FAIRLY FUNDAMENTAL FACTS ABOUT FORCES & STRUCTURES

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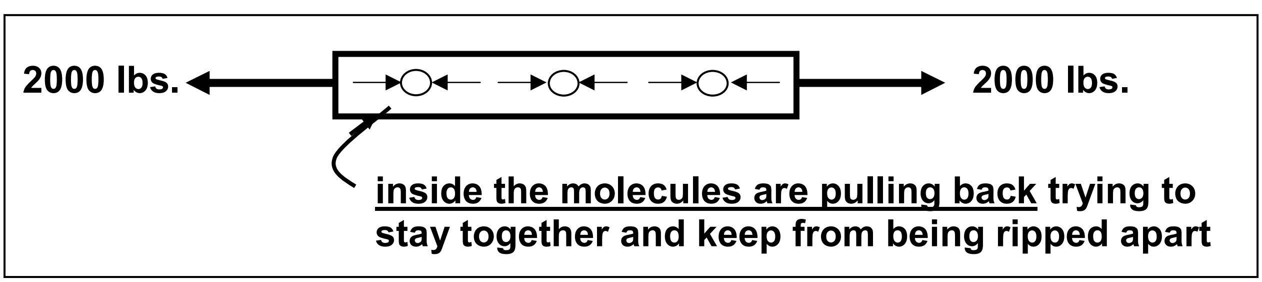
Everyone knows from experience that a **force** is a pushing or a pulling action which moves, or tries to move, an object. Engineers design **structures**, such as buildings, dams, planes and bicycle frames, to hold up weight and withstand forces that are placed on them. An engineer's job is to first determine the **loads** or external forces that are acting on a structure. Whenever external forces are applied to a structure, **internal stresses** (internal forces) develop inside the materials that resist the outside forces and fight to hold the structure together. Once an engineer knows what loads will be acting on a structure, they have to calculate the resulting internal stresses, and design each **structural member** (piece of the structure) so it is strong enough to carry the loads without breaking (or even coming close to breaking).

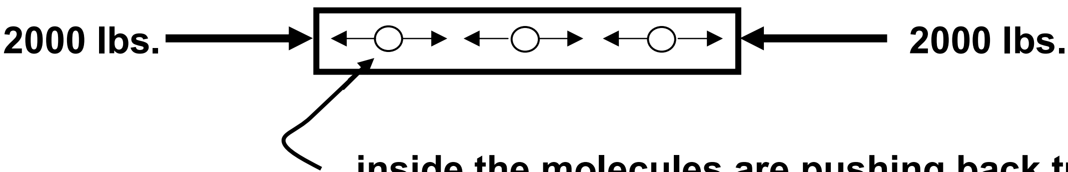
<u>The 5 types of loads that can act on a structure are tension, compression, shear, bending and torsion</u>

1) <u>tension</u>: **two pulling forces, directly opposing each other, that stretch out an object and try to pull it apart (ex. pulling on a rope, a car towing another car with a chain – the rope and the chain are in tension or are "being subjected to a tensile load")**



2) <u>compression</u>: **two pushing forces, directly opposing each other, which squeeze an object and try to squash it (ex. standing on a**

soda can, squeezing a piece of wood in a vise – both the can and the wood are in compression or are "being subjected to a compressive load")

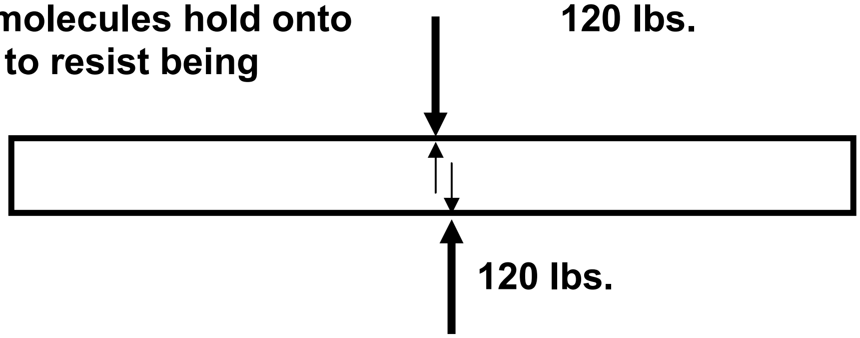


inside the molecules are pushing back trying to stay apart and not get crushed

3) shear: **two pushing or pulling forces, acting close together but not directly opposing each other – a shearing load cuts or rips an object by** sliding its molecules apart sideways

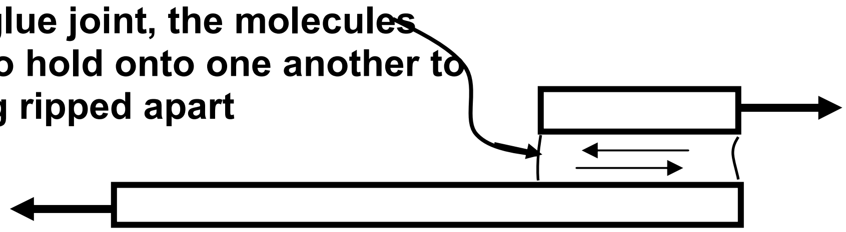
ex. pruning shears cutting through a branch
paper cutter cutting paper
(the branch and the paper are "subjected to a shear loading")

inside the molecules hold onto each other to resist being slid apart



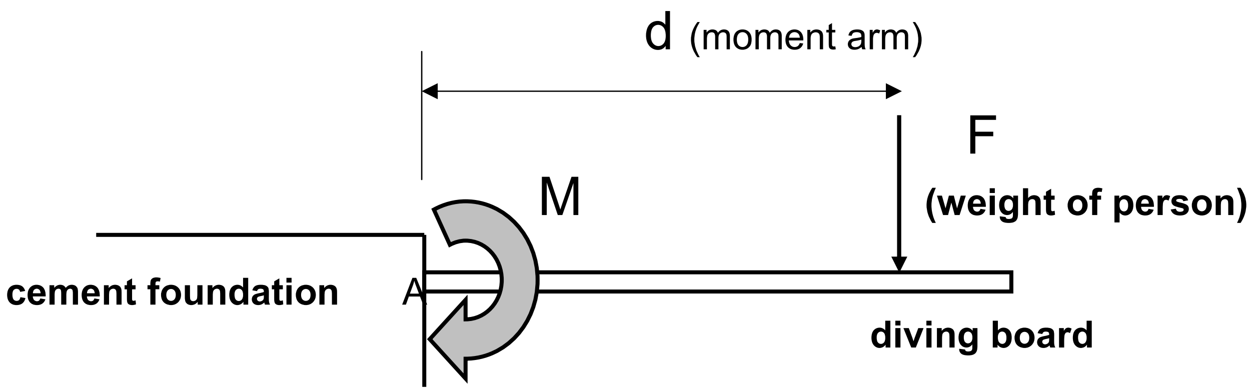
ex. pulling on two pieces of wood that have been glued together
(the glue joint is "being subjected to a shear loading")

inside the glue joint, the molecules are trying to hold onto one another to resist being ripped apart



A Moment of A Force

Before you can understand the last two types of loads, you need to understand the idea of a moment of a force**.** **A moment is a "turning force" caused by a force acting on an object at some distance from a fixed point. Consider the diving board shown below. The heavier the person, and the farther he walks out on the board, the greater the "turning force" which acts on the cement foundation.**



the force (F) produces a moment or "turning force" (M) that tries to rotate the diving board around a fixed point (A) – in this case the moment bends the diving board

The stronger the force, and the greater the distance at which it acts, the larger the moment or "turning force" which it produces.

A moment or "turning force" (M) is calculated by multiplying a force (F) by its moment arm (d) – the moment arm is the distance at which the force is applied, taken from the fixed point:

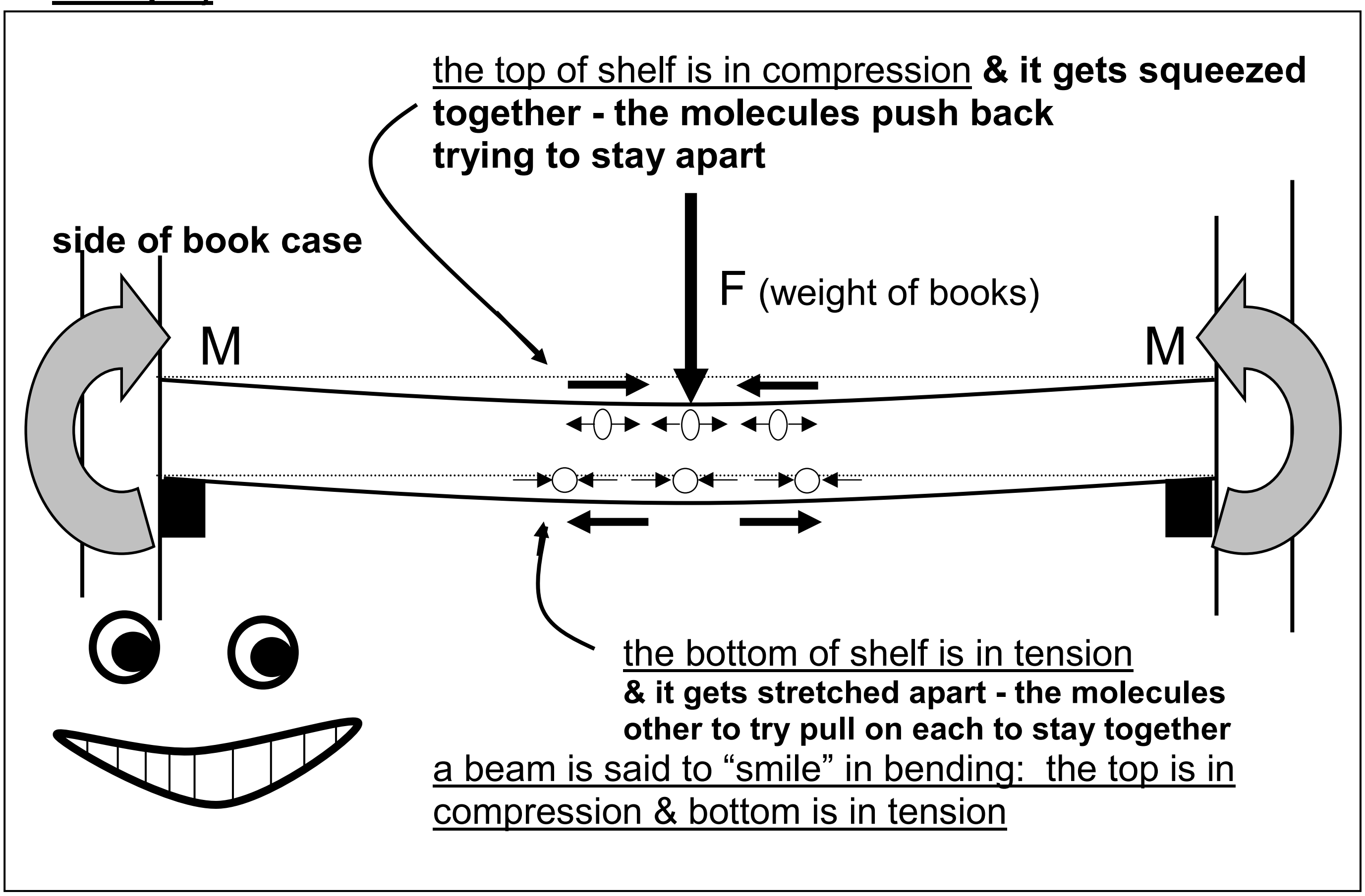
$$\boxed{M = F \bullet d}$$

(as long as the force acting on the object is perpendicular to the object) If you have a force measured in Newtons multiplied by a distance in meters, then your units for the moment are N-m, read "Newton-meters". If your force is measured in pounds and you multiply it by a distance given in inches, then your units will be lb-in., read "pound-inches".

The units for moments can be any force unit multiplied by any distance unit.

4) bending: **created when a moment or "turning force" is applied to a structural member (or piece of material) making it** deflect or sag (bend), moving it sideways away from its original position **- a moment which causes bending is called a** bending moment – bending actually produces tension and compression **inside a beam or a pole, causing it to "smile" – the molecules on the top of the smile get squeezed together, while the molecules on the bottom of the smile get stretched out –** a beam or pole in bending will fail in tension **(break on the side that is being pulled apart)**

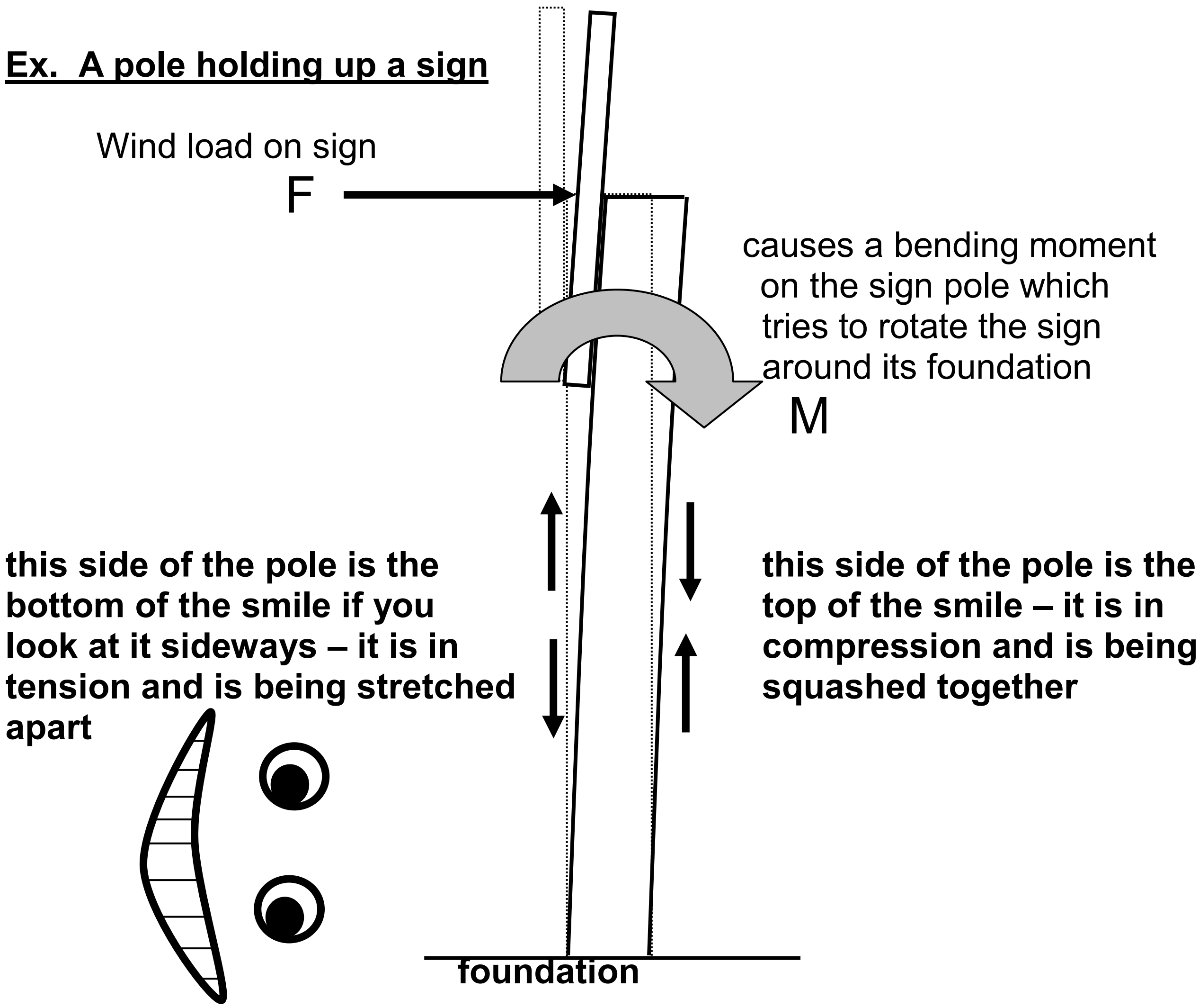
ex. a shelf in a book case (& the diving board from previous example)



Glue stick experiment to show tension and compression created by bending.
Take a glue stick used in a glue gun and use a ruler to mark four straight 4" lines which run down the length of the stick – the lines

should be spaced 90 degrees apart: one on the top, one on the bottom, and one on each side of the glue stick. Hold the glue stick between a finger and your thumb, and apply a force to the middle. Notice how the lengths and shapes of the lines change. <u>What happens to the line on the top of the glue stick (side where your finger pushes)? What happens to the line on the bottom? What happens to the lines on the two sides of the glue stick?</u>

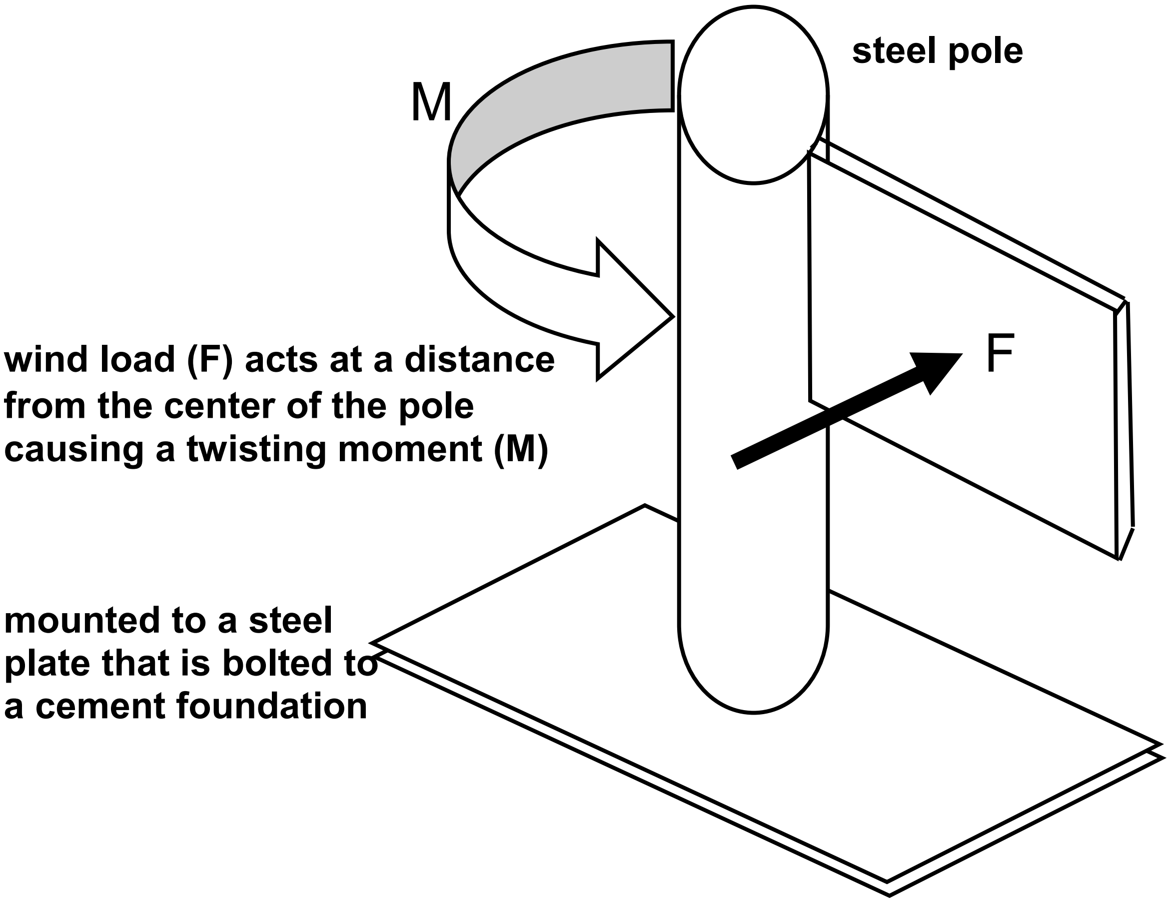
<u>Ex. A pole holding up a sign</u>



5) <u>torsion (twisting):</u> **created when a moment or "turning force" is applied to a structural member (or piece of material)** making it deflect at an angle (twist) **- a moment which causes twisting is called a** twisting or torsional moment – torsion actually produces shear stresses

inside the material - a beam in torsion will fail in shear **(the twisting action causes the molecules to be slid apart sideways)**

<u>ex. a pole with a sign hanging off one side</u>



<u>Glue stick experiment to show torsion.</u> **Again take a glue stick used in a glue gun and use a ruler to mark a series of straight lines along its length, similar to the experiment above. Hold one end of the glue stick, and get a partner to twist the other end as hard as possible. <u>What happens to the lines on the glue stick</u>? Imagine that each vertical line represents a line of glue molecules –** notice how they have been slid sideways out of position by the twisting moment – this is the sign of shear forces acting inside the material.