EVERYDAY EXAMPLES OF ENGINEERING CONCEPTS

S9: Eccentric loading

This is an extract from 'Real Life Examples in Mechanics of Solids: Lesson plans and solutions' edited by Eann A. Patterson, first published in 2006 (ISBN:978-0-615-20394-2) which can be obtained on-line at www.engineeringexamples.org and contains suggested exemplars within lesson plans for Sophomore Solids Courses. Prepared as part of the NSF-supported project (#0431756) entitled: "Enhancing Diversity in the Undergraduate Mechanical Engineering Population through Curriculum Change".

INTRODUCTION

(from *'Real Life Examples in Mechanics of Solids: Lesson plans and solutions'*)

These notes are designed to enhance the teaching of a sophomore course in mechanics of solids, increase the accessibility of the principles and raise the appeal of the subject to students from a diverse background[1]. The notes have been prepared as skeletal lesson plans using the principle of the 5Es: Engage, Explore, Explain, Elaborate and Evaluate. These are not original and were developed by the Biological Sciences Curriculum Study[2] in the 1980s from work by Atkin and Karplus[3] in 1962. Today they are considered to form part of the constructivist learning theory and a number of websites provide easy to follow explanations of them[4].

These notes are intended to be used by instructors and are written in a style that addresses the instructor, however this is not intended to exclude students who should find the notes and examples interesting, stimulating and hopefully illuminating, particularly when their instructor is not utilizing them. In the interest of brevity and clarity of presentation, standard derivations and definitions are not included since these are readily available in textbooks which these notes are not intended to replace but rather to supplement. Similarly, it is anticipated that these lessons plans can be used to generate lectures/lessons that supplement those covering the fundamentals of each topic.

Acknowledgements

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[1] Patterson, E.A., Campbell, P.B., Busch-Vishniac, I., Guillaume, D.W., 2011, The effect of context on student engagement in engineering, *European J. Engng Education*, 36(3):211-224.
[2] http://www.bscs.org/library/BSCS_5E_Instructional_Approach_July_06.pdf
[3] Atkin, J. M. and Karplus, R. (1962). Discovery of invention? *Science Teacher* 29(5): 45.
[4] e.g. http://www.science.org.au/primaryconnections/constructivist.htm

METHOD OF SUPERPOSITION

9. <u>Principle</u>: **Eccentric loading**

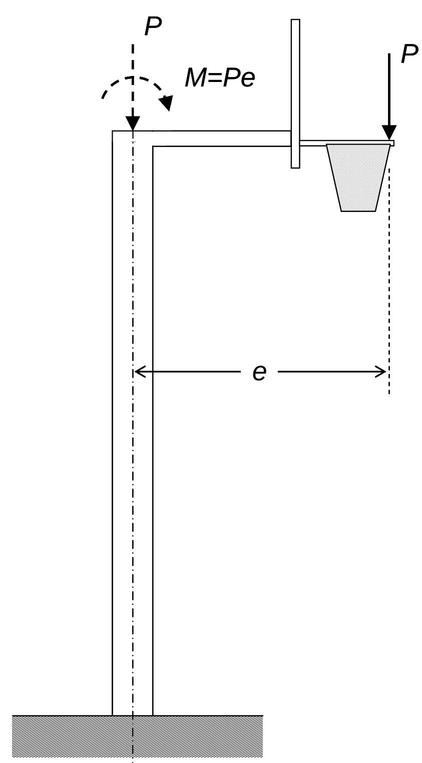
Engage:

Bounce a basketball into class.

Explore:

Discuss the loading on the basketball pole during different types of play, e.g.

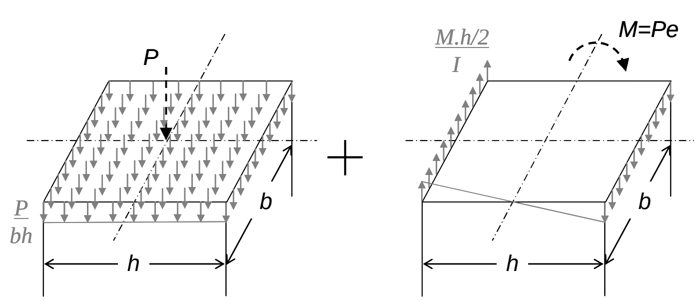
- Static compression with low level bending due to offset of backboard and goal;
- Additional low level bending during a goal**;**
- Dynamic bending when the ball bounces off the backboard from a long shot plus torsion if the shot is wide; and
- High level compression and bending during a slam dunk.



Explain:

Ask the students, working in pairs and sketching, to identify forces and moments acting about the center of the cross-section of the pole that are equivalent to the weight of a player hanging on the rim (*solid arrow*). The solution is a compressive force and a moment (*dashed arrows*).

Explain that if these two forces only produce linear elastic deformation then their effects can be added together, or superimposed. Discuss principle of superposition.



Elaborate:

For a pole 10cm square manufactured from aluminum with a 60cm offset when a player hangs from the front of the ring at an effective distance from the backboard of 50cm, the maximum tensile stress in the pole occurs on the back of the pole:

Maximum tensile stress = Maximum bending stress – compressive stress

$$\sigma_{max} = \frac{M(h/2)}{I} - \frac{P}{bh} = \frac{(Pe)h/2}{bh^3/12} - \frac{P}{bh} = \frac{6(Pe)}{bh^2} - \frac{P}{bh}$$

So, for a 90kg player, ignoring the mass of the backboard etc.

$$\sigma_{max} = \frac{6\left(90 \times 9.81 \times [60+50] \times 10^{-2}\right)}{\left(10 \times 10^{-2}\right)^3} - \frac{90 \times 9.81}{\left(10 \times 10^{-2}\right)^2} = 5827140 + 88290 = 5.9\,\text{MPa}$$

Evaluate:

Ask students to attempt the following examples:

<u>*Example 9.1*</u>

Calculate the tensile maximum stresses when a 90kg basketball player hangs from the side of the ring for a goal mounted on a 12cm square section pole with wall thickness of 3mm with an offset of 1m from the pole center to ring center. The ring diameter is 42cm.

<u>Solution:</u>

Hanging from the side will induce two bending moments about the front-back axis (M_{fb})and about the side-side axis (M_{ss}) of the pole, thus:

$$\sigma_{max} = \frac{M_{ss}(h/2)}{I_{ss}} + \frac{M_{fb}(h/2)}{I_{fb}} - \frac{P}{bh} = \frac{(P \times e)h/2}{I_{ss}} + \frac{(P \times r)b/2}{I_{fb}} - \frac{P}{bh}$$

Since the pole is square $I_{ss} = I_{fb}$ and $I = \frac{1}{12}\left[\left(12 \times 10^{-2}\right)^4 - \left(11.4 \times 10^{-2}\right)^4\right] = 3.21 \times 10^{-6}\,\text{m}^4$

$$\sigma_{max} = \frac{(90 \times 9.81 \times 1) \times 6 \times 10^{-2}}{3.21 \times 10^{-6}} + \frac{(90 \times 9.81 \times 0.42) \times 6 \times 10^{-2}}{3.21 \times 10^{-6}} - \frac{90 \times 9.81}{\left(12 \times 10^{-2}\right)^2}$$

$$\sigma_{max} = 16502803 + 6931178 - 61312 = 23.4\,\text{MPa}$$

Maximum tensile stress induced in the pole is 23.4MPa.

<u>*Example 9.2*</u>

Ask students to look for two other examples in their everyday life and explain how the above principles apply to each example.