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A targeted seismic upgrading method for precast roof beam–column connections using adaptable seismic safety key devices

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Summary

In this investigation, a new targeted seismic upgrading method (TSU method) for roof-beam column (RBC) connections was introduced, based on created innovative seismic safety key (SSK) devices, assuring their much better and more reliable seismic safety. The SSK upgraded connection will replace the classical method for upgrading of pin-based roof beam column connections, which provided very limited seismic upgrading effects of precast structures. The results obtained from the authors experimental tests of 1/2 scale prototype models of classical RBC connections and results obtained from the conducted extensive refined FEM based nonlinear analytical studies, clearly demonstrated the superior seismic upgrading performances of the RBC prototype connection upgraded with SSK devices. This study introduces technical procedure how the SSK, an innovative device newly developed by the authors, can be applied for targeted seismic upgrading of RBC connections in modern precast N systems. Specifically, for the newly assembled SSK-upgraded RBC connection, a high increase in safety was confirmed by the results of the studies performed using experimentally verified nonlinear three-dimensional micro-analytical model. The design feature ensures capability of the TSU method for efficient seismic upgrading of existing and newly designed precast industrial hall structures.

Performance of original and classically upgraded RBC connections

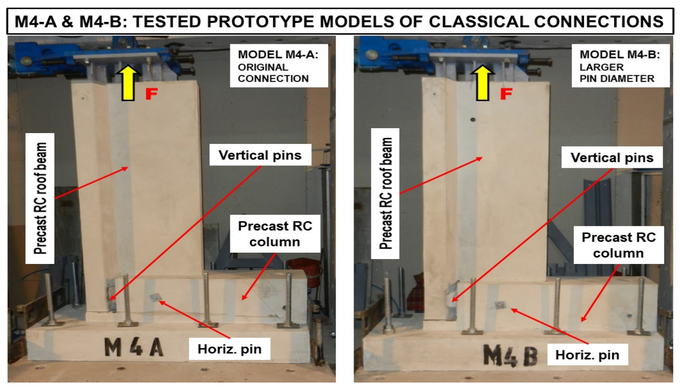


Figure 1. Figure 1. Tested prototype models M4-A and M4-B with classical roof beam–column (CRB) connections.

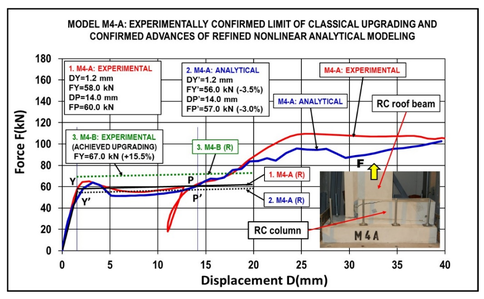


Figure 2. Prototype Model M4-A: Confirmed limitations of classical upgrading concept of RBC connections and confirmed advances in refined nonlinear analytical modeling.

Table 1. Parameters of bilinear models of original and classically upgraded connection prototypes.

No.	Prototype models of tested roof beam–column connections					
	Original connection			Classically upgraded connection		
1	*DY* [mm]	4.0	Exp.	*DY* [mm]	8.0	s.v.
2	*FY* [kN]	232.0	Exp.	*FY* [kN]	268.0	+15.5%
3	*DP* [mm]	29.0	Exp.	*DP* [mm]	36.0	-
4	*FP* [kN]	236.0	Exp.	*FP* [kN]	288.0	+22.05%
5	K_0 [kN/mm]	58.0	Exp.	K_0 [kN/mm]	33.5	s.v.

Prototype models of adaptive SSK-1 and SSK-2 upgrading devices

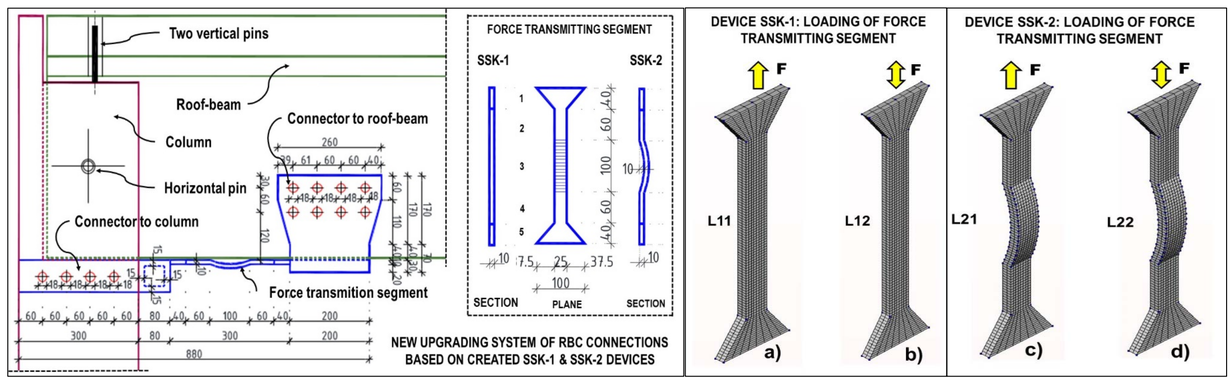
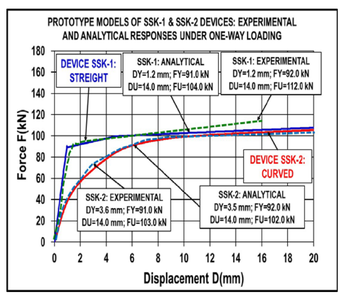
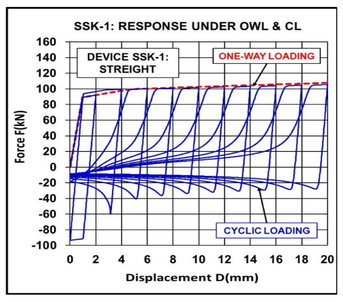


Figure 3. Concept of adaptive upgrading system of RBC connections based on installation of the innovative SSK-1 and SSK-2 devices created in this study.

Figure 4. Force-transmitting segments of the SSK-1 and SSK-2 devices with simulated loading cases





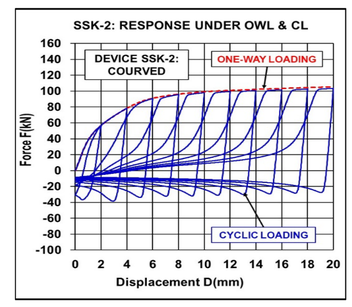


Figure 5. Experimentally and analytically defined responses of prototype models of the SSK-1 and SSK-2 devices under simulated one-way loading.

Figure 6. Characteristic responses of prototype models of the SSK-1 and SSK-2 devices under simulated one-way and cyclic loading.

Performance of upgraded roof beam–column connections with the SSK device

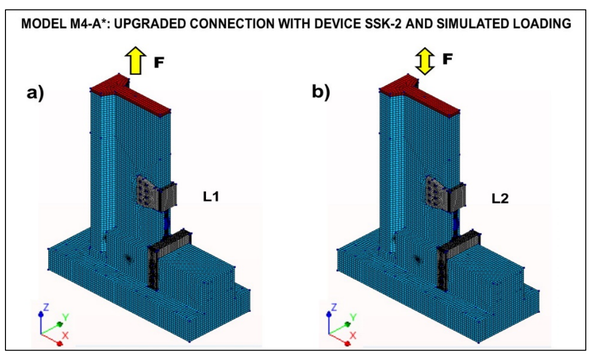


Figure 7. Formulated refined nonlinear analytical model and simulated characteristic loading cases of upgraded RBC connection M4-A with the adaptive SSK-2 device.*

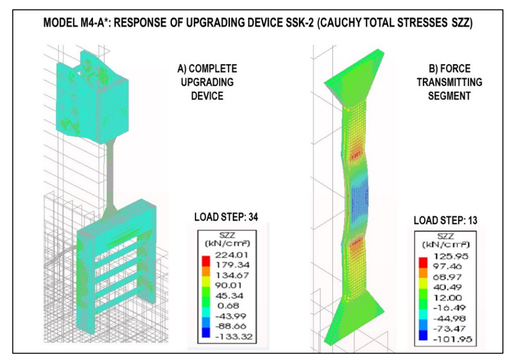


Figure 8. Response of Model M4-A representing upgraded RBC connection with SSK-2 device: Typical total stresses pattern SZZ for complete upgrading device and force-transmitting segment.*

Table 2. Parameters of bilinear model for prototypes of original and SSK-1 upgraded connection.

No.	Prototypes of tested roof beam–column connections					
	Original connection			SSK-1 upgraded connection		
1	*DY* [mm]	4.0	Exp.	*DY* [mm]	4.0	s.v.
2	*FY* [kN]	232.0	Exp.	*FY* [kN]	596.0	+156.8%
3	*DP* [mm]	29.0	Exp.	*DP* [mm]	28.0	-
4	*FP* [kN]	236.0	Exp.	*FP* [kN]	684.0	+189.8%
5	K_0 [kN/mm]	58.0	Exp.	K_0 [kN/mm]	149.0	s.v.

Table 3. Parameters of bilinear models for prototypes of original and SSK-2 upgraded connection.

No.	Prototypes of tested roof beam–column connections					
	Original connection			SSK-2 upgraded connection		
1	*DY* [mm]	4.0	Exp.	*DY* [mm]	5.6	s.v.
2	*FY* [kN]	232.0	Exp.	*FY* [kN]	528.0	+127.5%
3	*DP* [mm]	29.0	Exp.	*DP* [mm]	28.0	-
4	*FP* [kN]	236.0	Exp.	*FP* [kN]	640.0	+166.6%
5	K_0 [kN/mm]	58.0	Exp.	K_0 [kN/mm]	94.3	s.v.

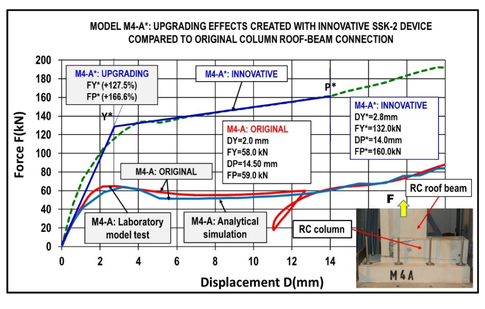


Figure 9 Model M4-A representing upgraded RBC connection with SSK-2 device: Upgrading effects with the SSK-2 device compared to actual performance of the original RBC connection.*

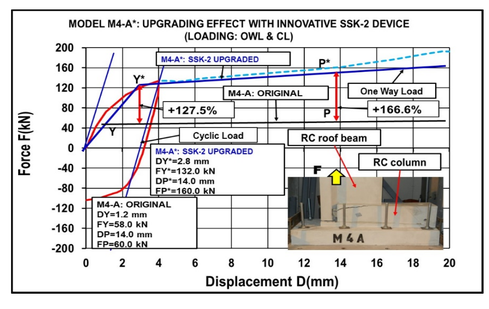


Figure 10. Model M4-A representing upgraded RBC connection with SSK-2 device: Confirmed actual upgrading effects with the SSK-2 device under simulated one-way and cyclic loading.*

Conclusions

The existing (original) RBC connections of the precast N system possess regular and uniform bearing capacity. However, in the event that stronger seismic forces are induced than those predefined during the design procedure, the connections may potentially be exposed to serious damage or even total failure. Since classical upgrading methods can provide only limited upgrading effects, ranging between 15% and 20%, they are not completely reliable as a safety solution.

The newly developed and experimentally proved novel targeted upgrading method for upgrading the original RBC connections based on the specific SSK-1 and SSK-2 upgrading devices created for this study represents an efficient tool for targeted safety upgrading of the original RB connections.