



## BMM 311L Biomaterials and Biomechanics Laboratory, Spring 2020

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### EXPERIMENT 1: 4-Point Bending Test for Metallic Bone Plates

#### 1. Scope

The goal of this experiment is to understand the bending stiffness, bending structural stiffness, and bending strength from a single cycle (static) bend test on metallic bone plates using cylindrical rod.

#### 2. Introduction

Bending strength or flexural strength is defined as a material's ability to resist deformation under load. The bending strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress.

Bending rigidity of the plates is one of the biomechanical issues arise in the design of fracture fixation plates. This is important because load sharing between bone plate and bone, which is influenced by the bending rigidity of plate vs. For this reason metallic bone plates need to undergo several tests before gaining approval as internal fixation devices of the skeletal system. Four point bend tests are commonly used to determine the flexural strength of a specimen. One standard, **ASTM F382-99**, defines the test methods for single cycle bend (static) testing and for determining the bending fatigue properties of metallic bone plates.

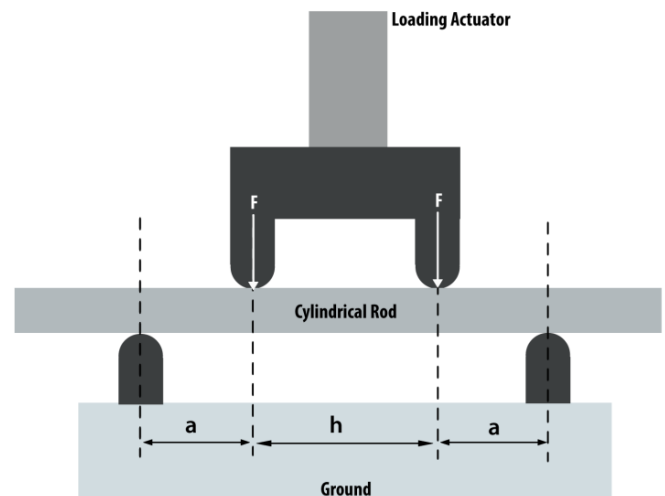
When a specimen is bent, it experiences a range of stresses across its depth. At the edge of the concave face of the specimen (point A), the stress will be at its maximum compressive value. At the convex face of the specimen (point B), the stress will be at its maximum tensile value. Most materials fail under tensile stress before they fail under compressive stress, so the maximum tensile stress value that can be sustained before the specimen fails is its bending strength. The bending strength would be the same as the tensile strength if the material were homogeneous. In the case of bones, the complex structure and small defects within the specimen serve to concentrate stresses locally, effectively causing localized weaknesses and lower bending strength values.

**Note:** This test method assumes that linear-elastic material behavior will be observed and therefore, the method is not applicable for the testing of materials that exhibit nonlinear elastic behavior.

#### 3. Test Specimen and Laboratory Equipment

The test specimen is a cylindrical rod and test apparatus was illustrated schematically in Figure 1. Instron 3369 universal testing system will be used to observe load-displacement graphs.

The cylindrical rod made of Ti-6Al-4V (6 mm diameter and 150 mm length).



**Figure 1.** Schematic illustration of test specimen and 4-point bend fixture.

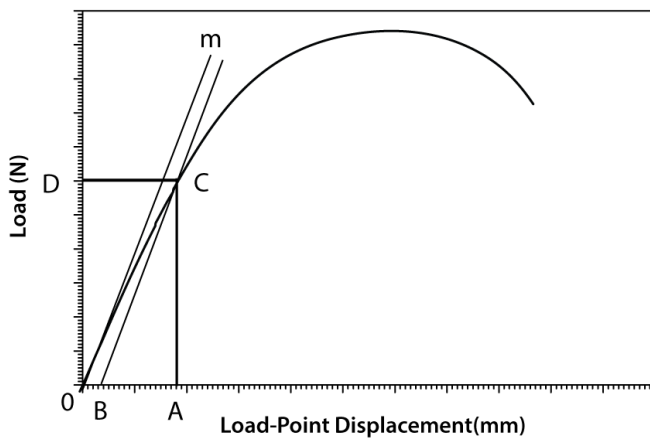
#### 4. Experiments and Procedure

Determine the bending stiffness, bending structural stiffness, and bending strength for each tested bone plate according to the method that follows:

A load versus load-point displacement curve (see Fig.2) is produced either autographically or from numerical data acquired during the test.

On the load versus load-point displacement diagram generated for the test, draw a best fit straight line (Om) through the initial (linear) portion of the load versus load-point displacement curve.

Determine the bone plate's bending stiffness (K) by calculating the slope of the line.



**Figure 2.** Diagram illustrating methods for determining bending properties of bone plates.

Determine the bone plate's bending structural stiffness  $El_e$  with the following expression:

$$El_e = \frac{(2h + 3a)Kh^2}{12}$$

where:

$K$  = the bending stiffness,  
 $a$  = the center span distance, and  
 $h$  = the loading span distance.

Calculate the 0.2 % offset displacement from the expression:

$$q = 0.0023 a$$

where:

$a$  = the center span distance.

On the load versus load-point displacement diagram lay off OB equal to  $q$ . Then draw line BC parallel to Om.

Locate the proof load at the intersection point of line BC with the load versus load-point displacement curve.

Calculate the bending strength of the bone plate from the expression:

$$\text{Bending Strength} = \frac{(Ph)}{2}$$

where:

$P$  = the proof load, and  
 $h$  = the loading span distance.

If the bone plate fractures prior to the load versus load-point displacement curve intersects the offset line BC, calculate the bending strength from the expression:

$$\text{Bending Strength} = \frac{F_{\max} \times h}{2}$$

where:

$F_{\max}$  = the fracture load, and  
 $h$  = the loading span distance.

#### References

[1] ASTM - Standard Specification and Test Method for Metallic Bone Plates, Designation: F 382 - 99 (Reapproved 2003).

#### Safety in Laboratory

1. Eye protection must be worn during the tensile test.
2. Wait for the Teaching Assistant before beginning the laboratory exercise so that they can guide you through testing your first sample.
3. Before beginning a test or moving/resetting the universal testing machine, make sure all items including hands, hair, etc. are clear of the machine.

#### Grading

Lab reports: (70%)\*

Short exam at end of 3<sup>rd</sup> and 6<sup>th</sup> experiments: (30%)

\* Late delivered reports will lead to lose of 10 points/day.

\* Each group delivers one report.

#### Labs

TOBB ETÜ Technology Center, B06 (Experiments 1-4), 201 (Experiments 5), 206 (Experiment 6).

#### Contacts

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