# BEHAVIOR OF WOOD-CONCRETE COMPOSITE BEAMS CONTINUOUS WOOD-CONCRETE-COMPOSITE SYSTEM

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**Abstract:** This paper introduces a continuous and a non continuous wood-concrete-composite system (wcc-system) which contains a steel mesh connecting wooden beams with a concrete slab and a non continuous wood-concrete-composite system which contains SFS screws connecting the wooden beams and the concrete slab . The shear connector acts as a rigid but ductile moderator between the materials wood and concrete. The system was tested in both shear and bending conditions to allow a better understanding on the structural behaviour under ultimate loading conditions. In order to allow a prediction of the non-linear behaviour of the specimens a mechanical model was developed. The comparison between actual test and the mechanical model shows a good correlation and puts trust in the simulation of the innovation. The advantages of this system compared to contemporary wcc-system solutions lay in improved strength, stiffness and manufacturing procedures. Its application potential can be found in floor, wall and roof systems of private and commercial buildings as well as in bridge structures.

**Keywords:** wood, concrete, metal, mesh, beam, bending, floors

## 1. INTRODUCTION

The modern and innovative constructions project through utilisation of modern composit materials and the new construction methods for jointing with the old materials.In this trend are also the wood concrete composit structures,wich have gain ground on todays construction market, specialy in the easy floors construction with wood beams, restoration of old buildings and constructions of attic floors,construction of lind walls. Through utilisation of this new matherials we can find economicaly cheap solutions for construction of easy floors with high resistence, and carrying capacity.

The possibility of executing this kind of composits from two different materials , wood and concrete is known in the practice since a long time, in Europe they experimented this matherial about 70 years.The first patent in this domain appears in Germany in 1939 fig.1 and the second in Swizerland in 1942 (Piccolin) both are dated near to the second world war and this was an conseqvence of politics for identification of cheap constructig solutions.As well is known the fact that in the tropichal regions the bambus was ans succesfull substitut for steel insetions in concrete floors, and in Austria where made such experiments with utilization of timber parts in construction of concrete floors for assumption of different bending moments.As a result for the many research projects made in this direction,this kind of structures have submit today a lot of safety and strenghtnes standards requirements, and attract the attention from market for using in in practice this product,but the continuous innovations ,the new liants and special concretes impose a continuation of

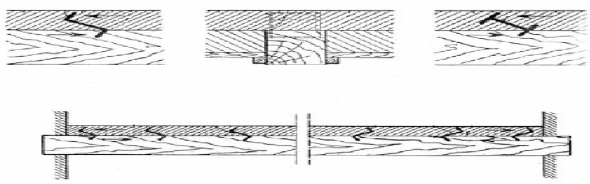

Fig 1 . Patent of a wood-concrete system matheatical simulations and experimenthat proof researches. Otto Schaub 1939

This paper introduces a continuous wood-concrete-composite system (wcc-system) which contains a steel mesh connecting wooden beams with a concrete slab. The shear connector acts as a rigid but ductile moderator between the materials wood and concrete. The wooden beams of the composite system obtain tensile stresses and the concrete slab compression stresses under bending conditions. The advantages of this system compared to contemporary wcc-system solutions lay in improved strength, stiffness and manufacturing procedures. Its application potential can be found in floor, wall and roof systems of private and commercial buildings as well as in bridge structures. The structural elements of the wood-concrete-composite system are shown by the following figures. The continuous shear connector - in form of a steel mesh - is inserted into a continuous slot within the wooden beam and connected by adhesive action. The continuous slot in the wooden beam is manufactured through a common circular sew in carpentry. The adhesive used is fire resistant up to approximately 200° C (392° F) and cures within 30 minutes. The shear connector acts as a support of the reinforcement and is fixed with the hardened concrete.

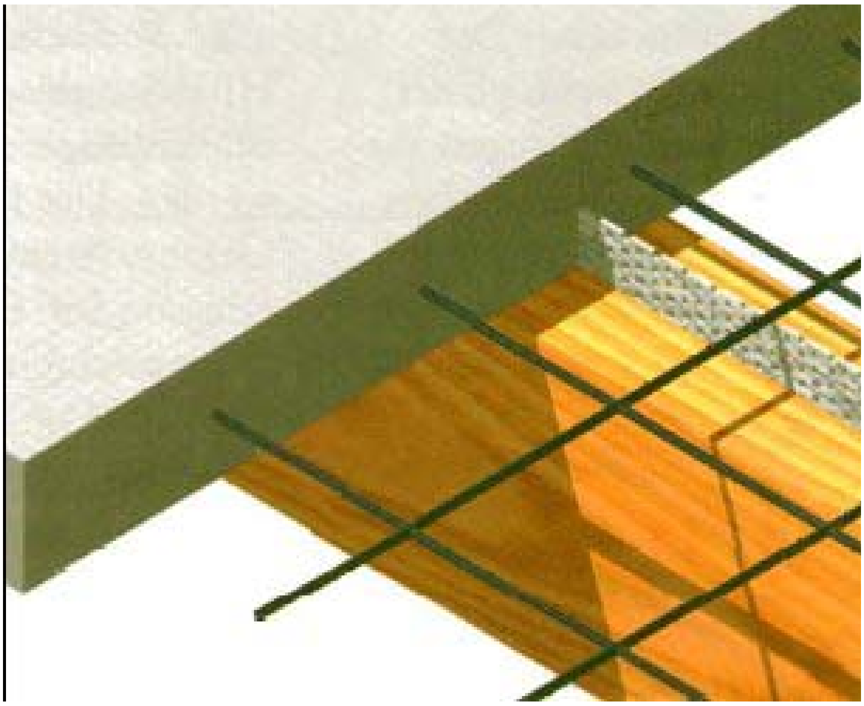

Fig.2 Structural elements of the wood-concrete-composite system

The degree of the composite action between the wooden beam and the concrete slab consists on the stiffness of the shear connector type.

The following figure shows various degrees of composite action. For instance a few nails between wood and concrete could only be described as a soft composite action under bending loading. However a glue line between wood and concrete would create a stiff composite action and would be comparable to the glue lam beams which are used now more than 100 years in timber structures all over the world. The composite system introduced in this paper claims a rigid but ductile connection between the materials wood and concrete and therefore allows a non-linear performance.

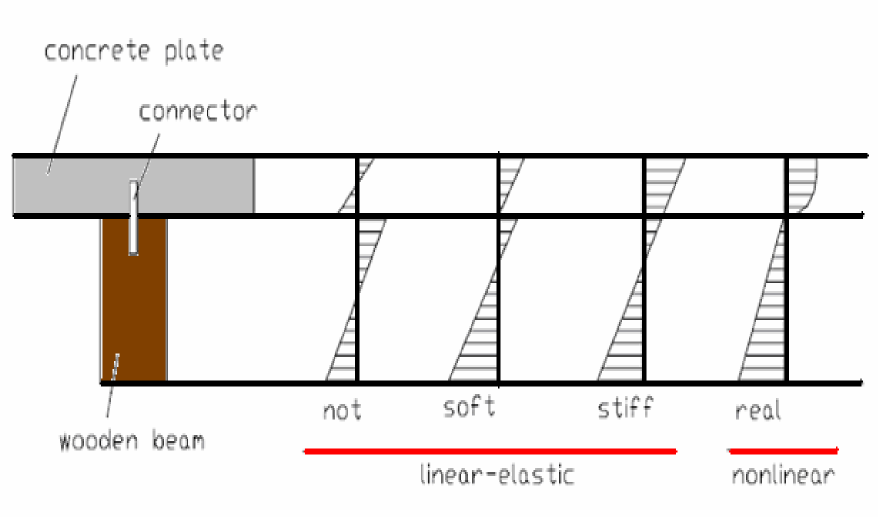


Fig.3 Various composite actions under bending action

**2. PROPERTIES OF WOOD – CONCRETE COMPOSITE STRUCTURES**.

As a result of many pilot research projects in field this composites are now used in constructions.The wood – concrete composites are an addition to wood beams based floors ,and trought utilisation of concrete this floors will achieve a better stability and strength.In the new constructions these structures will be realised on the contruction site trough concrete casting over the bridging joist fixed on the carrying wood beams.

As principal properties we mention:

- high strength reported to low weight of structure an trought this is possible the construction of floors with bigger opening in comparative with traditional wood beam floors
- the high stiffnes confer a peculiar rentability of structures ,which in this form can be realised by prefabricated carryin elements ,and the possibility of manufacturing on the construction sites;in this way we obtain lower transport costs.
- realization of floors with high stiffnes without loading the structure with supplementary weight and trought this a higer resistance in earthquaqes and natural disasters
- the vibration and the deformation of wood-concret based floors is smaller compared with traditional wood beam floors
- high acoustic isolation properties
- in fire case inside these rooms a lower gas emanation and longer resistace of floors until collapse
- reduced execution time trought a utilisation of a smaller quantitie of concrete and a faster harden
- utilisation of regenerable materials

This properties cumulated do that the wood- concrete systems to be used with success in todays constructions.In high developed countries like:Swizerland, Germany these materials are well known,not like in our country where we have much to recover in this area.

**3. TESTING**

Approximately 10 shear tests and two full scale bending tests were conducted to describe the performance of the system elastically and inelastically.

**3.1 Shear tests**

The tests were made following the EN 26891

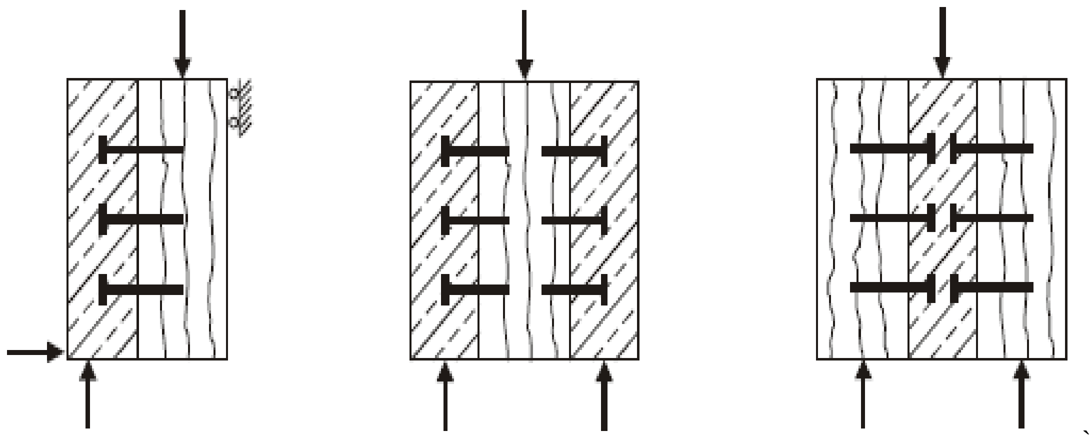

Fig.4 Test specimens according to EN 26891

The specimens were 400 mm long. The wooden cross section was 100 by 140 mm. The concrete cross section was 400 by 80 mm. The test set up can be seen in the following figure. The steel mesh reached 40 mm into the wooden and 40 mm into the concrete part of the composite system. The specimens were loaded statically through the concrete slab. The ultimate failure load was in the average of approximately 90.000 N with a displacement in the average of approximately 1,8 mm. The failure mechanism was primarily wooden shear failure. However, some specimens failed in the concrete plate and within the steel connection itself. The load-displacement performance of the wcc-system is shown in the following diagram.

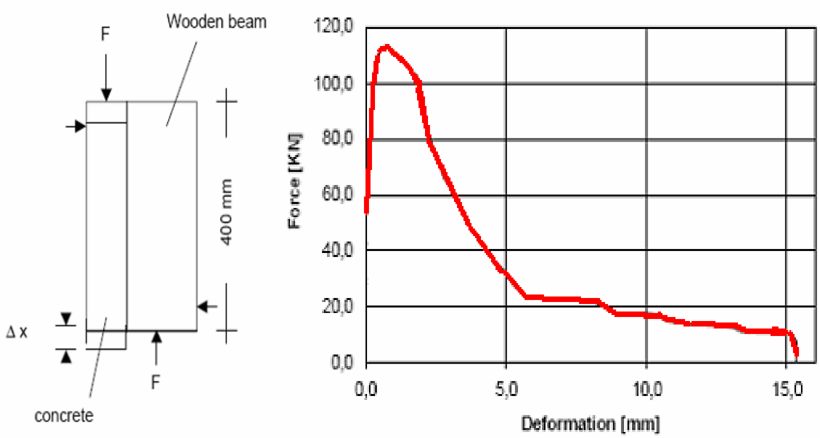


Fig 5. Test set up of the shear test and the load displacement diagram

### 3.2 Bending tests

The full scale bending test specimens were spanning 5.400 mm . The width of the concrete slab was 600 mm and its height 70 mm . The cross section of the wooden beam (glue lam beam) was 100 mm by 200 mm in height. The cross section of the connector was the same as used in the shear testing, 2 mm by 80 mm. The shear connectors were 1.000 mm long and continuously imbedded over the whole length of the test specimen. The test set up was a 4 point bending test. The specimens were loaded statically through the concrete slab. The ultimate failure load was in the average approximately 73.000 N with a mid-span deflection in the average of approximately 42 mm. The failure mechanism was wooden failure only. The tensile stress due to the bending moment caused a failure of the bottom layer of the glue lam beam in the area of a knot or finger joint.

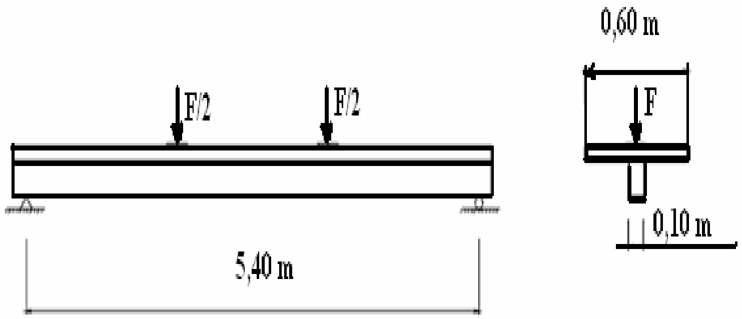


Fig.6 Test set up of the 4 point bending specimens

The load-displacement performance of the wcc-system is shown in the following diagram. The figure shows almost a linear performance up to failure which supports the observation of a wooden fracture.

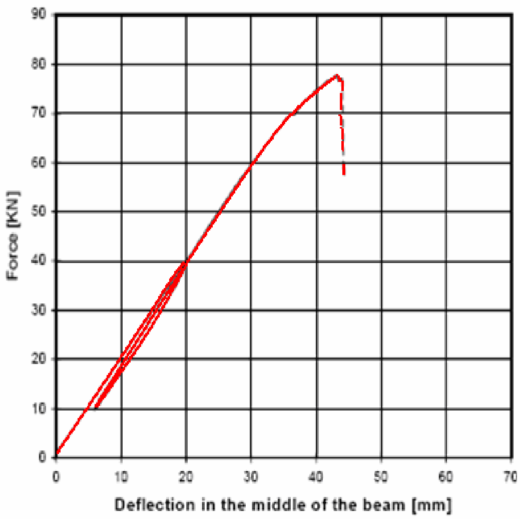


Fig.7 Load-Displacement Diagram

## 4. ANALYSIS

In order to evaluate the system performance analytically an adequate mechanical model had to be developed.

The following figure shows this model in detail. The material concrete and wood are represented by a stick with representing material properties.

There position to each other (y-direction) is secured by a artificial coupling which does not influence the system performance. The shear connector was simulated by multiple frame-systems which were connected by springs. The spring stiffness was derived from the shear and bending tests and takes into account the linear and nonlinear system performance. The analysis program was SOFISTIK out of Munich, Germany. The model allows the analysis of multiple systems with various loading conditions and provides the user w ith a number of applications which are not covered by various national design codes.

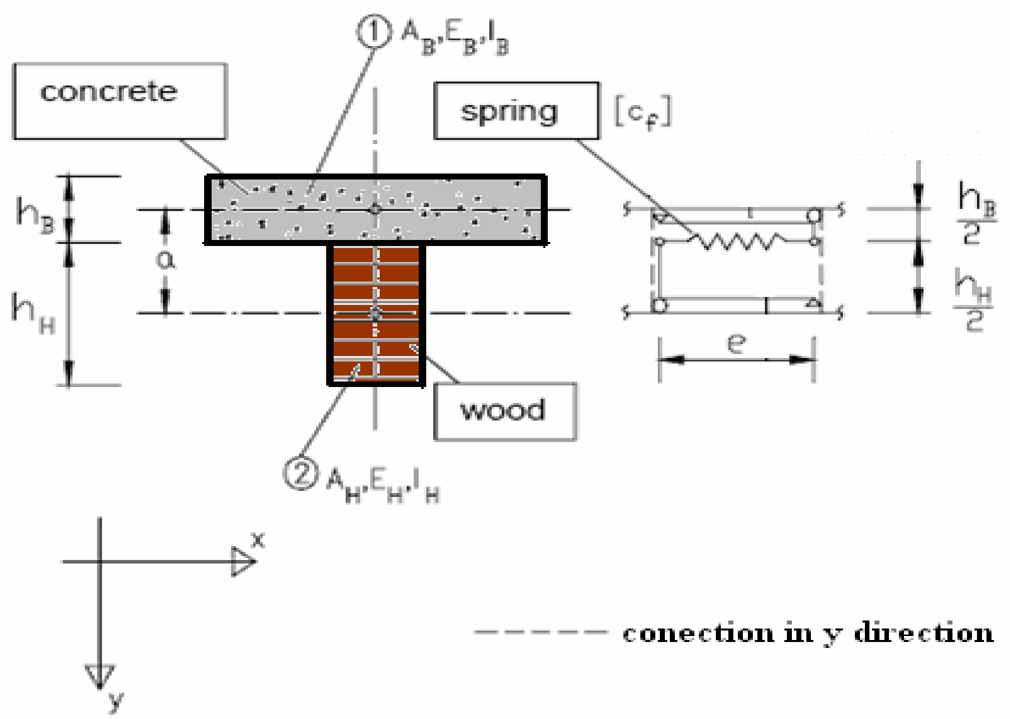


Fig. 8 Mechanical model for the non linear analysis

**5. COMPARISON**

The comparison between testing and simulation was done for the shear and bending specimens. Both comparisons were conducted with the load-displacements curves which were introduced earlier in this paper. Shear tests The following figure shows the load-displacement performance of the continuous wcc-system between 0 and 2 mm deformation. It therefore focuses on the significant portion of the load-displacement diagram which was introduced in Fig. 5. The following Fig. 9 contains three curves. The most upper curve (indicated by diamonds) is the arithmetical mean of all shear tests. Its edgy appearance is based on the irregular failure mechanism of some specimens. The curve next to it is the regression-curve (indicated by stars) of the test results and appears more natural than the arithmetical mean. The third curve (indicated by triangles) is the load-deflection performance based on the mechanical model which was introduced in the previous paragraph.

The Fig. 9 shows a good fit between the regression-curve of the shear tests and the simulation-curve which is based on the non-linear behavior of the mechanical model. Bending tests The following figure shows the load-deformation performance of the wcc-system for the bending test. Fig.10 contains three lines named specimen, simulation soft, non linear and simulation stiff.

The most upper curve (indicated by triangles) shows the simulation curve in case of a stiff spring and therefore indicates a linear behavior. The curve next to it (indicated by the stars) shows the simulation curve in case of the actual stiffness (non-linear performance) which was obtain through the shear tests. The third curve (indicated by squares) is the load-deflection performance obtained from the bending testing.
The Fig. 9 shows a good fit between the actual testing performance and the simulation-curve which is based on the nonlinear behavior of the mechanical model in correlation with the shear test results.

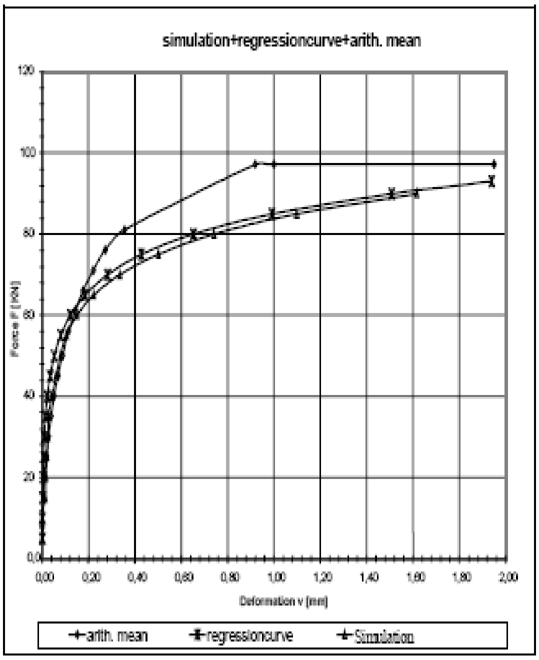


Fig. 9 Comparison of arithmetical mean, regression curve and analytical simulation

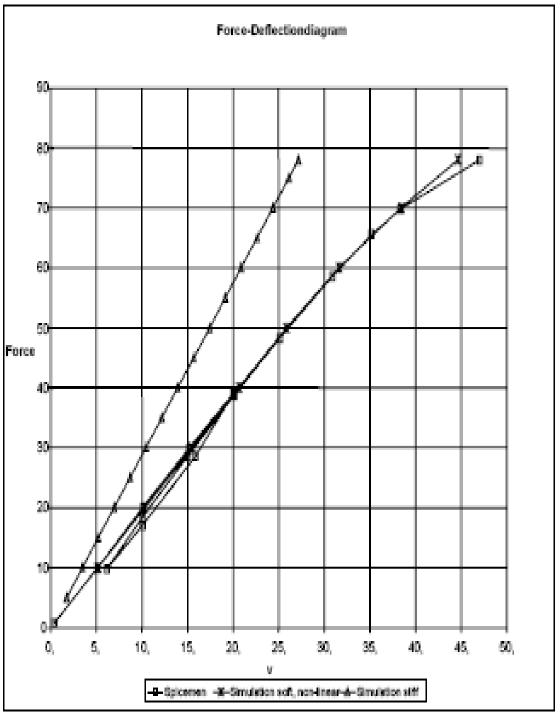


Fig. 10 Comparison of performance curves named specimen , simulation soft, non linear and simulation stiff

## 6. CONCLUSIONS

Structural rehabilitation of wooden floors is often carried out by means of a wood-concrete composite solution, using normal strength concrete (NSC) slabs, approximately 50-60 mm thick, and steel connectors.This paper introduces an innovative continuous wood-concrete-composite system which provides the user with high strength, stiffness and better manufacturing procedures. Furthermore it improves contemporary wood-concrete-composite solutions with a lower dynamic sensibility and an increase in acoustic performance.

The system was tested in both shear and bending conditions to allow a better understanding on the structural behavior under ultimate loading conditions. The tests were conducted at the Material Testing Laboratories Rosenheim which is located on the campus of the FH Rosenheim – University of Applied Sciences In order to allow a prediction of the non-linear behavior of the specimens a mechanical model was developed.

The comparison between actual test and the mechanical model shows a good correlation and puts trust in the simulation of the innovation. Its application potential can be found in floor, wall and roof systems of private and commercial buildings as well as in bridge structures.

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