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ADHESIVE BONDS AND CALCULATING THE STRENGTH OF ELASTIC-ADHESIVE JOINTS

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ABSTRACT
Elastic bonding is a relatively new fastening technique that complements traditional fastening methods. It joins two materials with a layer of permanently elastic adhesive and offers high peel strength, impact resistance, and flexibility. The most convenient way to describe the mechanical properties of adhesive bonds is in terms of the generalized elasticity factor or stiffness. To calculate the spring constant for an adhesive-bonded joint, multiply the stiffness value a dimensionless quantity by the known joint dimensions.
Keywords: composite beam, adhesives, stress and strain

1. COMPOSITION
Adhesives can be used for bonding a wide variety of similar and dissimilar metallic and non-metallic materials with different shapes, sizes, and thicknesses. They can be also combined with mechanical joining methods to further improve the strength of the bond. Adhesive joints are designed to withstand shear, compressive, tensile forces and should not be subjected to peeling. The force applied to a pressure vessel or its structural attachments are referred to as load and, as in any mechanical design, the first requirement in vessel design is to determine the actual values of the stress which the vessel will be subjected in operation. These are determined on the basis of past experience, design codes, calculation, or testing. Organic polymers of either natural or synthetic origin are the major chemical ingredients in all formulations of wood adhesives. According to ASTM, a polymer is a compound formed by the reaction of simple molecules having functional groups that permit their combination to proceed to higher molecular weights under suitable conditions. Polysaccharide sand proteins are high molecular weight natural polymers derived from plants and animals. These adhesives could not only be stronger, more rigid, and more durable than wood, but also have much greater resistance to water than adhesives from natural polymers. Synthetic polymers are chemically designed and formulated into adhesives to perform a great variety of bonding functions. Whether the base polymer is thermoplastic or thermosetting has a major influence on how adhesive can perform in service. Thermoplastics are long-chain polymers that soften and flow on heating, and then harden again by cooling. They generally have less resistance to heat, moisture, and long-term static loading than do thermosetting polymers.

1.1 Wood adhesives
Common wood adhesives that are based on thermoplastic polymers include polyvinyl acetate emulsions, contacts, and hot-melts. Thermosetting polymers make excellent structural adhesives because they undergo irreversible chemical change, and on reheating, they do not soften and flow again. They form cross-linked polymers that have high strength, have resistance to moisture and other chemicals, and are rigid enough to support high, long-term static loads without deforming. A

formulation of wood adhesive consists of a mixture of several chemically active and inert materials that vary in proportion with the basic adhesive polymer. Solvents disperse adhesive polymers; act as carriers of polymer and additives, aid wetting, and control flow and penetration of the adhesive. Water is used as the carrier for most wood adhesives, primarily because water readily absorbs into wood, is inexpensive, and is free of toxicity problems. Adhesive polymers can be brought into intimate, even molecular, contact with wood by water as the carrier. Organic solvents are used with elastomeric and contact adhesives; although water-based adhesive systems have lower toxicity and flammability. Construction and contact adhesives contain organic solvents that have low flash points. If these adhesives are used in unventilated areas where concentrations build to dangerously high levels, explosions can occur with an ignition source. Some adhesive producers now offer less flammable formulations based on chlorinated solvents. Organic solvents in these adhesives are toxic, but by following the manufacturer's handling and use instructions, coupled with adequate ventilation, harmful effects can be avoided. Health and safety regulations require that toxic and hazardous chemicals be identified and visibly labelled to warn of their dangers. Material safety data sheets or instructions are provided with adhesive products to advise of proper handling procedures, protective gear and clothing, and procedures for dealing with spills and fire, as well as to offer guidance for first-aid and professional treatment of injuries. The statements made in this section concerning safety of adhesives and effects on the health of the user are general and not meant to be all inclusive. The user should consult the MSDS and follow the manufacturer's instructions and precautions before using any adhesive. Adhesive selection is based primarily on Type of substrate, Strength requirements, type of loading, impact requirements, Temperature resistance, if required, Epoxy, Cyanoacrylates, an aerobics – metals, Silicones, Pressure sensitive adhesives.

2. BOX BEAMS AND I-BEAMS

Having established the design overlap for simple bonded joints, the elimination of adverse peel stresses is addressed next. These peel stresses occur for single-lap and single-strap joints having a primary eccentricity in load path and for double-lap and double-strap joints. While some have argued that it is more appropriate to modify the adhesive failure criteria to account for an interaction between shear and peel stresses, the author contends that the presence of any significant peel stresses necessarily detracts from the shear strength of the joint. Therefore, to improve structural efficiency, those peel stresses should be removed from the structure by simple modifications in design detail rather than be included in a more complicated failure criterion. Such a philosophy also simplifies the analyses by separating the tasks of characterizing the adhesive stress components. Box beams and I-beams with lumber or laminated flange and structural panel webs can be designed to provide the desired stiffness, bending, moment resistance, and shear resistance. The flanges resist bending moment, and the webs provide primary shear resistance. Proper design requires that the webs must not buckle under design loads. If lateral stability is a problem, the box beam design should be chosen because it is stiffer in lateral bending and torsion than is the I-beam. In contrast, the I-beam should be chosen if buckling of the web is of concern because its single web, double the thickness of that of a box beam, will offer greater buckling resistance. Numerical analysis was performed by the finite element method. Polyurethane glue SIKAFLEX 221 and Plain carbon steel properties are given in Tab. 1. The exact proportions in tapering the adherent or thickening the adhesive layer are not otherwise critical. If the overlap is long enough, it is impossible to overdo the peel-stress relief. The precise distribution of the shear stress transfer at the tapered end is modified, but the integral of those shear stresses is not. A structural member composed of two or more dissimilar materials joined together to act as a unit. There are two main benefits of composite action in structural members. First, by rigidly joining the two parts together, the resulting system is stronger than the sum of its parts. Second, composite action can better utilize the properties of each constituent material. Composites consisting of resin matrices reinforced with discontinuous glass fibres and continuous glass-fibber mats are widely used in truck and automobile components bearing light loads.

2.1 Tables for material properties

Table 1.Material properties Sikaflex 221 Epoksi

Material name:		SIKAFLEX 221	
Description:		Polyurethane	
Material Model Type:		Linear Elastic Isotropic	
Default Failure Criterion:		Max von Mises Stress	
Property Name	**Value**	**Units**	**Value Type**
Elastic modulus	3e+6	N/m^2	Constant
Poisson's ratio	0.48	NA	Constant
Shear modulus	1.5e+6	N/m^2	Constant
Mass density	1200	kg/m^3	Constant
Tensile strength	1e+6	N/m^2	Constant
Compressive strength	1e+6	N/m^2	Constant
Yield strength	1e+6	N/m^2	Constant

Table 2. Material properties Sikaflex22

Material name:		SIKAFLEX 221	
Description:		Epoksi	
Material Model Type:		Linear Elastic Isotropic	
Default Failure Criterion:		Max von Mises Stress	
Property Name	**Value**	**Units**	**Value Type**
Elastic modulus	2.4e+009	N/m^2	Constant
Poisson's ratio	0.35	NA	Constant
Shear modulus	8.9e+008	N/m^2	Constant
Mass density	1200	kg/m^3	Constant
Tensile strength	4.5e+007	N/m^2	Constant
Compressive strength	6e+007	N/m^2	Constant
Yield strength	4.5e+007	N/m^2	Constant
Thermal expansion	5.2e-005	Kelvin	Constant
Thermal conductivity	0.21	W/mK	Constant
Specific heat	1500	J/kgK	Cnstant

Table 3. Study results

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Body	N	-0.206856	4905.35	-0.105957	4905.35

Table 4. Free body Forces

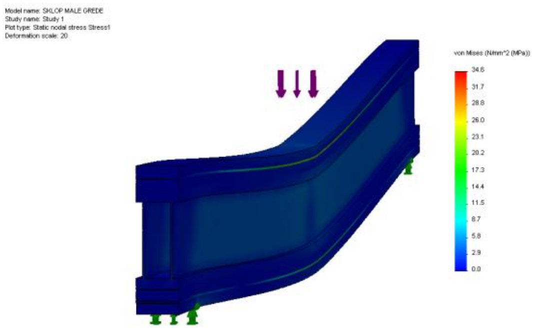
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Body	N	-0.001267	-1.19068	0.0037469	1.19069

Table 5. Free body Moments

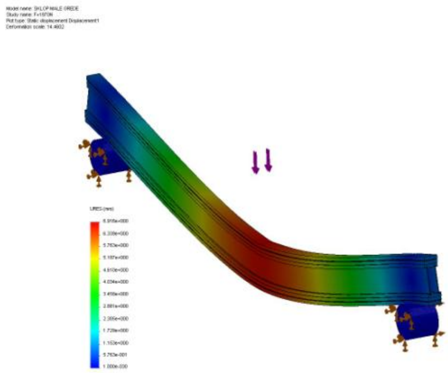
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Body	N-m	0	0	0	1e-033
Name	**Type**	**Min**	**Location**	**Max**	**Location**
Stress1	VON: von Mises Stress	0.0032756 (MPa) Node: 6810	(-19.9431 mm, -52.9717 mm, 110.626 mm)	377.31 (MPa) Node: 266	(-0.592 mm, 47.69 mm, 449.9 mm)
Displacement1	URES: Resultant Displacement	0 mm Node: 6299	(-20 mm, -25.3 mm, 0 mm)	18.6643 mm Node: 6291	(-22.26 mm, -37.7 mm, 449.6 mm)
Strain1	ESTRN: Equivalent Strain	6.92548e-006 Element: 646	(16.4459 mm,-15.1398 mm, 3.22413 mm)	0.430787 Element: 2131	(4.929 mm, -59.27 mm, 669.86 mm)
Stress2	VON: von Mises Stress	0.003275 (MPa) Node: 6810	(-19.9431 mm, -52.9717 mm, 110.626 mm)	377.31 (MPa) Node: 266	(-0.592 mm, -47.69 mm, 449.9 mm)

Table 6. Birch playwood

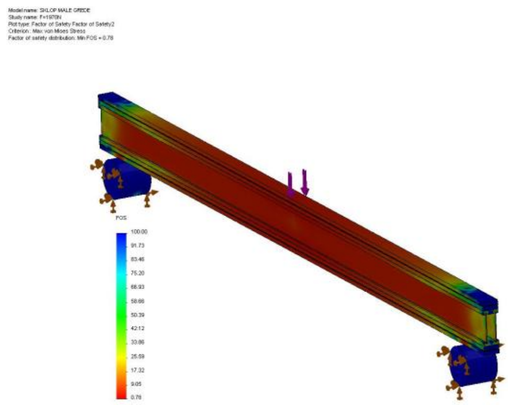
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Body	N-m	0	0	0	1e-033
Name	**Type**	**Min**	**Location**	**Max**	**Location**
Stress1	VON: von Mises Stress	0.0097145 (MPa) Node: 12568	(-20 mm, -63.7313 mm, 25.4518 mm)	160.008 (MPa) Node: 8660	(-7.52726 mm, 25.6509 mm, 632.292 mm)
Displacement1	URES: Resultant Displacement	0 mm Node: 12359	(-20 mm, -37.3494 mm, 62.5 mm)	6.91553 mm Node: 24733	(10.1563 mm, -71 mm, 500.144 mm)
Strain1	ESTRN: Equivalent Strain	5.68194e-008 Element: 32006	(,-19.2121 mm, 65.5166 mm 28.2772 mm)	0.391462 Element: 79804	(-8.62373 mm, -70.1315 mm, 669.86 mm)
Stress2	VON: von Mises Stress	0.003275 (MPa) Node: 6810	(-19.9431 mm, -52.9717 mm, 110.626 mm)	377.31 (MPa) Node: 266	(-0.592 mm, -47.69 mm, 217.26 mm)



Von-Misses Stresses - detailed view.



F=1970N-Displacement-Displacement1



F=1970N-Factor of Safety-Factor of Safety2

The results of numerical calculations of load and deformation of the composite beam were confirmed by testing the beam samples. In the box-beam bending, support distance was 900 mm, and the geometric characteristics of the beam were exactly the same as in the numerical model. Deformation was measured in the middle of the tested beam. That was also the position of the applied load. Examination of the solid beam was done in the same way, with the same support span of 900 mm. In examining the box-beam there was a fracture at the buckling force of 1970 N and deflection of 7.13 mm. Force values are higher because of greater rigidity of the beam materials. For the force range from 1962 N to 4905 N and the deflection of 5mm-13.2mm there was no beam fracture.

3. CONCLUSION

We can notice that the distributions of stresses due to the different elasticity modulus are not equal. This is a basic idea for usage of composite beams. This allows us beam calculation the to maximize potential of used materials. Data were obtained for samples of materials, which may not fully correspond to those included in testing. Using low quality wood material as bearer filling, gives significant advantage in comparison to laminated wood bearings in terms of price, producing simplicity, material acquisition and production time.

4. REFERENCES

[1] Hastin, Z. Analysis of Composite Materials", Journal of Applied Mechanics, Vol. 50/481, September 1983

[2] Sedmak, A. "Primena mehanike loma na integritet konstrukcije" Monografija, Masinski fakultet, Beograd, 2003.

[3] Chi Kin Iu "Inelastic finite element analysis composite beams on the basis of the plastic hinge approach", Engineering Structures (2008) Volume: 30.