

Effect of Outer Fiber Stress on Brace Design

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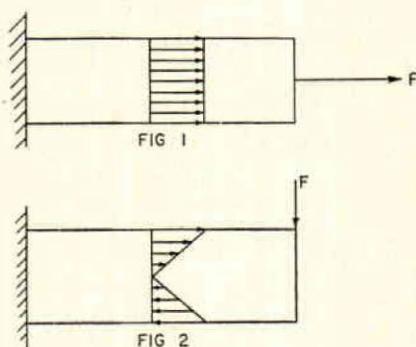
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Many bracemakers have probably wondered when a badly bent brace is returned to them for repairs how it is possible for a person who weighs only about a hundred pounds to bend a steel bar which, according to steel company reports, should not deform unless a pressure of 80,000 pounds per square inch were used. That would mean that a bar $\frac{1}{8}$ inch by $\frac{1}{8}$ inch, or $\frac{1}{64}$ square inch cross section, would not stretch until a load of 1,250 pounds were placed on it; yet every bracemaker knows that a bar of orthopedic steel, $\frac{3}{16}$ inch by $\frac{5}{8}$ inch about two feet long, will take a permanent set if it is fastened by one end in the flat position in a vise and a twenty-pound weight is attached to the other end. How can there be such a difference between fact and figures? The answer is, of course, that forces not apparent to the observer are involved. A very simple but fundamental principal of engineering explains the discrepancy: it is stress on the outer fiber or stress variation in a beam.

In a bar of steel subjected to a pure tensile load, all the material offers the same amount of resistance to the applied load (Fig. 1). This is the method applied by the steel company to get the 80,000 pounds per square inch mentioned in the first paragraph.

If the same bar is used as a beam



with the load at the end, as shown in Figure 2, the material does not offer a uniform resistance. Only the material on the outer surface gives as much resistance as the tensile bar in Figure 1. The rest of the material offers less resistance and some of the material offers no resistance at all. Naturally, since some of the material is not carrying its proper share of the load, the steel used as a beam cannot carry as much load as when used as a tensile bar.

One other factor lowers the amount of load that a beam can carry, and that is the effective increase in load due to leverage. The load on a tensile bar is not increased owing to any leverage, since no leverage is involved, but the load on a beam is effectively increased because of leverage.

A ring stretcher helps to explain both of these factors (Fig. 3). If

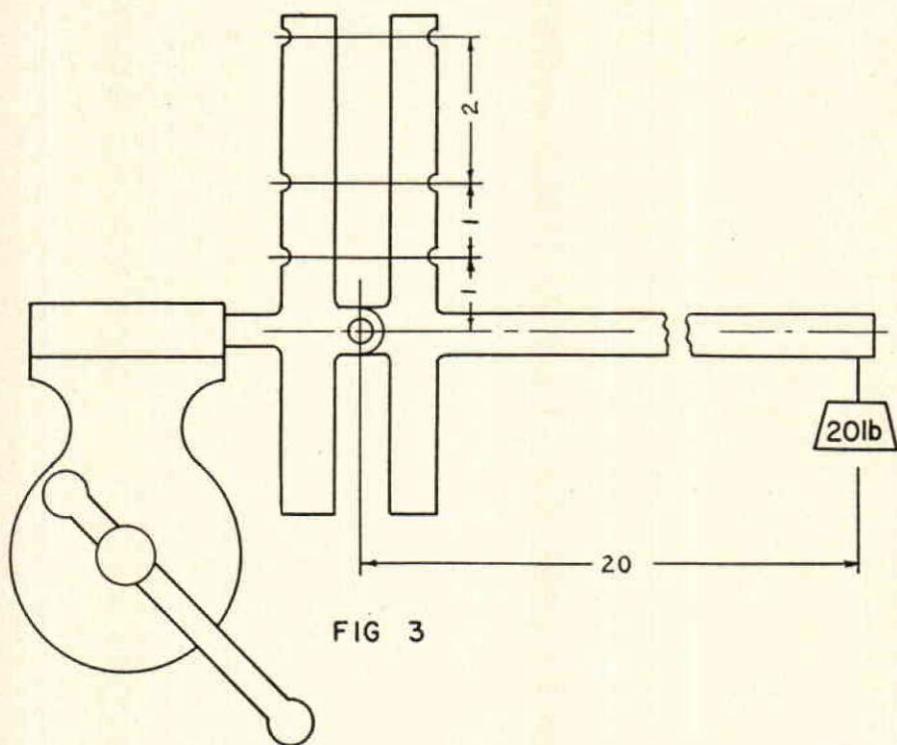


FIG 3

cord or string is used to support the vertical arm, it may take three turns of string in the four-inch position to support the twenty-pound weight. With the string in the two-inch position, it will require six turns of string; and in the one-inch position, twelve turns of string. This fact demonstrates that the material on the outer surface can offer more resistance to the load than the same material can when located close to the hinge.

If the twenty-pound weight remains on the ring stretcher, but the arm is lengthened to forty inches, it

will take to support the twenty-pound weight six turns of string in the four-inch position, twelve turns in the two-inch position, and twenty-four turns in the one-inch position. Thus the increased leverage of the applied load acts the same as an increased load.

A beam acts the same as the ring stretcher in that it behaves as though it had a hinge in the center, and the material furthest away from the hinge can provide the greatest resistance to the load. That is why tubing makes a strong, light brace. By increasing the length of the arm on the ring

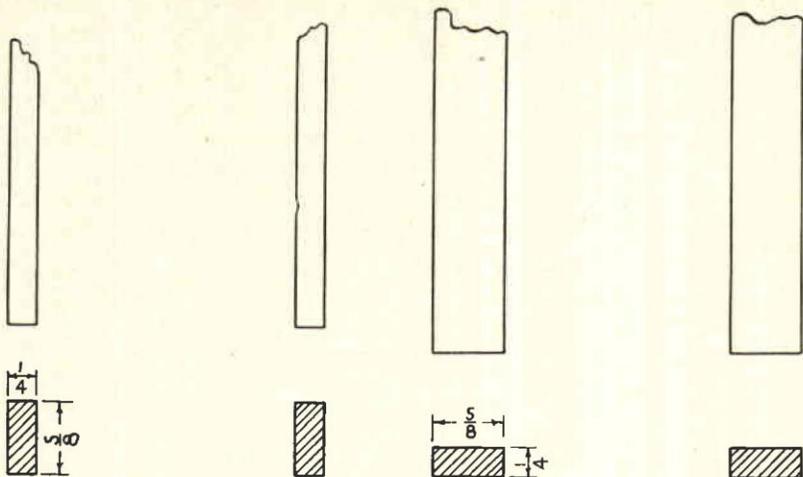


FIG 4

FIG 5

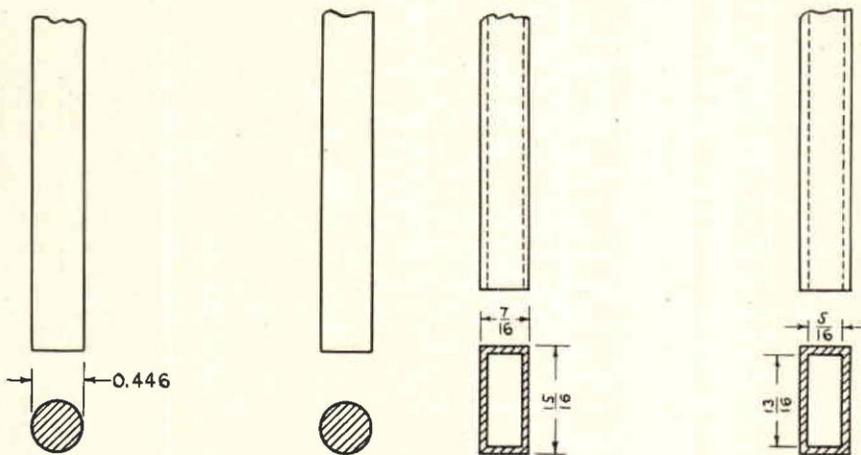


FIG 6

FIG 7

stretcher it was shown that more turns of string were required to support the twenty-pound weight. Obviously the amount of load that a beam can support depends upon how much leverage is involved. It is apparent that a short beam can hold a greater load than a long beam.

By understanding how a beam offers resistance to loads, a bracemaker can often make corrections to various

braces that are returned for repairs. He can also alter the design of braces to suit extra heavy patients or very light patients. A slight change in the cross-sectional shape of a beam often times means the difference between quick failure of a brace or long, safe service. It can mean the difference between a heavy, awkward brace and a light, easily handled brace.

The importance of the shape of a

bar can be readily seen on an ischial seat leg brace. If the side bars are made with a cross-section $\frac{1}{4}$ inch by $\frac{3}{8}$ inch, as illustrated in Figure 4, the brace will handle two and one half times as much load as a brace such as shown in Figure 5, yet there is the same amount of steel in both braces. The brace in Figure 4 will take 1.865 times as much load as the one in Figure 6, yet both have the same amount of material. Figure 7 shows a brace made of tubing with the same amount of material as in Figure 4, yet this tubing will handle over twice as much load as the solid bars in Figure 4.

If it is desired to increase the strength of the brace in Figure 4, it can be done by increasing the amount of material. If the shape is changed to $\frac{1}{2}$ inch by $\frac{3}{8}$ inch, an increase of material in the side direction, the brace will carry twice as much load. But if the dimensions are changed to $\frac{1}{4}$ inch by $1\frac{1}{4}$ inch, an increase of material in the front to back direction, the brace will carry four times as much load, yet the increase in material is the same in both cases.

It can readily be seen that, when brace parts act as beams, any material that is added to increase the strength should be added in the same direction as the loading. It is for this reason that material is added in

the side direction on a leg brace to handle a flail knee. In a similar manner, hip joints are strengthened by adding material in the side direction and back checks for artificial legs are strengthened by adding material in the front to back direction.

As a matter of interest to brace-makers who might like to experiment it should be noted that stress is something that cannot be seen. On the other hand, deflections are apparent. Beam strength, or load-carrying capacity, cannot be compared by comparing deflections. Beam strength varies as the square of the dimension in the direction of loading, while beam stiffness varies as the cube of the same dimension. If the dimension of a beam is doubled in the direction of loading, it will be four times as strong but eight times as stiff. A mild steel beam and a high-strength alloy aluminum beam with the same cross-section and length can carry the same load, but the aluminum beam will deflect three times as much as the steel beam. A good high-strength steel beam will carry more load than a cheaper low-strength steel beam, yet they both will deflect the same amount. The best way to compare the strengths of beams is to apply more load gradually until the beams take a permanent set. The beam that takes the most load is the strongest.

WHAT'S NEW(s)?'

• Hyman Jampol has an article "Physical Therapy Program for the Upper Extremity Amputee" which appeared in the November 1952 issue of the *Physical Therapy Review*. Reprints may be borrowed from OALMA, 336 Washington Building, Washington 5, D. C.

• Horcolite coated Nylon is now available as a covering for braces, trusses and pads and may be obtained from OALMA member, L. Laufer &

Co., 461 Fourth Ave., New York 16, N. Y. This product is a lightweight synthetic resin coated fabric. Among the advantages claimed for the product are these: it is crackproof, shrink-proof and resists most greases, oils and chemicals ordinarily encountered in hospitals; it does not become sticky when heated, nor will it crack when exposed to cold.

It can be boiled and will not peel. Horcolite is available in white or brown, both 45" wide. Samples and prices are available on request to L. Laufer & Co.