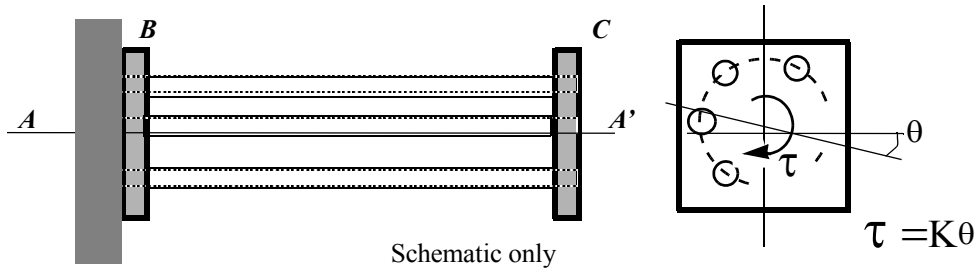


1.101 Structural Design Task Fall 2006

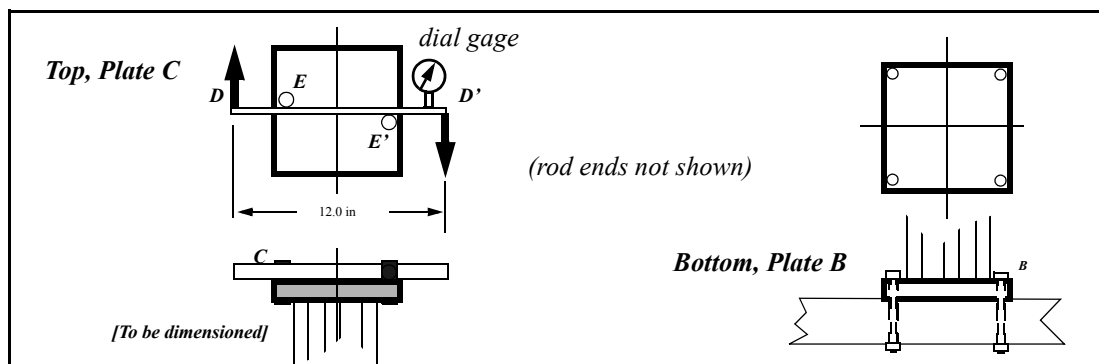
Your task is to design, fabricate, and test a model structure intended to give students a better understanding of two fundamental types of behavior of structural elements - the bending of a beam and torsion of a shaft - and, at the same time, allow them to verify the principle of superpositioning for linear elastic systems. Professor Bucciarelli has fixed upon a way to do this using one structure whose elements are identical circular shafts connected to two end plates. The whole structure will be fixed at one end - plate *B* in the figure. The other end - plate *C* - is free to rotate about the axis *AA'*, e.g., when subjected to a torque, τ , about that axis. The primary objective of the design task is to relate theory to the behavior of a structure and so realize the utility of the former in designing artifacts and systems to function in accord with requirements.



The elastic, solid or tubular, circular shafts - say n of them - are uniformly distributed around and fastened to the two end plates. The rods are rigidly fixed to the plate at the left end, *B*, in the figure and plate *B* is rigidly bolted to ground. The method of fastening of the rods at the other end is more complicated in that *two ways of fastening* are allowed. In one mode, the right ends of the rods are to be *fixed rigidly to the plate C*; in a second mode, they are to be fastened so that they remain *free to rotate relative to plate C*. The figure below shows how the torque at the top plate *C* will be generated via two equal and opposite forces applied at end points *D, D'* of a rigid lever and how the base plate *B* will be fastened to the rigid table. *E, E'* are pins fixed to the top plate *C*; they transmit the torque from the lever *D, D'* to the plate *C*. Note that the structure will be oriented vertically when tested.

How will this work? What will the two modes of experiment show? If the rods are free to rotate relative to plate *C*, then the torsional stiffness, K , of the whole structure, as measured by the resistance to rotation of plate *C* relative to that of the fixed plate *B*, is due to the *resistance to bending alone* of the n rods. If, on the other hand, the rods are rigidly fixed at both ends to the plates, then the torsional stiffness of the individual rods also contributes to the torsional stiffness of the whole structure¹. In the second case, we should see an increase in the torsional stiffness of the structure when compared to the torsional stiffness of the first case. How big and significant an increase depends upon your design, i.e., how you “size” the system elements.

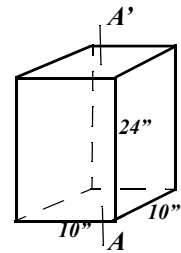
The engineering theories of beam bending and torsion of a circular shaft - hollow or solid - enable one to predict the torsional stiffness in both cases. In the second case, when the resistance to torsion is due both to the bending and torsion of the shafts, we rely upon the principle of superpositioning in making our analysis and predictive calculations



1. Engineering theories of bending and torsion as they apply to this structure are provided in a handout.

Here are the requirements:

- The contributions to the torsional stiffness of the entire structure due to bending of the rods is to be approximately the same as the contribution due to torsion of the rods.
- The torsional stiffness should be such that the rotation can be measured with a dial gage.
- Loading is to be accomplished using the 1/2 and 6 pound weights available in the lab.
- The apparatus should not fail, yield or break during experiment.
- Your structure should fit within a rectangular parallelepiped of dimensions 10in. by 10 in. by 24 in. (See figure at right).
- The *free end*, plate C, should interface with the loading beam (DD' in the figure previous page) as shown.
- The *fixed end*, plate B, should be bolted rigidly to the open grill, table surface as shown in the figure on the previous page.



Your task includes i) sizing the circular shafts (length, diameter, wall thickness if hollow), choosing n , their number, and the material out of which they are to be made ii) fabricating the elements of the structure paying special attention to how to fasten the ends of the rods to plate C in both modes of testing iii) assembly and testing of the structure. Available materials and rod stock sizes will be given in a table.