Research of the rheological slipping module on the composite wood-concrete structure samples

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RESEARCH OF THE RHEOLOGICAL SLIPPING MODULE ON THE COMPOSITE WOOD-CONCRETE STRUCTURE SAMPLES

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Original scientific paper

This paper researches rheological behaviour of a wood-concrete structure connected by dowels of a particular kind, i.e., behaviour under long-term constant load. In order to determine yielding of the joint, i.e. of slipping module, samples with two joint dowels were examined. Also, compounds with two diameter sizes of single dowels of particular types E48M12 and E75M16 were tested. Besides the impact of the dowel's size on the joint deformability, we also monitored the impact of indoor physical conditions on the behaviour of the composite structure.

Keywords: *concrete, composite structures, dowel, rheological behaviour, slipping, wood*

Istraživanje reološkog modula klizanja uzoraka spregnute konstrukcije drvo-beton

Izvorni znanstveni članak

U radu se opisuje istraživanje reološkog ponašanja kompozita drvo-beton spregnutog moždanicima naročite vrste, tj. ponašanje pri dugotrajnom konstantnom opterećenju. U cilju određivanja popustljivosti spoja, odnosno određivanja modula klizanja spajala, ispitivani su uzorci sa spojem pomoću dva moždanika. Ispitivani su spojevi s dvije vrijednosti promjera jednostranih moždanika naročite vrste E48M12 i E75M16. Osim utjecaja dimenzije moždanika na pomjerljivost spoja praćen je i utjecaj promjene okruženja u zatvorenom prostoru na ponašanje kompozita.

Ključne riječi: *beton, drvo, klizanje, moždanici, reološko ponašanje, spregnute konstrukcije*

1 Introduction
Uvod

Composing of various materials into a composite renders their basic properties utilized and improved. Wood as a material has good elastomechanical characteristics, such as: durability, orthotropy, and environmental friendliness. A disadvantage of wood is its deformability, and this is improved by wood-concrete composite structures. Such systems may be applied for ceiling structures in housing and other facilities; they are applied in adaptation of old buildings and construction of bridge structures.

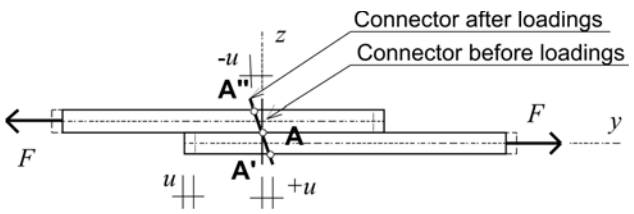

Figure 1 *Schematic display of slipping elements in combination*
Slika 1. *Shematski prikaz klizanja elemenata u spoju*

The slipping module for the samples of wood-concrete composite structures of C type dowels was determined by an experiment, by examining the shear on small samples using the following expression:

$$K_u = \frac{F}{u} \tag{1}$$

where:
K_u - static slipping module; F - force; u - (horizontal) displacement 1,5 mm.

The objective of the research is defining the rheological slipping module $K(t) = F/u(t)$. The slipping module describes the impact of yielding of connection on the distribution of stressing and strains along the height of a complex cross-section, which is significantly different in comparison with rigid connected cross-sections.

A key factor of behaviour of composite systems is the types of connections and mode of composing of wood and concrete. The mode of composing dictates the behaviour of the whole structure, its stresses and strains.

The paper examines the properties of composite wood-concrete structures of composite single dowels, in particular the kinds of the C type (according to DIN 1052 T2). Those dowels may carry substantial loads, are applied in wood-steel connections, they are produced serially, and are cost-

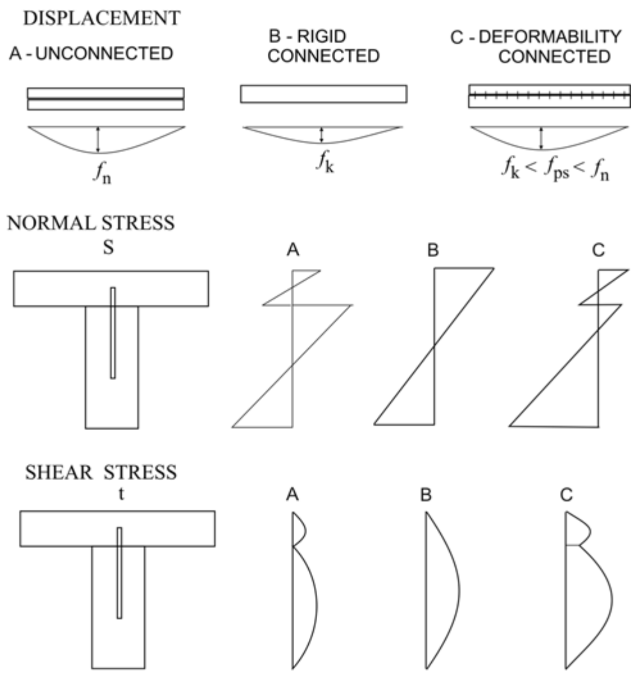

Figure 2 *Effect of connection method on the stress distribution of composite structures*
Slika 2. *Utjecaj načina sprezanja na raspodjelu naprezanja kompozita*

-costefficient. In theoretical terms, the slipping module is a value describing the stiffness of a joined system or constructed joint.

The examinations under the research covered the initial and rheological slipping modules, useable in the calculation of current and finite, i.e. long-term strains.

Testing wood-concrete composites were made in Croatia as part of the doctoral dissertation of V. Rajčić [9], without studying the rheology of slip joints, in the use of lightweight concrete and with different way of coupling. Numerical models of such systems processed Z. Žagar [10] as well.

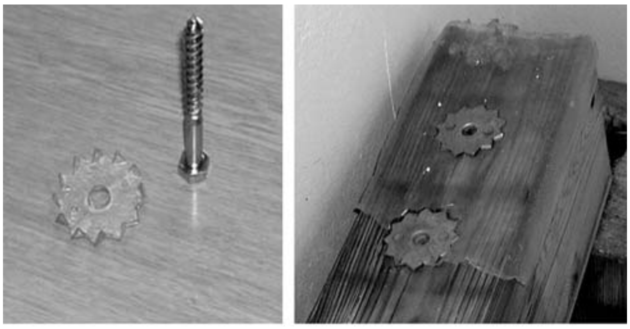

Figure 3 *Single dowel of the type C and the corresponding wood screw*
Slika 3. *Jednostrani moždanik tipa C i odgovarajući vijak za drvo*

2
Research program
Program istraživanja

The manner of composing wood and concrete and types of connections impact the distribution of stresses in composite cross-section (Fig. 2). As indicated above, this paper describes composing wood and concrete by dowels of a particular kind of C type according to DIN 1052 T2.

Examination was carried out on two models. Model 1 is a joint with E75M16 dowels, and model 2 with E48M12 dowels. For each model five samples were examined.

Sample 1

The sample 1 is 42 cm long, it is made of a beam of glued laminated wood made of class I fir-wood, MB 30 concrete, and two 75-mm diameter dowels, with centre spacing of 14 cm. Two 16-mm diameter bolts were fitted as well. Bolts provide for load transfer from concrete to the dowel, and from the dowel to the wood. The connection is concrete-bolt-dowel-wood. Wire fabric reinforcement (Q503) is inserted into the concrete slab, with 8-mm diameter rods due to possible take-up of the tension in the lower edge of concrete slab, as well as a foil between wood and concrete intended for reducing the impact of humidity on the wood-concrete joint.

Sample 2

The sample 2 is 36 cm long. It is made of a beam of glued laminated wood of class I fir-wood, MB 30 concrete and two 48-mm diameter dowels, with centre spacing of 12 cm. Two 12 diameter bolts were fitted as well. Wire fabric reinforcement (Q503) is inserted, with 8-mm diameter rods due to possible take-up of the tension in the lower edge of concrete slab, as well as a foil between wood and concrete intended for reducing the impact of humidity on the wood-concrete joint. During mounting the dowels are first impressed by means of a press for purpose of even impression and correct fitting. The schematic of sample dimensions is illustrated in Fig. 4.

3
Sample research methods
Provedba ispitivanja uzoraka

Dowels were examined during application of force of the intensity of the allowable bearing capacity. The allowable bearing capacity of sample 1 for 2 dowels is the value of bearing capacity of two dowels; for sample 1 it is 19,2 kN, whereas for sample 2 it is 10,6 kN.

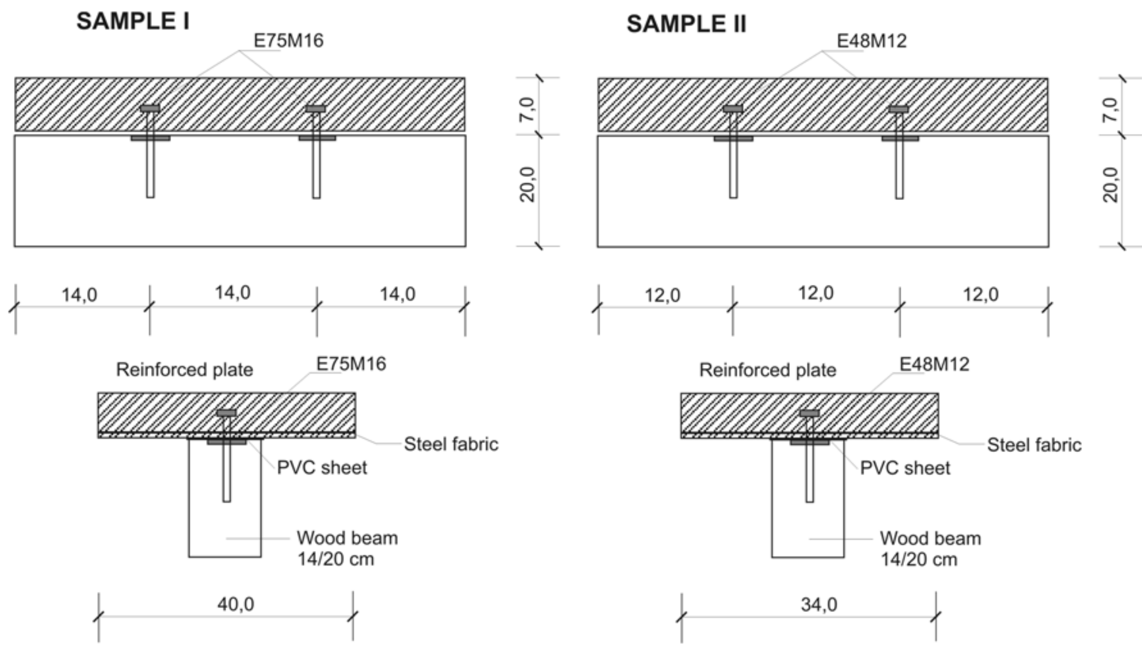

Figure 4 *Dimensions of testing samples, in cm*
Slika 4. *Dimenzije uzoraka za ispitivanje, u cm*

A device has been designed for applying loads which subjects samples to longitudinal force. The value of the force is controlled by a force transducer on the measuring station.

The testing device and placing of the sample are illustrated in Fig. 5.

Figure 5 *Device for testing samples*
Slika 5. *Uređaj za ispitivanje uzoraka*

Slipping in joint is measured by strain gauges on both sides of the model. Reading on 10 measuring points and recording the data was carried out for the first 8-10 days every day on a daily basis, and then in regular 7-day intervals. The testing was carried out in indoor heated space conditions with mostly even temperatures between 20 and 24 °C, with relatively constant 55 to 65 % air humidity.

4 Research results
Rezultati ispitivanja

Sample 1 was loaded for 343 days, and sample 2 for 426 days. The ruling slipping was obtained as an average value of all measured data. In sample 2 asymptotic approximation of slipping to the final value occurred after 427 days, whereas in sample 1 it occurred after 343 days.

Fig. 6 illustrates an average value of slipping from two sides of the sample. The Figure shows a clear difference of displacement from two sides, although the starting point was the presumption of the same elastomechanical characteristics of the samples. This was repeated for model

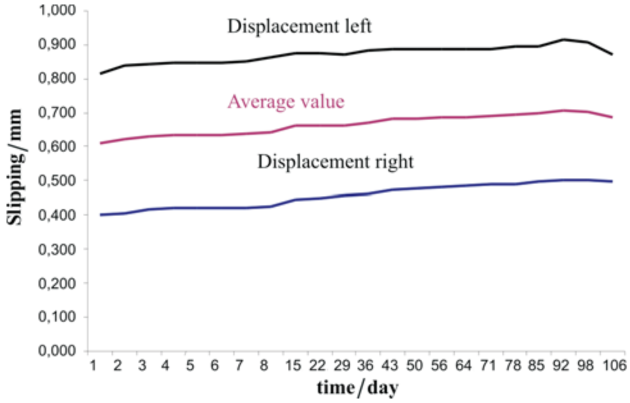

Figure 6 *The average slipping sample 2 in the first 106 days*
Slika 6. *Srednja vrijednost klizanja uzoraka 2 u prvih 106 dana*

1 and model 2.

Diagrams of slipping of sample 2 with E75M16 for all the 5 models are presented in Fig. 7. Sample slipping is an average value read from two sides of the sample, as indicated above.

Fig. 8 illustrates the diagrams of slipping for sample 1 with constant load intensity. All slipping curves are similar; curves for samples with connections E48M12 are "quieter" than the ones measured with E75M16 connections.

Sample 2 curves consist of several parabolic *f-s* with opposite parabolic directions.

The forms of slipping curves for both samples are similar, with a certain difference in the slipping values. Initial slipping module for E48M12 dowels is 8 684,21 N/mm. Rheological slipping module for long-term loads is 6 726,0 N/mm, it is by 22,5 % lower than the initial one.

The initial slipping module for dowels E75M16 is 26 301,0 N/mm. Rheological slipping module at the end of research is 16 410,0 N/mm, and it is lower by 37,5 % than the initial one.

A comparison of the values of rheologic modules of samples with different dowel diameters indicates that the slipping module of connections of larger diameters is significantly bigger.

Slipping increment was the biggest during the first 7 days after loading, and the slipping increment became stable after 340 days for sample 2, whereas it became stable for samples 1 after 200 days.

The slipping module decreases faster in the initial time of loading.

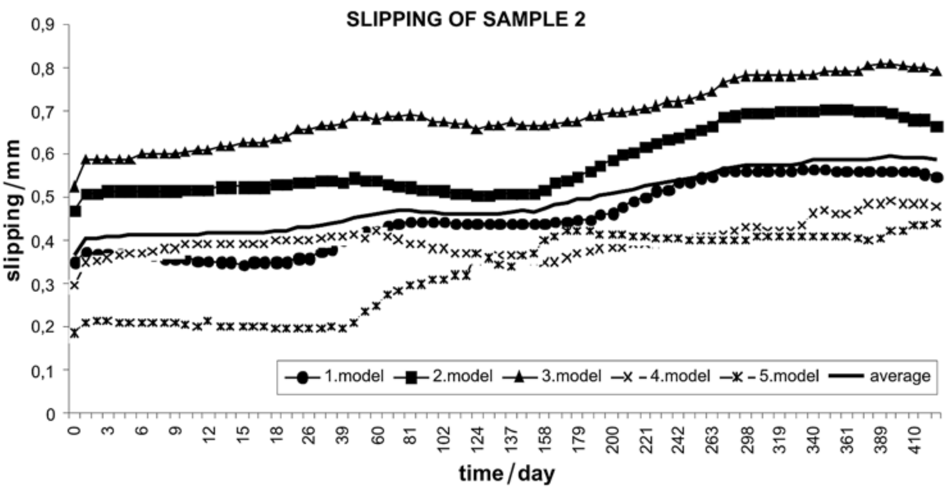

Figure *7 Slipping curves of samples 2*
Slika *7. Krivulje klizanja uzoraka 2*

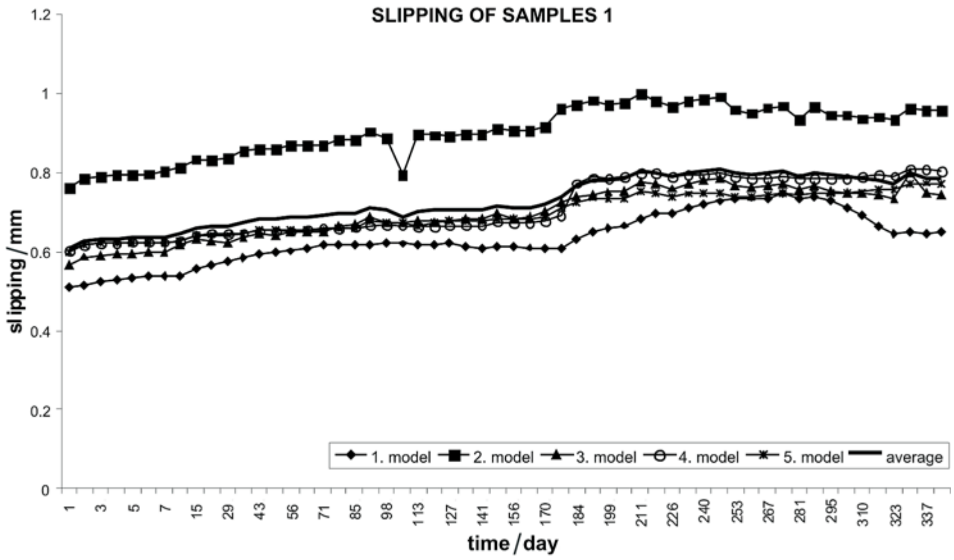

Figure 8 *Slipping curves of samples 1, and the relevant average value*
Slika 8. *Krivulje klizanja uzoraka 1, te mjerodavna prosječna vrijednost*

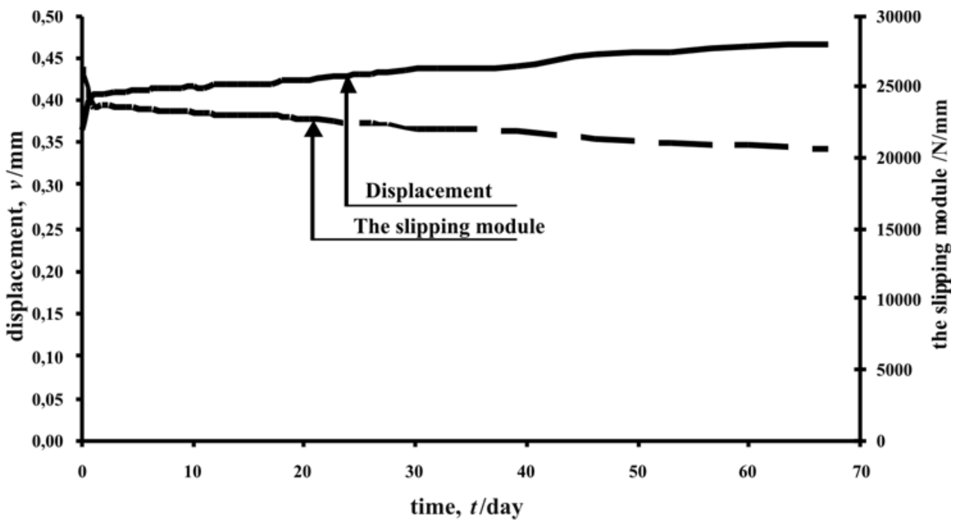

Figure 9 *Display of average displacement values and slipping module for E75M16*
Slika 9. *Prikaz srednjih vrijednosti pomaka i modula klizanja za E75M16*

There is a graphic presentation of the behaviour of the slipping module of connections. It has been shown that the slipping module decreases with time, as the slipping increases (Fig. 9).

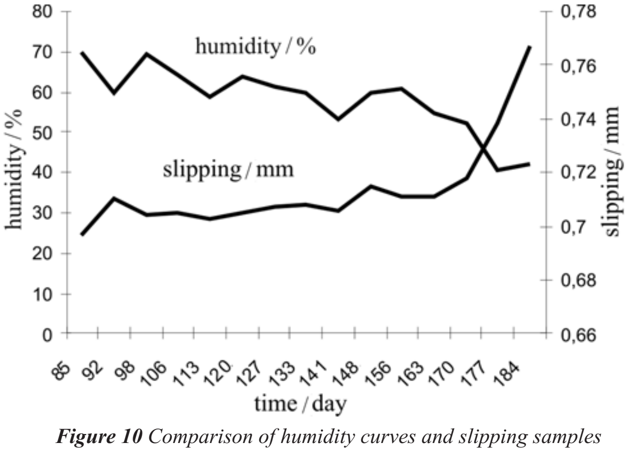

Figure 10 *Comparison of humidity curves and slipping samples at certain time*
Slika 10. *Usporedba krivulja vlage zraka i klizanja uzorka za isječak vremena*

Furthermore, it is evident that even with small variations of humidity over time there are outliers from standard slipping values.

Fig. 10 illustrates a comparison of the change of slipping sample 1, with the change in the air humidity of the environment in one time segment.

Reverse proportionality of measured values is evident: with the increase in humidity of the environment the values of the slipping module are reduced due to the change in the mechanical properties of wood, which itself changes the humidity, as already indicated.

On samples 1 behaviour after unloading was also measured. A graphic presentation of the results of that measurement is presented in Fig. 11.

Fig. 11 indicates that almost instantaneously after unloading the slipping values drop to the level that became stable almost immediately. The return slipping curve is a line with a small inclination angle – almost horizontal.

It means that there are no viscose strains. A comparison of the size of slipping after lifting load of 0,647 mm with current slipping of 0,608 mm shows large plastic strains. The reason for that is that connections with prescribed values per DIN 1052 were taken as bearing capacity values.

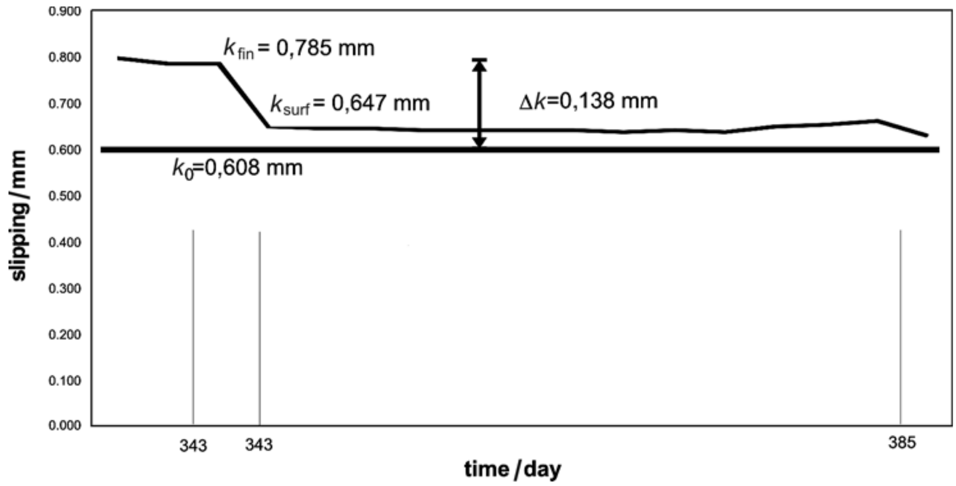

Figure 11 *Return sample slipping with the built E48M12*
Slika 11. *Povrat klizanja uzoraka sa ugrađenim E48M12*

5 Conclusion
Zaključak

An examination of small (shear) composite wood-concrete samples connected with single dowels of a special type established that there is a large increment in slipping over a certain period of time, that the connection diameter has a large impact on stiffness of connections and change of stiffness over a certain period of time.

For examined samples with two sizes of connections E48 and E75 modules of slipping for short-term and long-term loads were established.

Initial slipping module for E48 dowels is K_{ser}=8 684,21 N/mm, whereas the rheological slipping module for loads lasting for 343 days is 6 726,0 N/mm. The biggest ratio of rheological and initial slipping module is 1,33, read for day 246, and later on this ratio became stable and was approximately 1,3 for E48M12 after 200 days of loading.

The initial slipping module for dowels E75 is K_{ser}=26 301,0 N/mm, whereas the rheological slipping module for loads in the duration of 426 days is 16 410,0 N/mm. The biggest ratio of rheological and initial slipping module for E75M16 is 1,63, which was read on day 396, the ratio has become stable and is at the approximate level of 1,6 after 340 days.

The results are appropriate for serviceability variation 1 of wood, with shift in variation of humidity into serviceability variation 2. The biggest increment of slipping on small samples is in the initial seven-day period.

A change in the conditions of a micro-climate has a significant impact on slipping of small samples, as reflected in varying of the loads-slipping diagram, due to the hygroscopic property of wood, but also due to a big impact of changes on the characteristics of concrete and joint.

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