

Mechanics of Materials Lab manual

EMA 3702L

Spring 2015

Dr. S. E. Beladi, PE

Attachments:

1. General Course Objective and Syllabus
2. Course elementary and fundamental knowledge
3. Report Writing and Error Analysis
4. Lab Procedures:
 - a. Experiment One, Tensile Stress Testing
 - b. Experiment Two, Beam Deflection and Bending
 - c. Experiment Three, Torsional Tests of Solid circular Bars
 - d. Experiment Four, Principal of Stress and Strains
 - e. Experiment Five, Elastic and Inelastic buckling of Columns
 - f. Experiment Number Six, Hardness Tests of Material surfaces.

I. COURSE OBJECTIVES:

To verify mechanics of materials theories on real mechanical specimens.

Student Learning Outcome: The student will demonstrate the ability to:

- a. Identify when theory applies and when theory is limited by simplifying assumptions
- b. Identify the reasons why actual measurements will differ from theoretical calculations.

To learn to run an experiment

Students learning outcomes: The students will demonstrate the ability to :

- a. Perform pre- laboratory calculations to estimate the experimental parameters, outcomes and limits
- b. Develop an organized and meaningful data sheets
- c. Use software tools to reduce and analysis the data
- d. Organize a team to share responsibilities for operating equipment ad collecting data.

To learn to use testing equipment and measurement instrumentations

Student learning outcomes: The student will demonstrate the ability to:

- a. Use laboratory equipment correctly and safely to perform all experiments.

To learn to write a laboratory Report:

Student learning outcome: The student will demonstrate the ability to:

- a. Write experimental objectives and procedure for practical experiment set up and design
- b. Present results in organized and clear manner
- c. Draw graphs and figures and summarize key findings
- d. Put together a complete professional report including tables of content, references and appendices.

II. Pre-Lab CALCULATIONS

For each experiment discussed in this Manual, a set of calculations that must be completed and questions that must be answered in order to prepare the collection of data in the lab. Examples of types of calculations you will make include:

- Determination of the maximum allowable load on a specimen.
- Estimation or prediction of experimental results.

- Determination of simple relationships between independent and dependent variables.
- A data sheet, as described in the next section of this Manual.

Your laboratory preparation work will be completed and turned in during the session that meets prior to the session when actual lab is performed. (Usually first 15 minutes of each practical lab session). This insures that you are prepared so that accurate and complete data is collected and that a high quality report can be written. Incomplete or inadequate laboratory work will results in a similarly inadequate report. **[Please be advised, if the preparation has not done in advance and sample problems were not solved, you will not be allowed to conduct the experiment at this time and will affect your lab grades].**

Late laboratory preparation work will NOT receive credits.

Pre-lab calculations may varies from semester to semester, so do your own work.

In –Lab quiz questions on the theory and set up of the lab will be conducted and graded as part of your lab report and preparations.

If possible, calculations should be set up as a template in a spreadsheet or other computer applications so that the changes could be easily made. This can save time and effort if the experimental setup is found to differ from the description in this manual.

III. DATA SHEETS:

A prepared paper or spreadsheet template data sheet is required as part of each pre-lab. A copy of your paper data sheet or a printout of the spreadsheet template must be handed in with your pre-lab.

It is essential that you put some thought into how to plan to collect data before you come to the laboratory session. You must design it carefully in order to help you to collect complete and accurate data. Remember that you are very unlikely to write a good report with bad or incomplete data. Items to consider:

- Your data sheet should include a sketch of your test setup including the gauge location and appropriate dimensions so that you can check the experiment is set up correctly before you start. (Usually you can get this sketch from Laboratory manual).
- How many columns of data you need? You will generally need to have two columns for each data variable and sometimes three so that scale factor and/or zero offset calculations can be made.
- Each column should be labeled so that you can remember where the data came from and what it relates to.
- The units of the data you are taking should be in your column labels.
- How many rows you need? The rows will needed to be labeled as well.

- Is there a location to put comments that relate the test setup, procedure or the collection of data?

If you plan to use a spreadsheet and enter data directly into a computer, you need to design the spreadsheet with the same consideration as above. You want to design different sheets for different part of experiment.

A sample data sheet is included in the section of this manual for laboratory #1.

IV. ACCURACY AND ERROR ANALYSIS:

The number of significant digits displayed is an indication of the accuracy of the number. With digital calculators or computer spreadsheets, it is easy to overstate the accuracy of a number. When taking measurements, the least reliable digit relative to decimal point determines the precision of your measurement. Data should not be recorded more precisely than warranted. For example, assume you are reading load of the analog dial where are tick marks every 10 pounds. If the needle is between 50 and 60 pound tick mark you could guess that the load is 54 pounds, but the 4 is not very reliable. Certainly you would not want to write down 54.3 pounds. It is somehow harder to determine a reliable with digital machines, and one would have to read the testing machine manual to determine the reliability of each range, but normally two or three significant digits is all that can be expected for the equipment used in this lab.

Finally when doing calculations, the answer cannot be more precise than the data and constants you begin with. For example if you know that the dimensions of a rectangular bar are 25.5 mm (3 significant figure) by 30.01 mm (4 significant figure) the area of specimen would be:

$$25.5 \times 30.01 = 765.255 \text{ mm}^2 \cong 765 \text{ mm}^2 \text{ (3 significant figure).}$$

From time to time you may want your spreadsheet computer or calculator to have more significant figure to avoid round-off and truncation error, but your final answer should be more precise than the original data.

Error analysis and error propagation as results of experimental data and mathematical relations shall be established and calculated. **[There will be a lecture class, normally the first session, a discussions of error analysis and propagations and method of calculations will be discussed]**

V. LABORATORY REPORTS:

The format and requirements for your laboratory reports will be set forth either in each laboratory handout or by guidelines listed below:

1. Objective of Lab Reports:

The primary objective for a lab report is to convey to the client (general public, other engineers, the professors, etc...) the information that the experimenter has collected. The report should be organized so that someone who is not familiar with the particular experiment or test set-up can understand:

- What assumptions were made,
- What procedures were followed,
- What data collected,
- What analysis was completed, and
- Which conclusions were made.

The fundamental purpose of your report is to clearly demonstrate to the professor and the instructor that you fully understand the theories, methods, variable, accuracy, data analysis involved in the particular lab.

Furthermore, engineering reports, shall be organized such that one clearly could follow your methods and procedures step by step to come to same data, calculations, and conclusions under the same circumstances.

2. Report Organization:

In general each individual lab may have its own requirements, but in general a complete report shall have at least the following:

TITLE PAGE, listing the experiment number and title, laboratory professor and instructor, laboratory sessions identification (date and time of the week), date of submittal, and report author(s).

TABLE OF CONTENT, indicating sections, sub-sections and page numbers
MAIN BODY

Objective of the experiment (or introduction to problem statements)

Procedure

Theoretical Estimation of Experimental Results (pre-lab description)

Experimental set-up and apparatus arrangements

Presentation of data, in a clean format (not raw data)

Method of analysis and sample calculations

Results of experiments and final analyzed data presentations

Conclusions (how the objective were satisfied? Was the accuracy adequate? Does the theory work? In detail explanations, etc...)

REFERENCES (if needed, but will usually at least contain this lab manual as reference)

TABULATED DATA, and detail calculations, on a clearly labeled data sheet

GRAPHS AND FIGURES (properly labeled and numbered)

APPENDICES

Appendix A- Raw Data (including the actual data sheet used in the lab)

Appendix B. – Supporting Calculations

Appendix C. –Data reduction

All pages should be numbered. Often numbering starts over in the appendices and numbering such as A-1, A-2,..., B-1, B-2, etc. is used.

3. Objective of Experiment and procedures

The objective of the Experiment and the procedure may be adapted from the objective of the experiment manual, be sure the manual is cited in the text, and listed in the references section of your report. Procedures should explain in the text configuration as well as the steps to follow to complete the experiment. Use of bullets or numbering system in this section is acceptable and often makes for clearer, more concise organization. Be sure and clearly describe if and how your procedure or the setup varied from that provided in the experiment manual.

4. Theoretical Estimation of Experiment Results:

Each lab has a theoretical component, usually summarized and performed as part of Pre-Lab assignment. The theory should be clearly explained, including the key components of the theory, equations used, and any assumptions there were made and used. You should include sample of all calculations and then a table to summarize estimates of key experimental results completed during the Pre-Lab assignment. For example a table such as below may be useful:

Table1: Estimated Strains on Beam #2

Gauge Number	Load (lbs.)	Estimated Strains (μ inch/inch)
1	P	0.02P
2	P	0.04P
3	P	-0.03P

Equations should be written using appropriate software (such as Microsoft word, or Microsoft Equation maker, or similar software). Simple equation may be created using a traditional keyboard. All equations should be indented and numbered. Equation numbers should occur at the same tab stop for all equations. As an example:

$$\beta = \frac{1/\theta}{\pi} \int_{-2}^{+5} x dx \quad (\text{Eq. 1})$$

$$\sigma = \frac{P}{A} \quad (\text{Eq. 2})$$

5. Results of Experiments

The experimental measurements should be summarized and explained in this section. This section usually will not include raw data, since that will be reserved for Appendix A. Often you will want to include tables and plots to show the summarized results. Be very careful to present numerical results with appropriately accurate significant figures. In charts and graphs, you should not curve fit a line through data points since errors (which is always present) cause the individual data points to be offset from actual phenomena being measured. A chart that presents a theoretical relationship may be presented by a continuous line if theory results in a continuous equation. An example of a complete table is shown here:

Table 2: Results From Experiment 2			
Actual Load (lbs) (measured)	Strain ($\mu\text{inch}/\text{inch}$) (Measured)	Stress (psi) (Calculated)	Predicated Strains ($\mu\text{inch}/\text{inch}$)
0	0	0	0
1020	35	6700	32
2200	72	13700	69
2350	106	20200	105

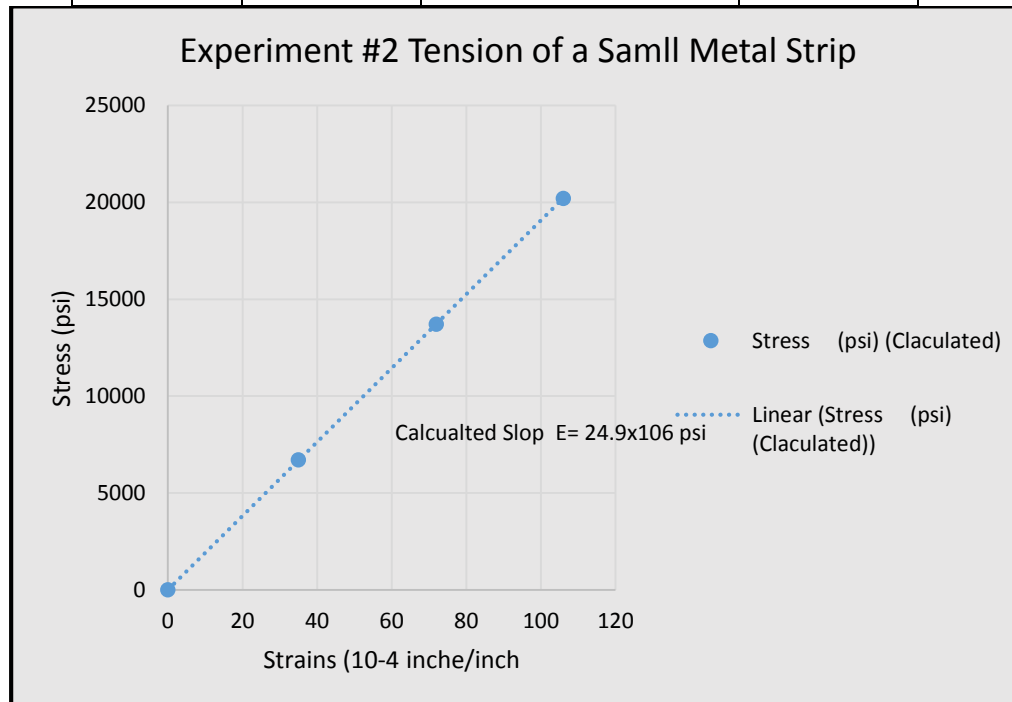


Figure 1. Stress –Strain relationship calculated from data taken in Experiment #2 on January 15, 2015 the curve was calculated using the least square function in Excel.

Note: If possible, you should present your data and prediction as plot for comparison. All plots for comparison should be the same scale. Present numerical comparisons in tables.

6. Conclusions

This section is for student to discuss the objective (found in the Manual) of the experiment were achieved and make observations and draw conclusions based on the comparison of the experimental data and the theoretical predictions Here are few examples of points that could be included:

- A qualification of difference between theoretical prediction and measured results.
- If the data and theoretical predictions are not the same, a discussion of reasons why this may have happened;
- Whether the theoretical model is appropriate for the real world specimen;
- Whether the test procedure is an appropriate method of validation of the theory;
- Difficulties that occurred in completing the experiment or data analysis.

In addition the conclusion should include at least one technical aspect of the experiment that the author understands clearly. This technical item could be related to the theory, or the assumptions that were made that would prevent the experiment from matching theory, or some functional aspects of the instrumentation, etc. If the report is a group report, the conclusion should contain one item clearly understood by each student in the group.

7. References

Any material, that is not written or derived by the lab report author(s), need to be referenced. The purpose of the citation is to provide the reader with information necessary to find item in library or internet.

8. Tables

Tables must include a table number, a title above the table, and labels at the top of each column that completely describes the content of the column, In some cases you may also need labels for the rows or subsections of the table. All labels should include units where appropriate. Since tables must be readable, you should not use a font smaller than 10 point. Tables may be presented in portrait or landscape mode.

9. Graphs

It is likely that you may use either excel or Matlab for drawing the graphs. It is very important that you understand the assumptions being made and limitations of the software

when you draw a graph. For example you should know that the difference between scatter graph and line graph in Excel.

In general data should be shown on the graph as markers without connecting lines. Theoretical predictions, or estimates of relationships developed from analysis of the data, should be shown as lines without markers. Generally a graph should be at least one half of a page so that you could fit all the relevant information on it and still use the a font that is 10 points or larger. A full page for each graph is normally recommended.

Do not fit curves to your data unless the curve being fitted is part of the theory being tested. If there is a theory being tested, the theory will provide an appropriate equation.

Graphs shall include a figure number with caption that give information about the data such as experiment number and date collected, a title at the top of the graph, the axis names and units, and an indication of which is the experiment data. You may use legend or may label points and lines. Example of a graph was given in preceding section.

10. Figures

Figures are any types of graphics that serve to support the laboratory report. Drawings of the test apparatus or specimens, as well as the graphs developed to display data are all figures. Drawings of the test apparatus and specimens are simple way to show dimensions, orientations, and loading configuration of each experiment. Figures of test set may be copied from laboratory manual if manual is properly cited, both in the figure and Appendices. Digital cameras are excellent way to acquire images to be used as figures in your report. Figures must include a figure number and a caption below the figure. The caption should clearly explain what is in the figure. If a figure is not drawn by the authors, but instead taken from another source, it must contain a citation to the reference.