Hybrid Timber-Structural Glass Systems Current Test Results

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The hybrid structural element

- The structural element is developed as an independent prefabricated load-bearing structural component for construction of seismic resistant, energy and resource efficient buildings.
- The hybrid element is constructed of cross -laminated ductile timber frame and 2-ply laminated glass infill.
- The glass-to-timber contact is designed to provide high energy dissipative properties to structural element.







Application of the hybrid element

- Bracing of existing flexible frame structures (steel, concrete, timber)
- New timber buildings
- Adaptive facades of new and existing buildings
- Strengthening and temporary supporting of heritage buildings









Performed tests

- Load bearing tests of laminated glass (3 tests)
- Cyclic tests of timber frame joints (30 tests)
- In-plane cyclic tests of laminated glass infilled timber frames (49 tests)
- Out-of-plane cyclic tests of laminated glass infilled timber frames (3 tests)
- Shake table test of box type structure (1 specimen, multiple test runs)



Capacity of 2-ply EVA laminated glass



Specime		D2 _{Fu}						
n	$F_{\mu}/1,25 (kN/m')$	(mm)	S _{3F11} (%0)					
1 - mono	138,14	21,42	0,29					
2 - mono	146,30	13,33	0,34					
3 - cyclic	102,14	21,04	0,29					

Hirvatska zaklada za znanost

Geometry of tested specimens









Repaired specimens









In plane racking and shake table tests



Hirvatska zaklada za znanost





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Boundary conditions



Racking load protocol





Yielding point defined according to the Yasumura and Kawai (1997)







List of in-plane tested specimens

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~		Horizontal load		Boundary		Vertical load O		
えんえん	Name	Original specimens		Repaired specimens	condition		Vertical load Q	
		Monotone	Cyclic	Cyclic	1	2	Panel weight	80kN( 25kN/m')
				- Single glazed	in-plane			
ž	SGF1	Х			Х		Х	
ğ	SGF1S			Х	Х		Х	
	SGF2		Х		Х		Х	
	SGF ₂ S			Х	Х		Х	
	SGF ₃	Х				Х	Х	
	SGF ₃ S			Х		Х	Х	
	SGF ₄		Х			Х	Х	
	SGF ₄ S			Х		Х	Х	
	SGF5		Х		Х			Х
	SGF5S			Х	Х			Х
	SGF6		Х			Х		Х
	SGF6S			Х		Х		Х
				Double glazed ·	- in-plane			
	DGF1	Х			Х		Х	
	DGF1S			Х	Х		Х	
	DGF2		Х		Х		Х	
	DGF ₂ S			Х	Х		Х	
	DGF3	Х				Х	Х	
	DGF ₃ S			Х		Х	Х	
	DGF ₄		Х			Х	Х	
	DGF ₄ S			Х		Х	Х	
	DGF5		Х		Х			Х
	DGF6*		Х			Х		Х
	DGF6S*		Х			Х		Х
				Double glazed - c	out-of-plar	ıe		
	DGF ₃ -S					Х	Х	
	DGF ₄ -S			Х		Х	Х	

za znanost

# **Definition of parameters**



$$K_{i} = \frac{F_{i}}{\mathsf{D}_{i}} \quad K_{e} = \frac{F_{e}}{\mathsf{D}_{e}} \quad \frac{K_{i}}{K_{e}} = \frac{C_{k}}{\frac{\mathsf{D}_{i}}{\mathsf{D}_{e}}} \quad \mathbf{C}_{k} = \frac{\mathbf{K}_{i}}{\mathbf{K}_{e}} \frac{\mathsf{\Delta}_{i}}{\mathsf{\Delta}_{e}}$$

C_k = factor of stiffness degradation K_e = effective stiffness, K_i = stiffness of corresponding loop,



 $\xi$  = equivalent coefficient of viscous damping  $A_h$  = surface of the corresponding hysteresis loop  $D_{max}$  = maximal displacement of the corresponding loop



max



#### Hysteretic response



### Hysteresis parameters







SGF6 and SGF6-S

0.5

0.4

Q.3

0.2

0.1

0

-0.5

0

Story drift  $\Delta$ (%)





1

0.5

SGF6 SGF6-S

1.5

2





Viscous damping coefficient

-2

-1.5

-1



## Hysteretic response



# Hysteresis parameters









Hirvatska zaklada za znanost

1st WORKSHOP of the VETROLIGNUM project



HRVATSKE ZAKLADE ZA ZNANOST



# Failure modes of frame joints









# Out of plane tests



### Conclusions

- Vertical load-bearing capacity of laminated glass sheet enables development of structural panels that can carry several floors above it.
- Laminated glass wood frame panel has a high racking resistance and can well dissipate the energy induced by horizontal earthquake actions
- Dynamic tests results showed very good agreement with the results obtained during the racking tests of the panels







### Conclusions

- The glass-timber panels can replace other frame bracing elements having many advantages because they also serve as adaptive façade elements.
- The glass-timber structural elements should be addressed both in Eurocode 5 and Eurocode 8, as well as in the new Eurocode 11 for glass structures.
- The simplified design models should be developed and added to codes in order to enable designers to use new generation of structural elements composed of wood and structural glass
- Models should include load bearing characteristics (EC5, EC8) and their dynamic characteristics (EC8)







# Thank you for attention!





