XXIII. microCAD
International Scientific Conference
19-20 March 2009

ITTC
Innovation and Technology Transfer Centre
University of Miskolc

O szekció: Anyagáramlási rendszerek. Logisztikai informatika

Section O: Material Flow Systems. Logistical Information Technology

NKTH

Nemzeti Kutatási és Technológiai Hivatal

A projekt a Nemzeti Kutatási és Technológiai Hivatal támogatásával valósult meg.

Társrendező: *MTA Közlekedéstudományi Bizottság Logisztikai Albizottság*

Kiadja *a Miskolci Egyetem Innovációs és Technológia Transzfer Centruma*
Kiadásért felelős: *Dr. Dobróka Mihály rektorhelyettes*
Szerkesztők: *Dr. Lehoczky László osztályvezető*
Nyomda: *ME Sokszorosító Üzeme*
Üzemvezető: *Kovács Tiborné*
Nyomdaszám: *ME.Tu-115/2009.*
ISBN 978-963-661-866-7 ö
ISBN 978-963-661-880-3

DESIGN AND EXPERIMENTS OF A STEEL-TIMBER COMPOSITE STRUCTURE

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An international IT company had a problem with a steel-timber composite ramp. In some cases the original construction, which was steel and laminated pinewood combination could not carry the necessary load, which acted while the equipment moved from the pallet through the ramps to the floor.

We made a detailed calculation and series of measurements, to find the best material and the best dimension of the structure. We have made finite element calculations, strength calculations and a great number of elastic and fracture tests. We used SPIDER8 measuring device and CATMAN3.2 program for measuring the force, deflection and strains, using strain gages and EXCEL and ORIGIN programs to evaluate the measured values. For finite element calculation the ANSYS and COSMOS program were used (see Figures 1, 2).

We have compared different kinds of woods, like laminated pinewood, birchwood and beechwood. Homogenous beechwood, steel channel sections, polymer sections have also been investigated. In the first part the different wood materials were tested with small specimens. In the second part laminated and homogeneous pine-, birch- and beechwood ramps were tested *without* steel sheet on the top. In the third part laminated and homogeneous beechwood ramps were tested *with* steel sheet on the top. These tests include not only elastic, but fracture tests too. In the fourth part polymer ramp sections were tested.

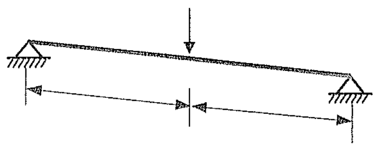


Figure 1 Measurement of the ramp

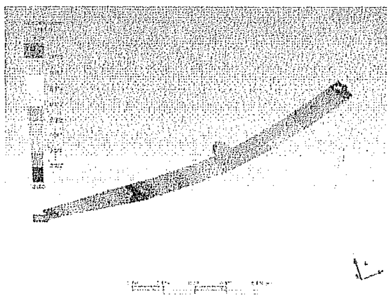


Figure 2. FEM calculation of deflection

We have compared the different kinds of woods, determined the scatter of the material properties and load bearing capacity. When we saw, that using 'better' wood we can reduce the thickness of the ramp, we made a test program to find the proper thickness. The following evaluation criterions have been considered: material cost, approximate manufacturing cost, tool cost, quality/stability/ robustness, mad safeness/easy to handle/resistance against something, reusability, recycling opportunities and mass. Finally we could reach a reliable ramp using homogenous beechwood with reduced thickness with a small fixed leg on, which helps in load bearing, when the deformation is large.

MEASUREMENTS ON LAMINATED PINEWOOD RAMPS (M, 35 mm)

Measurements showed (*fracture tests*), that at laminated pine wood ramps (*M-series of pine wood*) the ultimate force was between 2800-8000 N (see Figure 3). The calculated design force including safety factors was 5000 N. One specimen was far ***below*** this limit, and 6 specimens in total out of 11 ramps were also below.

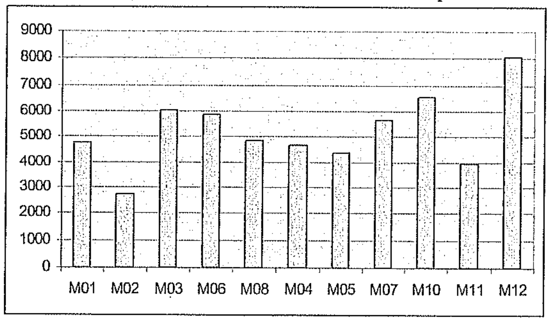


Figure 3. Measurements on M-series of laminated pine wood

MEASUREMENTS ON H-SERIES OF LAMINATED BIRCHWOOD

Similar measurements (*fracture tests*) were made with laminated birch wood ramps (*H-series of birch wood*). The ultimate force was between 10000-19000 N (see Figure 4), so all of the specimens were far ***above*** the limit.

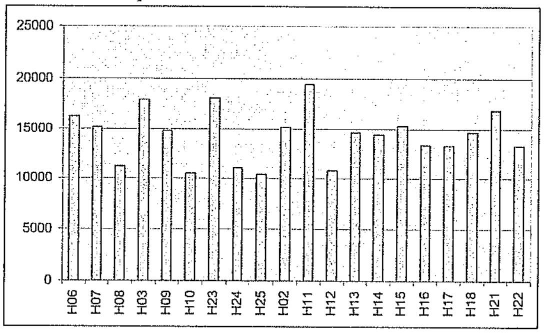


Figure 4. Measurements on H-series of laminated birch wood

MEASUREMENTS ON O-SERIES OF LAMINATED BIRCHWOOD

Similar measurements (*fracture tests*) were made with laminated birch wood ramps from the other producer (*O-series of birch wood*). The ultimate force was between 8600-17500 N (see Figure 5), so all of the specimens were far ***above*** the limit.

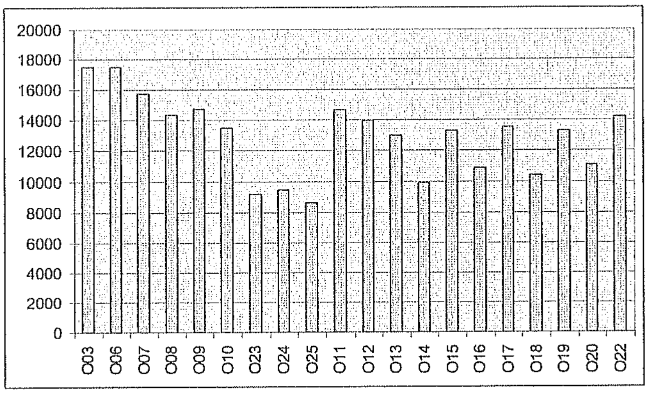


Figure 5. Measurements on O-series of laminated birch wood

MEASUREMENTS OF HOMOGENEOUS BEECHWOOD (BT,BTR, 35 mm)

The measurements (*fracture tests*) were made with two kind of homogeneous beech wood ramps, where BT-series specimens were made of '*good looking*' material, series of BTR were made of '*bad looking*' material.

At BT-series specimens the ultimate force was between 24500-40000 N (see Figure 6), so all of the specimens were ***far-far above*** the limit. This behaviour indicated the idea to reduce the thickness of the ramp to nearly half size.

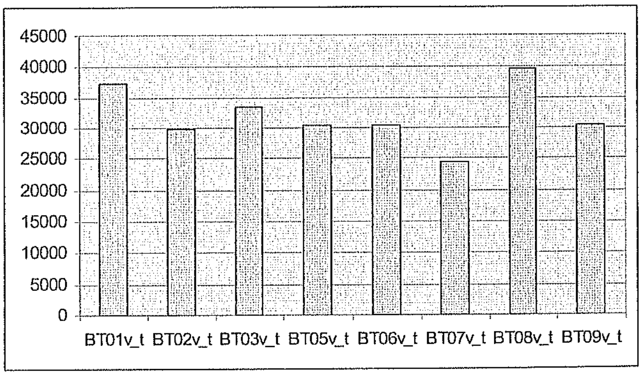


Figure 6. Measurements on BT-series of homogeneous beech wood (35 mm)

At BTR-series specimens the ultimate force was between 10800-11600 N (see Figure 7). The specimens were not equipped with steel sheet on the top. For comparison we have put 3 other specimens, one BT-series and 2 BR-series specimens. Figure 9 shows, that the values of the ultimate forces are similar, between 8100-11600 N. It indicates, that 'bad looking' beechwood materials with visible cracks have good strengths also.

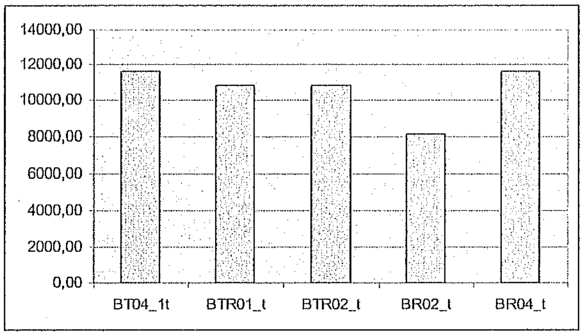
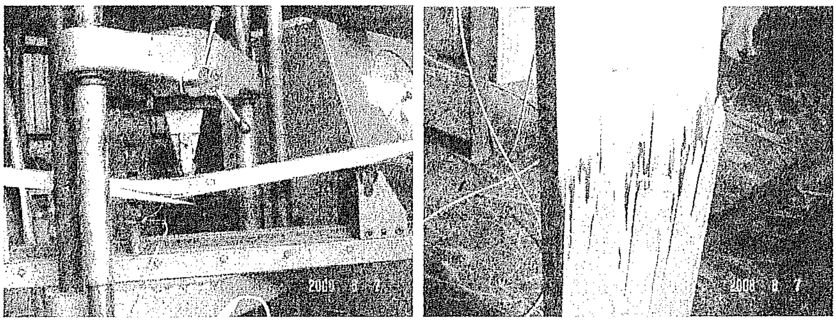


Figure 7. Measurements and comparison on BTR, BT-series of homogeneous beech wood and BR-series of laminated beech wood (35 mm thickness)



Figures 8-9. Crack measurement of a BT specimen

MEASUREMENTS OF LAMINATED BEECHWOOD RAMPS (BR, 35 mm)

At BR-series specimens the ultimate force was between 13100-23600 N (see Figure 10). The values of the ultimate forces are ***far beyond*** the limit 5000 N. It also indicates, to reduce the thickness of the ramp to 25 mm.

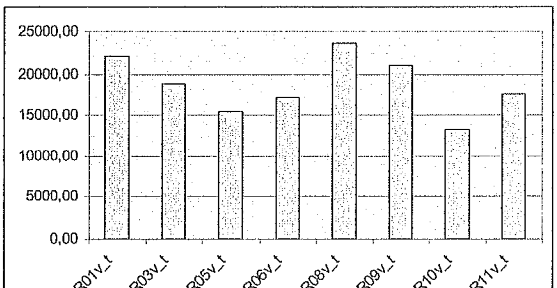


Figure 10. Measurements on BR-series of laminated beech wood

STEEL CHANNEL AND POLYMER SECTIONS

Table 1 shows the evaluation of the U channel section. At all evaluation criterions the maximum score is 10.

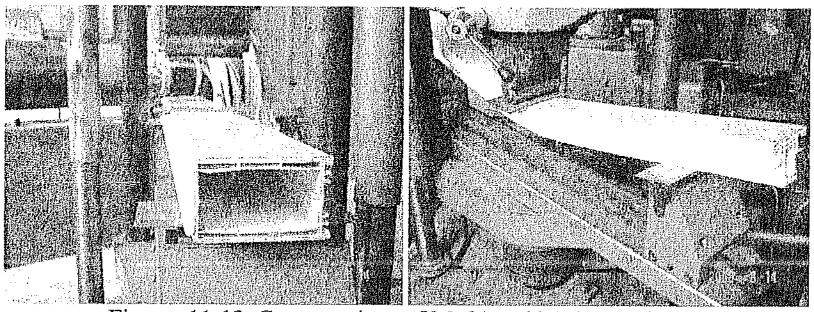
Table 1. Evaluation criterion of the U channel section

Evaluation criterion	Weighting	Evaluation	Score
Material cost Approximate manufacturing cost Tool cost	35 %	3	1.05
Quality / stability / robustness	35 %	10	3.5
Mad safeness/ easy to handle / resistance against something	7 %	6	0.42
Reusability	3 %	10	0.3
Recycling opportunities	10 %	10	1
Mass	10 %	6	0.6
Total	100 %		**6.87**

Table 2. Maximum elastic force at polymer specimens

Specimen	Maximum elastic force [N]
Mu01	4000
Mu02	4000

Table 2 shows, that the polymer specimens are not rigid enough to carry the 5000 N force.



Figures 11-12. Cross sections of Mu01 and Mu02 specimens

MEASUREMENTS OF HOMOGENEOUS BEECHWOOD (FB, 25 mm)

Measuring the beech wood ramps we found, that the strength is large enough to reduce the thickness to 25 mm. In this new series of measurements we used natural beech wood with and without steel sheets on and small legs below the ramps.

First we made the elastic measurement of some ramps, when the maximum force is about 5000 N, the limit of the loading including safety factors.

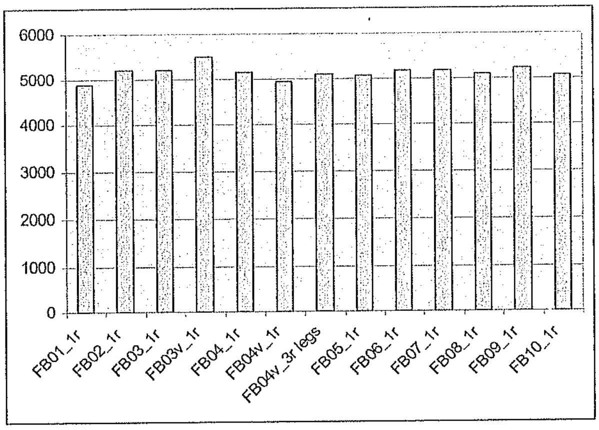


Figure 12. Elastic measurements on FB-series of homogeneous beechwood (25 mm thickness)

Elastic test shows, that at 5000 N the deformations are not too large at a reduced thickness 25 mm. Deflections were between 18.92-25.15 mm.

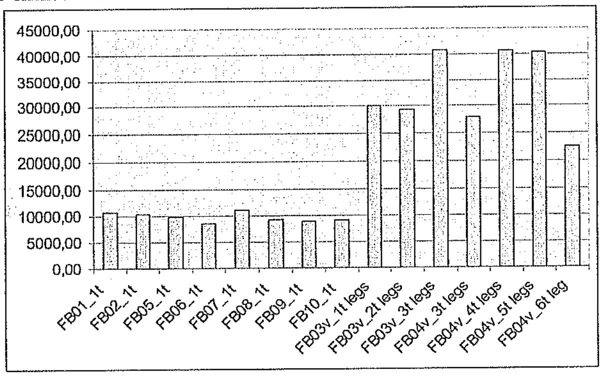
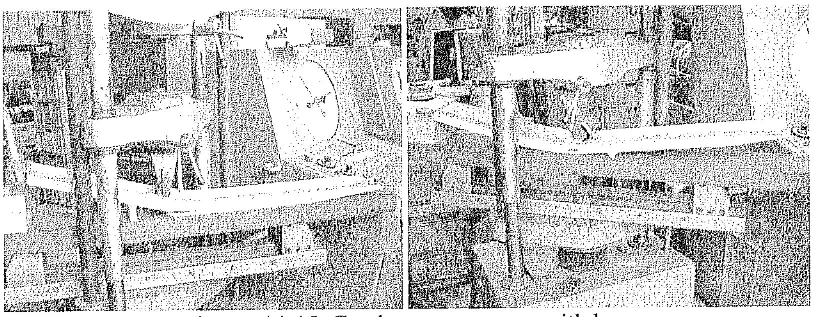


Figure 13. Crack measurements on FB-series of homogeneous beech wood (25 mm thickness)

Crack test shows on natural wood, that the ultimate force is between 8600-10700 N, so far beyond the 5000 N limit. The ramp with the reduced thickness is reliable even if there are inhomogeneous materials are used. Deflection of ramps with leg was between 7.13-13.36 mm at very high loading 22546,11-40329,48 N.

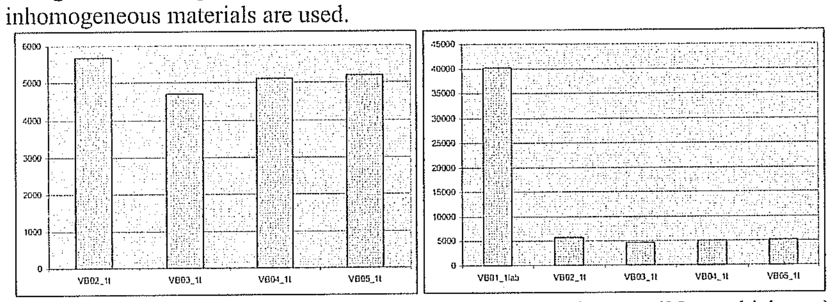
Crack tests with legs show, that legs at the edges are not good, nor the parallel legs with the length of the ramp at the middle, because they are not visible. A good solution is the perpendicular legs (two not one) at the middle of the ramp. Using these small legs, the ultimate force goes up to 4 tons! Also a good and mad safe version is fixed leg, on the other part of the ramp. The total thickness of the ramp should not exclude 60 mm.



Figures 14-15. Crack measurements with legs

MEASUREMENTS OF HOMOGENEOUS BEECH WOOD RAMPS (20 mm)

Crack test shows on natural wood, that the ultimate force is between 4700-5700 N, so around the 5000 N limit. It should be mentioned, that at these measurements there was no steel sheet fixed on the top of the ramp, which also increase the strength. The ramp with the reduced thickness is reliable even if there are inhomogeneous materials are used.



Figures 16-17. Crack test of the homogeneous beechwood ramps (20mm thickness) and comparison with legs

Figure 17 shows, that using legs, the load bearing capacity of the ramp goes up to 8 times! The best solution is the perpendicular legs (two not one) at the middle of the ramp. Using these small legs, the ultimate force goes up to 4 tons! If the person does not take care of these legs, the ramp itself can hold the force. Reducing of the thickness of the ramp the material problems can cause greater effect! The great difference between thicknesses 25 and 20 mm is in their costs. Using 25 mm ramp, the original thickness of the wood, which is manufactured 2". Using 20 mm ramp, the original thickness of the wood is 1". The leg thickness is 15 mm, two legs are used and they strengthen each-other. They are perpendicular to the ramp length.

The legs when fixed on the ramp cannot reach the bottom. There is about 20 mms left. At loading, first the ramp works, when the load goes close to the middle, the legs contact the bottom and help to carry the load. This variation is better than the longer leg variation, because at that case the leg carries the load mainly and the end of the ramp is elevated, which is not good. With the new solution the ramp takes part in load carrying and the end of the ramp has a better position. It is easy to activate the legs. For fixed leg, no activation is needed, what is a benefit at the evaluation.

Table 3. Evaluation of the different ramps

Evaluation criterion in total	Score
M-series, Laminated pine wood ramp (35 mm)	**5.59**
H-series, Laminated birch wood ramp (35 mm)	**8.4**
O-series, Laminated birch wood ramp (35 mm)	**8.2**
BT-series, Homogenous beech wood ramp (35 mm)	**8.9**
BR-series, Laminated beech wood ramp (35 mm)	**7.54**
Steel U channel section (50 mm)	**6.87**
Polymer RHS steel section (50 mm)	**4.62**
FB-series, Homogenous beech wood ramps (25 mm thickness)	**9.2**
VB-series, Homogenous beech wood ramps (20 mm thickness) with two turning rectangular legs	**9.51**
HB-series, Homogenous beech wood ramps (22 mm thickness) with fixed triangular leg (20 mm height)	**10.0**

In Table 3 the higher score means better performance. The first is HB-series, second VB-series, third FB-series.

CONCLUSION

The measurements and calculation show, that the both laminated birchwood and beechwood ramps are useful for this application and show better performance, that the pine wood ramps. Homogeneous beechwood ramps are very rigid, performed better. Reducing the thickness from 35 mm to 25 mm, the beech wood ramp has still higher load bearing capacity. Reducing the thickness from 25 mm to 20 mm, we are getting close to the limit 5000 N. Introducing legs, where the two thicknesses are 35 mm ($20+15^{leg}$ mm) and 42 mm ($22+20^{leg}$ mm), the ramp is still good and has less weight. The steel channel thickness is 17 mm on the top.

ACKNOWLEDGEMENT

The research was supported by the Hungarian Scientific Research Fund within the project OTKA T 75678, which is gratefully acknowledged.

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