TWO-DIMENSIONAL FRAME – SOLUTION IN ROBOT SYSTEM









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1. Type of project and regional settings

Definition of example. Solve the given portal frame plotted in Fig. 1 using the ROBOT package. Assume:

- material: concrete C20/25 (E = 30 GPa)
- RC beam: rectangular $A_1 = 0.3 \text{ m} \times 0.5 \text{ m}$
- RC column: rectangular $A_2 = 0.3 \text{ m} \times 0.3 \text{ m}$



Fig.1. Diagram of portal frame.



(a) Window of project selection.

Fig.2. Type of project (selection).

(b) Frame 2D icon.

Type of project. Firstly we select the analysis of two-dimensional frame from among possible tasks (cf. Fig. 2(a) or Fig. 3(a) in case of ROBOT 2012). In this case button like in Fig. 2(b) or Fig. 3(b) should be pressed.



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Languages General Parameters View Parameters Desktop Settings Toolbar & Menu Printout Parameters Authorization Key Advanced	Regional settings: Working language: Printout language:	Eurocode English English	

Fig.4. Regional settings.

Regional settings. Immediately after project selection we select language and proper standards. From the top menu we pick $Tools \rightarrow Preferences$ and change the following window options: Regional settings: Eurocode, Working language: English. Printout language self-adapts. We accept this settings (cf. Fig. 4).

2. Sections and material definition

Before we construct the model of the portal frame we should determine necessary bar cross-sections and the type of material.

Sections. We choose from the top menu *Geometry* \rightarrow *Properties* \rightarrow *Sections* or the icon called *Bar Sections* from the toolbar on the right. In the window we define *New Section* – this is the icon with small white blank page. In the next window we set the section type as *RC beam*, rectangular, and complete dimensions: b = 30 cm, h = 50 cm. Label *BR 30x50* remains without change. At the end press button *Add*. In case of problems please refer to Fig. 5(a).

Analogically we define the next section as rectangular RC column with dimensions b = 30 cm, h = 30 cm. Label CR 30x30 is the default (cf. Fig. 5(b)). It is important that button Add and button Close should store the settings and turn off the windows.

Material. Now we can assign a material to the sections defined previously. We choose the icon called *Materials* from the right-hand toolbar or the following options from the top menu: Geometry \rightarrow *Materials*. In popup window we select concrete C20/25 as material and next point to the suitable label of section (*BR 30x50* and then *CR 30x30*). Apply confirms our selection, then press *Close*.

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	I IPE 100 RK 50x4 RK 100x5	*	a.	ħ.;
→ C 45x45	New Section			J .
Apply	Label: B R30x50 Color Auto -		h	10 10
* *		Basic dim	ensions (cm)	
	Reduction of mom. of inertia Use tapered section	Basic dim b 30 h 50	ensions (cm)	

(a) RC beam section.



(b) RC column section.

Fig.5. Definition of sections.

3. Construction of structure together with supports

column	ģ.			Contract		
Number:	1		ti i	Step:	1	
Name:	Colu	imn_1				
Properties						
Section t	уре:	RCo	olumn	0		
Section:		C R30x30 -				
Default n	nateria	əl:	[220/25		
Geometry	(m)					
Begin	ning:	0;0				
He	eight:	7				
Orienta	ation:	🗿 Up	(Z+)	1		
		© Do	wn (Z)		

Fig.6. Definition of column.

First building block. To construct the structure model in a proper way we open the *Column* window starting from the top menu *Geometry* \rightarrow *Columns*. In the window we pick properties, write geometry parameters according to Fig. 6 and *Add* this element. We do not close the window. Now we can change insertion point and height in geometry parameters – *Beginning* has coordinates 0; 7 and column *Height* is equal to 6. We *Add* second column and *Close* the window.

Analogical operations are performed for the beams. Starting from $Geometry \rightarrow Beams$ we open the window and introduce all settings as in Fig. 7 for both lower and upper beams.

Number 3	Step : 1	Number 4	Step : 1
Name : Bea	m_3	Name : Bea	m_4
Properties		Properties	
Section type:	RC beam 🔹	Section type:	RC beam
Section :	B R30x50 ▼	Section :	[B R30x50 ▼]
Default materia	al: C20/25	Default materia	al: C20/25
Geometry (m)		Geometry (m)	
Beginning :	0; 7,00	Beginning :	0,00; 13,00
End :	6.7	End :	6,00,13,00
	V Horizontal beams		V Horizontal beams
	C Drag		🕅 Drag

(a) Lower beam.

(b) Upper beam.

Fig.7. Definition of beams.

	Insert	
	Merging paramete	ers:
Supports	Reference node:	1
) 🗙 🖬 🖬 🖬 🗶	Insertion point:	6,00; 0,00; 0,0
odal	Scale and rotation	<u>(</u>);
X Delete	Scale and fotation	ь. Г.
Pinned	Scale Coefficient.	1
9 PodUZ	Alpha:	0
9 UZ	Beta:	0
	Gamma:	0
irrent selection		
*	Add as object?	🖲 Yes 🖱 No

Fig.8. Support and merging structure windows.

 Select		Template: Standard	- 🔪 🔂 🕻	
Previous Selection	ı	Favorites	Name	
Rotate 3D		Nodes Bars	Bar description Symbols	
- Window	Ctrl+ Alt+1	Panels / FE	Section - shape	
<u></u>	CUITAILTE	Loads	Section - area	
₽• Pan		View (Open-GL version)	Sections - legend by colors	
^{₽ª} <u>R</u> edraw		Structure	Member types - legends by colors	
700m All	Ctrl+Alt+D		Cables	
<u>A 2001111</u> 11	Current D	-	Advanced properties	
Snap Settings	•		Numbers of calculation elements	
Display				
🖽 <u>T</u> ables			l.	
💁 <u>S</u> creen Capture	Ctrl+Alt+Q	Symbol size: 30	Display attributes of selected objects	only for
Object Properties		Help	OK Cancel	Apply

Fig.9. Displaying different attributes.

To define boundary conditions we select from the top menu *Geometry* \rightarrow *Supports*, pick *Fixed* option in the window as in Fig. 8(a) and assign to node 1 (coordinates 0; 0; 0) using mouse or writing node number. The small square denotes that the rotation as well as horizontal and vertical translation are blocked (all degrees of freedom).

Copying building block. Firstly, we should mark all elements of the structure which have been created until now. We can use shortcut key Ctrl + A or from the top menu $Edit \rightarrow Select All$. Copypaste operation works as usual $(Ctrl + C - Ctrl + V \text{ or } Edit \rightarrow Copy - Edit \rightarrow Paste)$, but we decide where the duplicated part should be inserted. In the window as in Fig. 8(b) we introduce insertion point 6;0;0 and choose Yes answering the question Add as object?. To confirm we press button Apply. We

4. LOADING



Fig.10. Display of section-shape attribute of the frame.

repeat the whole procedure of copying, but the second time the insertion point is 12;0;0. After pressing Apply we confirm using OK. Now we should unmark the structure (Esc).

The last operation is copying the originally first and second columns together with the support at node 1. We mark this part of the structure, run copy-paste, introduce insertion point 18;0;0 and again select Yes answering the question Add as object?. Buttons Apply and OK confirm our action.

Division of building blocks. Using $Edit \rightarrow Substructure modification \rightarrow Explode Object from the top$ menu we decompose the whole structure in order to have capability to modify of each element separately.

Display of attributes of the structure. If we would like to display e.g. the section shape for all elements of the frame we should press the right mouse button and select in the window Display... option as in Fig. 9(a). In the second window presented in Fig. 9(b) among Bars attributes we tick Section-shape and confirm using Apply and OK. The structure will be shown as in Fig. 10. In a similar way we should untick attributes in order to return to the original view.

Loading **4**.

Case desi	cription		37	Case des	cription	
Nature:	dead 💌	New		Nature:	Live1	New
Number:	1 Label:	DL1		Number:	2 Lab	el: LL1
Name:	DL1			Name:	LL1	
_ist of def	ined cases:			List of def	ined cases:	
No.	Case name	Nature	4	No.	Case name	Nature
≁1	DL1	dead	S	1 →2	DL1 LL1	dead Live1
•	m.		•		m	
Modify	Delete	Delete al		Modify	Delete	Delete all
	Close	Help			Close	Help

(a) Dead load.

Fig.11. Load types window.

	*	Case No: 2 : LL1 Selected:	
Р 	20	Node Bar	Self-weight and mass
Values			
p (kN/m) *	√ (Deg)		
X: 0,00	0,0		
Y: 0,00	0,0		
Z: -15,00	0,0		
		Apply to	
Coord. system: 🧕 Global 🥚) Local	4,8,11,12	
Projected load	\$ 5		
Loads on eccentric	ity .	Apply	

(a) p = 15 kN/m.

P	Case No: 2 : LL1 Selected: Uniform load Node Bar Self-weight and mass
Values	
Z: 45,00 0,0 . Coord. system:	Apply to 37
Projected load Loads on eccentricity Add Close Help	Apply Close Help

(b) p = 45 kN/m.

Fig.12. Loading definition.



Fig.13. Model of frame with loading and supports.

5. CALCULATION AND RESULTS

Load types. Before we define the loading of the frame structure we should create suitable types of loading. Firstly, we generate dead load to avoid an automatic addition of this load to the next type. Starting from the top menu $Loads \rightarrow Load$ Types we open a window and push button New (or Add in case of ROBOT 2012). Now the dead load is created. We change load nature into Live similarly to Fig. 11(b) and once again push button New (or Add in case of ROBOT 2012) to create live load. This load remains active, so we can Close the window.

Load definition. We execute $Loads \rightarrow Load Definition$ from the top menu or right-hand toolbar. In the window we choose Bar options and pick first icon Uniform load as shown in Fig. 12(a). In the new window we enter -15 kN/m in direction Z and confirm this value by button Add. Now we tick elements in the workspace which should have this loading applied to, or write in the previous window numbers of elements in the field Apply to, cf. Fig. 12(a). Analogical operation should be performed for the larger load equal to -45 kN/m in direction Z, cf. Fig. 12(b). The model with loading and supports is presented in Fig. 13.

5. Calculation and results

Our analysis is static, elastic and the most important aim is the presentation of generalized stresses (cross-section forces) as a result.

Calculation. We choose from the top menu $Analysis \rightarrow Calculations$ or press the icon \square called *Calculations* in order to compute the structure.

Results – **diagrams.** The results for the portal frame can be presented if we open *Diagrams* window. From the top menu we select *Results* \rightarrow *Diagrams for Bar.* Before we draw the diagrams we should check if live load 2:LL1 is active. Next we can set the last option *Parameters* according to

Fig. 14. Going back to *NTM* option we can draw suitable diagrams for shearing forces or/and bending moments or/and normal forces. Please, see Fig. 15 to verify your computations.

NTM	Reactions Reinforcement Parameters
Deformation	- Diagram description
Stresses	
Reactions	
Reinforcement	Values: Local extremes
Parameters	Min Max
3	Positive and negative values
	💮 undifferentiated 💿 differentiated
	I fence I filled

Fig.14. Parameter settings for diagrams.



(a) Shearing forces F_z .



(b) Bending moments M_y .



(c) Normal forces F_x .

Fig.15. Diagrams of forces.

5. CALCULATION AND RESULTS



•	§?	2:LL1	÷						
Node/Case	FX (kN)	FZ (kN)	MY (kNm)						
1/ 2	3,82	154,71	8,47						
6/ 2	-0,83	393,70	-2,40						
9/ 2	-1,81	278,78	-4,6						
12/ 2	-1,18	72,81	-3,23						
Case 2									
Sum of val.	-0,00	900,00	-1,83						
Sum of reac.	-0,00	900,00	-7020,00						
Sum of forc.	0,0	-900,00	7020,00						
Check val.	-0,00	-0,00	0,00						
Precision	2,15584e-016	1,84482e-032							

(a) How to display reactions in table?

(b) Displaying of reactions.

Fig.16. Reactions in table.

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Fig.17. Setup of reactions – options in diagrams window.

Results – reactions. Reactions can be observed in two manners. If we choose from the top menu $Results \rightarrow Reactions$ like in Fig. 16(a) then the table given in Fig. 16(b) appears. The other way is running $Results \rightarrow Diagrams$ for Bar and opening option of Reactions in Diagrams window, cf. Fig. 17. Next we select suitable settings and analyze all reactions. Fig. 18 shows reactions together with loading.

		: 		p	Z=-	15.00			p	Z=-1	5.00];		-	p	Z=-1	5.00	1	
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			8	22	Ċ.	<u></u>	10	1	8	52	<i>*</i>		<u>*</u> 2	*	20	23	<u>*</u> :	3	50
			ೆ	p	Z=	45.00	*		p	Z=-4	5.00	1	*	*	*	1	*	5	<i>t</i> :
			5				6						¥1	÷	p	Z=-1	5.00	-9	i.
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			31		2	1	*		8	*/	×		*/		*	14		53	t:
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~	MY	=8,	47		άř.	12	MY=	2,40	Ň	21	4	d	MY=-4	1,67		57	. (MY=-	3,23
8							<u>р</u> .	32	e						- 25		*:		t.

Fig.18. Reactions and loading.