Action TU0904
Integrated Fire Engineering and Response
Application of Structural Fire Design, 29 April 2011, Prague, Czech Republic

University "Ss. Cyril and Methodius"
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RC FRAME EXPOSED TO FIRE AFTER EARTHQUAKE

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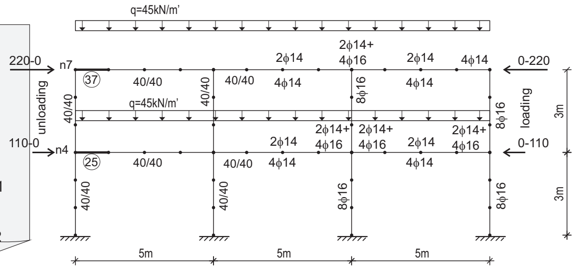
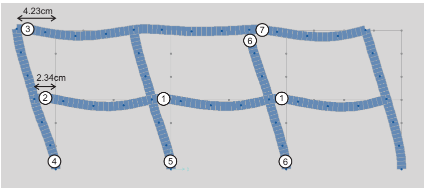
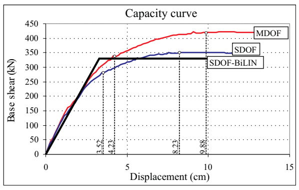
1. Gravity load (q=45kN/m')
2. Gravity load + ISO fire scenario 1
3. Gravity load + SDHI fire scenario 1
4. Gravity load + ISO fire scenario 2
5. Gravity load + SDHI fire scenario 2
6. Gravity load + Pushover (loading + unloading) + ISO fire scenario 1
7. Gravity load + Pushover (loading + unloading) + SDHI fire scenario 1
8. Gravity load + Pushover (loading + unloading) + ISO fire scenario 2
9. Gravity load + Pushover (loading + unloading) + SDHI fire scenario 2
10. Gravity+Pushover (loading+ unloading +opposite loading+ unloading) + ISO fire scenario 1
11. Gravity+Pushover (loading+unloading+opposite loading+ unloading)+ SDHI fire scenario 1
12. Gravity+Pushover (loading+unloading +opposite loading+ unloading)+ ISO fire scenario 2
13. Gravity+Pushover (loading+unloading +opposite loading+ unloading)+SDHI fire scenario 2

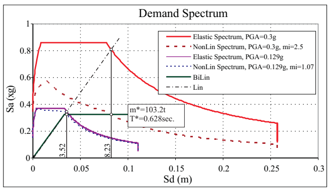


The object of the numerical analysis is a two-story three bay planar reinforced concrete frame structure. Concrete compressive strength is fc=30MPa, reinforcement yield strength is fy=400MPa. Structure self weight is included in the permanent and live loads, applied on beams as cumulate uniformly distributed, q=45kN/m'. Total weight of the structure is W=2x(45.0x15.0)=1350kN. The reinforcement of beam cross sections is taken in such a way that the stresses in steel bars due to nominal load q are approximately 60% of the yield strength. The percentage of column reinforcement is taken to be 1%.

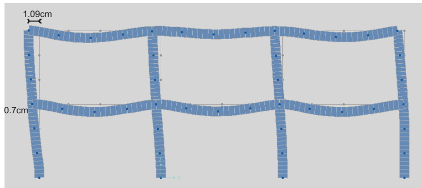
displacements after Pushover case





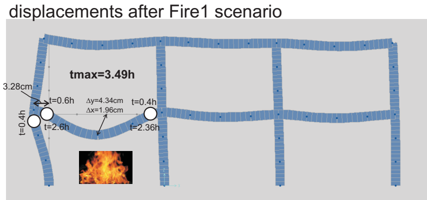


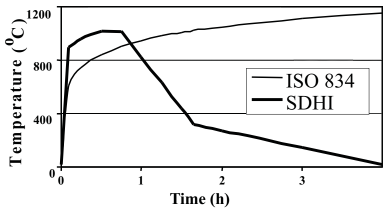
residual displacements after Pushover case



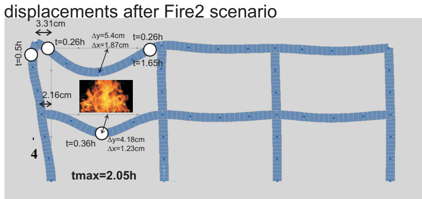
The reinforcement of the RC frame cross sections is defined from criteria that do not take into acount seismic provisions. In order to see what is the seismic capacity of the structure and to what level of seismic demand corresponds the assumed base shear of 330kN, the N2 method was implemented. Base shear of 330kN and the obtained displacement of 4.23cm at node 7 corresponds to elastic demand spectrum for PGA=0.129g. By inverse procedure, it was found that this RC frame has capacity (base shear of 420kN and target displacement of 9.88cm) to sustain elastic demand spectrum for PGA=0.3g. All loading cases were reapplied such that the horizontal forces were increased up to a base shear of 393kN (corresponding approximately to 94% of frame's capacity). Due to limited space only few results for displacements for nodes 4 and 7 are listed. For base shear=393kN, Δx4=4.19cm, Δx7=7.31cm. For base shear=0kN (unloading), Δx4=1.98cm, Δx7=3.04cm (residual displacements). It is worth mentioning also, that increased resistance in case of fire scenario 1 was observed. The structure has sustained fire load after earthquake in duration t=3.76 hours.

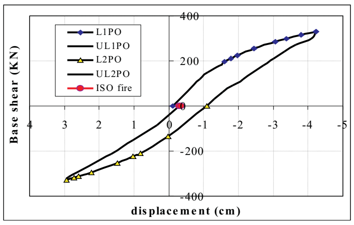
displacements after Fire1 scenario





displacements after Fire2 scenario

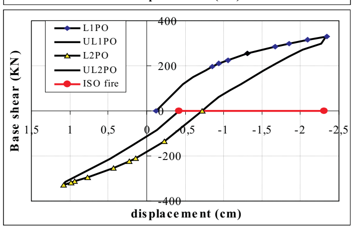




node	Displac. (cm)	only "g" and fire action				"g"+ seismic action + fire action					
		g	g+ISO t=3.3h	g+SDHI t=1.1h	g+SDHI t=5h	g	g+LPO	residual displac.	residual + ISO t=3.49h	resid.+SDHI t=1.1h	resid.+SDHI t=5h
4	Δx	-0.12	-2.85	-1.83	-1.08	-0.12	-2.34	-0.72	-3.28	-2.23	-1.49
7	Δx	-0.13	-0.27	-0.20	-0.19	-0.13	-4.23	-1.09	-1.12	-1.03	-1.01
9	Δy	-0.43	-4.14	-1.27	-1.61	-0.43	-0.64	-0.78	-4.34	-1.45	-1.78

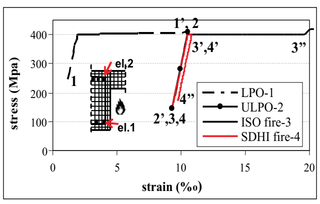
node	Displac. (cm)	only "g" and fire action				"g"+ seismic action + fire action					
		g	g+ISO t=2.0h	g+SDHI t=1.1h	g+SDHI t=5h	g	g+LPO	residual displac.	residual + ISO t=2.0h	resid.+SDHI t=1.1h	resid.+SDHI t=5h
4	Δx	-0.12	-1.62	-1.22	-0.70	-0.12	-2.34	-0.72	-2.16	-1.79	-1.27
7	Δx	-0.13	-2.62	-1.98	-1.89	-0.13	-4.23	-1.09	-3.31	-2.67	-2.25
9	Δy	-0.43	-3.67	-2.68	-1.53	-0.43	-0.64	-0.78	-4.18	-3.23	-2.46
12	Δy	-0.56	-5.34	-3.29	-4.26	-0.56	-0.59	-0.73	-5.41	-3.27	-4.29

As expected, residual horizontal displacements of nodes 4 and 7 as well as the residual vertical displacements of nodes 9 and 12, are slightly higher when fire action is applied after pushover, then in the case when no seismic action was applied. This trend is observed in both fire scenarios and both fire models. Interesting results are obtained for the capacity of this reinforced concrete structure to sustain fire load. Namely, the duration of time that the structure survived the ISO fire after a pushover episode was higher then the duration of time that the structure survived the ISO fire without a seismic action in fire scenario 1, 3.49 hours against 3.3 hours (loading case 6). In fire scenario 2 the duration of time, for both cases, was almost equal, t=2.0 hours (loading case 8). That was even more emphasized in loading cases 10 and 12, when a full cycle (loading, unloading, loading in opposite direction and unloading from opposite direction) was completed.

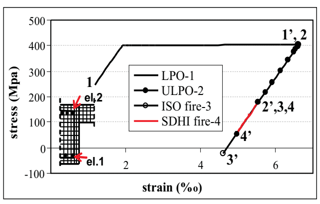


node	Displac. (cm)	"g"+ seismic action in two directions+ fire action						
		g	g+L1PO	residual displac.1	g+L2PO	residual displac.2	residual + **fire 1** t=3.54h	residual + **fire 2** t=2.43h
4	Δx	-0.12	-2.34	-0.72	+1.12	-0.42	-2.31	-1.60
7	Δx	-0.13	-4.23	-1.09	+3.05	-0.30	-0.36	-1.55
9	Δy	-0.43	-0.64	-0.78	-0.87	-0.96	-3.70	-4.20

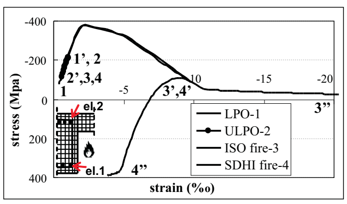
The stress-strain relation for some reinforcement bars is doubly presented, as for example bottom bar, Node 4, fire scenario 1 and bottom bar, Node 7, fire scenario 2. The left graph presents real stress-strain relations during time history of loading and on the right graph stresses are normalized as percentage values of the reduced yield stress due to elevated temperature, fy(T).

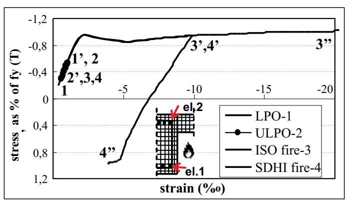


Top bar, Node 4, fire scenario 1

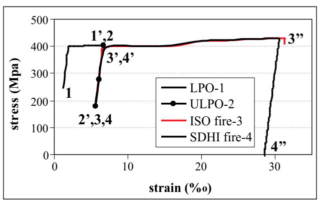


Top bar, Node 7, fire scenario 1

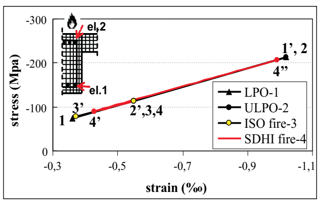




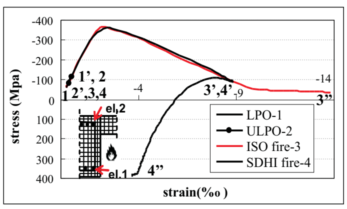
Bottom bar, Node 4, fire scenario 1

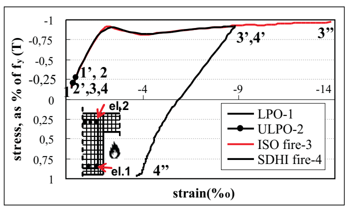


Top bar, Node 7, fire scenario 2



Bottom bar, Node 4, fire scenario 2





Bottom bar, Node 7, fire scenario 2