The Concept of Shear Between Layers

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Concept: Shear (between layers)
Model: Plastic layered beams with and without adhesives between layers.

A shear force or stress is one which induces a sliding action in parts of a body relative to the remainder of it, or between two different bodies at the surface at which they meet. The force or stress acts in directions parallel to the surface of the material(s).

The main concept of this model is to apply the concept of shear, to implement a horizontal shear resistance and show how that acts in a body, by using a strong adhesive between plastic or laminated strips. In theory, the plastic strips will deform under load without the adhesive applied between layers, but once the adhesive is applied between the layers, the strips of plastic should all act as one rigid beam, and there will be little to no deformation under application of the same load.

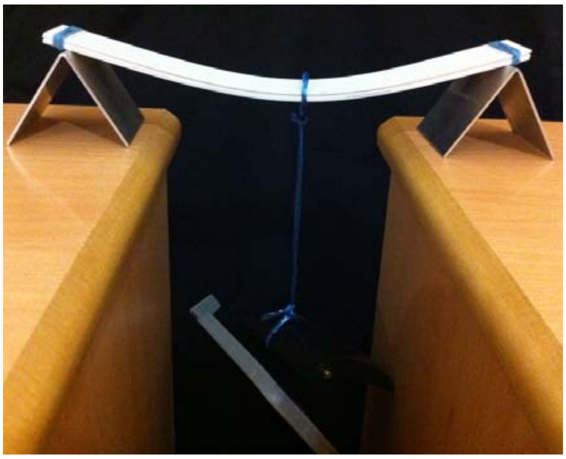
Before load is applied:

(a)

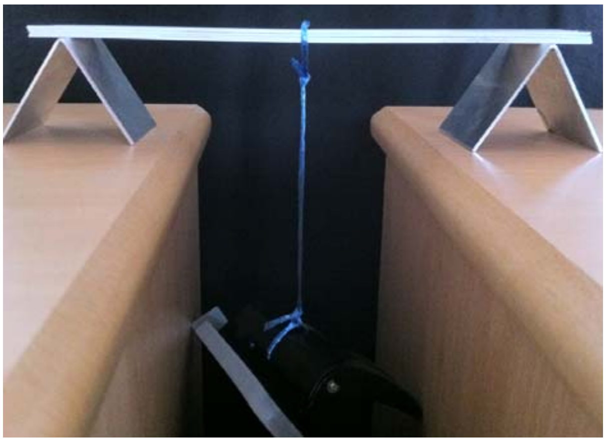
(b)

After load is applied:

(c)

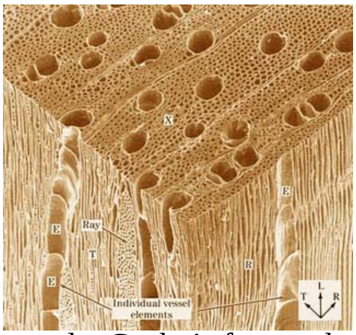
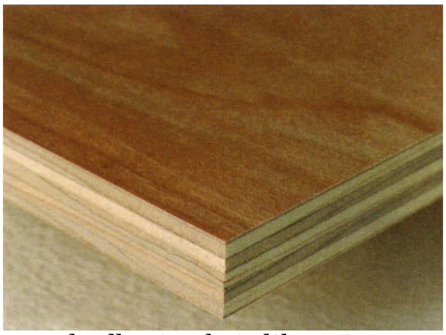
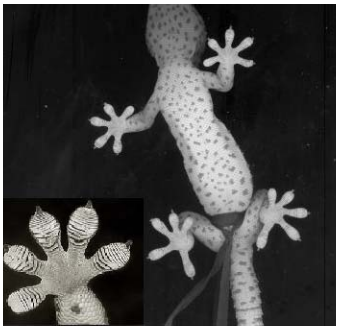


(d)



Pictures (a) and (b) show the two beams which are both consisted of 4 rectangular smooth plastics strips. The beam on the left has nothing in between the layers and is held together by two rubber bands on either side, picture (b) shows the beam with adhesive between the layers on the right. After the load is applied, in pictures (c) and (d), the beam on the left side, in picture (c) has deflected greatly, as there is no shear resistance between the layers and they can slide past each other freely, allowing for a large deflection. Picture (d) shows the same load applied to the beam with adhesive between the layers and little to no deflection invoked. The shear resistance between the layers comes as a result of the adhesive, which therefore has greatly enhanced the rigidity and stiffness of the beam.

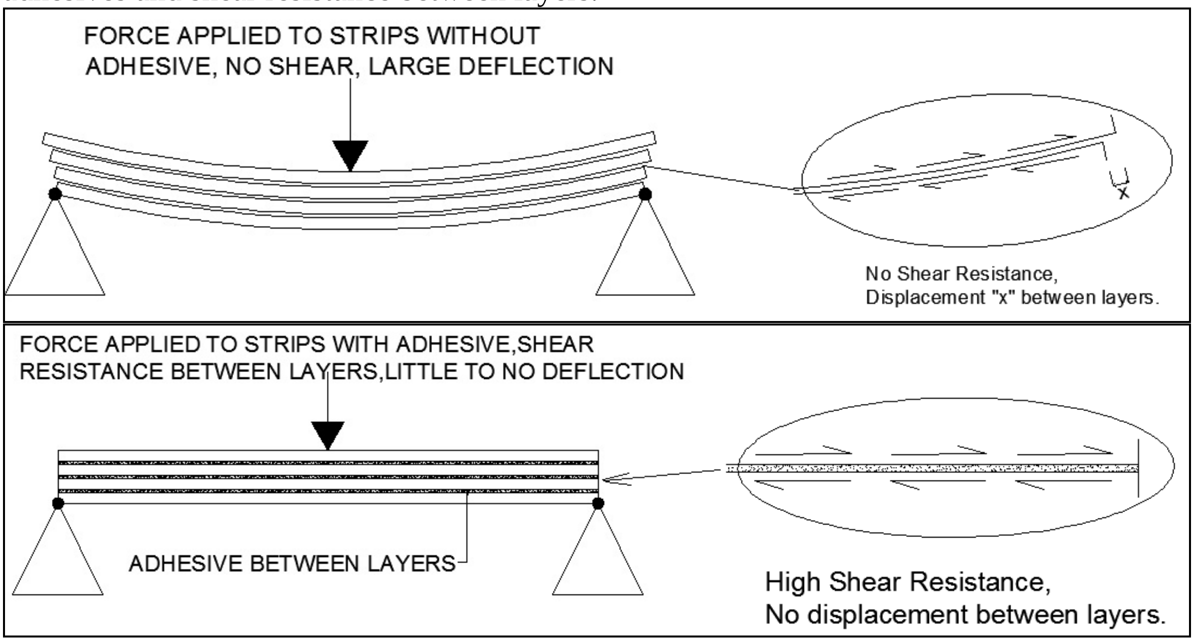
This model aims to mimic the microstructure of a timber beam. Timber is comprised of parallel columnar cells, which can be considered as elongated fibres embedded in a matrix of the polymer lignin, see picture (e). Timber achieves its strength as a result of the horizontal shear resistance between the tubes, which is induced by the polymer lignin matrix. The model also demonstrates how laminates such as plywood work to increase stiffness and rigidity of glued layered sections of wood. There are many natural applications of shear resistance as well, for

(e)  (f)  (g) 

example; Gecko's feet apply a natural adhesive hair like microstructure over a large surface area so that they can increase their shear resistance and suction, and stick to walls without slipping. From left to right: (e). Microstructure of timber showing tubules surrounded by a polymer lignin matrix (http://smartmaterials2009.blogspot.com/2009/09/wood_14.html), (f) Plywood Laminate with adhesive between layers, offering enhanced rigidity, "http://www.mauilaminates.com", (g) A gecko sticking to a smooth surface, and enlarged view of a Gecko foot, "http://www.uakron.edu/id/ib/GRI_research_2008.php".The deflection due to a point load on a simply supported beam is equal to: (Youngs Modulus of Plastic used: $2.6*10^3$ N/mm^2, Second Moment of Area of strip with base 30 mm and height 1mm : 2.5 mm^4.In the case with no adhesive we consider the strips acting together having a collective EI value of: 4EI = 26000 Nmm^2).No Adhesive: $\delta = \frac{WL^3}{48*(4EI)} = \frac{(0.5*9.81)*230^3}{48*4*(2.6*10^3)*2.5} = 47.8\,mm$A large deflection is obtained concordant with that observed in the model.

With Adhesive: $EI = \frac{WL^3}{48*\delta} = \frac{(0.5*9.81)*230^3}{48*0.1} = 12.4 \times 10^6 Nmm^2$

With an adhesive, assume a very small deflection, 0.1 mm, for calculation of EI (stiffness). An increase in stiffness from EI value of 26000 Nmm^2 without an adhesive, to an EI value of 12.4 x 10^6 Nmm^2 with an adhesive can therefore be quantitatively observed in these equations. A massive increase in stiffness and rigidity is therefore obtained with the application of adhesives and shear resistance between layers.



The diagrams above show a cross section of the beams and the shear stresses acting along the strips when the force is applied. As the bottom layers are put under tension and the top under compression and the layers are free to move past each other, and there is displacement between them without adhesive, but this displacement is restricted with adhesive present.

In further work it is possible to show the shear strength of the same adhesive by applying a shear force to it. Two Perspex strips were glued to another Perspex strip over an area of 30 mm x 50 mm, and holes drilled at either end. A weight was hung from the strip to give a rough idea of shear strength of the adhesive applied.

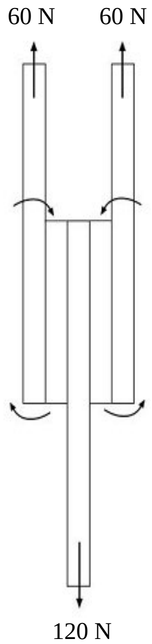
<u>Model 2:</u>

Concept: Adhesive Shear Stress
Model: Double Lap Joint

Plan View:

Side View:

Force Applied to Double Lap Joint:



Water is added to the pot until 12 liters is added, a weight of approximately 12 kilos hanging off of the double lap joints shows that the adhesive itself can comfortably provide a resistant shear stress of 0.4 N/mm^2 in this model as:

$$\tau_a = \frac{0.5 * P}{A} = \frac{0.5 * 9.81 * 12}{30 * 50} = 0.04\ N/mm^2$$

τ_a: *Adhesive Shear Stress Applied*, P: *Force Applied*, A: *Area of Adhesive Applied*

This applied shear stress only shows a small fraction of what the adhesive is capable of though. In further research the maximum adhesive shear stress for this type of adhesive (Tensol 12) was found to be approximately 20 N/mm^2, therefore a force of P_{MAX} :

$$P_{MAX} = 0.5 * A * \tau_{MAX} = 0.5 * 30 * 50 * 20 = 15000\ N = 15\ kN$$

on each lap can be applied, a total force of 30 kN on the double lap joint, a weight of approximately 3 tons!! It is therefore possible to hang a car, in theory, from this small sample!! The concept is again reinforced that adhesives between layers which provide shear resistance can offer a simple way to increase rigidity and stiffness of simple bodies, as in laminates.

References:

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