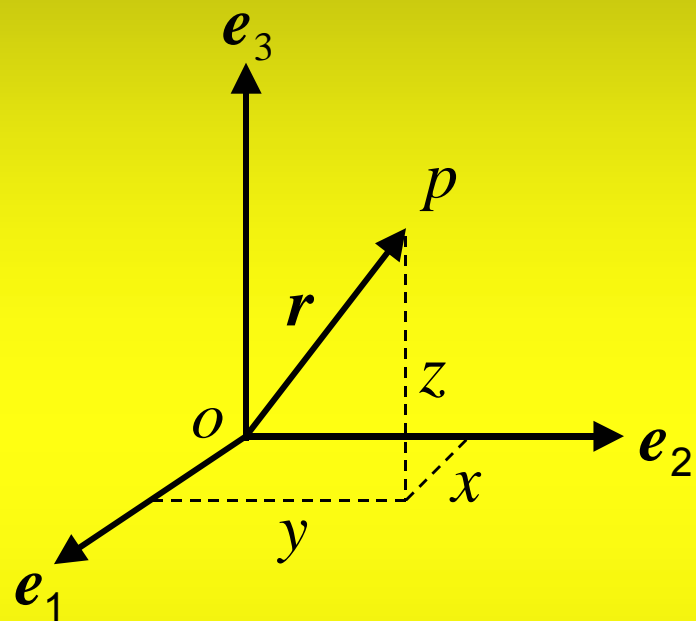


Figura 6.2: Esempio di terna di riferimento assunta da un Osservatore.

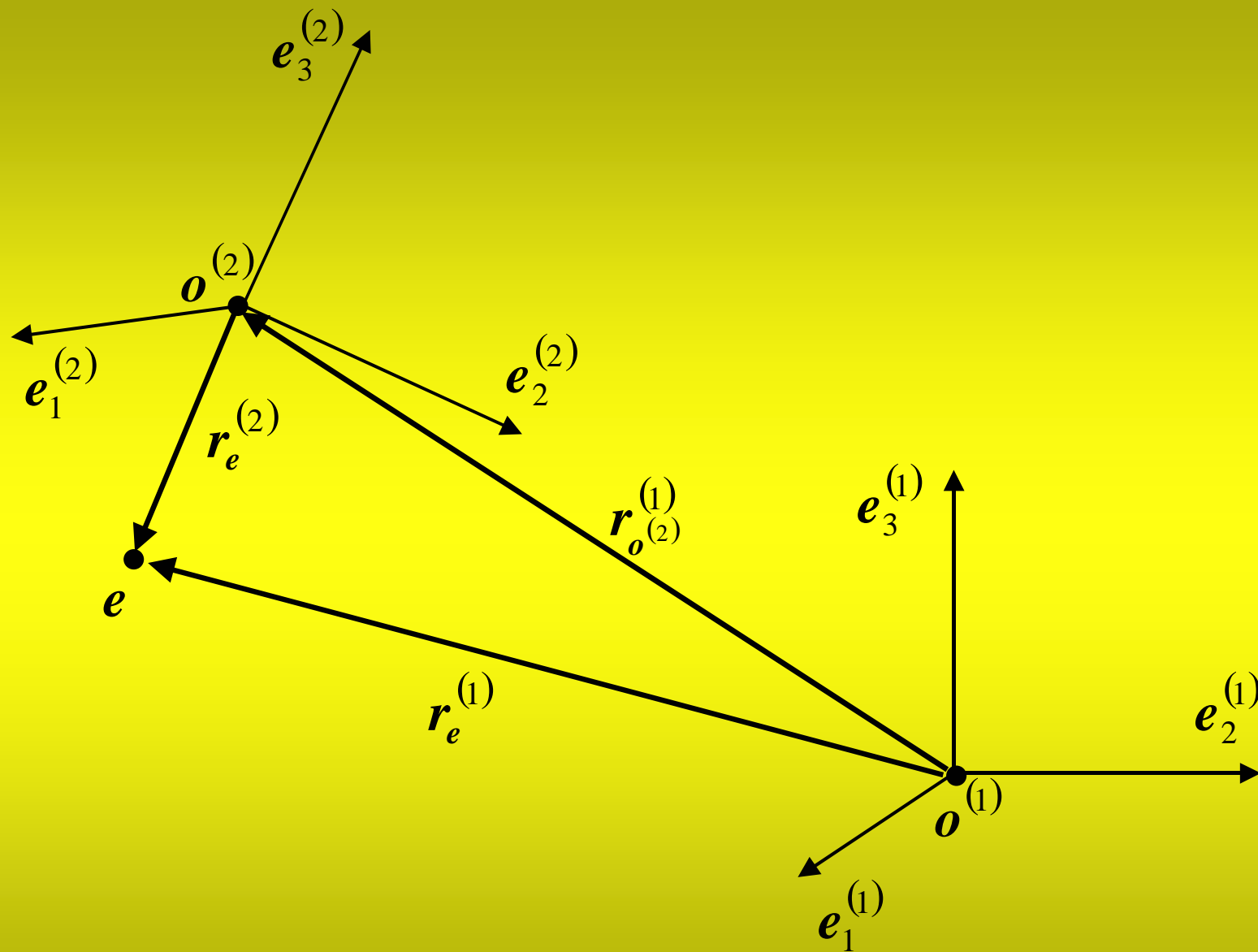


Figura 6.3: Sistemi di riferimento per l'Osservatore $O^{(1)}$ e per l'Osservatore $O^{(2)}$.

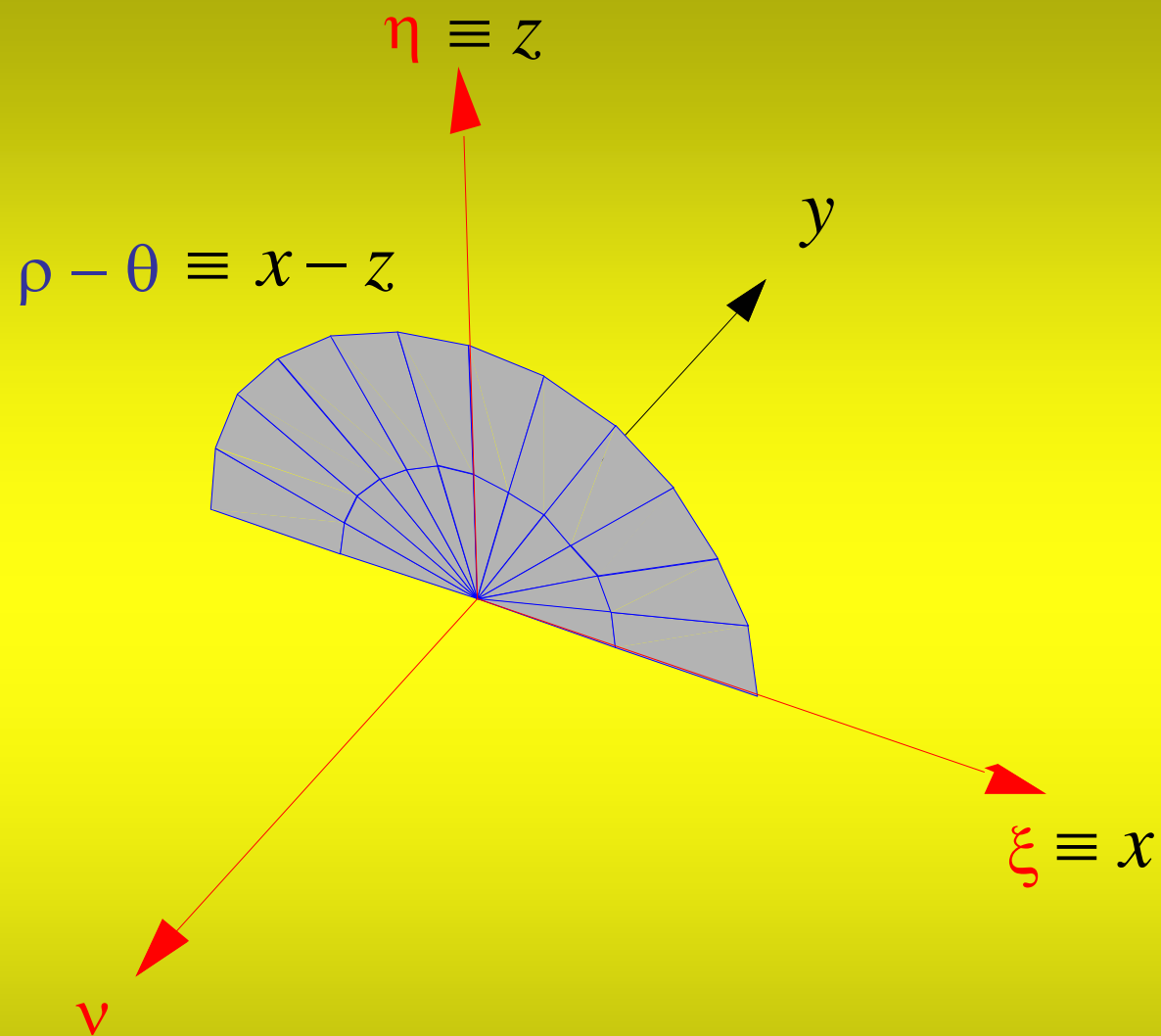


Figura 6.4: Osservatori che usano coordinate rettangolari, (x, y, z) e (ξ, η, ν) , e Osservatore che usa coordinate cilindriche (ρ, θ, ζ) .

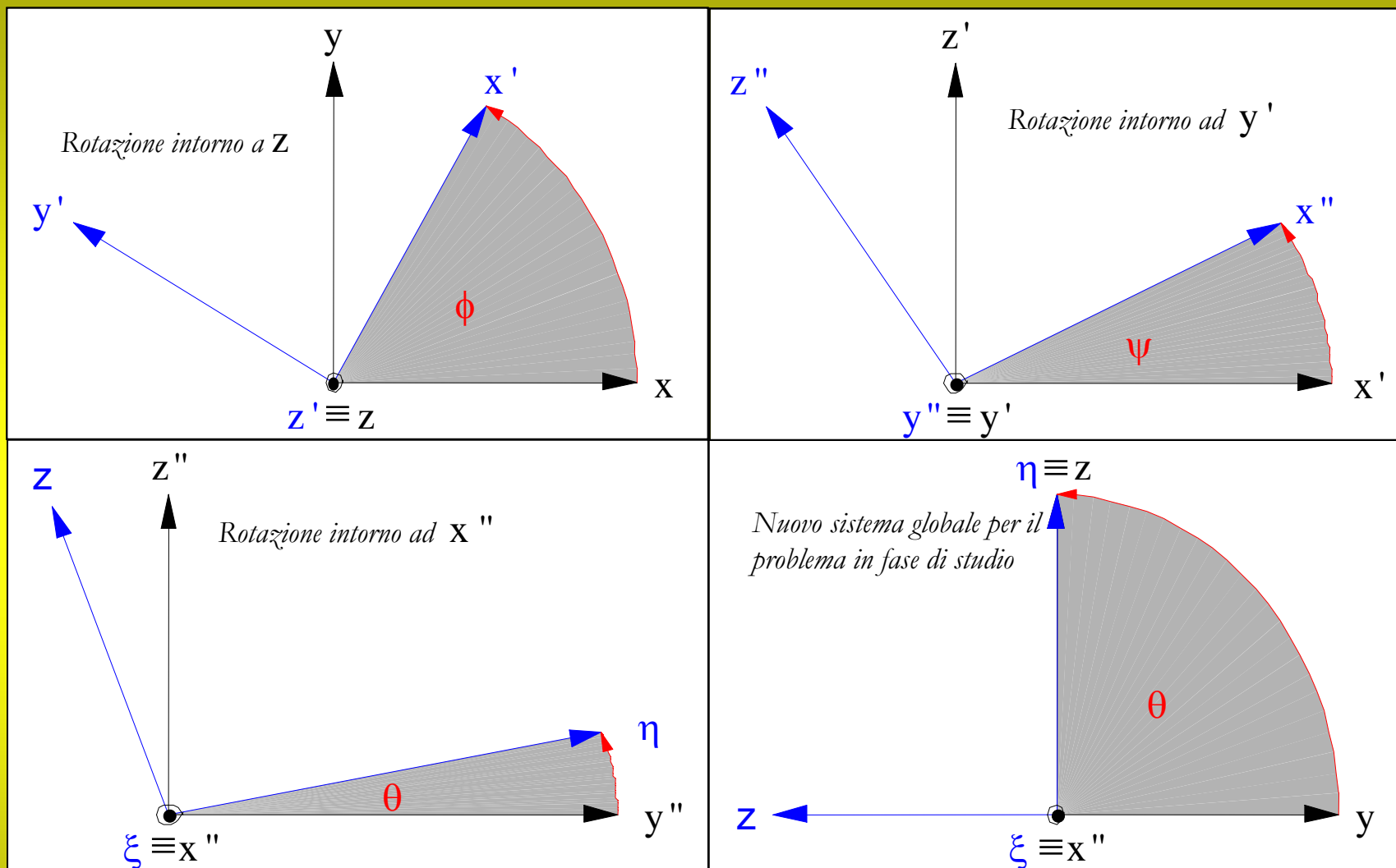


Figura 6.5: Visualizzazione delle rotazioni intorno alle direzioni Z , Y' e X'' . Nuovo sistema di riferimento globale.

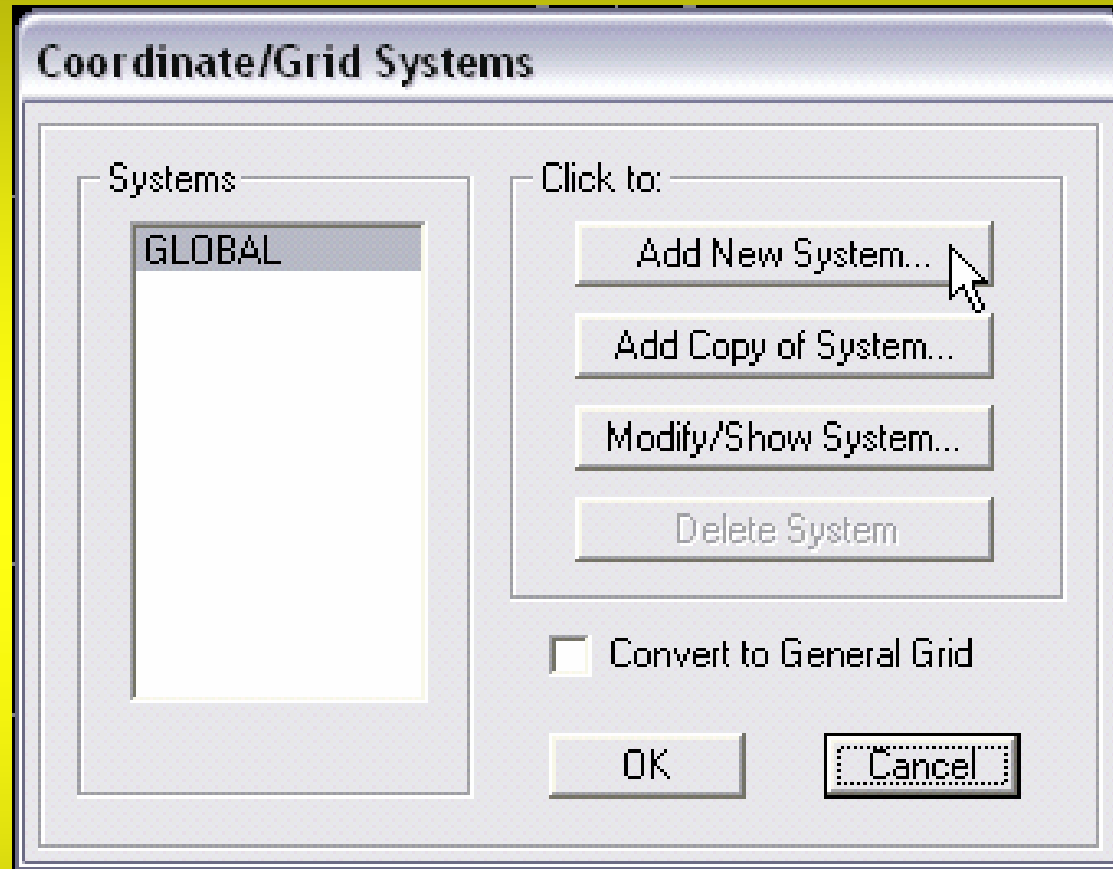


Figura 6.6: Menù di specifica/controllo di un sistema di riferimento.

New Coord/Grid System

Cartesian Cylindrical

System Name CSYS1

Number of Grid Spaces

along Radius	1
along Theta	12
along Z	1

Grid Spacing

along Radius	2,5
along Theta (deg)	15
along Z	1

Figura 6.7: Definizione di un insieme di **Grid Lines**.

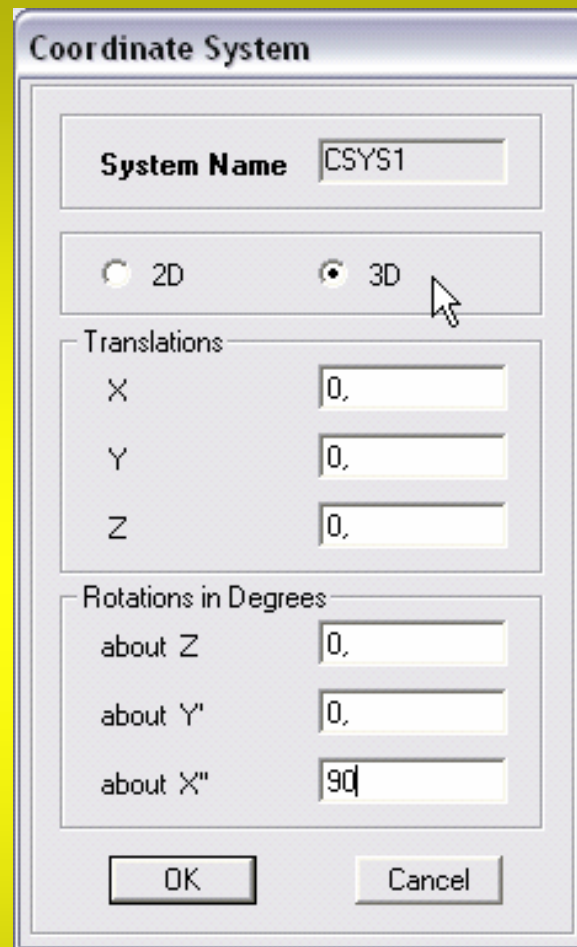


Figura 6.8: Definizione di un sistema di riferimento.

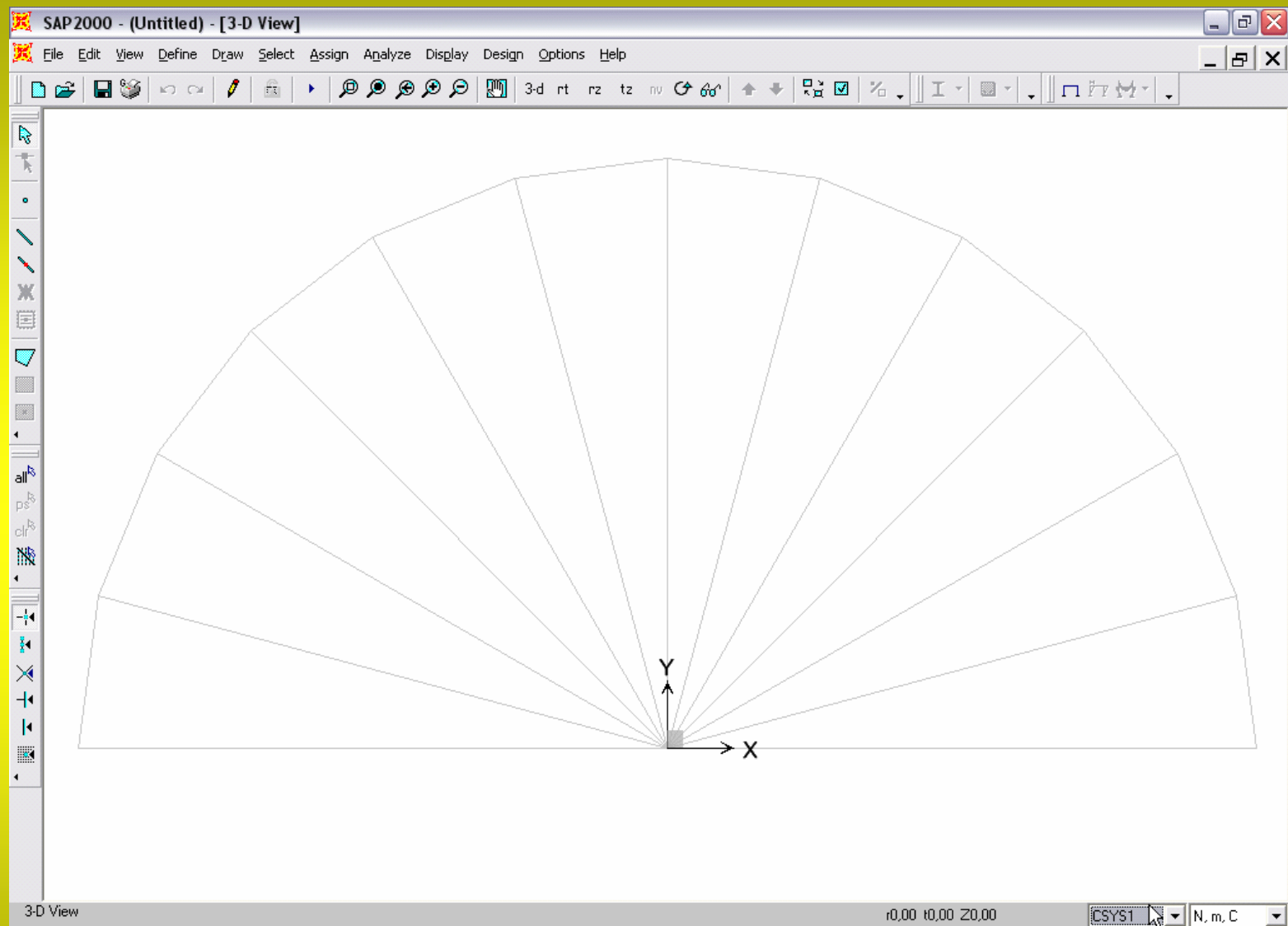


Figura 6.9: **Grid Lines** cilindriche.

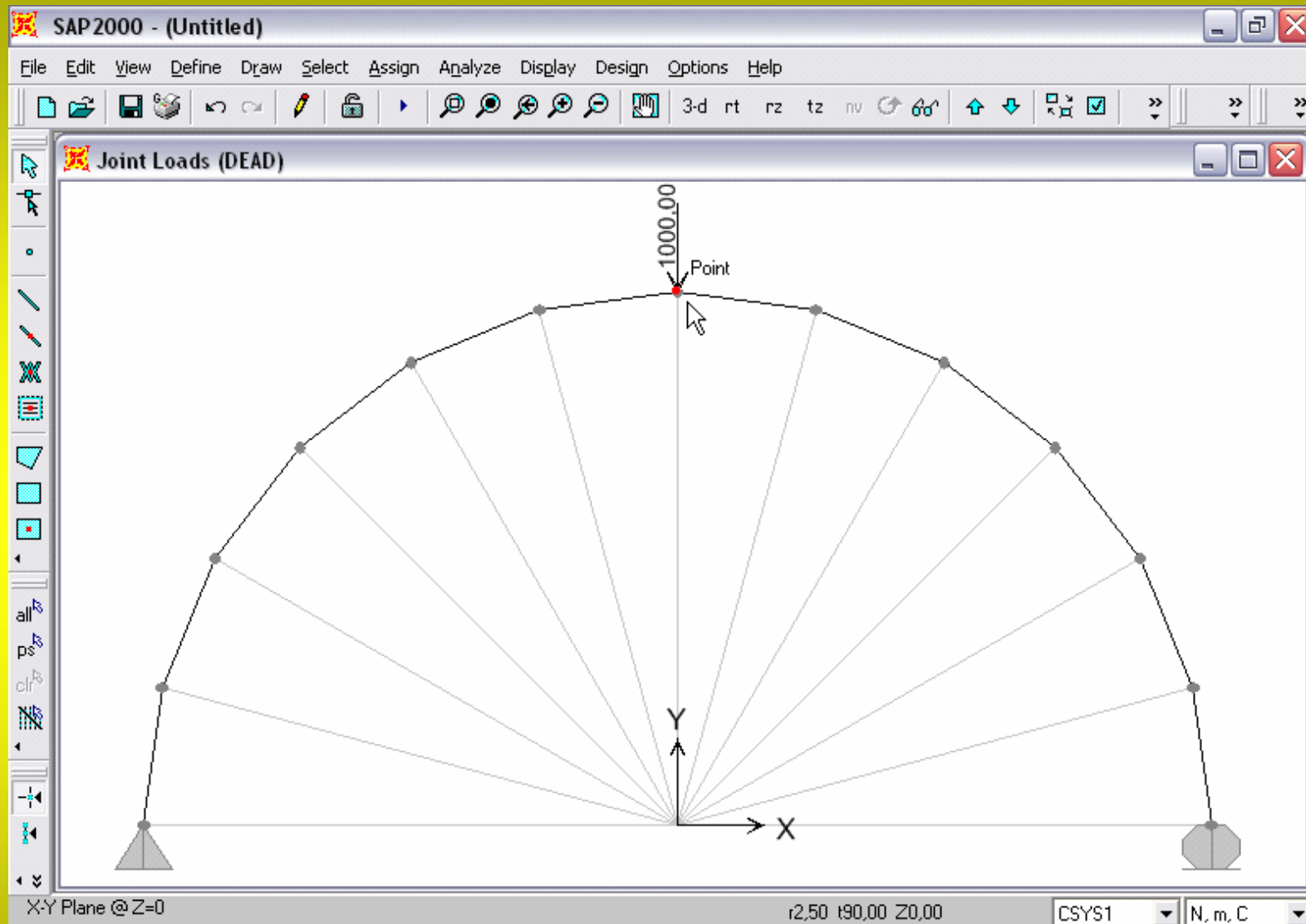


Figura 6.10: Struttura da analizzare.

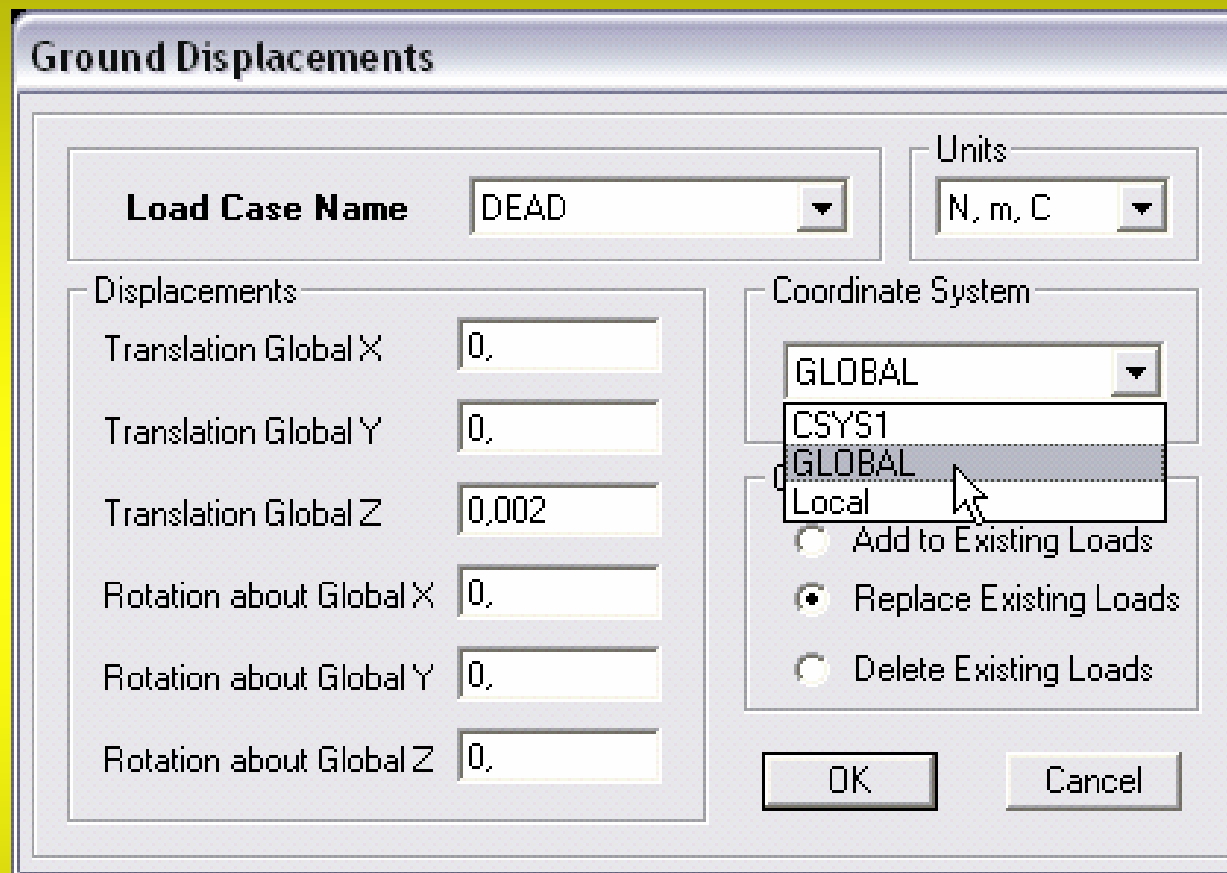


Figura 6.11: Assegnazione di un cedimento vincolare.

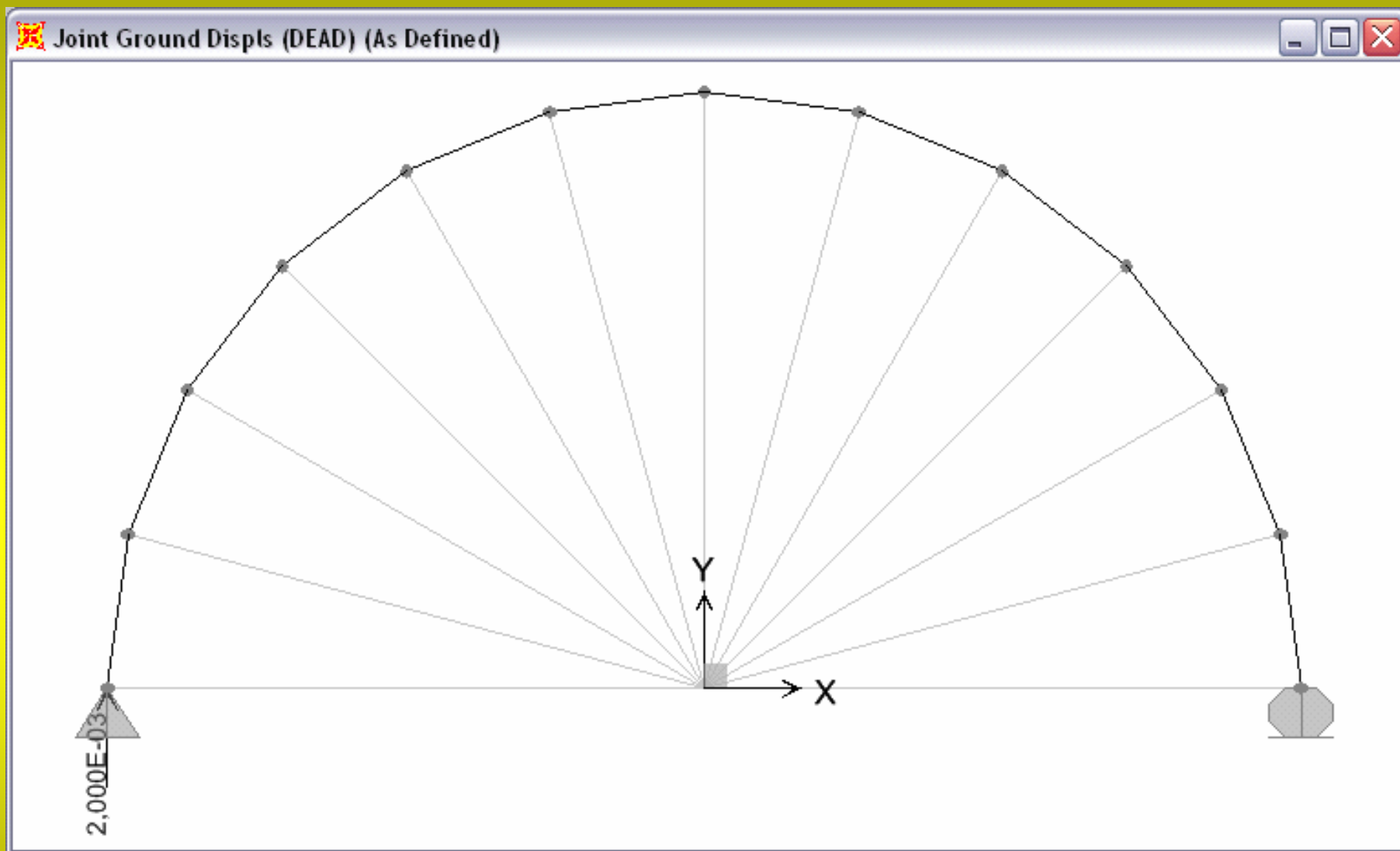


Figura 6.12: Visualizzazione di un cedimento vincolare.

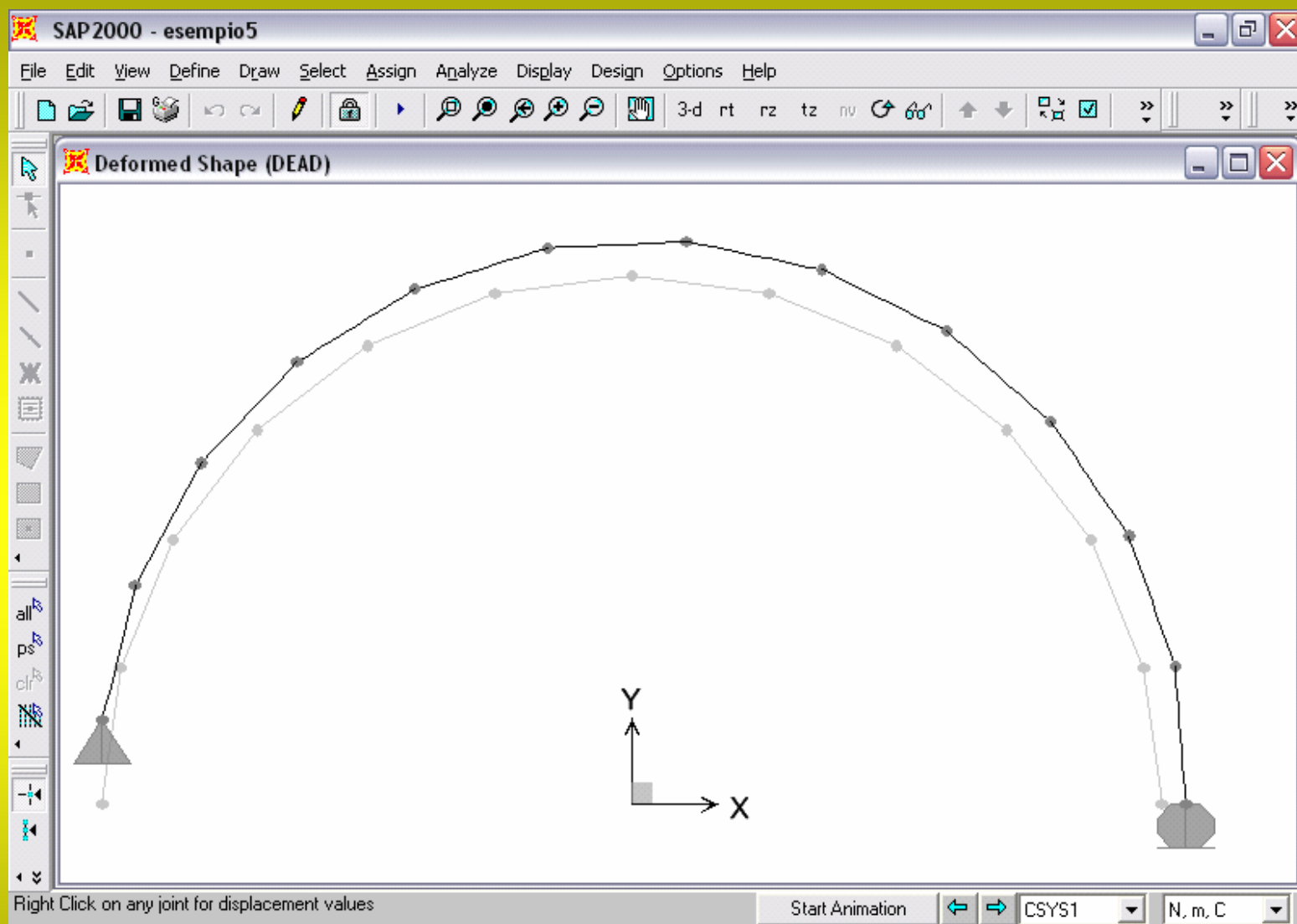
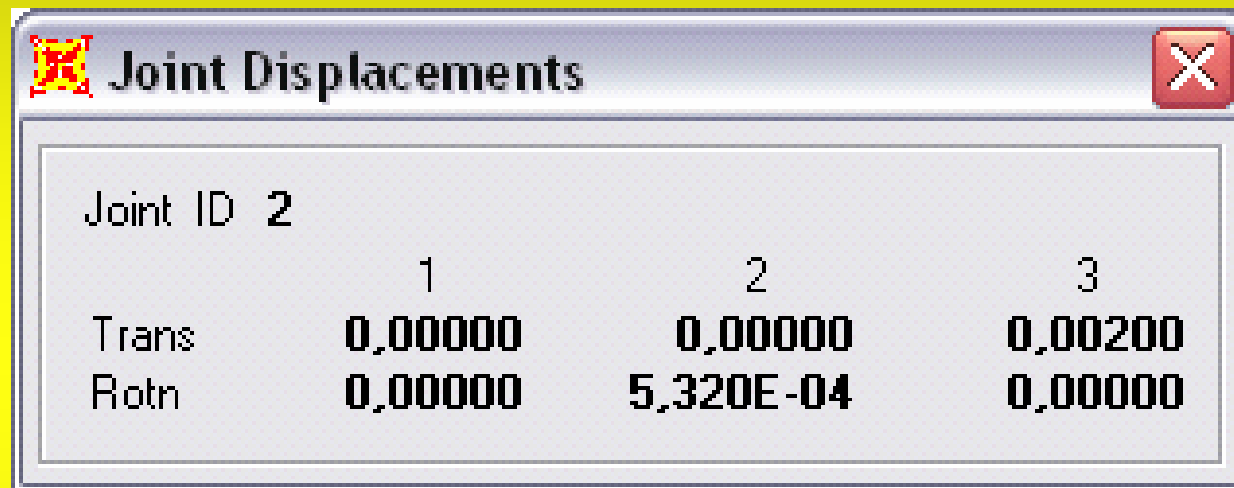


Figura 6.13: Configurazione deformata.



The image shows a software window titled "Joint Displacements" with a close button in the top right corner. The window contains a table of data for Joint ID 2. The table has three columns representing different components (1, 2, 3) and two rows representing Trans (Translation) and Rotn (Rotation).

Joint ID	2			
		1	2	3
Trans		0,00000	0,00000	0,00200
Rotn		0,00000	5,320E-04	0,00000

Figura 6.14: Componenti di spostamento e di rotazione per un **Joint**.

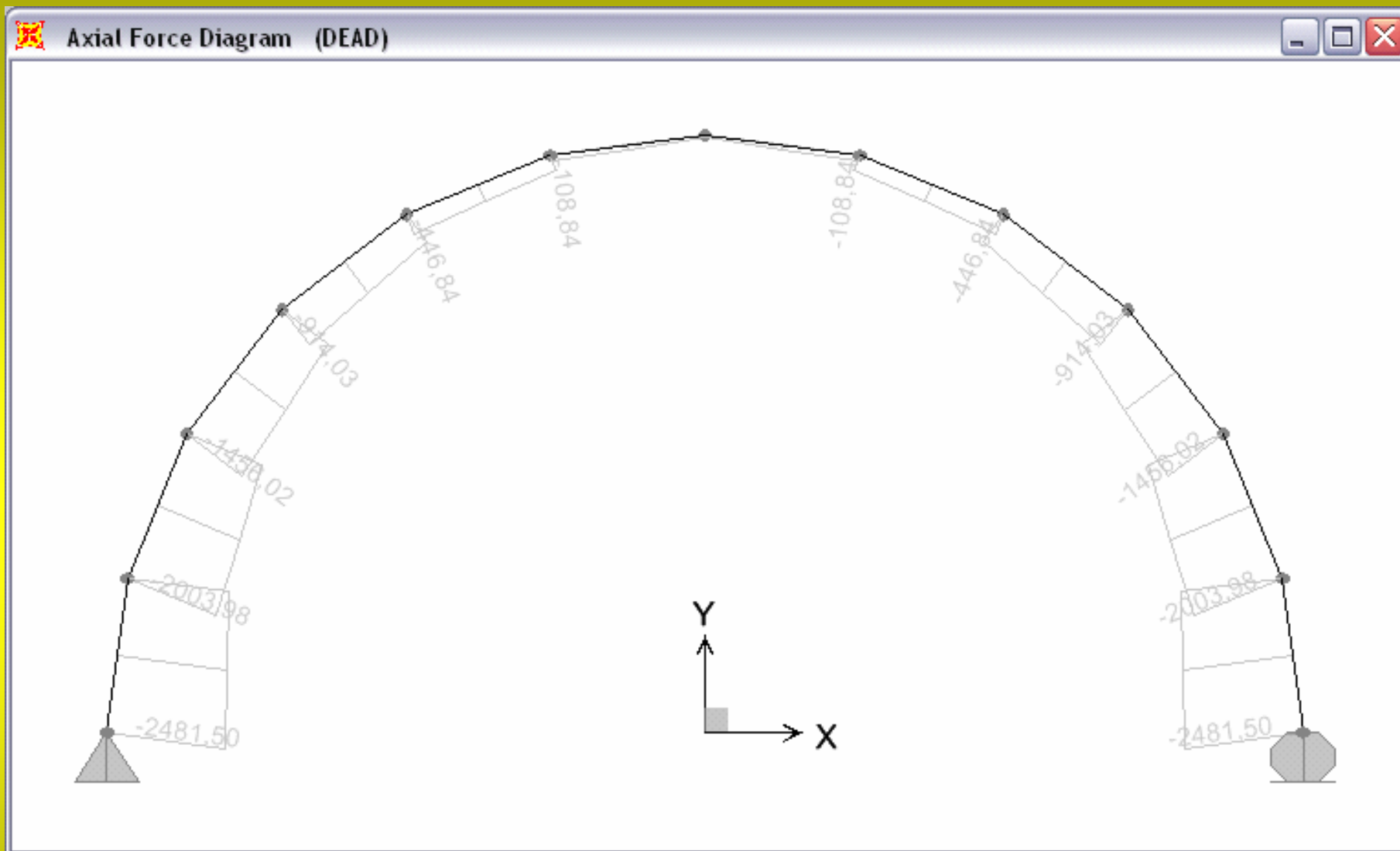


Figura 6.15: Componente assiale della forza di contatto.

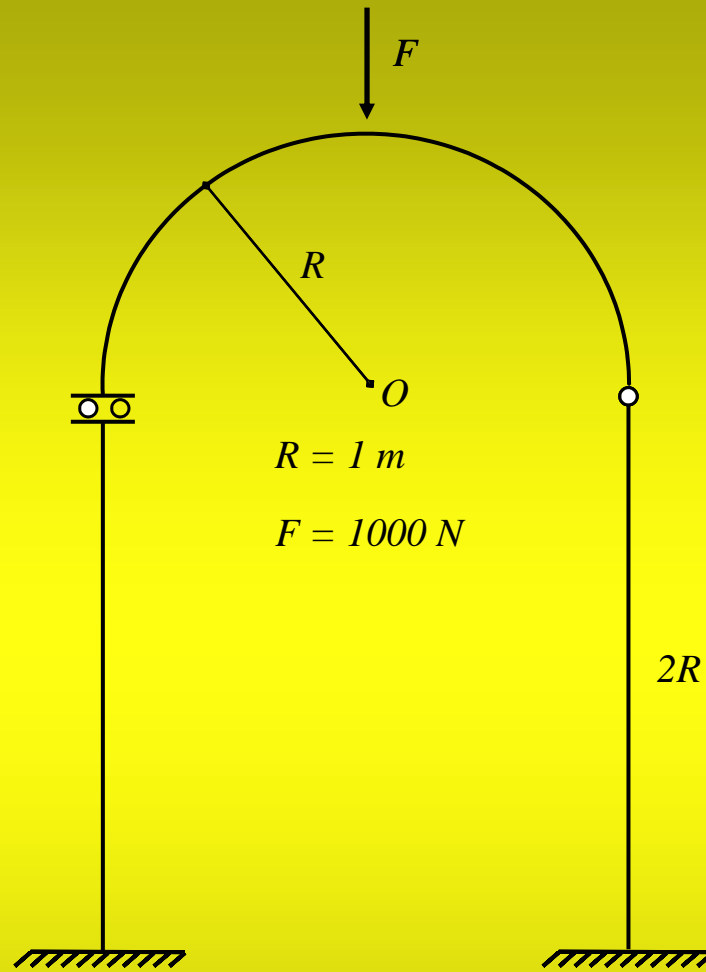


Figura 6.16: Ideogramma del modello.

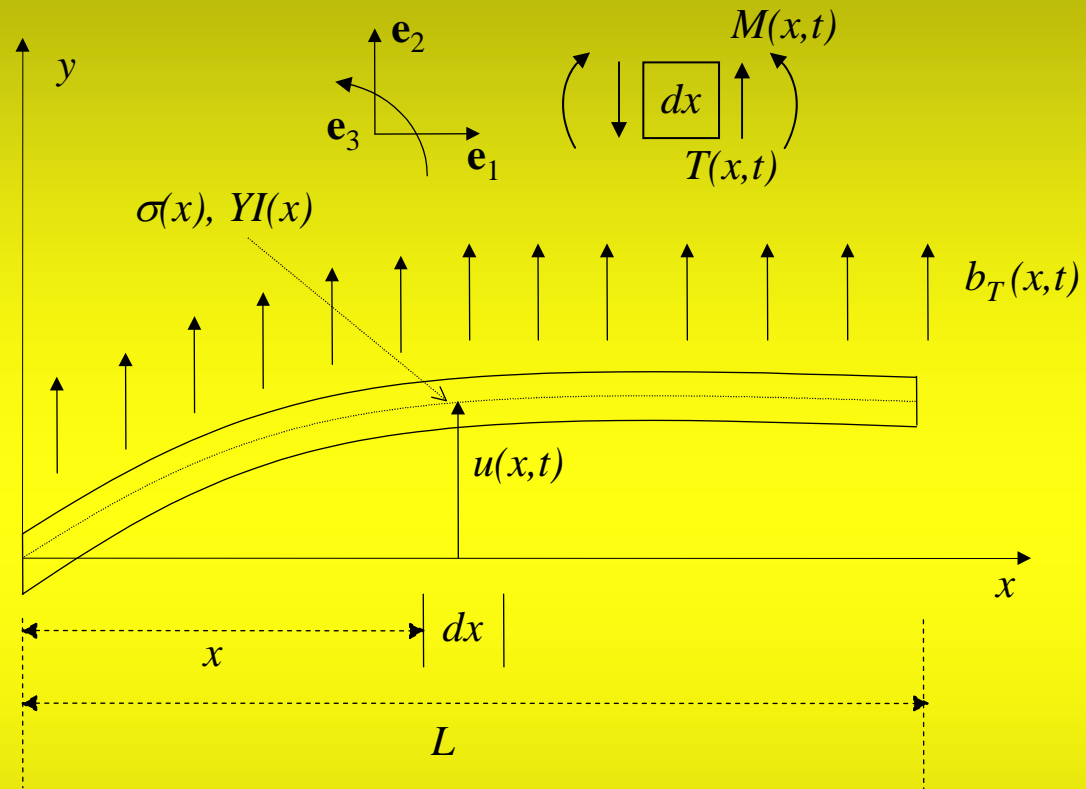


Figura 7.1: Schema di principio per la Trave di Eulero incastrata-libera in flessione trasversale.



Figura 7.2: Ideogramma del modello.

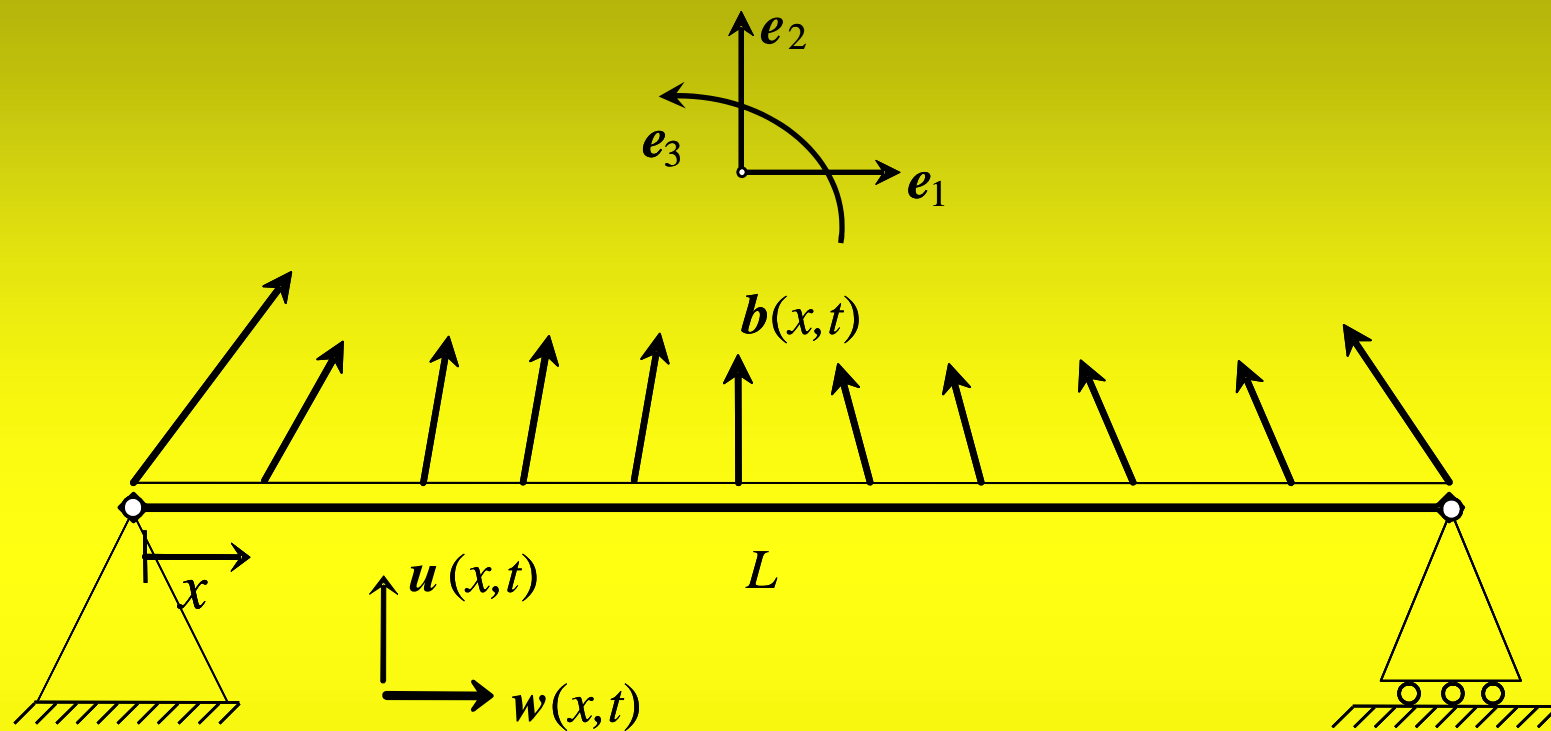


Figura 7.3: Trave appoggiata con distribuzione di forza per unità di linea.

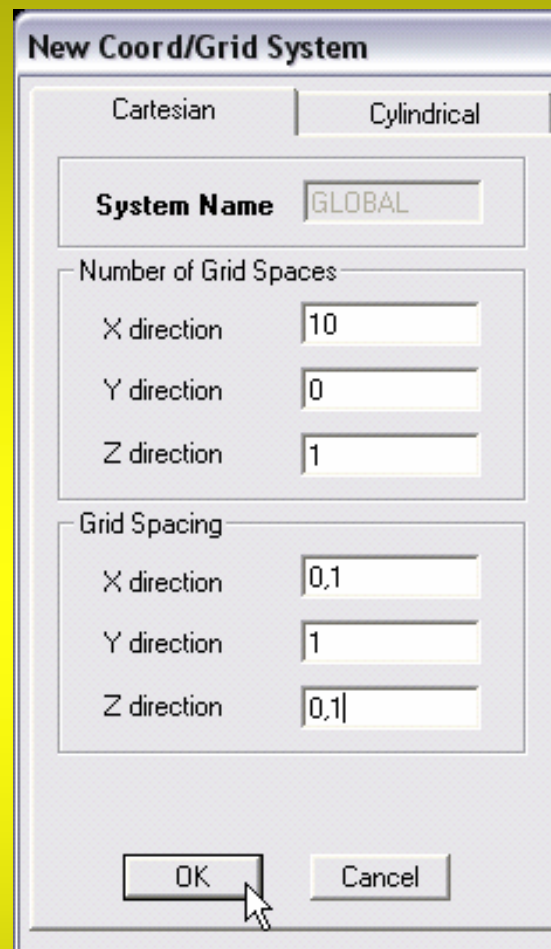


Figura 7.4: Impostazione delle **Grid Lines**.

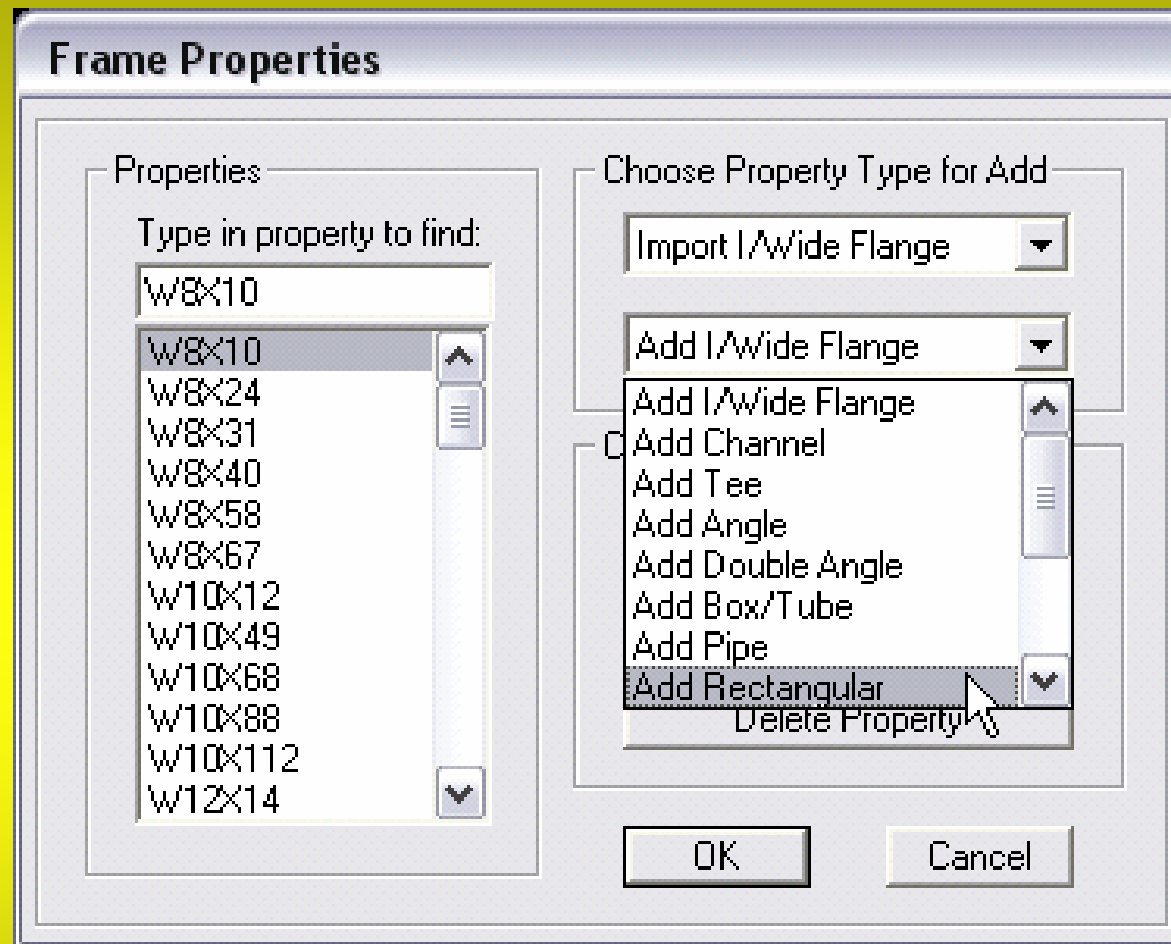
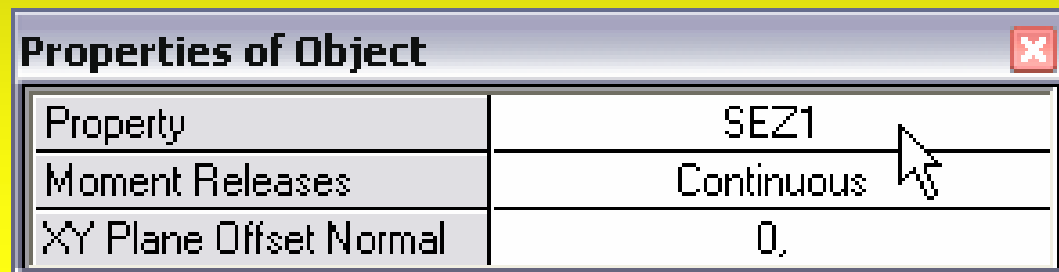


Figura 7.5: Definizione della sezione e del materiale costituente.



Properties of Object	
Property	SEZ1
Moment Releases	Continuous
XY Plane Offset Normal	0,

Figura 7.6: Proprietà dell'oggetto.

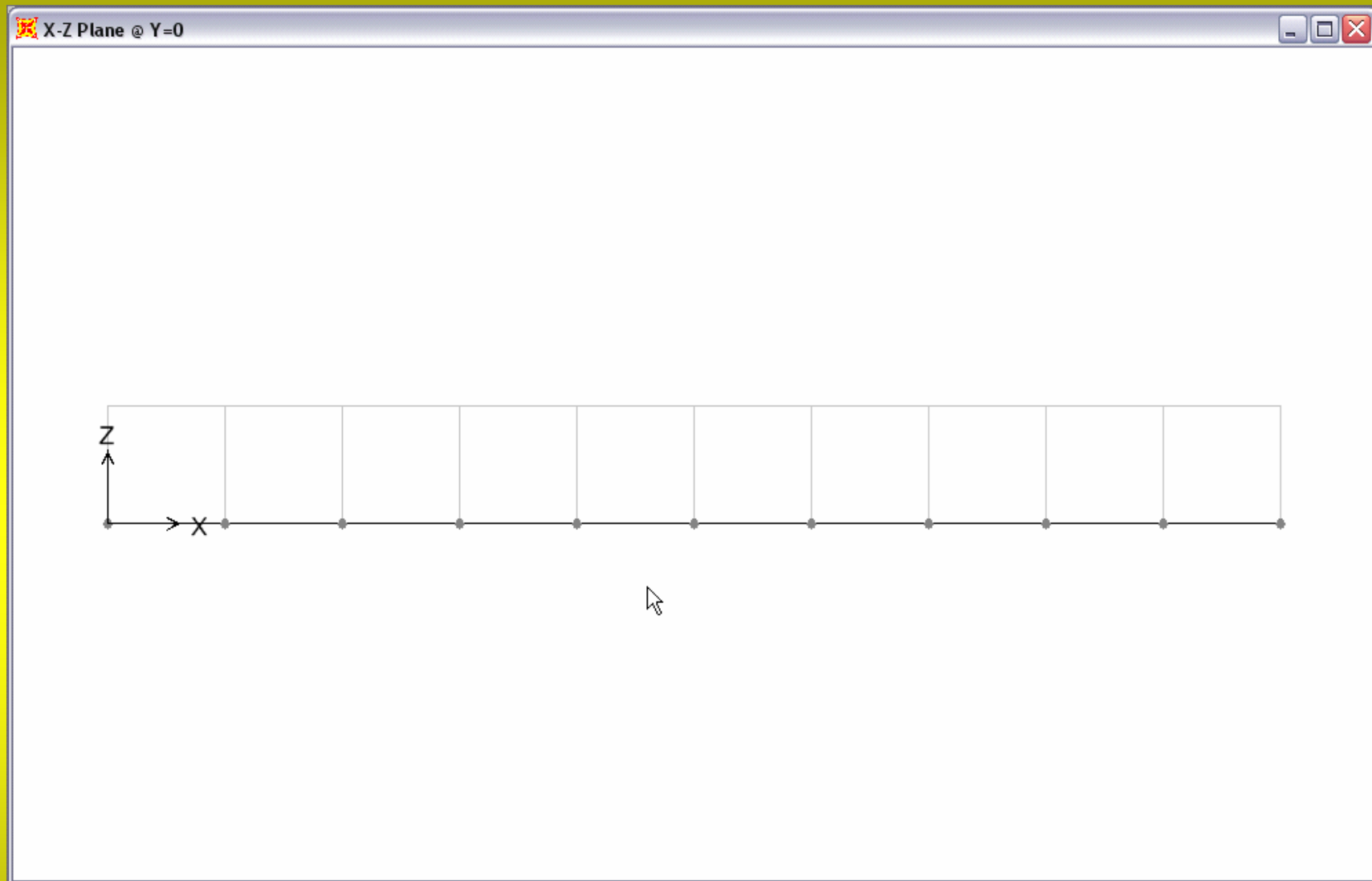


Figura 7.7: Struttura discretizzata.

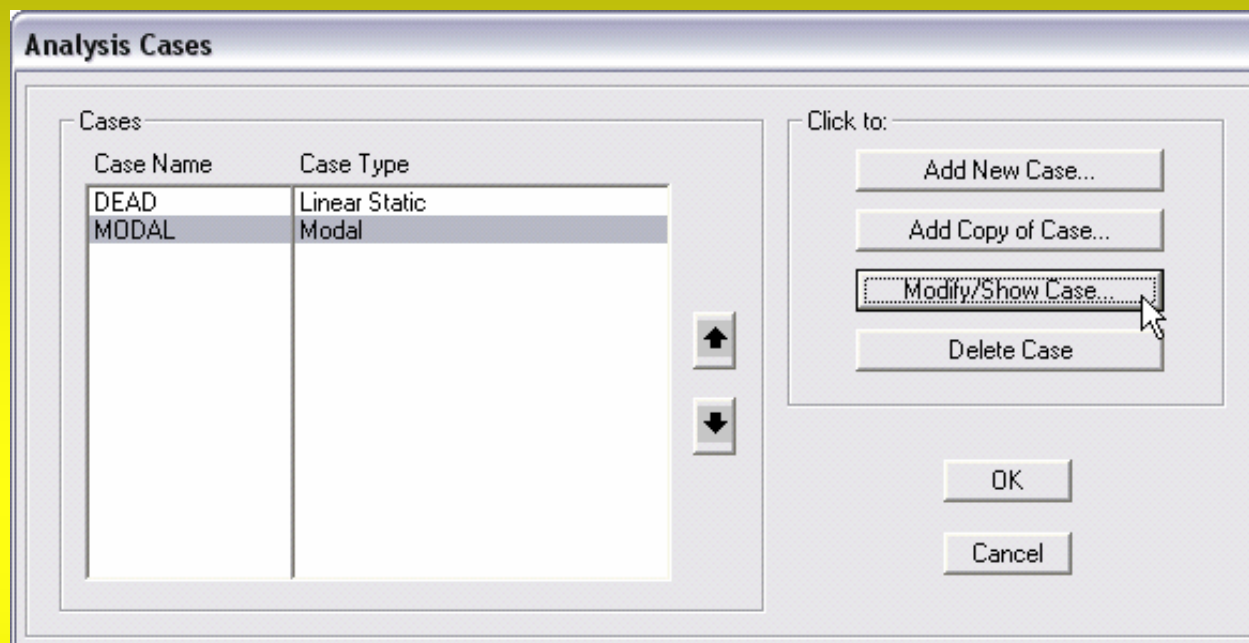


Figura 7.8: Definizione dei tipi di analisi.

Analysis Case Data - Modal

Analysis Case Name MODAL

Analysis Case Type Modal

Stiffness to Use

- Zero Initial Conditions - Unstressed State
- Stiffness at End of Nonlinear Case

Important Note: Loads from the Nonlinear Case are NOT included in the current case

Type of Modes

- Eigen Vectors
- Ritz Vectors

Number of Modes

Maximum Number of Modes

Minimum Number of Modes

Loads Applied

Show Advanced Load Parameters

Other Parameters

Frequency Shift (Center)

Cutoff Frequency (Radius)

Convergence Tolerance

Figura 7.9: Specifica per l'analisi modale.

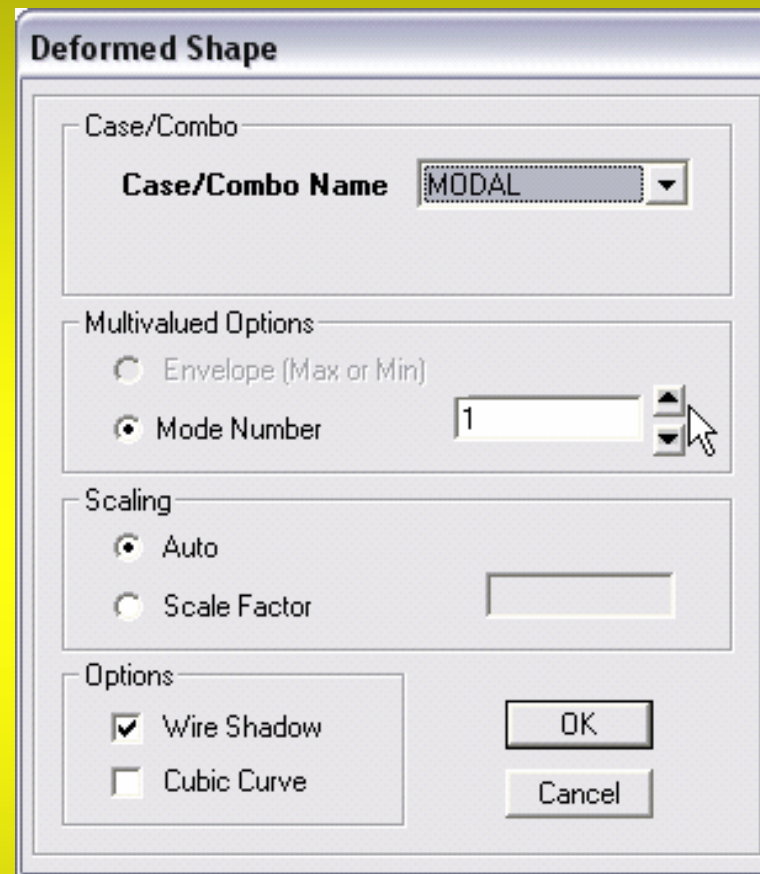


Figura 7.10: Impostazioni per la visualizzazione dei modi naturali.

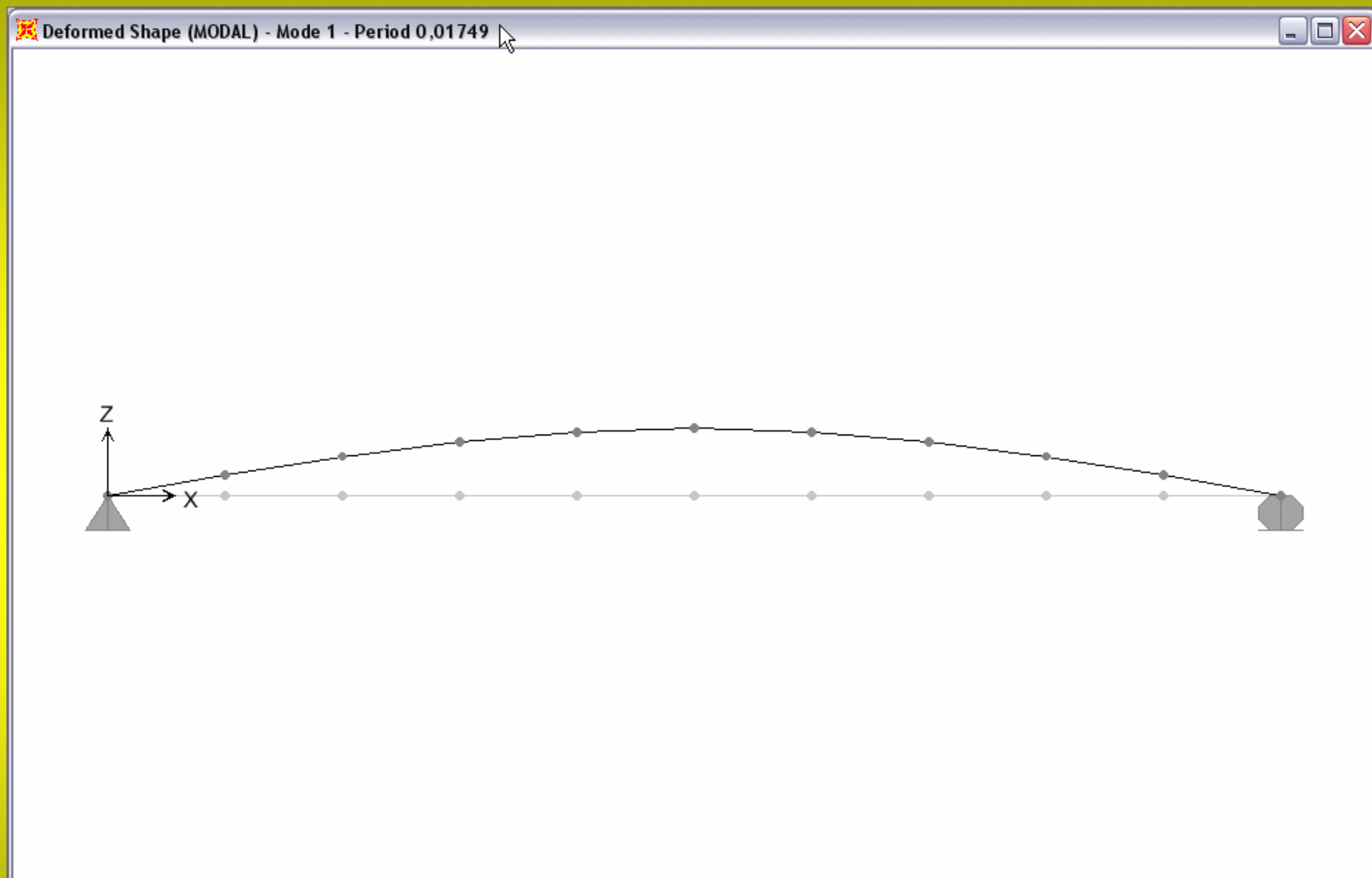


Figura 7.11: Primo modo naturale di oscillazione.

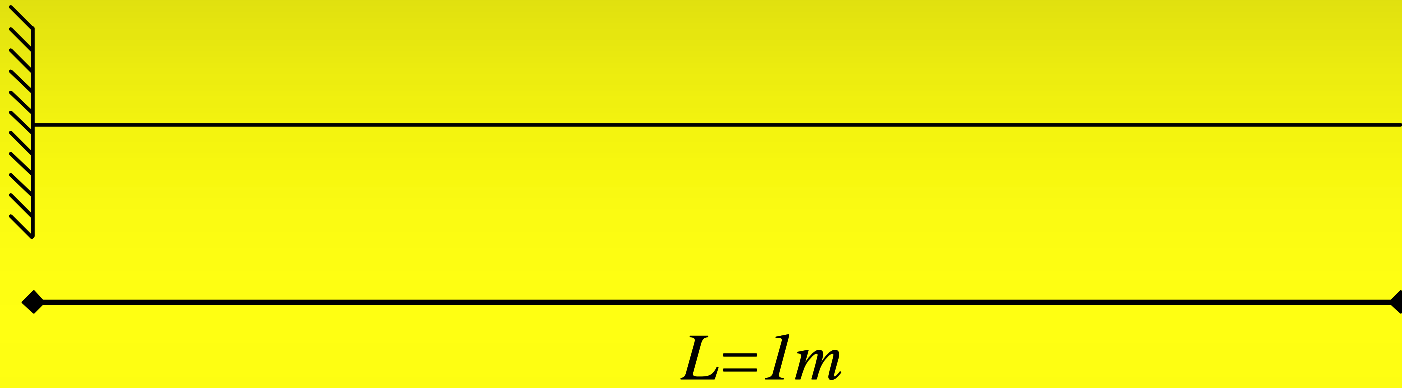


Figura 8.1: Ideogramma del modello.

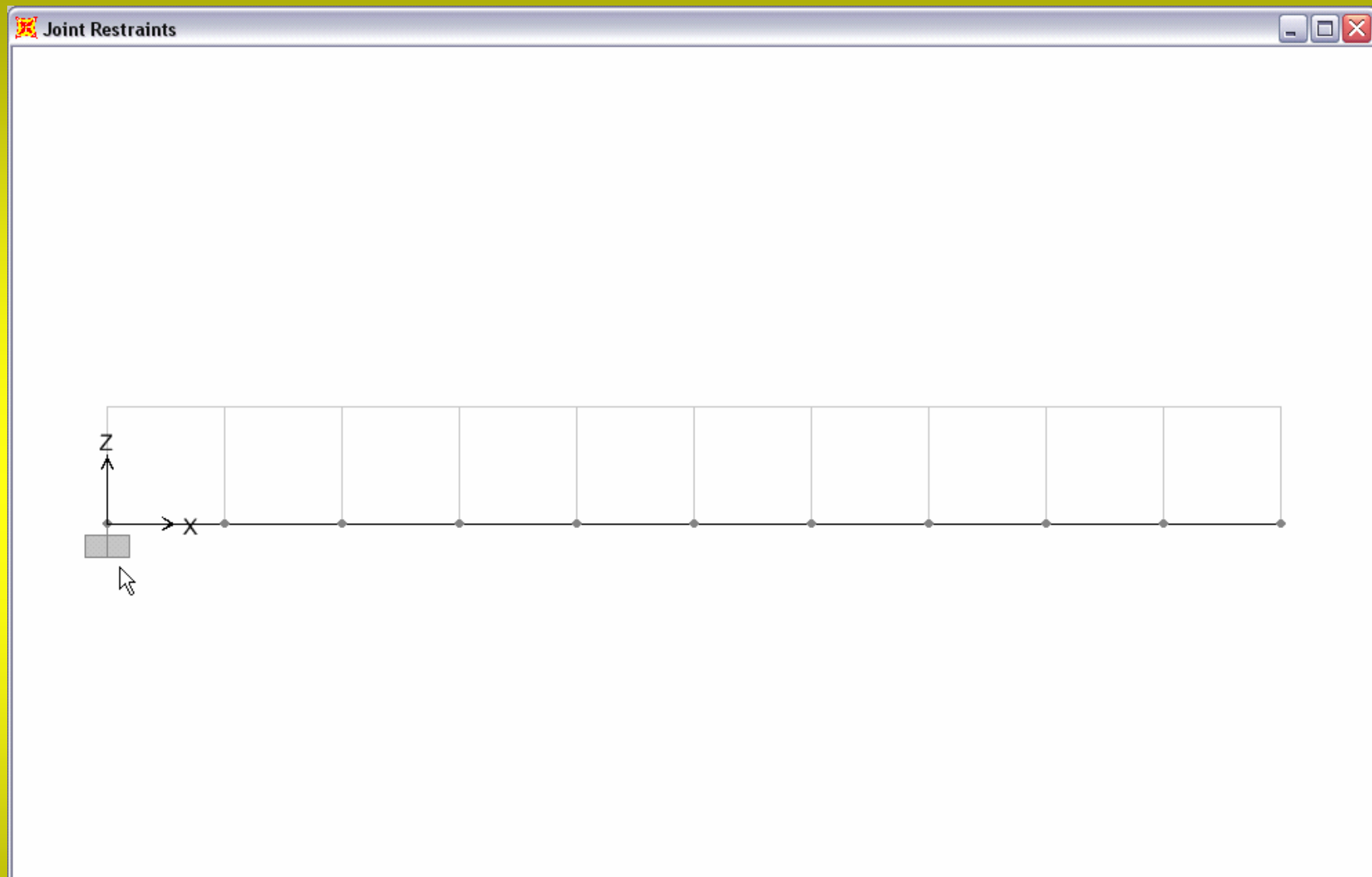


Figura 8.2: Struttura da analizzare.

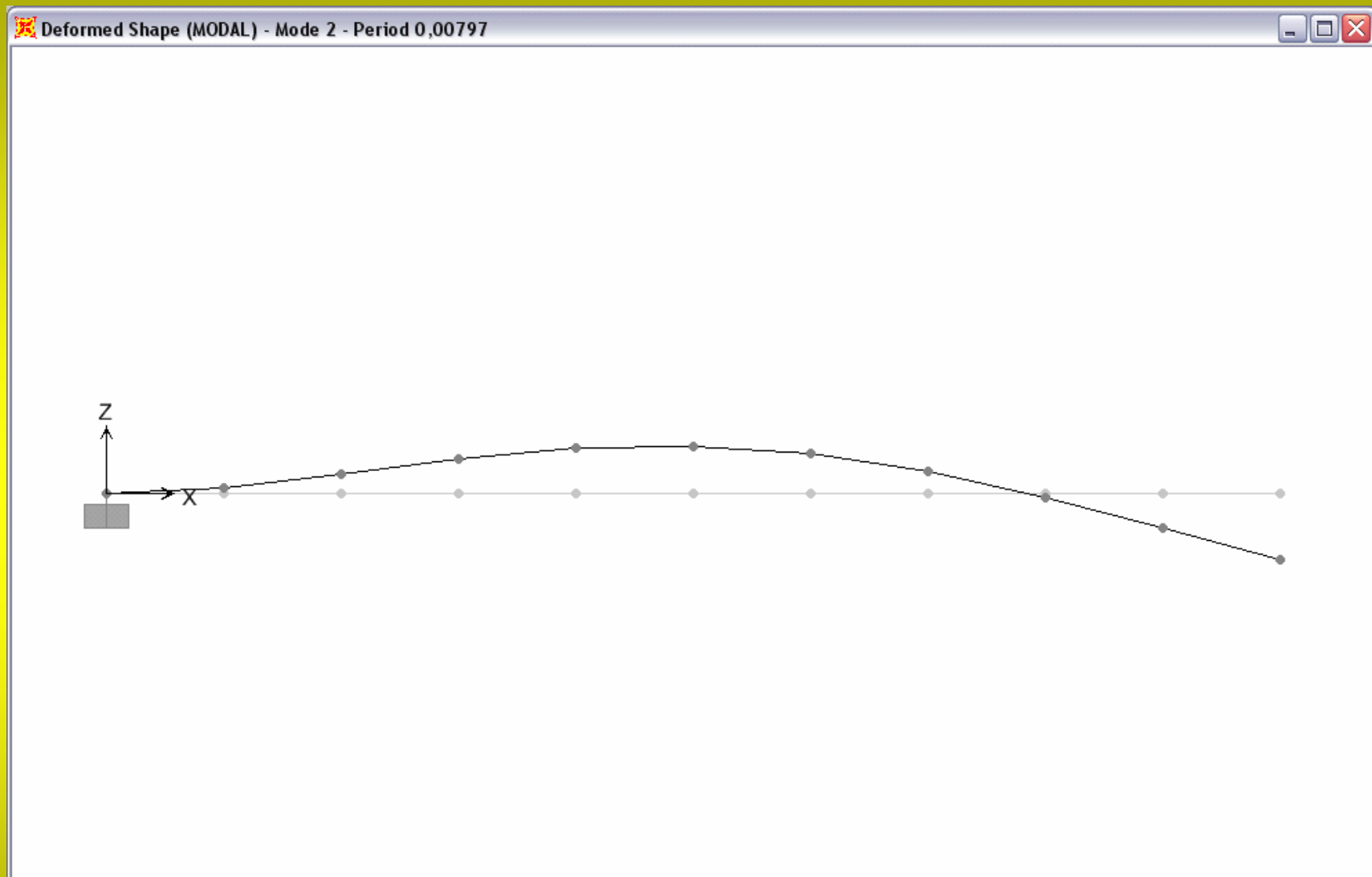


Figura 8.3: Secondo modo naturale di oscillazione.