

## Unified Quiz 7M

May 4, 2005

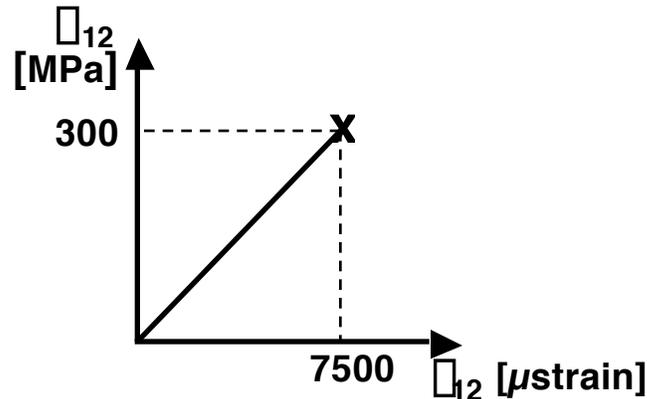
- Put your MIT ID# (last four digits) on each page of the exam.
- Read all questions carefully.
- Do all work on that question on the page(s) provided. Use back of the page(s) if necessary.
- Show all your work, especially intermediate results. Partial credit cannot be given without intermediate results.
- Show the logical path of your work. Explain clearly your reasoning and what you are doing. *In some cases, the reasoning is worth as much (or more) than the actual answers.*
- Please be neat. It will be easier to identify correct or partially correct responses when the response is neat.
- Be sure to show the appropriate units. Intermediate answers and final answers are not correct without the units.
- Report significant digits only.
- Box your final answers.
- **Calculators, handwritten “crib sheets”, and Unified Handout “CONCEPT REVIEW SHEET for Unified Q7M” allowed.**

### EXAM SCORING

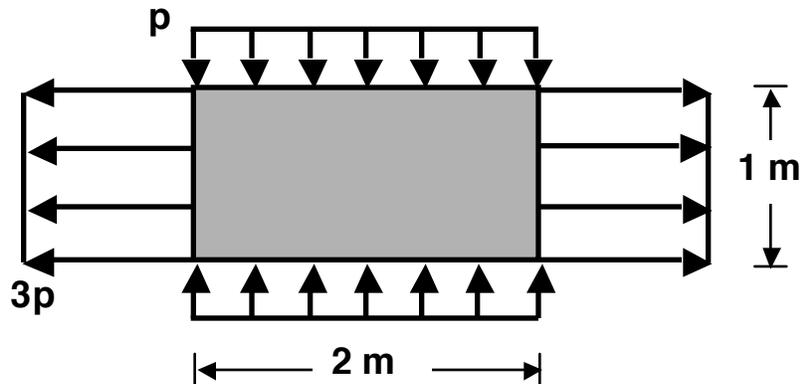
#1M (25%)	
#2M (35%)	
#3M (20%)	
#4M (20%)	
FINAL SCORE	

**PROBLEM #1M (25%)**

You are asked to consider the characteristics and failure of an unknown isotropic material. You are provided with stress-strain data determined from a torsional test on a rod of the material. The shear stress versus tensorial shear strain diagram that results from this test is shown below.



Use this data to determine the failure of a rectangular plate made of the same material. The plate is 2 meters long by 1 meter wide and 10 mm thick. The plate is loaded in a special machine that applies a line load (force per unit length) along each side. The line load is tensile with a magnitude of  $3p$  along the width and is compressive with a magnitude of  $p$  along the length. Determine the value of the loading parameter  $p$  at which this plate will fail (under perfect load distribution conditions).

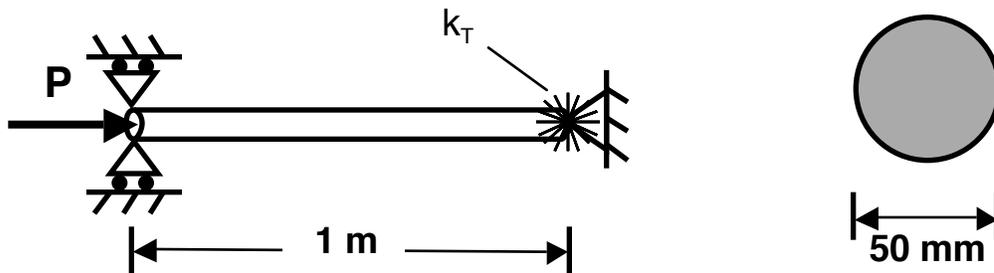


**PROBLEM #1M (continued)**

**PROBLEM #2M (35%)**

A component of a drive system of a piece of international heavy machinery has a circular cross-section. This piece can be modeled as a component that is connected to a roller support at one end, where the load is applied, and is attached via a torsional spring of stiffness  $k_T$  at the other end. The component is sized so that it will not yield or crush and is 1 meter long with a diameter of 50 mm. The component is made of machinery-grade steel with a modulus of 200 GPa.

**Cross-Section**



- (a) Set up the equation(s) needed to determine the response of this component assuming that manufacturing, alignment, and loading are “perfect”. This includes any deformation prior to instability. Describe how you would use the resulting equation(s) to determine the response but **DO NOT SOLVE**. As much as possible, describe the *nature* of the solution that results. Use figures if/as appropriate.

**PROBLEM #2M (continued)**

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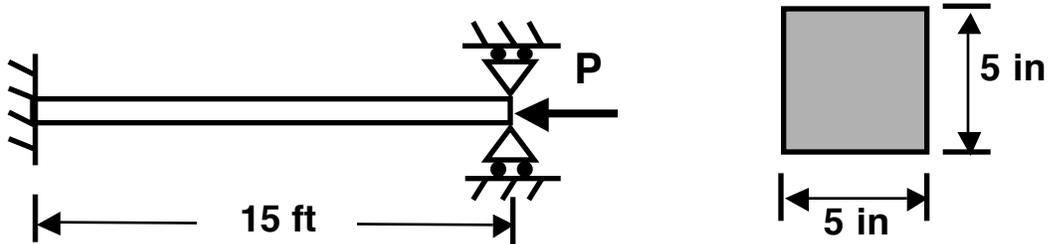
- (b) **Describe** the differences in the approach to determine the response when imperfections must be considered. Set up any needed equations but **DO NOT SOLVE**. As before, as much as possible, describe the *nature* of the solutions that result. Use figures if/as appropriate. In this overall description, do not use numbers, but only describe in a generic sense.

**PROBLEM #2M (continued)**

**PROBLEM #3M (20%)**

A structural component of a bridge is loaded in compression along its longitudinal axis. The component is clamped at one end and has a roller support at the other end where the compressive load is applied. The component is 15 feet long, has a square cross-section that is 5 inches to a side, and is made of steel ( $E = 30 \text{ Msi}$ ,  $\nu = 0.3$ ,  $\sigma_{ult} = 200 \text{ ksi}$ ).

**Cross-Section**

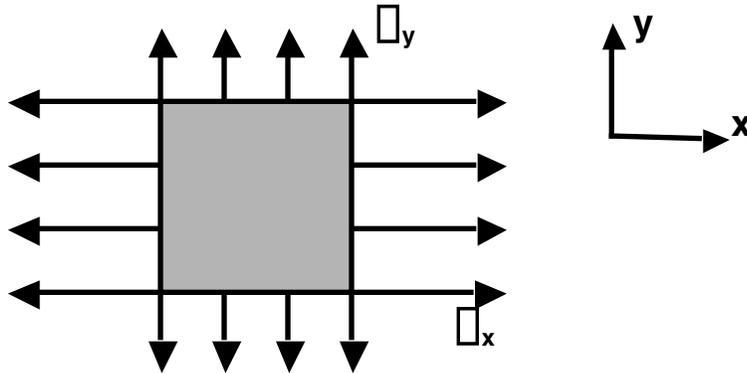


A replacement for such components is being considered to be made out of aluminum ( $E = 10 \text{ Msi}$ ,  $\nu = 0.3$ ,  $\sigma_{ult} = 50 \text{ ksi}$ ) due to corrosion concerns and resulting maintenance and lifetime issues. Determine the cross-sectional dimension of the square component needed to mimic the behavior exhibited by the steel component. Include both perfect and imperfect considerations.

**PROBLEM #3M (continued)**

**PROBLEM #4M (20%)**

An aircraft structure is to be designed using either the basic strength approach or the damage tolerance approach. The component is loaded such that analysis shows that the material is subjected to a biaxial stress state with the stress in the x-direction being twice the stress in the y-direction. There is no shear stress. Titanium is being considered for this piece. The particular titanium has a modulus of 16.4 Msi, a Poisson's ratio of 0.31, a value of the tensile ultimate strength of 135 ksi, and a value of fracture toughness of  $59 \text{ ksi}(\text{in})^{1/2}$ .



Using the numbers given as the design values, determine the size of the crack that must be tolerated via the damage tolerant approach, in order to design for the same loading ability as via the basic strength approach.

*In applying both approaches, consider the ultimate load condition. For the basic strength approach, use the von Mises criterion. For the damage tolerance approach, only consider the stress perpendicular to the crack and assume that the geometric factor associated with the assumed crack configuration is equal to 1.*

**PROBLEM #4M (continued)**