BMM 311L Biomaterials and Biomechanics Laboratory, Spring 2020

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EXPERIMENT 3: Bone Compression Test

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1. Scope

The goal of this experiment is to examine the intrinsic mechanical response of the bone under compression forces. Instability is aimed using compressive forces and finally we aim to observe degeneration of vertebrae.

2. Introduction

In the living body, most of the bones are subjected to bending action as a result of gravity, muscular activity during movement, and blows. Consequently, the bones are subjected to a combination of tension, compression, and shearing rather than to a single pure force. The question then arises as to why the strength of bone is usually determined by testing the specimens under a pure force. The answer to this question is on mechanical grounds. There are, however, other valid reasons for testing the strength of bone under pure tension or compression.

The spinal (or vertebral) column consists of 24 vertebrae stacked one atop the other in such a way to allow for even distribution of weight in upright posture. There are four sections of the spinal column: cervical (7 vertebrae), thoracic (12 vertebrae), lumbar (5 vertebrae), and the sacrum & coccyx.

Compression fractures are quite common in the bodies of the vertebrae, especially those in the lumbar region. The rationale for determining the strength of bone under direct compression is that these regions of the bone are normally subjected to compression forces in the erect posture. Specimens from other regions were similarly tested for comparative purposes.

For most materials, it is important to know the elastic limit so that you don’t permanently deform the material and/or run the risk of increasing the odds for failure (when the material no longer works as you want it to). Medical professionals use this information when planning surgical repair with pins or plates, or during physical therapy, and more.

3. Test Specimen and Laboratory Equipment

One segment of sheep vertebrae was stored in -20 °C until 24 h before the experiment.

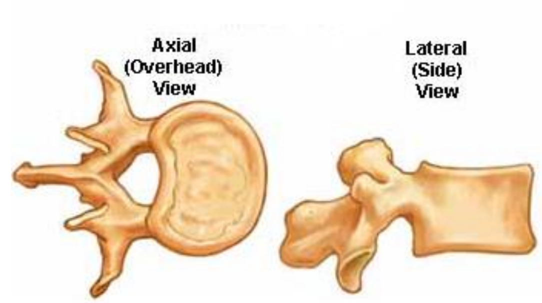

Figure1. Schematic illustration of lumbar vertebrae (Image Credit: www.spineuniverse.com)

The distribution of compressive stress on the vertebrae will be proved using Instron 3369 universal testing system.

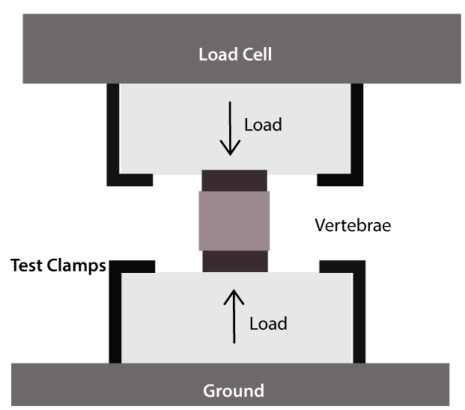

Figure 2. Schematic illustration of test apparatus for bone compression test.

4. Experiments and Procedure

There are a number of biomechanical parameters that can be used to characterize the integrity of bone. The key relationship is that between load applied to a structure and displacement in response to the load-displacement curve (Figure 2). The slope of the elastic region of the load-displacement curve represents the extrinsic stiffness or rigidity of the structure (S). Besides stiffness, several other biomechanical properties can be derived, including ultimate force (F), work to failure (area under the load-displacement curve, U), and ultimate displacement (du). Each of these measured parameters reflects a different property of the bone: ultimate force reflects the general integrity of the bone structure; stiffness is closely related to the mineralization of the bone; work to failure is the amount of energy necessary to break the bone; and ultimate displacement is inversely related to the brittleness of the bone. The "equilibrium" stress-strain curve for a specimen of vertebrae tested under a constant low– strain-rate condition is shown in Figure 3.

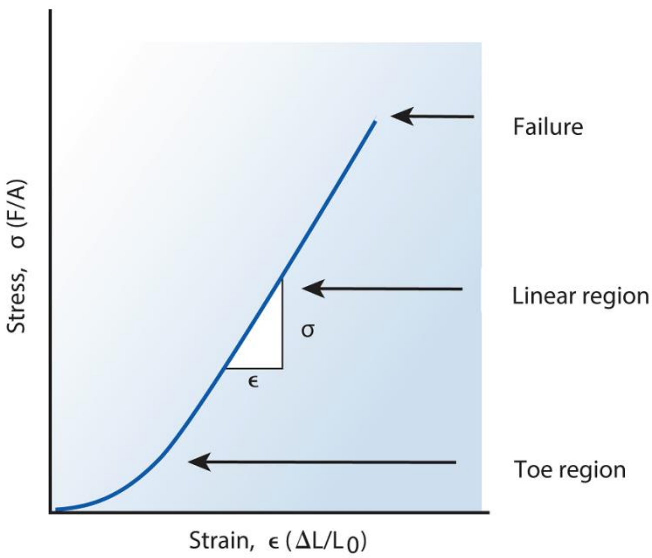

Figure 3. Typical compression stress-strain curve for bone compression test.

Rather, a tangent modulus, defined by the tangent to the stress-strain curve, must be used to describe the tensile stiffness of the tissue.

Morphologically, the cause for the shape of the tensile stress-strain curve for large strains is depicted in the diagrams on the right of Figure 3. The initial toe region is caused by collagen fiber compression and realignment during the initial portion of the compression experiment. The "Toe region" is the non-linear amount of "pre-stretching" an object needs to get it into the elastic realm. After pre-stretching (ie, pre-loading), additional force applied to the object shows elastic behavior. This means that there is a direct relationship between the applied force and the change in length, ie, Hooke's Law is valid. This also means that when the force is removed, the object returns to its original shape, no matter how many times the force is applied and removed.

References

[1] Margareta Nordin, Basic Biomechanics of the Musculoskeletal System, Lippincott Williams & Wilkins, a Wolters Kluwer business, 2012.

[2] Daniel M. Skrzypiec, Phillip Pollintine, Andrzej Przybyla, Patricia Dolan, Michael A. Adams, The internal mechanical properties of cervical intervertebral discs as revealed by stress profilometry, Eur Spine J (2007) 16:1701–1709.

[3] http://www.ninds.nih.gov

[4] http://www.oandplibrary.org

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 3rd and 6th 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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