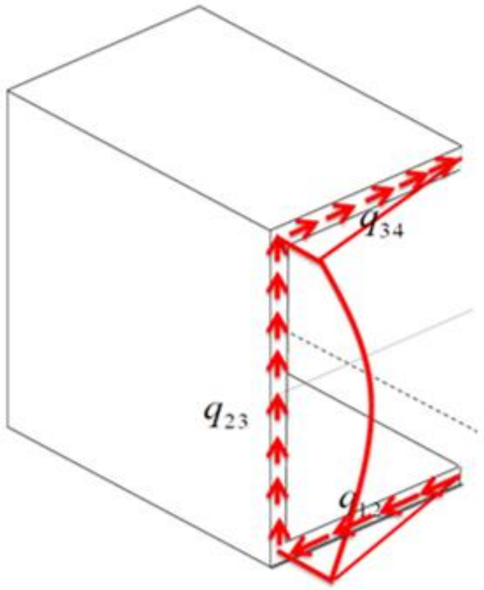
Shear Centre and Principal Axes

Laboratory Report



Imperial College London
Department of Aeronautics

Student: Xerxes Chong Xian

CID: 01389744

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Shear Centre Experiment

Experimental Procedure

1. The width, height and length of the moment arm are b, h, and W respectively.
2. Record initial inclinometer reading as the zero-value
3. Place a load of $5N$ on the hangar W_1 and record the reading from the inclinometer in mV
4. Increase the load on W_2 in increments of $0.5N$ to $2.5N$. Record each inclinometer reading.
5. Repeat step 3 and 4 for W_1 =10N and W_1 =$15N$
6. For all values of W_1, plot Inclinometer Reading vs W_2 and find intercept, $W_{2,0}$, with zero-value.
7. With $W_{2,0}$ and W_1, solve for $X_{E,Exp}$ using moments equilibrium about shear centre

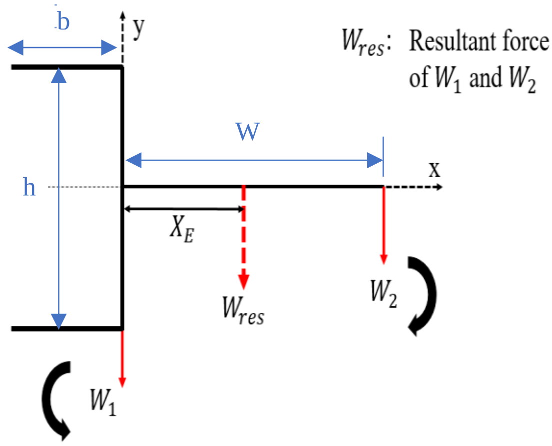

Figure 1. Experimental setup showing the dimensions and the location of the shear centre relative to the hangars

Experimental Results

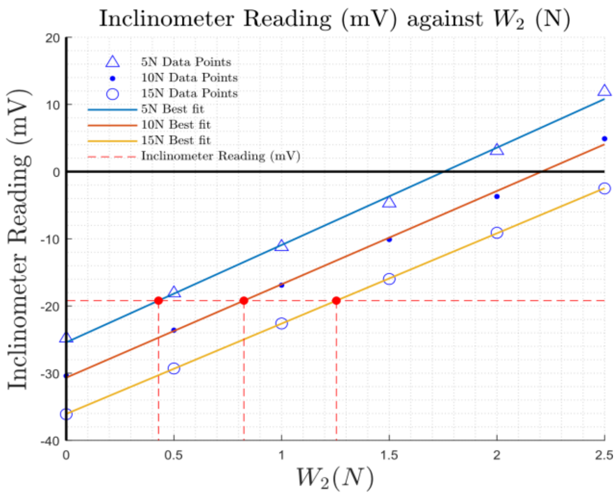

Figure 2. Graph of Rotation (mV) vs W_2 (N)

Table 1. $W_{2,0}$ and $X_{E,Exp}$

W_1 (N)	$W_{2,0}$ (N)	$X_{E,Exp}$ (cm)
5	0.426	0.986
10	0.825	0.953
15	1.255	0.965

The channel section beam is symmetrical about the x-axis, the assumption is made that the shear centre lies along the x-axis, with y=0cm. Taking moments equilibrium about the shear centre, the x-coordinate is $X_E = \frac{W \times W_{2,0}}{W_1+W_2}$. The mean of X_E found for all 3 cases of W_1 is found to be $0.97cm$. The range of theoretical values, taking into account uncertainties is found using $X_{E,Theo} = \frac{3\mu b}{1+\mu}$, with $\mu = \frac{b}{h}$.

Error analysis

The mean $X_{E,Exp}$ falls outside the range of $X_{E,Theo}$($0.907cm < X_{E,Theo} < 0.959cm$) The deviation can be attributed to the errors below,

1. The use of a ruler introduced a degree of uncertainty, $\pm 0.05cm$ into the theoretical readings given the ruler's precision of $\pm 0.1cm$. The curvature of the corners of the channel section beam also made measurements difficult. The use of a digital Vernier calliper will have reduced this degree of uncertainty to $\pm 0.01mm$.
2. The inclinometer set-up at the centre of the beam will have altered the properties of the beam. The mass of the clamp was not taken into the account during the experiment. This additional mass mounted on the beam will have contributed to the twisting of the beam, altering the experimental X_E.
3. The zero-load reading on the inclinometer increased from a value of $-19.2mV$ to $-19.1mV$ before and after the experiment was conducted. This suggests elastic hysteresis is present due to internal friction within the beam that resisted the twisting motion. This would have lowered $X_{E,Exp}$.
4. W_1 was assumed to be aligned with the centroid of the vertical wall of the beam. Any small misalignments ($\pm$) from the centroid, will have contributed to a deviation in the zero-value on the inclinometer. It is postulated that there was a positive misalignment, towards W_2, contributing to a larger positive rotation of the beam, and hence the larger than expected $X_{E,Exp}$ obtained.

Principal Axes Experiment

Experimental Procedure

1. Measure the width, height of the bar are **b** and **h**
2. Zero strain gauge dials for displacements δ_y and δ_x
3. Place 5N on the hangar W_y. Increase W_x in increments of 0.5N from 0N to 3N. Record gauge readings
4. Unload hangars. Record values on the strain gauges.
5. Repeat step 2 and 4 for W_y =10N. Increase W_x in increments of 0.5N from 0N to 5N
6. For each W_y, plot displacement ratio, $\frac{\delta_x}{\delta_y}$ vs weight ratio, $\frac{W_x}{W_y}$ and a line of best fit. Find intercepts with the line $R_D = R_W$.

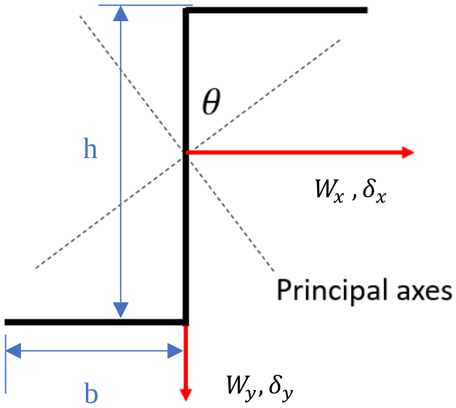

Figure 3. Experimental setup showing the dimensions and principal axes orientation

Experimental Results

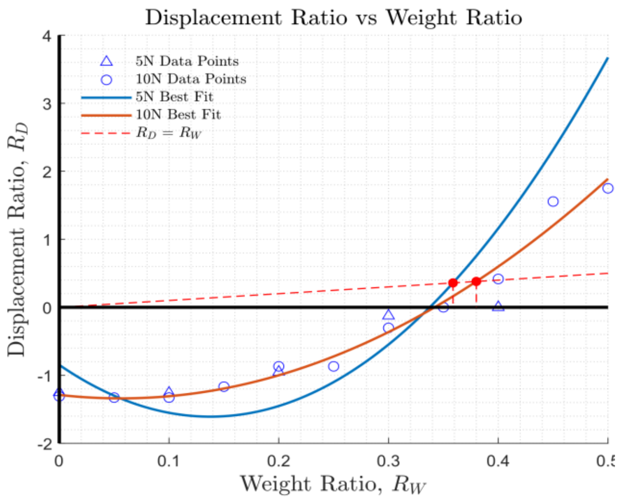

Figure 4. Displacement Ratio to Weight Ratio

Table 2. $R_{W,intercept}$ and θ_{Exp}

W_y (N)	$R_{W,intercept}$	θ_{Exp} (°)
5	0.359	19.7
10	0.380	20.8

From the intercepts of the graph, the theoretical orientation is $\tan\theta_{Exp} = R_{W,intercept}$. The mean of θ_{Exp} for the 2 cases of W_y is found to be 20.3 °. This resultant force applied is acting in a direction 20.27 ° *from the vertical axis*. From observation, the channel section beam's length is at least $20\times$ of its width, **b** and of its thickness, **t**, satisfying the Engineer's Theory of Bending definition of a long slender beam. Hence the theoretical orientation of its principal axes, after accounting for uncertainties in calculating μ, gives θ_{Theo}, $21.7° \leq \theta_{Theo} \leq 22.8°$.

Error analysis

The mean θ_{Exp} lies outside the range of θ_{Theo}. This deviation is attributed to the errors below;

1. Like the shear centre experiment, the use of a ruler to measure the dimensions **b**, **h** and **t** introduced a degree of uncertainty, 0.05cm into the theoretical readings given the ruler's precision of $\pm 0.1cm$. The curvature of the corners of the channel section beam also made measurements difficult. The use of a digital Vernier calliper will have reduced this degree of uncertainty to $\pm 0.01mm$.
2. The wires attached to the strain gauge set-up for δ_y and δ_x are assumed to be parallel to the y and x-axis respectively. As the loads on W_x are increased, the increasing deflections would have caused the wires to bend, increasing or decreasing the amount of strain recorded by the gauges. The mass of the clamp was not taken into the account during the experiment. In addition, the mass of the clamp mounted on the beam will have further contributed to this deflection.
3. The reading on the strain gauges after the hangars were unloaded were not at zero values. Like the shear centre experiment, this indicates elastic hysteresis. In this case, this is largely attributed to the kinks in the wires attached to the strain gauge. The loading and unloading of weights will have unwounded the some of these kinks, leading to a non-zero reading at the end of experiment. The internal friction within the bar that resist deflection will have possibly lowered the strain readings.
4. The hangars for the weights were attached using pulleys. The friction between the wires and pulleys as well as the presence of kinks affects the transmission of force applied. Hence not all the force was used to deflect the beam and was instead used to overcome friction/unwound kinks. Therefore, more weight will be needed attain a similar theoretical outcome.

Appendix

Table A.1 Chamber section dimensions in (cm)

Beam width, b	Beam height, h	Beam thickness, t	Length of moment arm, W
2.50	5.10	0.15	12.50

Table A.2 Z-section dimensions in (cm)

Beam width, b	Beam height, h	Beam thickness, t
2.60	5.20	0.20

Table A.3 Inclinometer readings in (mV) for shear centre experiment

	W_1 (N)					
W_2 (N)	0	0.5	1	1.5	2	2.5
5	-24.8	-18.1	-11.2	-4.7	3.1	11.9
10	-30.4	-23.6	-16.9	-10.1	-3.7	4.9
15	-36.1	-29.3	-22.6	-16.0	-9.1	-2.5

Table A.4 Horizontal and vertical strain gauge readings in (mm) for principal axes experiment. The readings highlighted in red were identified as erroneous and excluded from the polynomial fitting.

		W_1 (N)										
W_2 (N)	Axis	0	0.5	1	1.5	2	2.5	3.0	3.5	4	4.5	5
5	δ_x	-0.150	-0.170	-0.095	-0.001	0.00	**0.110**	0.110	-	-	-	-
	δ_y	0.120	0.135	0.100	0.008	0.008	**0.150**	0.150	-	-	-	-
10	δ_x	-0.360	-0.365	-0.365	-0.315	-0.165	-0.165	0.00	0.500	0.140	0.140	0.00
	δ_y	0.275	0.275	0.275	0.270	0.190	0.190	0.140	0.120	0.009	0.800	0.140