Conference Proceedings 4th ICTB (2022)
https://doi.org/10.24451/mgfx-n234

SHARP METAL FOR TIMBER CONNECTIONS

Stephan Schindlauer[1]

1 Introduction

Rothoblaas Sharp Metal is an innovative connection system suitable in all the application where the stiffness of the joints has a significant influence on the overall behaviour of the structure.

Sharp connector has a large number of fastening elements, distributed along the surface of the hooked plates. This guarantees excellent strength and stiffness, creating surface "apparent" adhesion with values comparable, for practical application, to a glued connection.

Since no chemical adhesion, as with the common gluing process, this application eliminates the variability and risks associated with the moisture variation and the treatment (sanding, cleaning, dust) of the surface in the practical field of application.

This aspect makes the application of these elements extremely interesting in case of restoration or structural reinforcement. Through the application of additional wooden elements, it is possible to create composite beams with significantly higher performance to make up for structural deficiencies or / and load increases.

The achievement of a high stiffness can be useful both for the reduction of the deformation and to improve the behaviour in terms of vibration (ie: floors).

Often the initial slippage due to the clearance between holes and dowels in steel plates can have a great influence on long span beams deflection even if the total design load bearing capacity is achieved. In this case, according to [2], the slippage "gap" should be added to the contribution stiffness of the fastener.

Another interesting field of application, currently under investigation, Is the use of hooked plate to reduce the splitting and other brittle failure on the loaded end of members connected by means of dowel type fasteners. This can ensure higher resistance spreading the loads on higher loading bearing area and creating higher confinement in joints of trussed subjected to higher loads (trusses diagonal in tension).

The development tests and experimental values indicated in this paper has been determined by laboratory tests at the Universität Innsbruck Institut für Konstruktion und Materialwissenschaften.

2 Sharp metal – overview

Sharp metal plates can transfer shear forces through a series of small pins organized in several (pair) rows.

Compared to the punched plates in which a limited number of large-sized teeth are made and bent from the sheet, the Sharp metal production process involves "lifting" of small size hooks by "scratching" the plate surface without a perforation, thus creating a very high number of small-sized teeth.

The plates are currently produced with two different "densities" of hooks on the surface, namely HL high density and LD low density. The plate has a thickness of 0.75mm and the teeth measure approximately 2mm on each side.

Plates with a larger number of teeth ensure higher stiffness and load bearing capacity. However, significative pressure forces should have to be applied to ensure these high values, while the system with lower density of hooks has less resistance and stiffness but requires lower pressure for penetration of the teeth.

The minimum pressure required to completely close the gap was determined experimentally with a universal testing machine. For HD plates this pressure is between 1.5 and 2 MPa, depending on timber density, while for LD it is approximately half.

The mean pressure was calculated from load displacement curves at the point where the path shows a variation in the slope (knee-shaped curves). The first part identifies the stiffness to the penetration of the teeth while the second the stiffness (EA/l) of the wood at 90 °.

[1] Stephan Schindlauer, field Engineer; Rothoblaas srl Italy; stephan.schindlauer@rothoblaas.com

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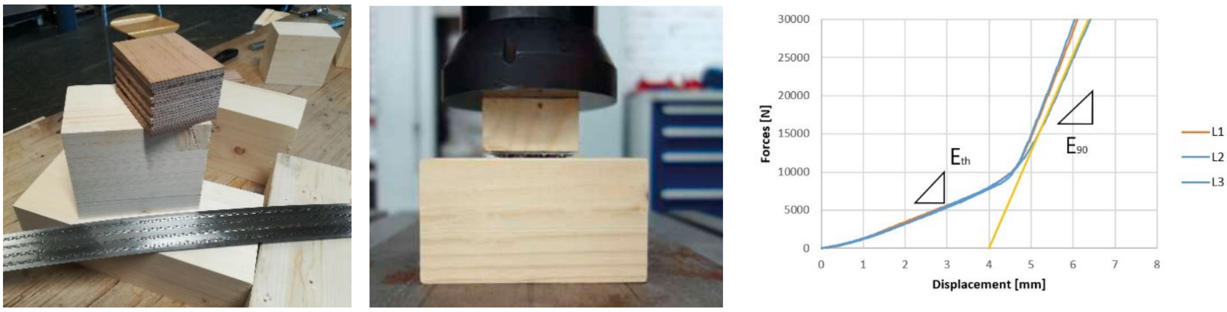


(a) (b) (c)

Figure 1: Sharp metal LD 1200mmx50mm (a) – Tests to assess the force to close the gap (b) - Schematic shape of load displacement curve for compression tests.

In practical applications where presses or similar tools are not available, the clamping force can be applied using the axial capacity of large head screws - (washer head screws Rothoblaas TBS). In this case the performance is lower than the ideal condition since the penetration is potentially not complete, depending on the material density/wood species.

To facilitate the assembly phases, and reduce the penetration length required, applications with hammer insertion as in traditional single-sided punched plates have also been tested using hard wood tools with grooves that are inserted between the rows of teeth. The result in terms of effectiveness / time required seems to be positive.

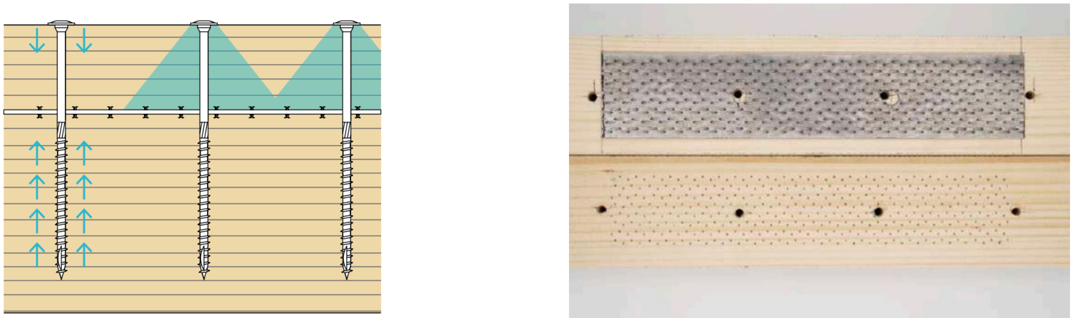
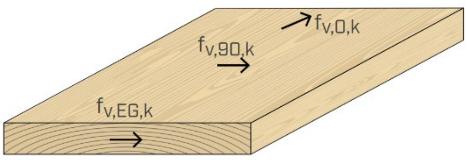


Figure 2: Installation of Sharp metal LD 1200mmx50mm with screws

The outcome of mechanical shear tests, in which screws were used to close the gap (condition of real application) shown good shear performance in all the different directions of the load; parallel (fv, 0), perpendicular (fv, 90) and along the wood fiber (fv, EG).

Table 1: Characteristic strength (without considering screws) The overall stiffness of the K_{ser} connection [N/mm] is determined by multiplying the k_{ser} coefficient by the plate surface.



Type	$F_{v,0,k}$ [MPa]	$F_{v,90,k}$ [MPa]	$F_{v,EG,k}$ [MPa]
LD	0.93	0.20	1.03
HD	1.15	0.51	1.03

Table 2: Characteristic strength (sharp metal + TBS 8x160 screws spacing 80mm)

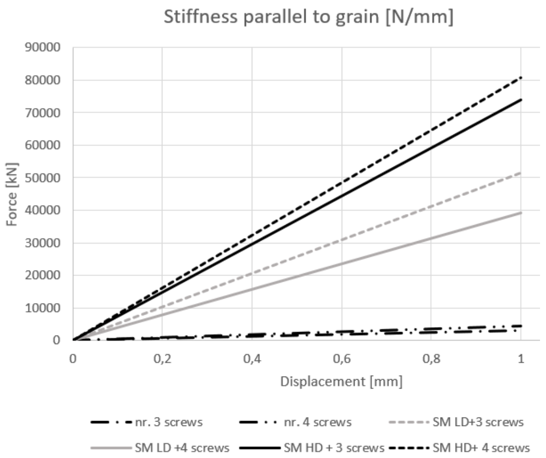
Type	$F_{v,0,k}$ [MPa]	$F_{v,90,k}$ [MPa]	$F_{v,EG,k}$ [MPa]	$K_{ser,0}$ [N/mm]*[1/mm²]	$K_{ser,90}$ [N/mm]*[1/mm²]	$K_{ser,EG}$ [N/mm]*[1/mm²]
LD	2.02	2.11	1.92	3.13	0.65	4.19
HD	2.24	2.42	1.92	6.47	0.90	5.00

Table 3: Characteristic parameters of the experimental tests (from UIBK test report-acc. to EN14358).

Screws	Sharp metal Type - length [mm]	F_{mean} [kN]	F_k [kN]	K_{ser} [N/mm]
3x TBS 8x160	-	15.8	13.2	2911
4x TBS 8x160	-	20.8	15.1	4346
4x TBS 8x160	LD 250	33.0	28.0	39133
4x TBS 8x160	HD 250	40.0	31.1	80876

Table 3 summarize the results of shear tests on joints with and without sharp metal. It worth notice the performance of the connections using sharp metal is significantly higher. To highlight the differences in terms of stiffness and strength, tests has been carried out using the same type, number of screws and timber grading.

For the sample with 4 screws an average experimental strength of 20.8kN and a stiffness of 4346N /mm was obtained. The same number of screws, same timber elements also using a strip of Sharp metal LD 50x250mm the strength was 32kN and the stiffness about 39133N/mm. Using an HD strip with the same dimensions the values increase to 39.9kN and 80876N /mm.



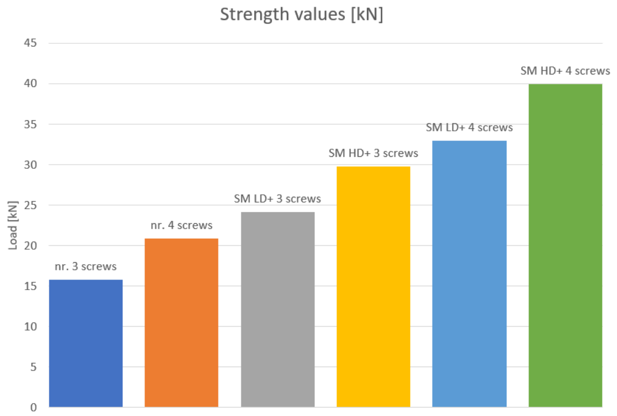


Figure 3: Outcome of tests- comparison of stiffness and strength.

With the aim of evaluate the effect of timber moisture variations several tests have been currently run at the University of Innsbruck. The first evidence shows a good behaviour of the connections in the case of an increase in humidity (swelling), while the effect of the decrease in water content creates distortions that lower the contact (shrinkage). To reduce this effect, screws should be positioned along the width during installation to reduce distortion (transversal deviation).

However, this problem affects all the rigid connection such as bonding or traditional joints. With sharp metal the main advantage is that only the shrinkage can affect the strength.

This aspect is important for timber bridge connections, given that humidity variations can often locally and for short periods reach high values even in protected structures (normally within service class 2). This problem could limit the application of adhesive for some particularly sensitive applications.

Regarding structural applications of sharp metal, one of the possible cases, where good results were obtained is the application on ribbed floors or hollow box build-up section.

For these type of structures, high stiffness is required to create an efficient load transfer between the component such as upper panels and ribs creating an efficient build up section. The modularity of strips with constant and reduced width (50mm) allows great versatility and timesaving.

In this case, especially when the application cannot be performed in shop, for instance due to transport limits, considerable costs and time are saved (curing, assembly, control). As already mentioned, in terms of results, during the tests, the fundamental parameter for evaluating the correct installation of Sharp metal is the closure of the gap. This is an easy and effective to control parameter.

Tests were carried out on ribbed floors which showed that the use of Sharp metal allows the achievement of excellent performance in terms of effective section.

Test were carried out on rib-floors composed of glue laminated timber beams (GL) with an integrative panel in cross laminated timber (CLT). All the tests were performed in the laboratory of the University of Innsbruck.

Different connection system has been tested to assess the different performances of screws, glue, and sharp metal. In this case, screws were used to ensure the embedment pressure of the hooks. The results shown in the table highlight that the solution with sharp metal has an intermediate behavior between glue and screws. Both in terms of strength and stiffness.

Table 4: Mean strength and stiffness values (F_{max}; K_{ser}) of rib panels assembled with screws, sharp metal and glued.

Test	**Fmax** [kN]	**K_{ser}** [N/mm]
Screwed (2 row 12d - TBSmax 8x240mm)	72.3	1473
	96.0	1617
	89.6	1439
Sharp metal (1 row 15d - TBSmax 8x240mm+HD 50/6000mm)	99.2	1935
Sharp metal (1 row 18d - TBSmax 8x240mm+LD 50/6000mm)	67.5	1489
Sharp metal (1 row 20d - TBSmax 8x240mm+LD 50/6000mm)	80.1	1169
	81.7	1341
Glued connection (2 row 20d)	128.3	2326
	145.5	2444

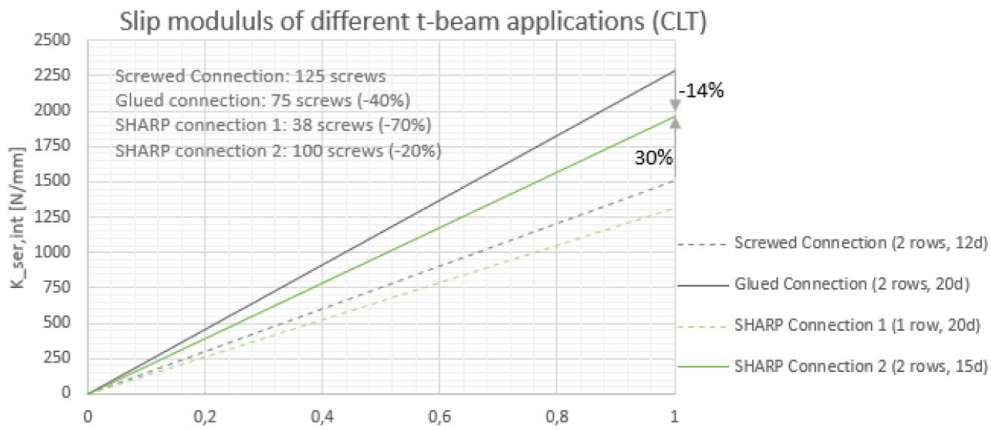


Figure 3: Slip modulus $k_{ser,int}$ for different t-beam applications with CLT-panels and Glulam-beams; Glued connection, screwed connection and SHARP-Metal connections

Figure 4: Stiffness of rib-panels (GL-CLT).

The advantage over structural bonding is a greater ductility of the connection (ultimate displacement) and less dependence on the assembly conditions. The use of this system can also be extended, as reported in the introduction, to the structural strengthening of elements of bridges or other structures that require a restoration due to localized degradation or a reinforcement for a variation of intended use. In this case, the intervention is easily removable.

Using sharp metal, as for structural bonding, surface preparation, such as flatness, presence of cracks, etc. has great influence on the results. Anyway, unlike gluing it is not necessary to use a primer or other similar treatment. This is because resistance is achieved by mechanical meshing and not by chemical adhesion.

Great importance for practical use is covered by the stiffness of the connected element since this value can affect the pressure value achievable with the screws. It has been observed that this parameter greatly influences the pressure needed to close the gap between the two elements.

In the case of panels with similar stiffness, the strips can be inserted on at least one element by hammering. This solution is easily achievable using "LD" type strips where the number of rows of teeth leave a flat nontoothed parts that can be used to rest the protruding parts of the tool. According to this scheme, the tool can be made through a simple portion of hard wood with grooves corresponding to the teeth.

This application is more complex on the "HD" type but conceptually still feasible.

Figure 5: Use of sharp metal and alternative "traditional" methods using screws-tool to hammer the plates.

3 Conclusion

Sharp metal is an innovative connection technology, made with a surface hooked element, which can be used to transfer shear forces. The mechanical performance in terms of strength and stiffness are significantly higher than cylindrical dowel type connectors.

The type of connection allows its use in environment or part of the structure in which it is not possible/easy to guarantee the conditions in terms of humidity and temperature for correct bonding.

The maximum performance is obtained when the gap between the two parts to be connected is completely closed. This operation can be carried out using hydraulic or vacuum presses for mass production.

If screws are used, probably the maximum performance cannot be reached but anyway excellent performance for the main application can be achieved.

In case of moisture changing the main problems occur when the moisture content decrease (shrinkage). However, these problems are lower compared to the same geometry with a glued joint. Increasing the values of moisture this effect less problematic.

Future developments will concern the verification of extreme humidity conditions and applications to verify the operational application in reducing the distance from the edges of dowel type fasteners.

Acknowledgement

The authors would like to thank the scientific partners, University of Innsbruck. This paper and the research behind it would not have been possible without the exceptional support of Roland Maderebner. Special thanks also to Julian Meyer and all the staff of the laboratory for testing material.

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[3] Rothoblaas srl Datasheets product catalogue, Rothoblaas srl Via dell'Adige 2/1 39040, Cortaccia (Bz) Italy