CIVL2201 Structural Mechanics

Laboratory Instructions – Bending of a Channel Section

Graphs due: No later than 4 pm Thursday 21 May 2009
Report due: 2 pm Thursday 28 May 2009

General Instructions

Students are required to perform three small experiments with a common theme during the semester. This gives students the opportunity to experience some structural behaviour at close hand. The results of the experiments will be compared with the theory developed in lectures and tutorials. The experimental sessions are designed to be "self-serve" and performed without supervision.

The laboratory sessions are to be performed at a time of the students' convenience and should take approximately 1.5 - 2 hrs. The laboratory location is Room 379, in the structures lab mezzanine. To get to this room head towards the Civil Engineering Drawing Office, but just before the set of 4 stairs leading to the Drawing Office, take the long corridor on the right and Room 379 is the last door on the left.

Students are to form groups of four of their own choosing. If desired two groups of four may join together to perform each experiment and share the data. Students are encouraged to perform the experiments early in the semester, to avoid congestion at the end of the semester.

There are two beam set ups that students can use in the mezzanine lab. Students may use either. Students may need to share some equipment (eg strain gauge reader) with the other group if both beams are being used at the same time.

For safety reasons, suitable footwear should be worn in the Materials and Structures Laboratory; thongs or sandals are not permitted. Staff in the structures lab should be advised of any problems during the sessions.

Some specific and valuable equipment is required to perform the experiments. When groups arrive in the laboratory they should consult one of the laboratory technical staff (most likely Paul Burrell, Brett Jones, or Paul "Ozzy" Busstra) either in Room 276 or in the laboratory itself (downstairs). One student should give his/her student card to the staff member, who will give you the required equipment. The student card will be returned when all the equipment is safely returned at the end of your session.

The laboratory is open from approximately 8.30 am to 5.00 pm. Note that laboratory staff will generally be unavailable at morning tea (10.30 – 11.00 am) and lunch (1.00 pm – 2.00 pm). Students will not be able to commence a session after 3.30 pm. Students should allocate approximately 1.5 - 2 hours for their session.

Groups

Students are to form groups of four of their own choosing for the laboratory sessions, and should fill in the electronic form at http://www.civil.usyd.edu.au/current/undergraduate/structuralmechanicsgroups.php.

Reports

Each group is to submit a set of four reports, and each student in the group should prepare one of the reports. Each member of the group is to perform a "peer assessment" of one other member in their group using the same guidelines as the Material Properties Laboratory Report.

Laboratory reports are to be submitted by 2 pm Thursday 28 May 2009. Electronic versions of the word file and excel file should be made via WebCT. Hard copy submissions should be made directly to your tutor. Students should note that the analysis of the results and preparation of the report might take 8 - 10 hours, so students should plan to perform the experiment well before the due date.

There is a separate instruction sheet on the requirements and marking scheme for the laboratory report.

There may be an exam question related to the experimental work.

Directly copying parts of this information sheet (such as the experimental method) is not permitted in the report. The report should be in the student's own words.

It is academic dishonesty to copy and paste either word or excel data from a current or former student into your report. It is academic dishonesty to allow a student to copy your work.

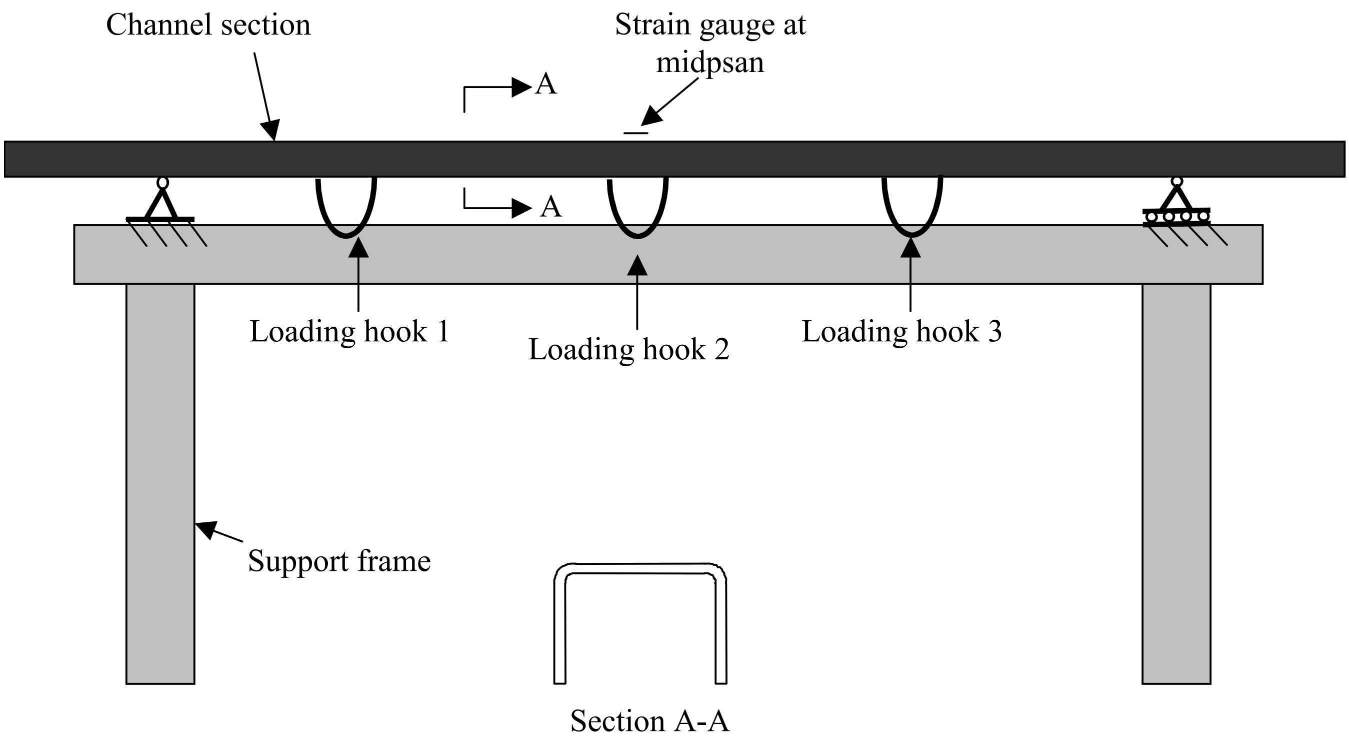
Milestone Submission - Graphs

To ensure students have sufficient time to complete the report, each group is to show a print out of their experimental result graphs or results to the lecturer no later than **4 pm Thursday 21 May**, but preferably before that time. This will also help to identify any errors that may have occurred.

The following graphs/tables are required:

Experiment 1 – Graph - Load vs displacement at midspan
Experiment 1 – Graph – Moment v curvature at midspan
Experiment 3 – Table – Strain comparison
Experiment 4 – Graph - Load vs displacement at point 1.

Diagrammatic Representation of the Test Set Up



Equipment List

2 × 300 mm steel rules
Micrometer
Wooden metre rule
3 × dial gauges for measuring deflection plus magnetic stands
Electronic strain gauge reader

Students will be required to give their student card to the staff member when the equipment is issued and it will be returned when the equipment is safely returned to the staff member.

Safety requirements and instructions

- **Enclosed shoes must be worn.**
- **Please treat all equipment with appropriate care and respect – your colleagues will be using this equipment after you.**
- **Please report any faults or damage to the laboratory staff.**

- **Read the instructions in full before commencing the experiment.**
- **Is the beam correctly centred between the supports?**
- **Do the results seem logical and consistent?**
- **Is linear elastic behaviour expected? Since the load is being increased/decreased by a constant increment, how should the displacement and strain measurements change each time?**
- **The beam clearly deflects more as more load is applied, and hence the strain must be changing. If the strain gauge readings do not change notably between increments that would suggest that either the strain gauges are not connected properly, or the battery is low or dead in the strain gauge box.**
- **Take great care not to damage the strain gauge wires.**

- **Please sign the attendance sheet on the noticeboard when you return the equipment.**
- **Please leave the work area in a clean and tidy state and take all rubbish with you.**

Experiment 1: Second Moment of Area

Outline

For a simply supported beam of length L loaded by a central point load P, the mid-span deflection is given by $PL^3/48EI$. By loading the beam and measuring the deflection, the value of I can be determined experimentally. I can also be determined from the measured dimensions of the cross-section or obtained from a table of section properties calculated by the manufacturer. **The aim of this experiment is to calculate the second moment of area, *I*, in several ways, and to compare the results.**

Prework

- Determine whether the channel is being bent about the x axis or the y axis.
- Tables of section properties are available in the appendix of the text book which is online at http://www.civil.usyd.edu.au/courses/civl2201/section_properties.pdf. The relevant table for OneSteel channels is near the very end of that document **Obtain the nominal value of *I* from that appendix**. The section being tested is nominally a 75 × 40 × 3.8 cold-formed channel section (it may be listed as a DuraGal Channel Section 75 × 40 × 4.0).

Method

- **Read all the instructions before commencing the experiment.**
- Measure the relevant cross section dimensions of the beam and the distance between supports. **Ensure that the middle hook is located at half way between the supports.**
- Attach the weight-carrying hook to the middle hook (#2) of the beam. Measure the deflection at midspan with the dial gauge. This will become the **zero reading**.
- Carefully place a 10 lb mass on the hook and determine the deflection at midspan (hook #2).
- Repeat the previous step, adding 10 lb each time and determining the deflection until the total hanging mass is 50 lb.

Results:

The section on results in each report should address at least the following issues. This section should also contain text that describes the results and should not be just a series of unrelated diagrams, graphs and equations.

- Note the *nominal* value of I from section property tables. Denote this value as $I_{nominal}$.
- Tabulate the nominal cross-section (from the appendix) and the measured dimensions and compare.
- Calculate I from the measured cross-section dimensions (I_{calc}).
- Tabulate the experimental results showing the mass (lb), force (N), and deflection (mm).
- Plot the force (y axis) against midspan deflection (x axis). Note that some data manipulation may be required to ensure that the origin of the data points is (0, 0).
- What does the slope of the graph represent? From the slope of the graph, calculate the experimental value of the of the flexural rigidity $(EI)_{exp}$ and hence the second moment of area (I_{exp}). Should the graph be a straight line? What type of behaviour does the straight line indicate? What method has been used to calculate the slope of the line?
- Include a table which clearly shows the different values of I that have been determined.

Discussion

The discussion should include anything that may be important in the experiment. The discussion should also address the following points.

- Is there a difference between the nominal dimensions published by the manufacturer and the measured dimensions? Suggest reasons why there may be a difference and how this may cause a discrepancy between $I_{nominal}$ and I_{calc}.
- What assumptions have been made in the calculation of I_{exp}?
- Which result is the best estimate of the second moment of area and why?
- Discuss any other relevant points.

It is suggested that a paragraph of approximately 100 words may be sufficient to address each of the points listed above.

Conclusion

The report should contain any conclusions that can be derived from the results of the experiment.

Refer to the general instruction sheet on lab report writing for guidance on how to write a report. The underlying question that should be asked when writing a report is "Would another engineering student from another university be able to understand this report and replicate the experiment?"

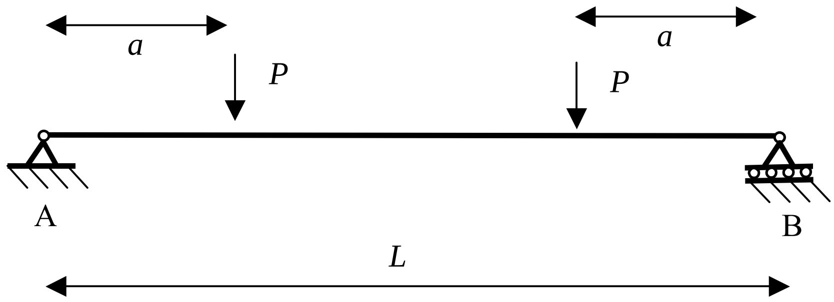
<u>Experiment 2: Stiffness & Experiment 3: Strain</u>

Outline

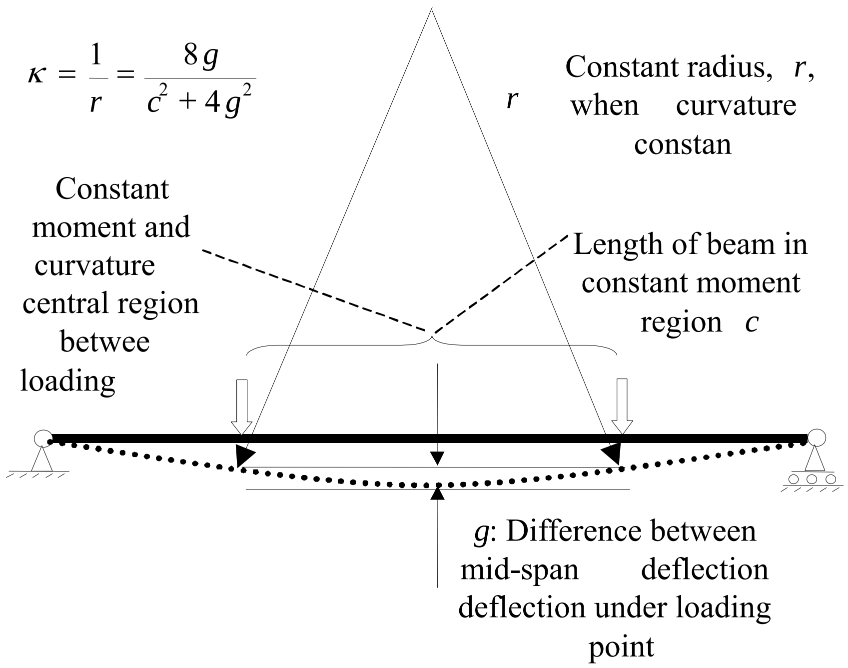
Two different experiments are combined into one. The first part involves examining the stiffness of the beam through two types of deformation – deflection and curvature. The second part calculates the strain in several ways.

Theory

In this experiment the simply supported beam will be loaded as follows. From Example 3.3.3 in the Lecture Notes, it is known that in the central region of the beam, the bending moment is constant. This implies that the curvature must be constant as well.



The curvature, κ, in the middle zone can be calculated as follows.



Method

- **Read all the instructions before commencing the experiment.**
- **Ensure that the middle hook is located at half way between the supports.** Measure the location of the outer hooks relative to the supports.
- Attach a weight-carrying hook to each of the outer hooks (# 1 & 3) of the beam. Do not load the middle hook (#2). Measure the deflection at midspan (#2) and the load points (# 1 & 3) with the dial gauge. Three separate dial gauges are required.
- Determine the strain at midspan from the strain gauge - instructions below (the strain from one of the strain gauges on the channel is required – not both). These will become the **zero readings**.

- Carefully place a 10 lb mass on hook #1 & another on hook #3 and determine the deflection at the three points (#1,2 & 3). Take the strain gauge measurement.
- Repeat the previous step, adding 10 lb each time to each of hooks 1 & 3 and measuring the deflections and strain until the hanging mass is 50 lb on each hook.

Results: (Experiment 2: Stiffness)

- Assuming each load is *P*, draw the BMD.
- For each value of load, calculate the curvature from the deflection (κ) using the theory explained above. Plot the midpsan moment (*y* axis) against the curvature (κ). What does the slope of the graph represent? From the slope of the graph, calculate the experimental value of the flexural rigidity $(EI)_{curv}$. Should the graph be a straight line? What type of behaviour does the straight line indicate? What method has been used to calculate the slope of the line?
- Plot *P* against the midspan deflection. For this loading condition, it can be proved that the midspan deflection is $Pa(3L^2 – 4a^2)/24EI$. Using similar methodology to experiment 1, calculate the experimental value of the flexural rigidity $(EI)_{defl}$.

Results: (Experiment 3: Strain)

- At each load level, calculate and tabulate the strain on the outside web face three ways:
  - Directly from the strain gauge (ε_{gauge})
  - From the moment & experimental stiffness, $\varepsilon_{exp} = (M_y\ x)/(E\ I_y)_{exp}$. (Use *EI* calculated in Experiment 2 above)
  - From the curvature determined from the deflected shape, $\varepsilon_{defl} = \kappa_{defl}\ x$ (Use κ calculated in Experiment 2 above (where *x* is the distance from the centroid to the strain gauge) for each load level.)

Discussion: (Experiment 2: Stiffness)

The discussion should include anything that may be important in the experiment. The discussion should also address the following points.

- Compare the values of *EI* calculated in this experiment, with the value of *EI* calculated in experiment 1. Comment on any differences and any possible reasons for the difference.
- What assumptions have been made in these calculations that may not be strictly true? Discuss
- Discuss any other relevant points.

It is suggested that a paragraph of approximately 100 words may be sufficient to address each of those points.

Discussion: (Experiment 2: Stiffness)

- Comment on the sets of values of strain and discuss any discrepancies between them.
- How does a strain gauge work? (about 200 words and a diagram please)
- What assumptions have been made in these calculations that may not be strictly true? Discuss
- Discuss any other relevant points.

Conclusion

The report should contain any conclusions that can be derived from the results of the experiment.

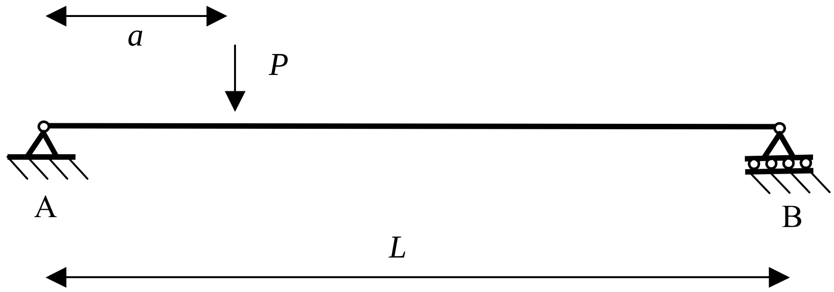
Refer to the general instruction sheet on lab report writing for guidance on how to write a report. The underlying question that should be asked when writing a report is “Would another engineering student from another university be able to understand this report and replicate the experiment?”

<u>Experiment 4: Deflections</u>

Outline

This experiment investigates the deflections of beams. The experimental deflections are compared to those predicted by theory. The deflection will be measured in two places.

Loading



Loads are placed on hook #1 only, and the deflection is to be measured at hooks # 1 & 2.

Method

- **Read all the instructions before commencing the experiment.**
- Attach a weight-carrying hook to point #1. Measure the deflection at points # 1 & 2. These will become the **zero readings**.
- Carefully place a 10 lb mass on hook # 1 and measure the deflection at points # 1 & 2.
- Repeat the previous step, adding 10 lb each time and determining the deflection at all three points until the total hanging mass from hook #1 is 50 lb.

Results:

- Draw the BMD for the general case of a load *P*.
- Write an expression for the bending moment using Macauley bracket notation.
- Determine the boundary conditions, and hence use the theory developed in lectures to establish a general equation for the deflection at any point in terms of *P* and *EI*.
- Tabulate the experimental results showing the load, and the three values of deflections.
- Plot the 2 sets of results from the previous step on the same load v deflection graph.
- Using the value of *EI* calculated in experiment 2, graph the theoretical relationship between load and deflection for point #1. Show the experimental results on this graph.
- Ignoring the applied loads, calculate the midspan deflection due to self-weight only assuming a steel density of 7850 kg/m^3.

Discussion

The discussion should include anything that may be important in the experiment. The discussion should also address the following points.

- Compare the predicted deflections with the experimental deflections. Comment on any differences and any possible reasons for the difference.
- What assumptions have been made in these calculations that may not be strictly true? Discuss.
- Has the self weight deflection affected the results?
- Discuss any other relevant points.

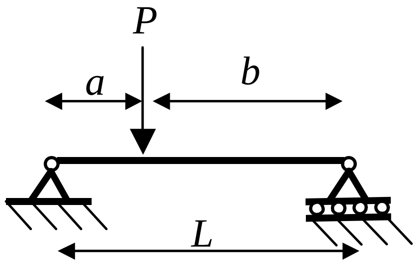
It is suggested that a paragraph of approximately 100 words may be sufficient to address each of the points listed above.

Conclusion

The report should contain any conclusions that can be derived from the results of the experiment.

Refer to the general instruction sheet on lab report writing for guidance on how to write a report. The underlying question that should be asked when writing a report is "Would another engineering student from another university be able to understand this report and replicate the experiment?"

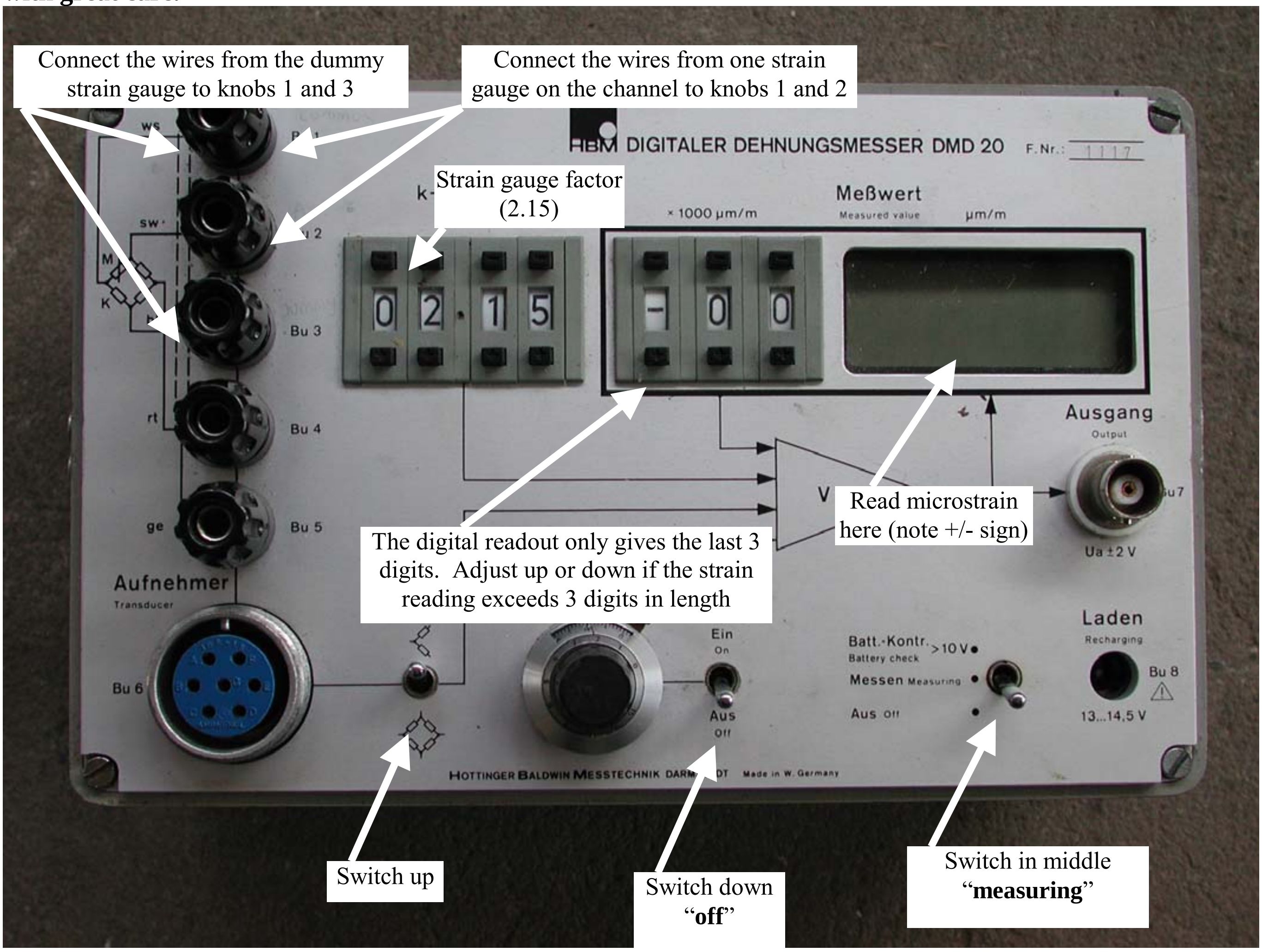
HINT



When determining the theoretical deflections in Experiment 3, students may find it easier to use the general case shown on the left, and determine deflections in terms of L, a and b, rather than using numerical values (eg 2000 mm, 1200 mm etc), and then substituting in the values of L, a and b at the very last stage. It is quite easy to make errors in these calculations, so using a and b etc is preferable.

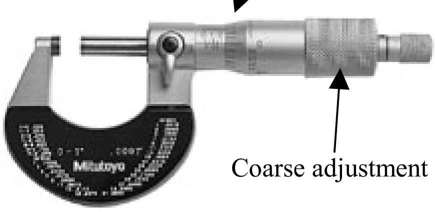
How to Obtain the Strain Gauge Reading

There are 3 strain gauges, two are on the web of the channel at midspan, and one is a "dummy" strain gauge on a separate piece of steel. To measure the strain one of the strain gauges on the channel and the dummy strain gauge must be connected to the electronic strain gauge reader. **Please treat the strain gauges and the strain gauge box with great care.**



How to use a Micrometer (to measure the thickness of the specimen)

Take readings from the barrel



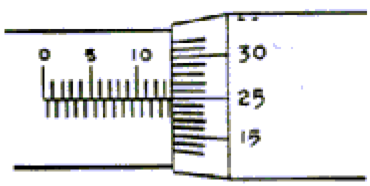
Fine adjustment (rotate until the ratchet clicks **once**)

Coarse adjustment

(Image taken from http://www.mitutoyo.com/)

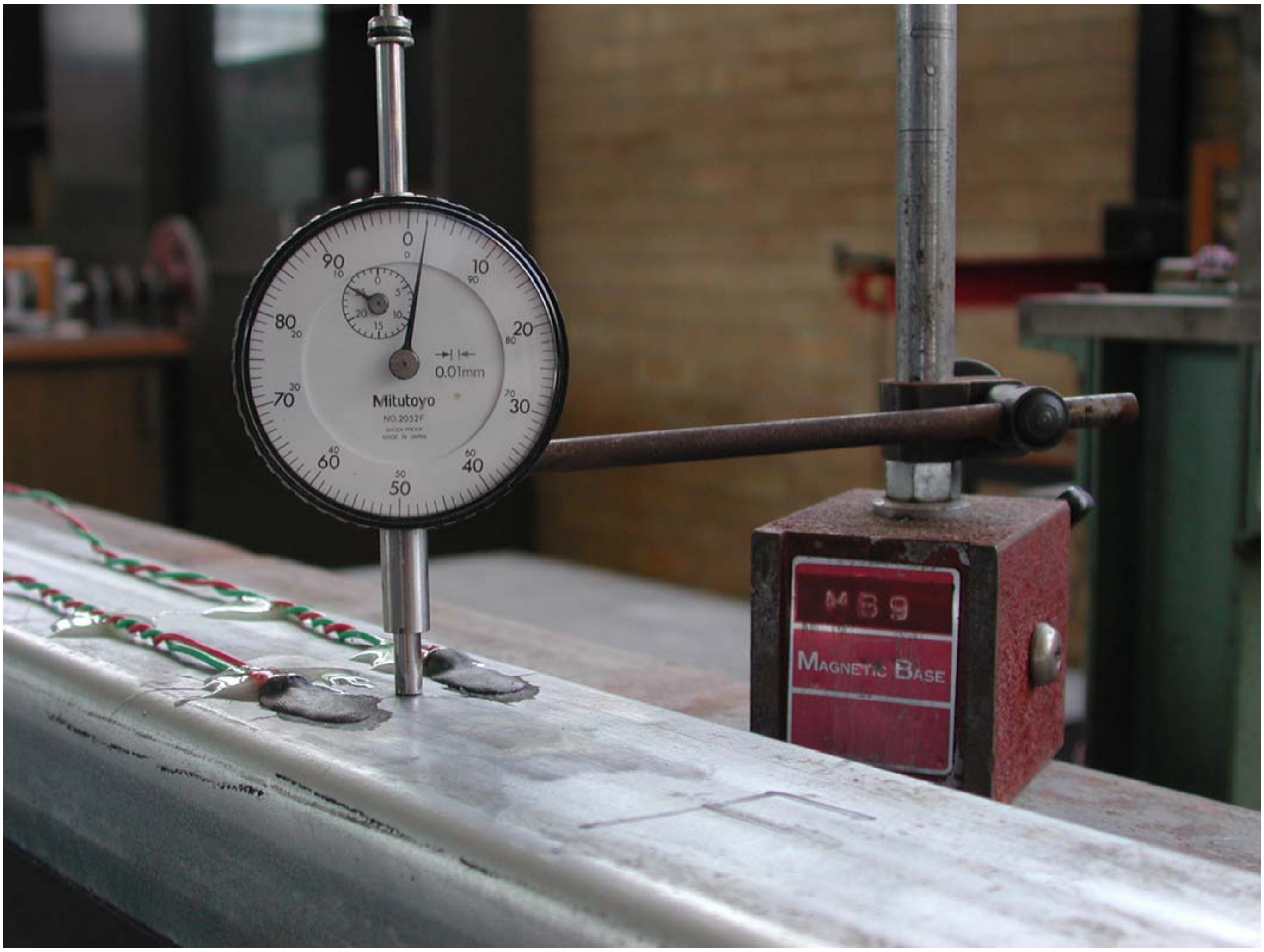
Here is another example of reading a metric micrometer:

number of whole millimeters	13	=	13.00mm
0.50mm division showing?	Yes	=	0.50mm
divisions on thimble scale	25	=	0.25mm
TOTAL		=	13.75mm



(taken from http://cghintra1.glan-hafren.ac.uk/open/quilt/engineering/reading_a_metric_micrometer_scal.htm)

How to Use a Dial Gauge to Measure Deflection



- Ensure the dial gauge is vertical.
- The large dial is in increments of 0.01 mm, and one revolution is 1 mm. The small dial shows the millimetres. This gauge reads 25.02 mm.

Zero Reading

The beginning of the experiment is normally the benchmark against which other measurements are compared. However, at the start of the experiment the instruments do not always give a reading of zero. For example at the beginning the dial gauge may show a deflection of 10.1 mm. All measurements are then relative to this. So if the next reading is 11.2 mm, then the actual deflection is 1.1 mm. A similar situation exists for the strain gauge readings.

How to Measure the Corner Radius of a Channel Section