Laboratorio di Progettazione Strutturale 1M – Prof. Ginevra Salerno

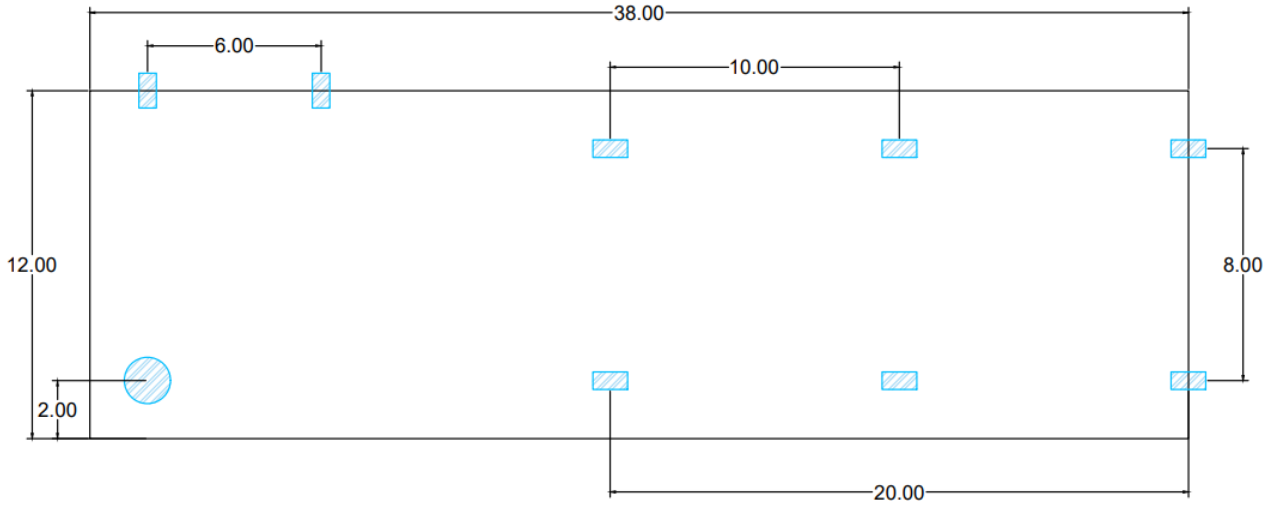
Esercitazione 5: Dimensionamento di un graticcio di travi inflesse

Studenti: *Patryk Rynkowski, Luca Santilli*

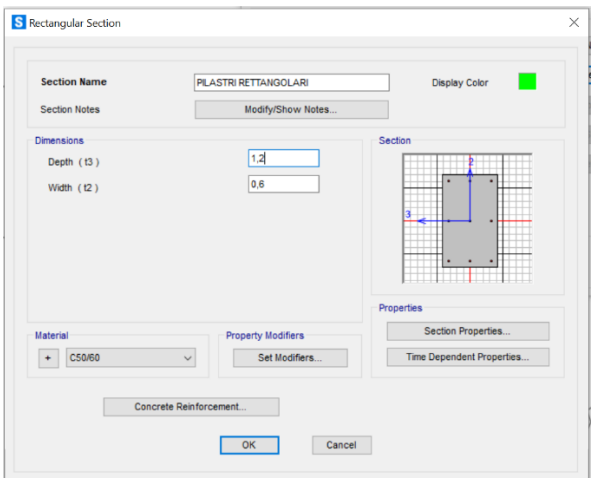
L'obiettivo di questa esercitazione è quello di dimensionare, partendo da una piastra, un graticcio di travi inflesse estrapolato dal caso di studio del nostro progetto.

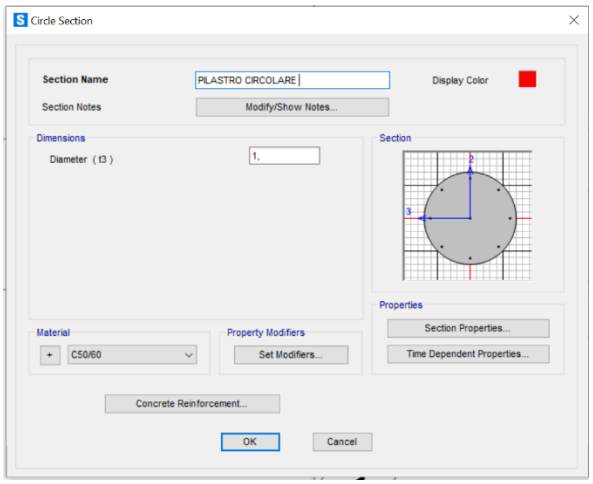
Iniziamo con il disegno su Autocad della piastra di dimensioni 38x12. Questa sarà costituita in cls C50/60. I pilastri rettangolari al di sotto della piastra avranno una dimensione di 1,2x0,6, mentre il pilastro circolare in prossimità dell'angolo un diametro di 0,8.

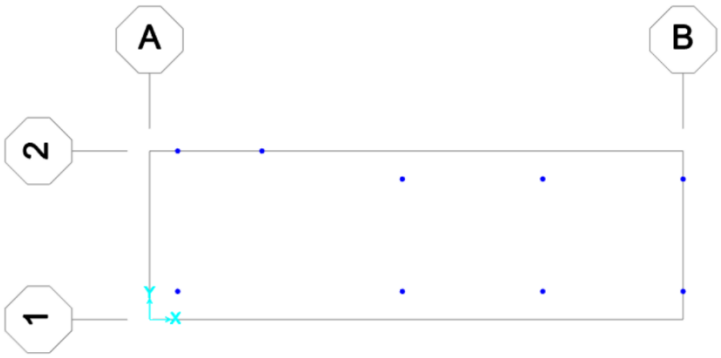
Pianta:



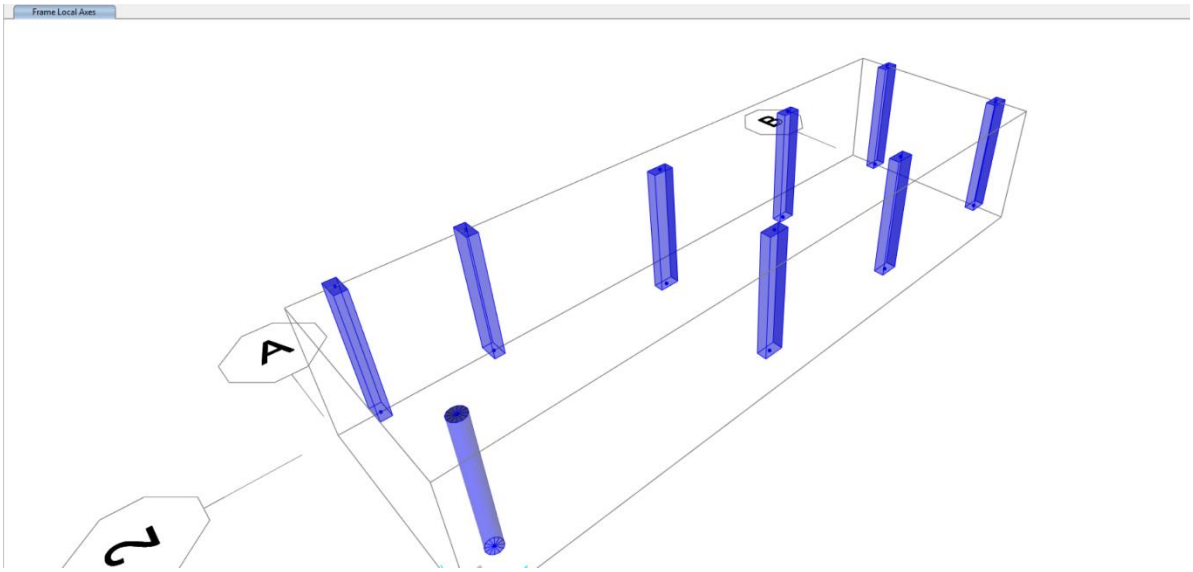
Ora passiamo su SAP2000 e ridisegniamo la nostra struttura.



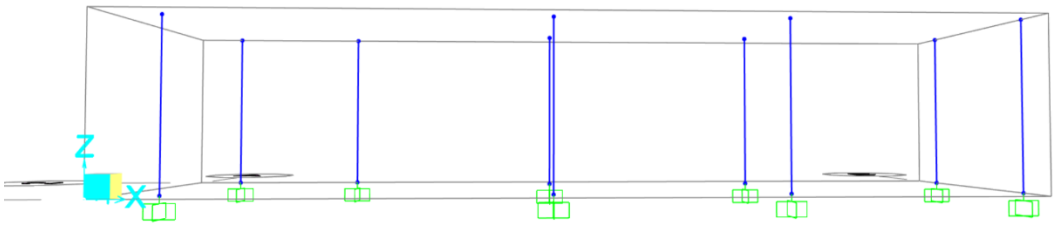


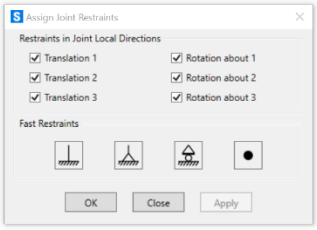


Qui cambiamo immediatamente l'asse locale di alcuni pilastri perché si ottenga l'inerzia maggiore verso la direzione dello sviluppo del graticcio. (Assign-Frame-Load Axes → ruotiamo di 90 Qui cambiamo immediatamente l'asse locale di alcuni pilastri perché si ottenga l'inerzia maggiore verso la direzione dello sviluppo del graticcio. (Assign-Frame-Load Axes → ruotiamo di 90°)



Procediamo con l'assegnazione di un vincolo esterno, in questo caso l'incastro.

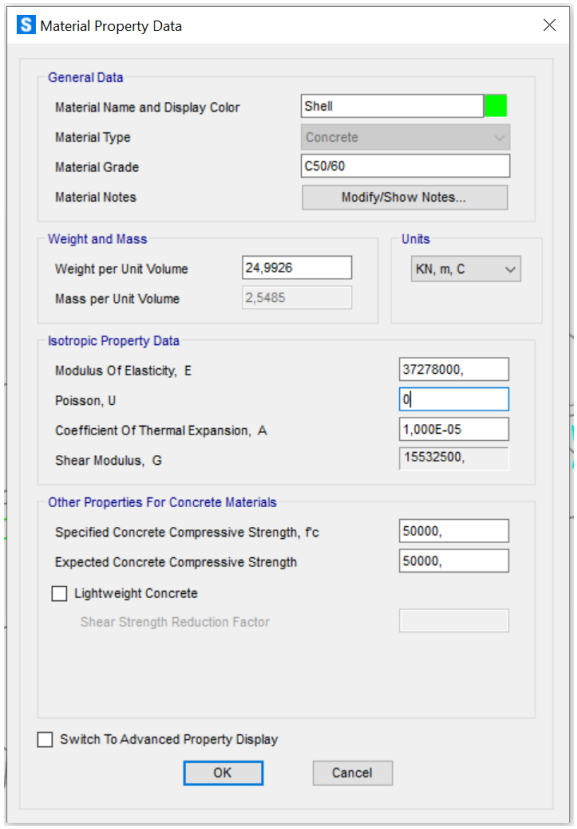




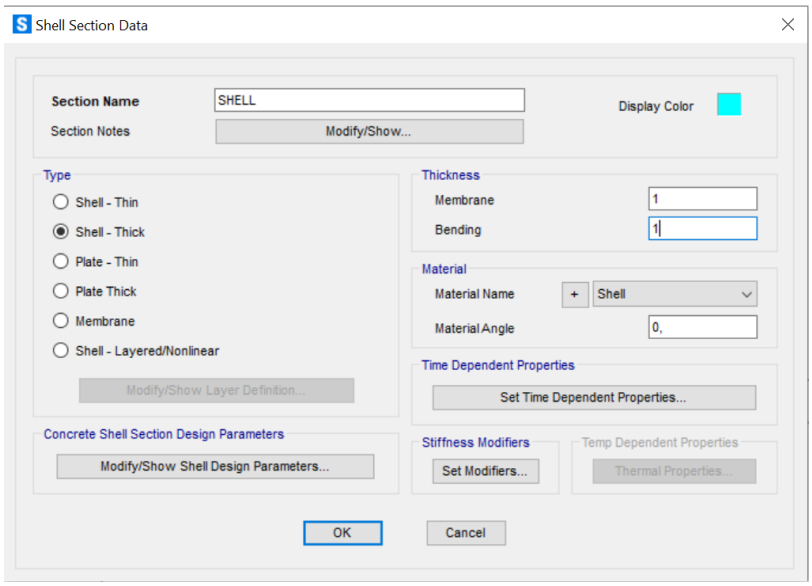
Dato che la piastra è un elemento pieno, il suo coefficiente di Poisson è diverso da 0. Si utilizza quindi una piastra per avere una simulazione del graticcio. Con quest'ultimo infatti si hanno dei vuoti dove la deformazione non dà effetti secondari.

Il coefficiente di Poisson ci dice che lo sforzo normale sulla faccia di un materiale produce deformazioni primarie nella direzione dello sforzo normale, una deformazione secondaria invece nella direzione perpendicolare, di segno opposto (deformazione laterale).

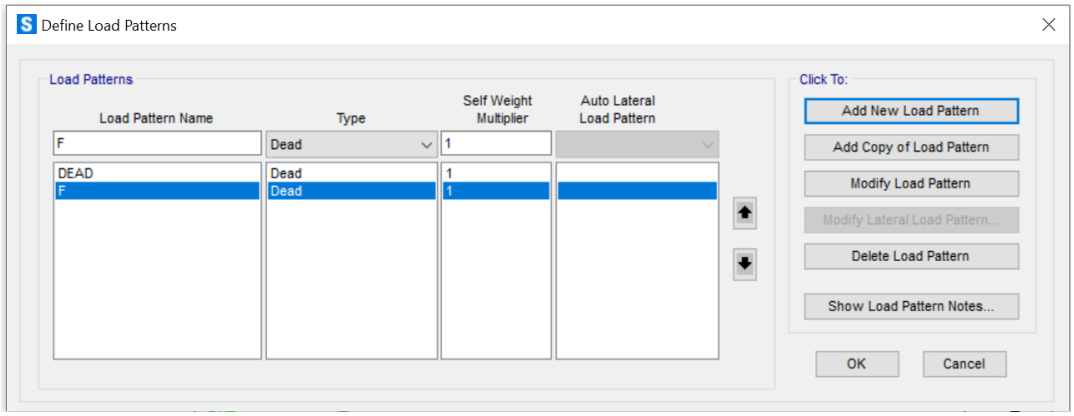
Definiamo quindi il materiale per la piastra cambiando il coefficiente di Poisson, ponendolo uguale a 0, per simulare il comportamento di un sistema discreto. In questo modo si annullano gli effetti delle deformazioni nelle altre direzioni del materiale.



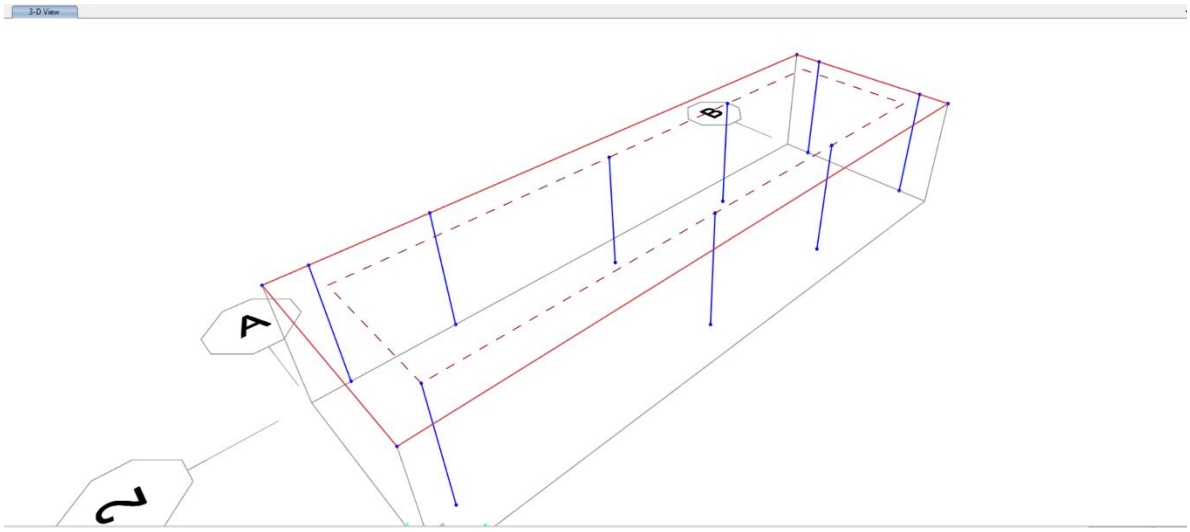
A questo punto definiamo la sezione della piastra (Shell section data).



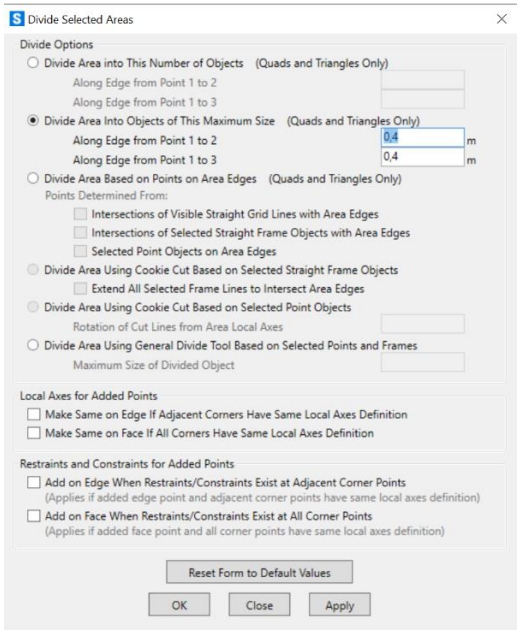
Ora definiamo il Load Pattern per assegnare dei carichi puntuali sui nodi, ponendo il moltiplicatore di Peso Proprio (Self Weight Multiplier) uguale a 1.

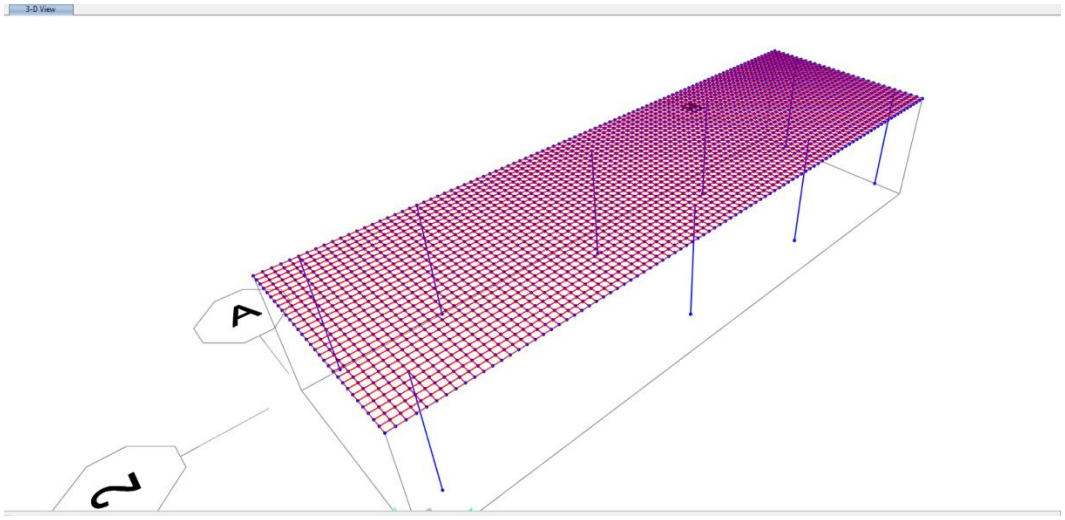


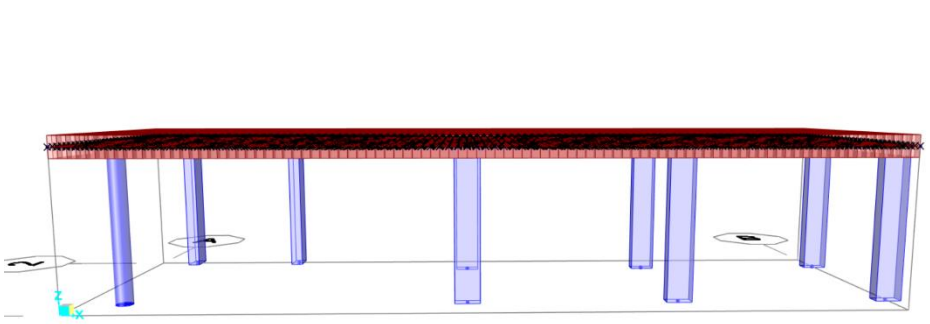
Procediamo nel disegno della struttura costruendo l'area (Draw Poly Area).

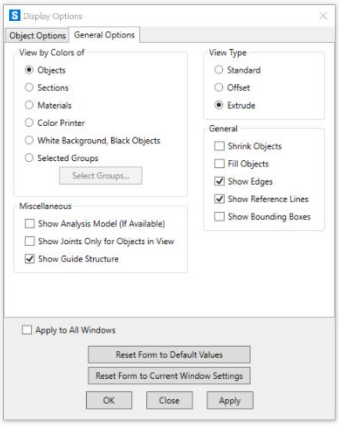


Discretizziamo successivamente l'area appena creata in moduli 0,4x04. (Divide select areas)


Divide Selected Areas
Divide Options
Divide Area into This Number of Objects (Quads and Triangles Only)
Along Edge from Point 1 to 2
Along Edge from Point 1 to 3
Divide Area Into Objects of This Maximum Size (Quads and Triangles Only)
Along Edge from Point 1 to 2
0,4
m
Along Edge from Point 1 to 3
0,4
m
Divide Area Based on Points on Area Edges (Quads and Triangles Only)
Points Determined From:
Intersections of Visible Straight Grid Lines with Area Edges
Intersections of Selected Straight Frame Objects with Area Edges
Selected Point Objects on Area Edges
Divide Area Using Cookie Cut Based on Selected Straight Frame Objects
Extend All Selected Frame Lines to Intersect Area Edges
Divide Area Using Cookie Cut Based on Selected Point Objects
Rotation of Cut Lines from Area Local Axes
Divide Area Using General Divide Tool Based on Selected Points and Frames
Maximum Size of Divided Object
Local Axes for Added Points
Make Same on Edge If Adjacent Corners Have Same Local Axes Definition
Make Same on Face If All Corners Have Same Local Axes Definition
Restraints and Constraints for Added Points
Add on Edge When Restraints/Constraints Exist at Adjacent Corner Points
(Applies if added edge point and adjacent corner points have same local axes definition)
Add on Face When Restraints/Constraints Exist at All Corner Points
(Applies if added face point and all corner points have same local axes definition)
Reset Form to Default Values
OK
Close
Apply


3-D View
A
2




Display Options
Object Options
General Options
View by Colors of
Objects
Sections
Materials
Color Printer
White Background, Black Objects
Selected Groups
Select Groups...
Miscellaneous
Show Analysis Model (If Available)
Show Joints Only for Objects in View
Show Guide Structure
View Type
Standard
Offset
Extrude
General
Shrink Objects
Fill Objects
Show Edges
Show Reference Lines
Show Bounding Boxes
Apply to All Windows
Reset Form to Default Values
Reset Form to Current Window Settings
OK
Close
Apply

Suddividiamo i nodi per angolari, perimetrali e centrali.

Applichiamo i carichi:

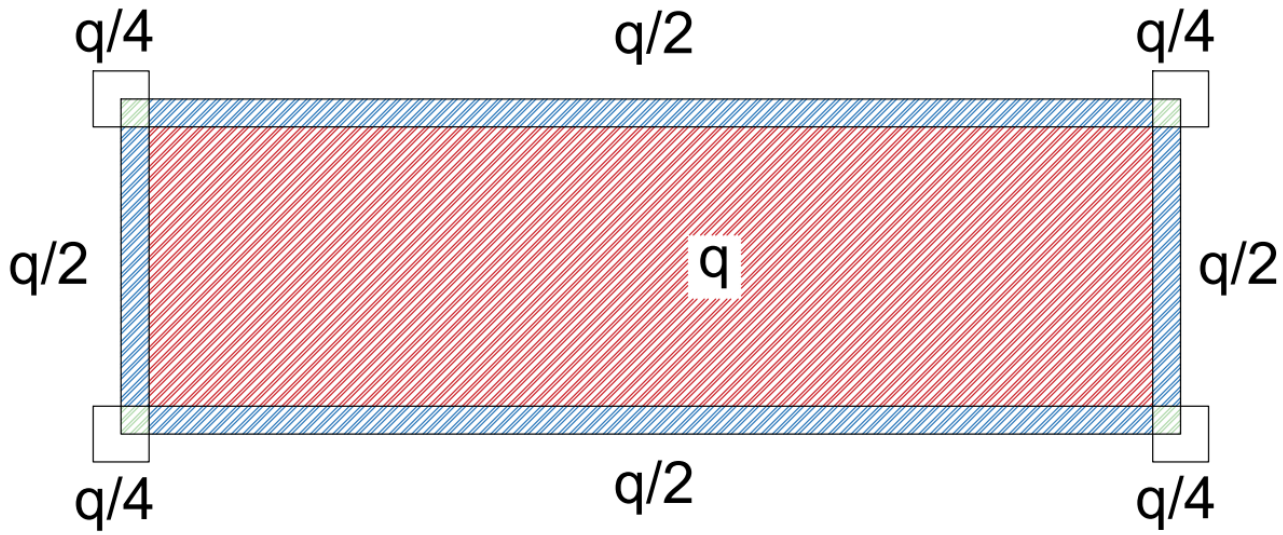
Area 456m^2

Qu = 12 kN/m^2

Numero piani: 3 Q Piano 5472 kN/m^2

Q Piano * 3 = 16416 kN/m^2

Calcoliamo le aree d'influenza



Q angolo = ¼ q

Q perimetrale = ½ q

Q centrale = 1 q

Numero nodi totale = 2976

Centrali (2726) q Perimetrali (246) q/2 Angolari (4) q/4

Totale = 3100 Nodi

16416/3100 ➔ 5,29 kN su ogni nodo

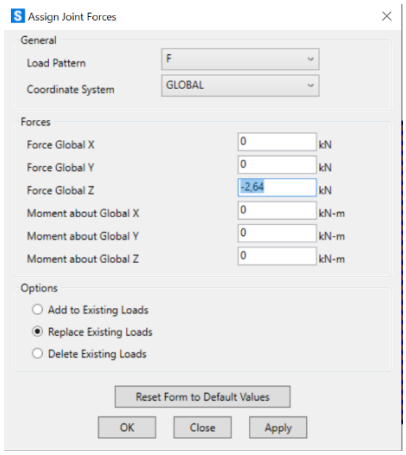
N centrali = 5,29 kN

N perimetrali = 2,64 kN

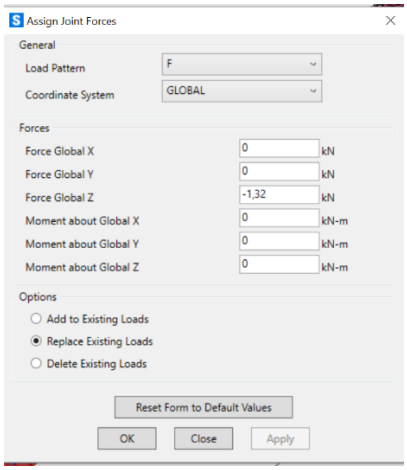
N angolari = 1,32 kN

Ora assegniamo F sui nodi

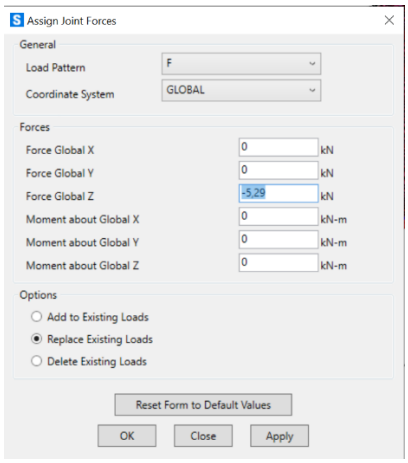
Perimetrali:



Angolari:

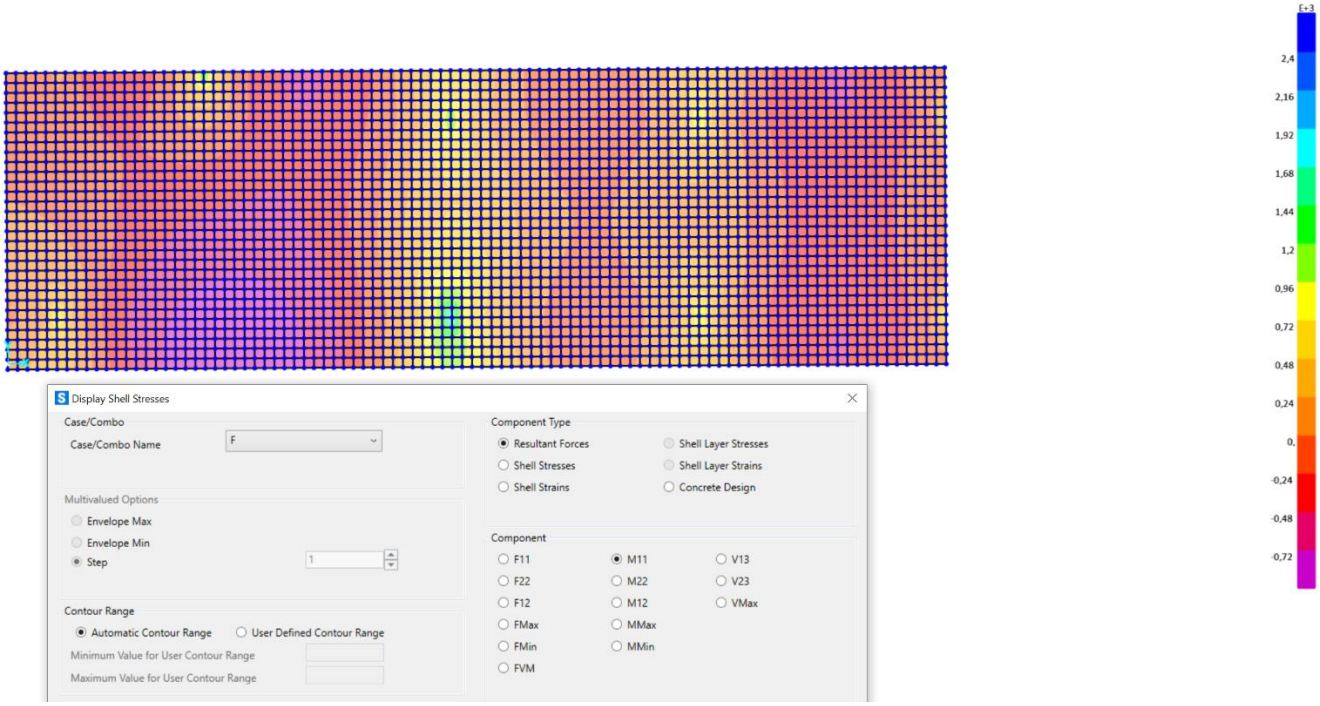


Centrali:

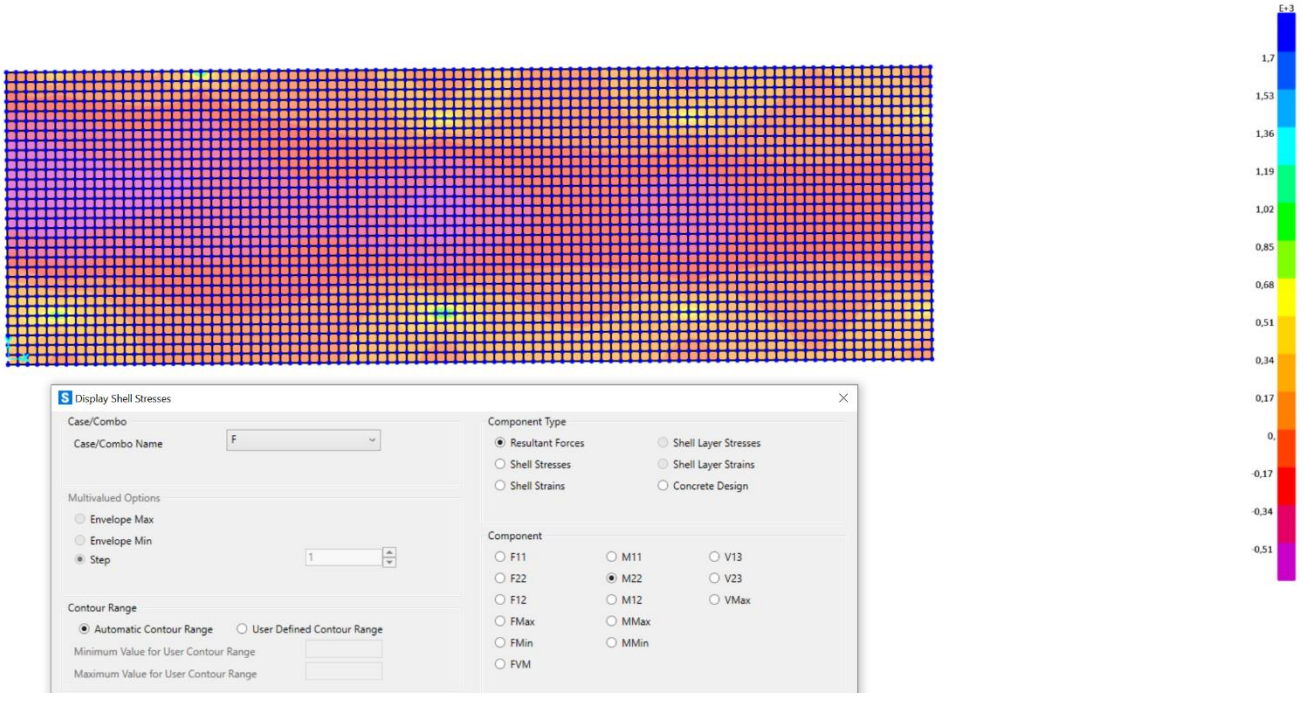


Si passa ad avviare l'analisi.

Momento M11



Momento M22



M Max = 2419,48 kN m

A questo punto visualizziamo le tabelle su Excel per i risultati del dimensionamento.

B=100cm hu = 63cm H = 68cm VERIFICATA

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	interasse (m)	q_s (KN/m^2)	q_p (KN/m^2)	q_a (KN/m^2)	q_u (KN/m)	luce (m)	M_{max} (KN*m)	f_{yk} (N/mm^2)	f_{yd} (N/mm^2)	f_{ck} (N/mm^2)	f_{cd} (N/mm^2)	β	r	b (cm)	h_u (cm)	δ (cm)	H_{min} (cm)	H	H/l	area (m^2)	peso unitario (KN/m)
2																					
3	4,00	3,50	3,00	2,00	48,20	5,00	150,63	450,00	391,30	28,00	15,87	0,38	2,46	30,00	43,76	5,00	48,76	55,00	0,10	0,17	4,13
4					53,56	5,00	167,38	450,00	391,30	28,00	15,87	0,38	2,46	30,00	46,13	5,00	51,13	verificata			
5	1,00	3,50	3,00	2,00	12,05	4,00	24,10	450,00	391,30	28,00	15,87	0,38	2,46	25,00	19,17	5,00	24,17	35,00	0,09	0,09	2,19
6					14,89	4,00	29,79	450,00	391,30	28,00	15,87	0,38	2,46	25,00	21,32	5,00	26,32	verificata			
7	10,00	3,50	3,00	3,00	135,50	8,00	2419,48	450,00	391,30	50,00	28,33	0,52	2,16	100,00	63,00	5,00	68,00	80,00	0,10	0,80	20,00
8					161,50	8,00	1292,00	450,00	391,30	50,00	28,33	0,52	2,16	100,00	46,04	5,00	51,04	verificata			
9					0,00		0,00														
10					0,00		0,00														
11					0,00		0,00														

Dato che i pilastri non sono posizionati lungo il perimetro della struttura, non c'è stato bisogno di allargare la trave di bordo.

Inerzia della piastra:

$bh^3/12 = 0{,}833$ $\underline{Ix = bh^3/12}$

Inerzia di un passo da 2 mt

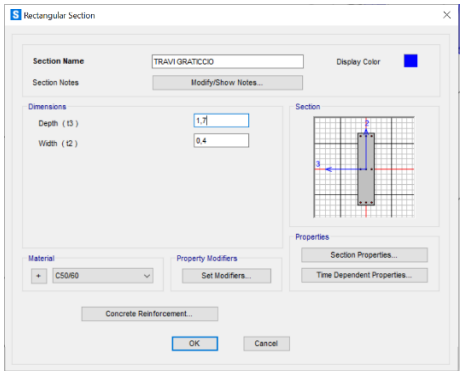
$Ix = 2/12 \rightarrow 0{,}16m^4$

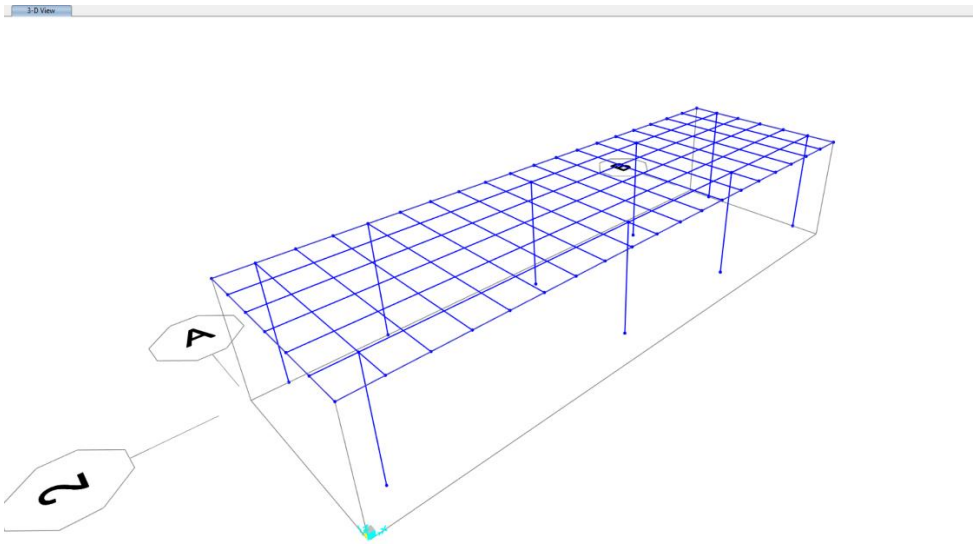
$H = \sqrt[3]{Ix\text{-}12/b} \rightarrow \sqrt[3]{0{,}16\text{-}12/0{,}4} \rightarrow \sqrt[3]{4{,}8} \rightarrow 1{,}69$

Width = b=0,4m

Depth = h = 1,70m

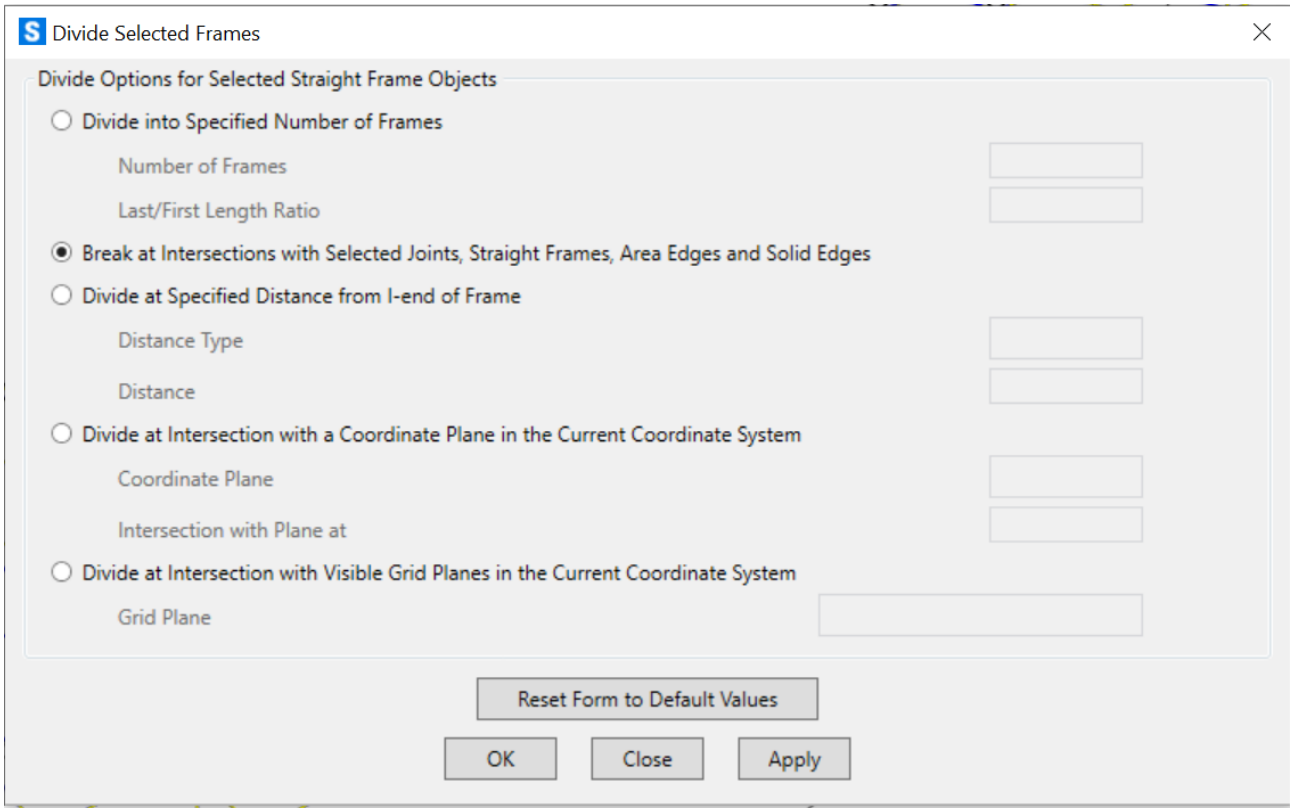
Ora definiamo la sezione delle travi del graticcio

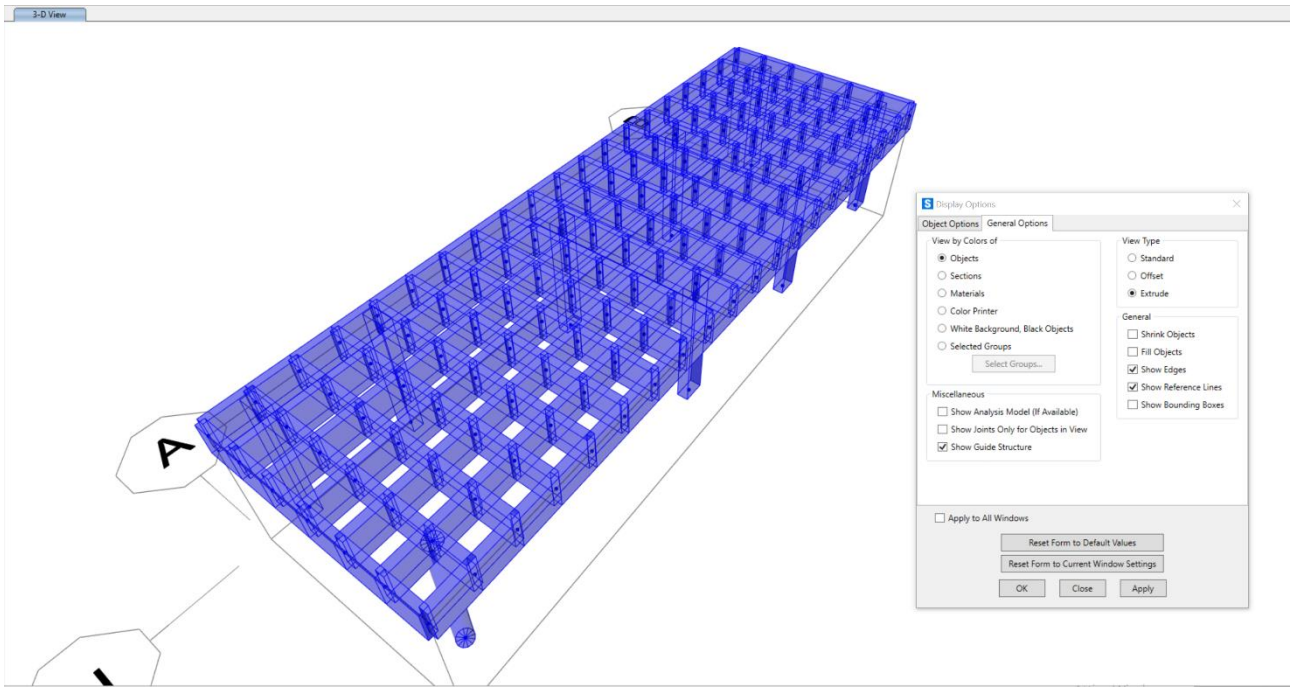




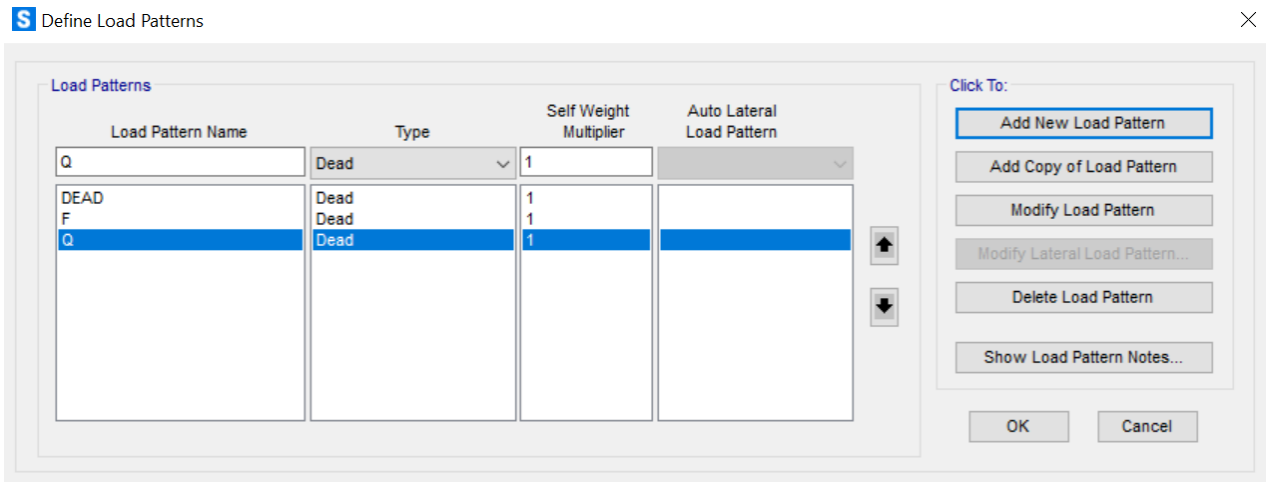
Ora dobbiamo assegnare il nodo rigido al graticcio e quindi interrompere la trave nell'intersezione.

(Divide selected frames)





Definiamo un nuovo Load Pattern Q



Q Tot = 16416 kN/m^2

N nodi centrali = 90 q → 90

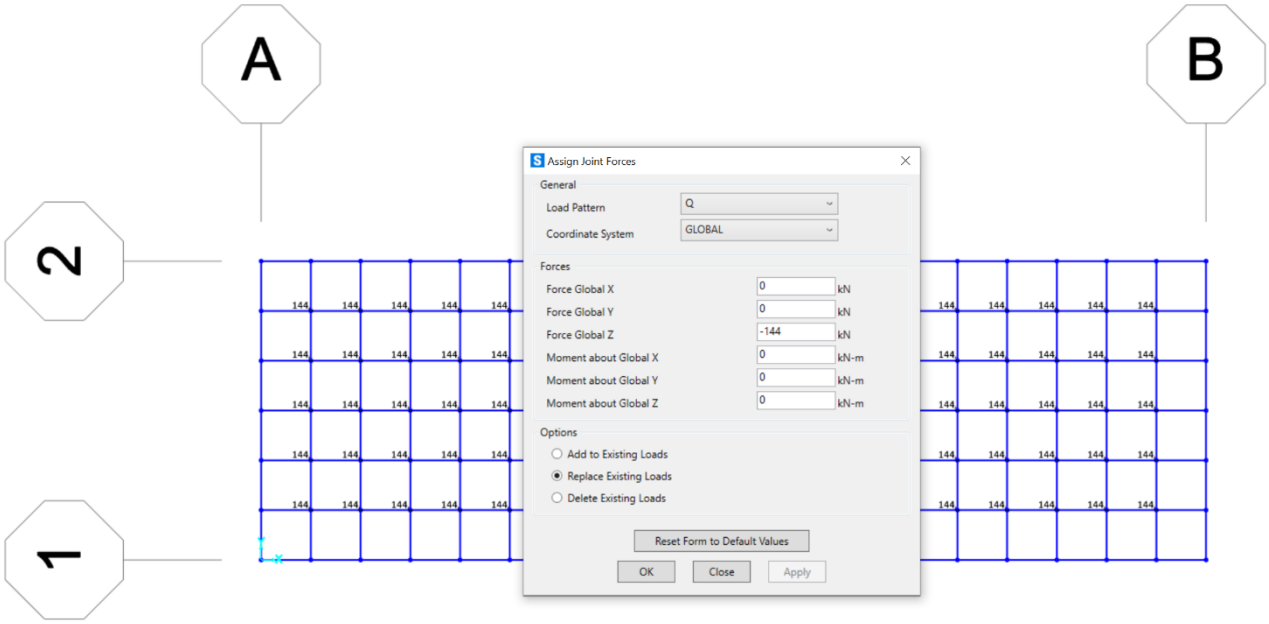
N nodi perimetrali = 46 q/2 → 23

N nodi angolari = 4 q/4 → 1

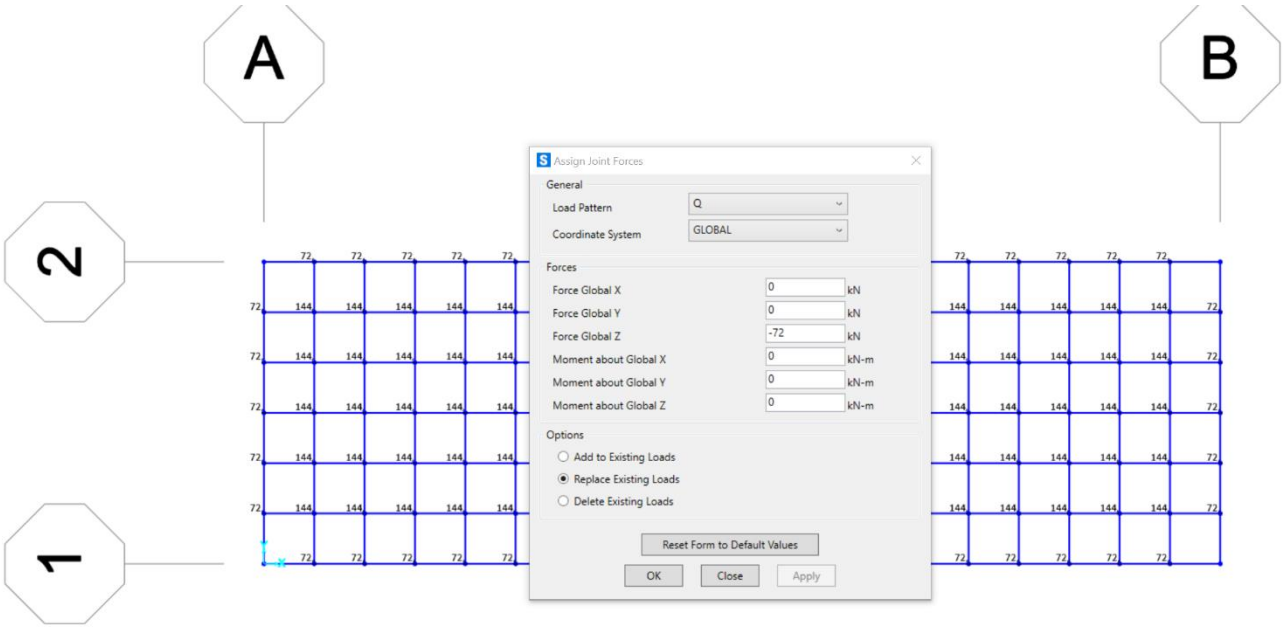
N nodi tot = 114

16416 kn/m^2 / 114 → carico concentrato sui nodi = 144 kN

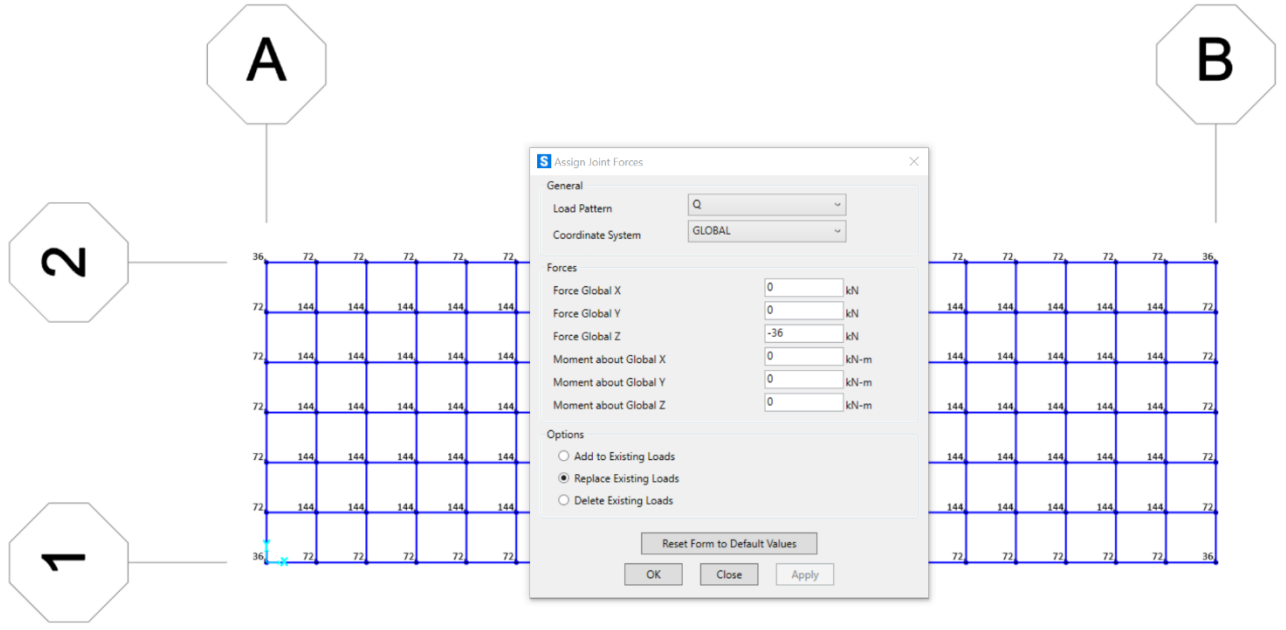
144 kN → nodi centrali



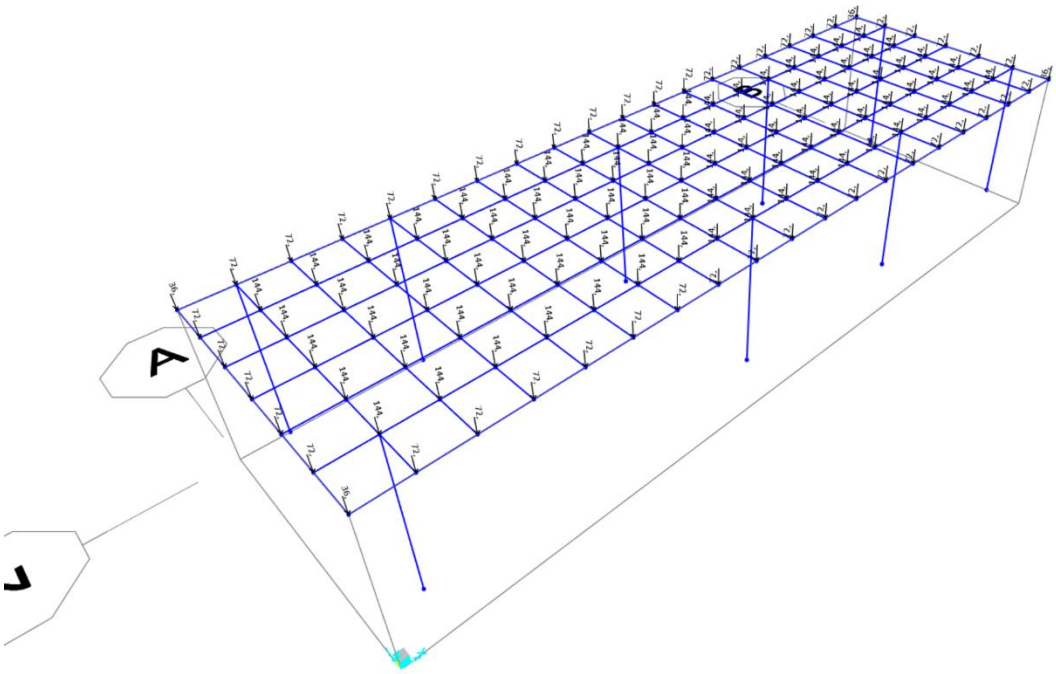
72 kN → nodi perimetrali



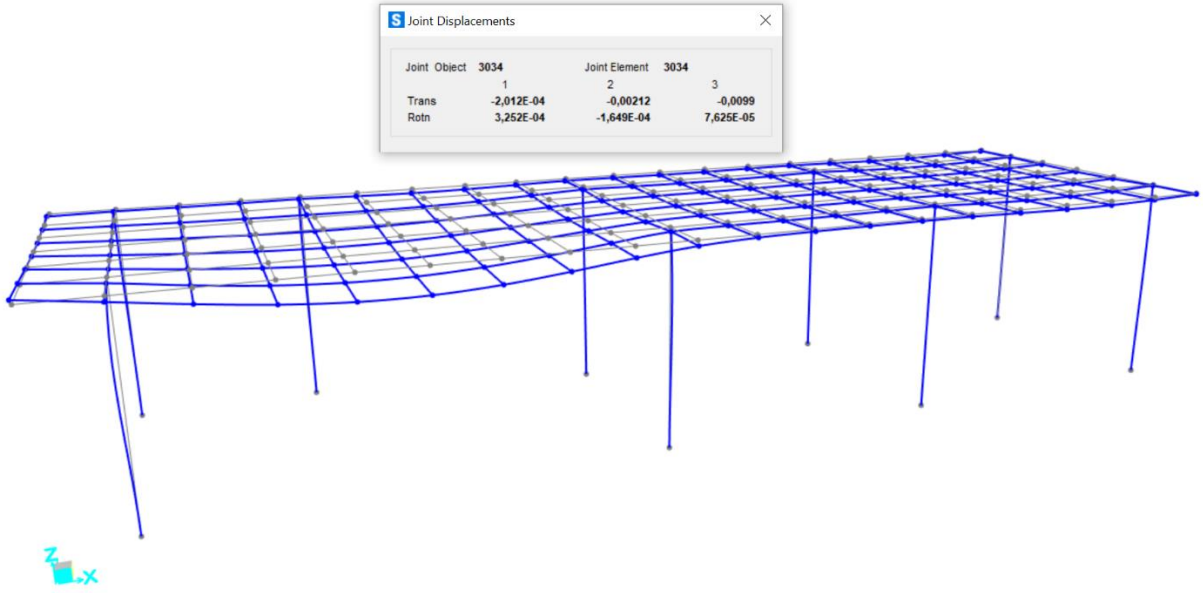
36 kN → nodi angolari



Visualizziamo tutte le forze



Avviamo nuovamente l'analisi e visualizziamo la verifica ad abbassamento:



Δz = 0,0099m --> 9,9mm Verificato 0,009 < 1/200l

M33 Max graticcio 3450 kN/m sulle travi (FRAME 92) <u>verificata</u>

Element Forces - Frames

File View Edit Format-Filter-Sort Select Options

Units: As Noted

Filter:

Element Forces - Frames

	Frame Text	Station m	OutputCase	CaseType Text	P KN	V2 KN	V3 KN	T KN-m	M2 KN-m	M3 KN-m	FrameElem Text
▶	92	2	Q	LinStatic	-96,838	1597,718	-14,29	-28,4341	15,6534	-3450,5035	92-1
	92	1,5	Q	LinStatic	-96,838	1589,22	-14,29	-28,4341	8,5085	-2653,7692	92-1
	93	0	Q	LinStatic	50,983	-1084,958	-5,598	-26,3806	-5,6535	-2624,6529	93-1
	93	0,5	Q	LinStatic	50,983	-1076,461	-5,598	-26,3806	-2,8545	-2084,2982	93-1
	250	2	Q	LinStatic	-24,004	1380,062	15,251	8,519	-15,4389	-1967,2285	250-1
	92	1	Q	LinStatic	-96,838	1580,723	-14,29	-28,4341	1,3636	-1861,2835	92-1
	251	0	Q	LinStatic	6,632	-968,409	-0,379	45,8277	-2,54	-1811,9356	251-1
	168	2,00001	Q	LinStatic	0,292	974,367	-14,007	-39,1278	15,2066	-1804,8747	168-1
	73	2	Q	LinStatic	-23,261	556,599	-4,568	15,4619	5,1406	-1784,4953	73-1
	169	0	Q	LinStatic	-6,774	-885,447	-8,043	-25,6445	-8,2239	-1768,7805	169-1
	74	0	Q	LinStatic	-22,882	-305,82	2,064	-75,4311	3,3587	-1738,6675	74-1
	174	0	Q	LinStatic	-61,852	-944,319	-1,824	2,9001	-2,0167	-1602,9932	174-1
	74	0,5	Q	LinStatic	-22,882	-297,323	2,064	-75,4311	2,3266	-1587,8817	74-1
	111	2	Q	LinStatic	-18,734	520,686	-16,115	-67,1773	16,8781	-1568,8937	111-1
	112	0	Q	LinStatic	-14,075	-390,553	-8,967	15,3939	-8,4377	-1550,5869	112-1

Record: << < 1 > >> of 1265 Add Tables... Done

					142,80	8,00	1140,80	450,00	391,30	50,00	28,33	0,52	2,16	40,00	68,40	5,00	73,40	verificata					
	10,00	3,50	3,00	2,00	120,50	8,00	3450,00	450,00	391,30	50,00	28,33	0,52	2,16	40,00	118,95	5,00	123,95	170,00	0,21	0,68	17,00		GRATICCIO

M33 Max pilastri 1074 kN/m (FRAME 8) <u>verificata</u>

Element Forces - Frames

File View Edit Format-Filter-Sort Select Options

Units: As Noted

Filter:

Element Forces - Frames

	Frame Text	Station m	OutputCase	CaseType Text	P KN	V2 KN	V3 KN	T KN-m	M2 KN-m	M3 KN-m	FrameElem Text
▶	8	0	Q	LinStatic	-1957,446	159,877	-30,916	6,6783	-126,8137	1074,1468	8-1
	1	0	Q	LinStatic	-3514,759	118,137	-74,617	4,1756	-302,2911	577,99	1-1
	8	3,7	Q	LinStatic	-2024,026	159,877	-30,916	6,6783	-12,4244	482,6024	8-1
	7	7,4	Q	LinStatic	-5308,308	-163,451	-39,328	8,4081	137,7863	346,3761	7-1
	11	0	Q	LinStatic	-3359,199	83,342	-2,703	7,4218	6,9943	326,2136	11-1
	9	7,4	Q	LinStatic	-1475,479	-1,675	-20,236	5,2778	75,6258	297,2197	9-1
	9	3,7	Q	LinStatic	-1408,898	-1,675	-20,236	5,2778	0,7514	291,0207	9-1
	5	0	Q	LinStatic	-3056,659	64,754	-32,299	7,4918	-139,8135	285,4429	5-1
	9	0	Q	LinStatic	-1342,318	-1,675	-20,236	5,2778	-74,1229	284,8217	9-1
	2	7,4	Q	LinStatic	-1622,78	-98,905	-13,847	6,9576	36,4439	191,701	2-1
	1	3,7	Q	LinStatic	-3561,241	118,137	-74,617	4,1756	-26,2084	140,8815	1-1
	10	7,4	Q	LinStatic	-1574,651	-65,882	10,275	6,852	-22,3733	60,9393	10-1
	5	3,7	Q	LinStatic	-3123,24	64,754	-32,299	7,4918	-20,3083	45,8545	5-1
	11	3,7	Q	LinStatic	-3425,779	83,342	-2,703	7,4218	16,9968	17,8483	11-1
	12	0	Q	LinStatic	-3678,822	10,852	-5,683	8,263	13,6574	-38,3177	12-1

Record: << < 1 > >> of 27 Add Tables... Done

4					53,56	5,00	167,38	450,00	391,30	28,00	15,87	0,38	2,46	30,00	46,13	5,00	51,13	verificata					
5	10,00	3,50	3,00	2,00	120,50	4,00	1074,00	450,00	391,30	50,00	28,33	0,52	2,16	60,00	54,19	5,00	59,19	120,00	0,30	0,72	18,00		PILASTRO
6					143,90	4,00	287,80	450,00	391,30	50,00	28,33	0,52	2,16	60,00	28,05	5,00	33,05	verificata					

Sforzo normale sui pilastri:

Element Forces - Frames

File View Edit Format-Filter-Sort Select Options

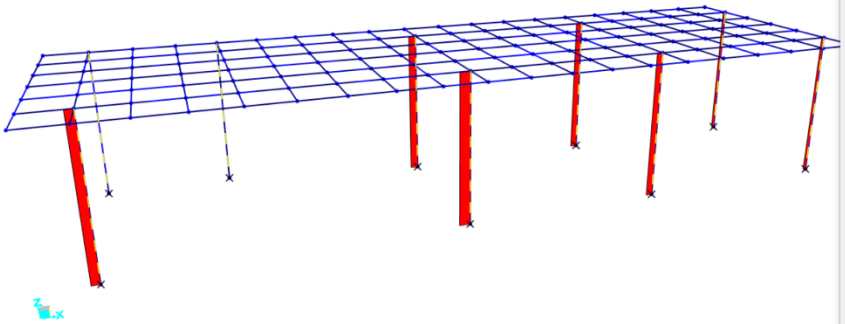
Units: As Noted

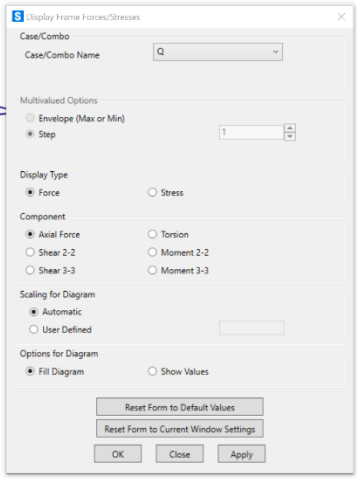
Filter:

Element Forces - Frames

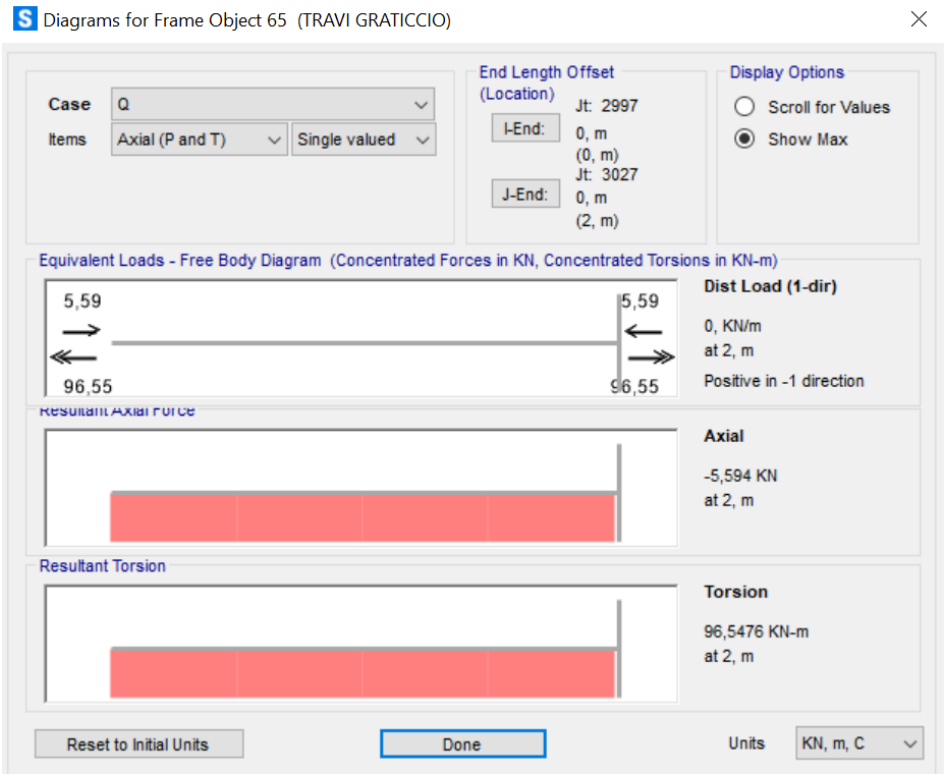
	Frame Text	Station m	OutputCase	CaseType Text	P KN	V2 KN	V3 KN	T KN-m	M2 KN-m	M3 KN-m	FrameElem Text
▶	7	7,4	Q	LinStatic	-5308,308	-163,451	-39,328	8,4081	137,7863	346,3761	7-1
	7	3,7	Q	LinStatic	-5241,727	-163,451	-39,328	8,4081	-7,7265	-258,3916	7-1
	7	0	Q	LinStatic	-5175,147	-163,451	-39,328	8,4081	-153,2393	-863,1594	7-1
	12	7,4	Q	LinStatic	-3811,982	10,852	-5,683	8,263	55,7115	-118,6217	12-1
	12	3,7	Q	LinStatic	-3745,402	10,852	-5,683	8,263	34,6845	-78,4697	12-1
	12	0	Q	LinStatic	-3678,822	10,852	-5,683	8,263	13,6574	-38,3177	12-1
	1	7,4	Q	LinStatic	-3607,723	118,137	-74,617	4,1756	249,8743	-296,227	1-1
	1	3,7	Q	LinStatic	-3561,241	118,137	-74,617	4,1756	-26,2084	140,8815	1-1
	1	0	Q	LinStatic	-3514,759	118,137	-74,617	4,1756	-302,2911	577,99	1-1
	11	7,4	Q	LinStatic	-3492,36	83,342	-2,703	7,4218	26,9993	-290,517	11-1
	11	3,7	Q	LinStatic	-3425,779	83,342	-2,703	7,4218	16,9968	17,8483	11-1
	11	0	Q	LinStatic	-3359,199	83,342	-2,703	7,4218	6,9943	326,2136	11-1
	5	7,4	Q	LinStatic	-3189,82	64,754	-32,299	7,4918	99,197	-193,7339	5-1
	5	3,7	Q	LinStatic	-3123,24	64,754	-32,299	7,4918	-20,3083	45,8545	5-1
	5	0	Q	LinStatic	-3056,659	64,754	-32,299	7,4918	-139,8135	285,4429	5-1

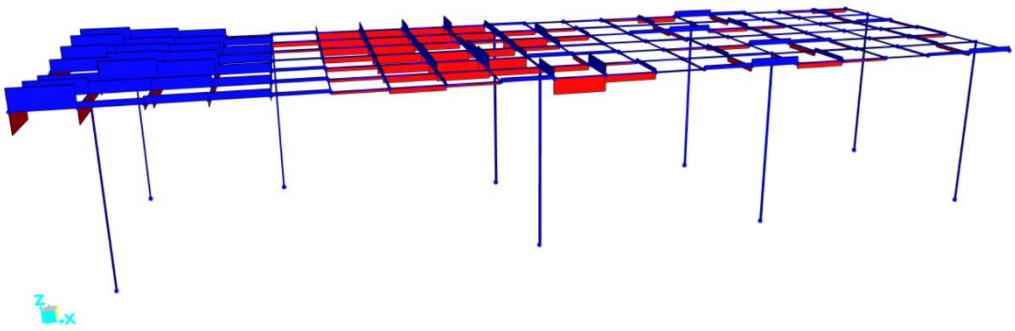
Record: << < 1 > >> of 27 Add Tables... Done





Momento torcente sulla trave di bordo:





$M\tau$ = 96,54 kN/m → 96,54*10^6 N*mm

T = ȧ*Mτ/b*a^2

ȧ = 3+1,8*(0,4/2) = 3,36

ȧ = 400m ß = 200m

τ = 3,36*96,54*10^6 / 2000*400^2 = 1,01 N/mm^2 = 1,01 Mpa < 8 Mpa VERIFICATA A TORSIONE

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