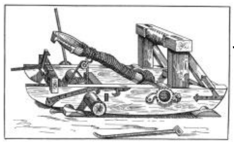
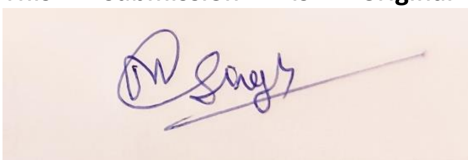


NAME: Meharamt Singh Roll No: 102003241 Group: 2CO10

This submission is original work and no part is plagiarized (signed)



(Date) 19.10.2021

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

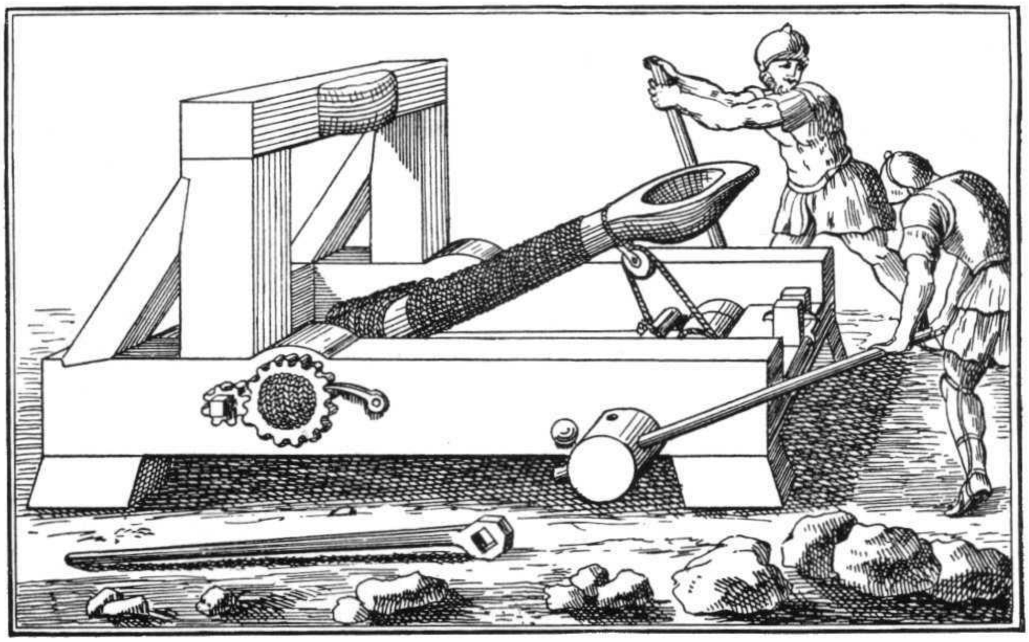
MECHANICAL ENGINEERING DEPARTMENT

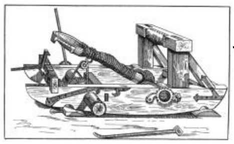
Thapar Institute of Engineering and Technology, Patiala

ASSIGNMENT - 3.
DESIGN AGAINST FAILURE UNDER *STATIC* ACTIONS

UTA016 Engineering Design Project-I

Name – Meharamt Singh
Roll No. – 102003241
Group – 2CO10





NAME: Meharamt Singh Roll No: 102003241 Group: 2CO10

ASSIGNMENT - 3

STRUCTURAL ENGINEERING COMPONENT
DESIGN AGAINST FAILURE UNDER *STATIC* ACTIONS

Complete the following **individually, copying will be dealt with severely.**

Instructions:

1. Data to be used for excel spreadsheets graphs to be created for Q1, Q2 and Q3 is (will be provided by the respective lab instructors):

Exp. No	Span, L mm	Width, b mm	Height, d mm	Failure load, mass kg
1				
2				
3				
4				
5				
Average				

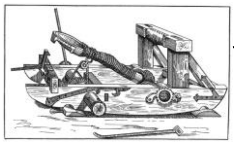
2. **Excel spreadsheets graphs to be created for Q1 and Q2 will evaluated by end of tutorial class**. Remaining questions is to be submitted before next tutorial class (if it is a holiday, then as instructed).

Despite this list, try and enjoy the assignment and try to think around the subject as much as possible and take from it any tips that you might use with your own Catapult.

When you have built your own mangonel, with your own choice of rotating arm, L2 part (i.e. spoon: material, diameter and length) and having measured the rotational velocity on impact using the electronic component of this project, then the procedures in Assignments 3 and 4 should allow you to make a reasonable prediction as to whether your chosen arm is likely to fail statically when fully loaded or dynamically when the missile is released. It would clearly be desirable to avoid an unexpected structural failure of any part during the final showcase.

Marking Scheme: Assignment 3 (5 Marks)

1. **Evaluation at end of Tutorial: 2.5**
2. **Evaluation from printout submission:2.5**



NAME: Meharamt Singh Roll No: 102003241 Group: 2CO10

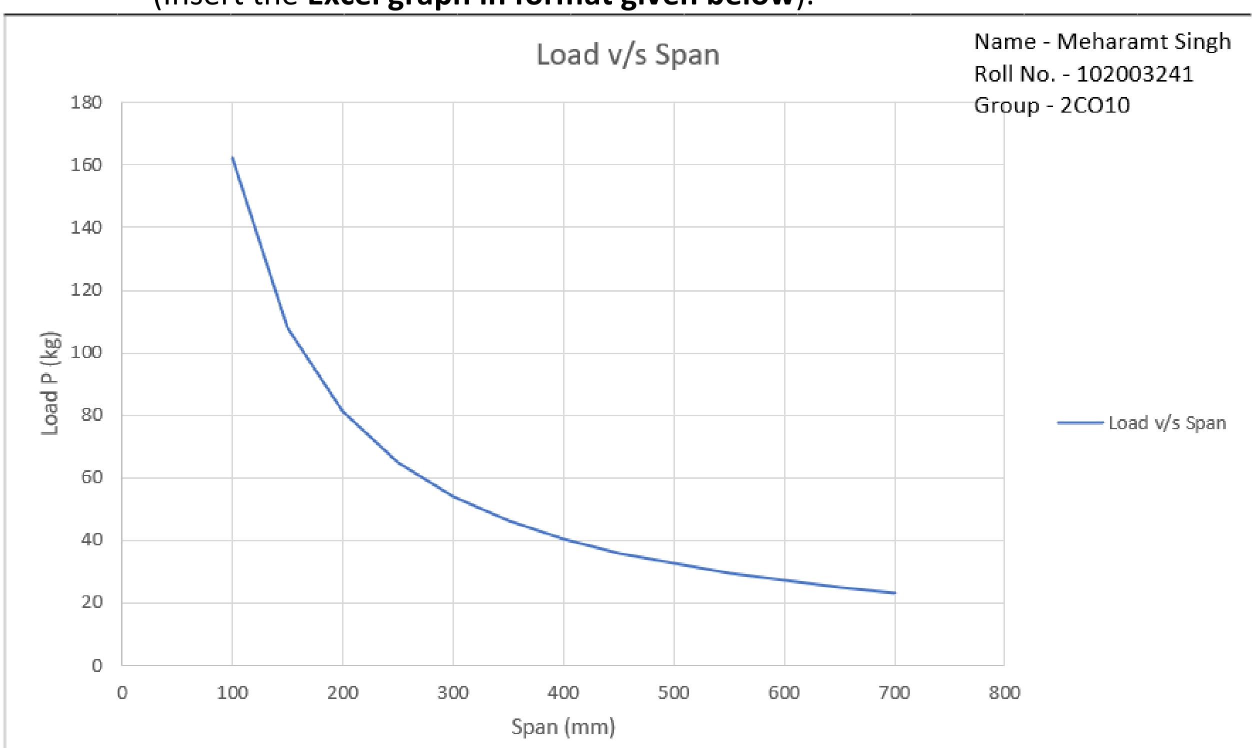
Q1 From experiments, you measured experimentally the bending stress at failure of a timber beam (**Calculate in Excel sheet the Average Stress at failure for the experiments**). (**<u>Evaluated on laptop, use format below</u>**)

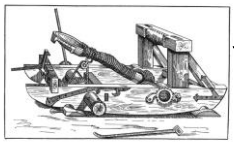
	Measured				Calculated				
Exp No	Span L mm	Width b mm	Depth d mm	Failure load mass Kg	Failure Force P N	M=PL/4 Nmm	y=d/2 mm	I=bd^3/12 mm^4	Strength σ MPa(N/mm^2)
1	300	9.65	4.88	6.3	61.803	4635.225	2.44	93.45564	121.0194328
2	300	9.8	5.26	5.35	52.4835	3936.263	2.63	118.85709	87.10392779
3	300	9.7	5.35	5.5	53.955	4046.625	2.675	123.78039	87.45102665
4	300	10	5.1	4.25	41.6925	3126.938	2.55	110.5425	72.13235294
5	300	9.99	5.06	4.7	46.107	3458.025	2.53	107.85388	81.11718242
6	300	9.99	5.06	6.7	65.727	4929.525	2.53	107.85388	115.6351324
Av	300	9.855	5.118333	5.46666667	53.628	4022.1	2.559167	110.38951	**94.07650917**

Q2 Using the average strength of wood from Q1 calculate the theoretical variation in failure load, P, when the span of the beam is varied over the range from 100-700 mm, for the same dimensions in Q1, and **draw a plot** of the relationship. (**<u>Evaluated on laptop</u>**)

$P=4\sigma I/yL$

(Insert the **Excel graph in format given below**).

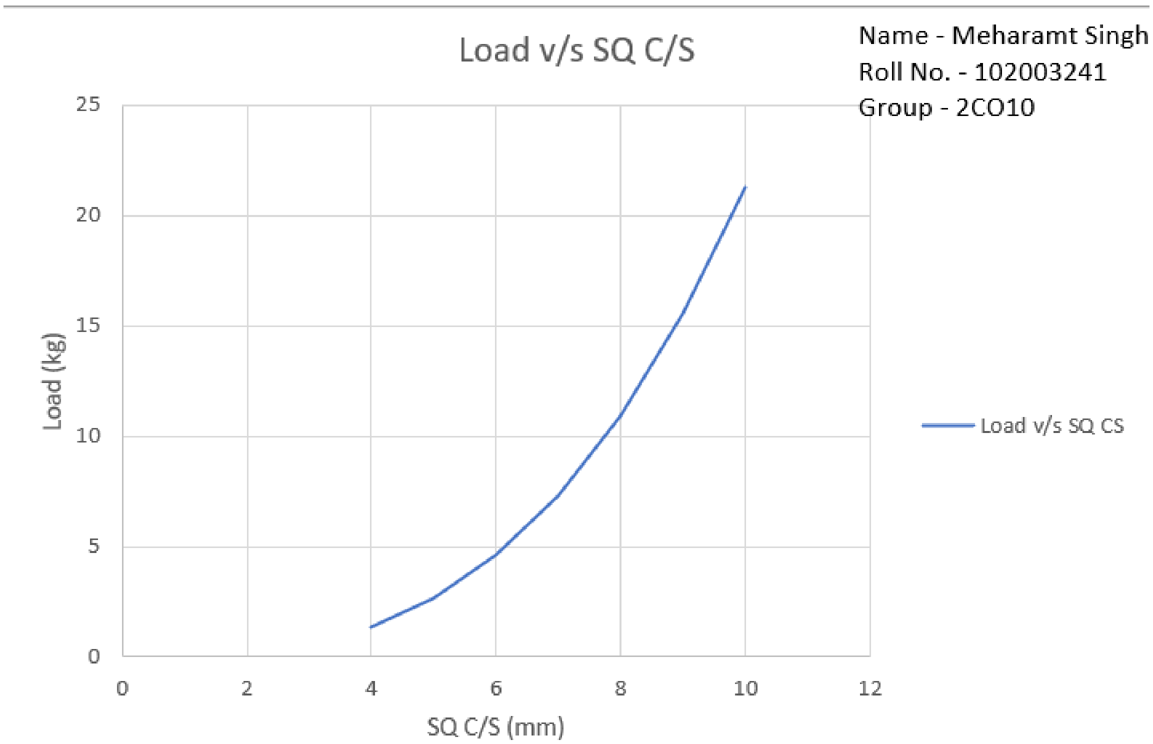


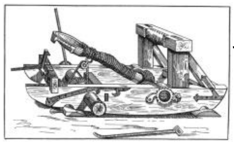


Q3 Using the average strength of wood from Q1 calculate the theoretical variation in failure load, P, when the cross sectional dimensions of the beam are varied over the range from square of 4-10 mm (for the same span as was used in Q1 and **draw a plot** of the relationship.

(Insert the **Excel graph in format given below**).

$P=2\sigma d^3/3L$





NAME: Meharamt Singh Roll No: 102003241 Group: 2CO10

Q4 For Q1. Assuming the square cross section of 6 mm and a span of L = 200 mm calculate **theoretically** the failure stress (strength) for a simply supported beam which fails due to a 5 kg weight.

(4). $L = 200\ mm$ $b = d = 6mm$ load $= 5\ kg$

Failure force $= P = mg = 5 \times 9.81 = 49.05N$

$M = \frac{PL}{4} = \frac{49.05 \times 200}{4} = 2452.5\ N\,mm$

$I = \frac{d^4}{12} = \frac{6^4}{12} = 108\ mm^4$

$y = \frac{d}{2} = \frac{6}{2} = 3\ mm$

failure stress (strength)

$\sigma = \frac{My}{I}$

$= \frac{2452.5 \times 3}{108}$

$= 68.125\ N/mm^2$

Failure load $= \frac{2\sigma d^3}{3gL} = \frac{2 \times 68.125 \times 6^3}{3 \times 9.81 \times 200}$

$= \underline{5kg}$

Q5 A second beam of dimensions 9x9 mm and span L = 500 mm was tested and found to fail at 7 kg. Theoretically, what value should it have failed at? Explain any discrepancy in your result if there is one. What do you learn from this?

(5) Dimensions = 9x9 mm $L = 5$ m $b = d = 9$ mm

Failure Load = 7 kg $y = \frac{d}{2} = \frac{9}{2} = 4.5$ mm

Failure force = $P = mg = 7 \times 9.81$

$M = \frac{PL}{4} = \frac{68.67 \times 500}{4} = 8583.35$ N mm

$I = \frac{bd^3}{12} = \frac{9^4}{12} = 546.75$ mm

Failure stress (strength) = $My/I = \frac{8583.75 \times 4.5}{546.7} = 70.64$ N/m

Failure load = $\frac{2\sigma d^3}{3gL} = \frac{2 \times 70.64 \times 9^3}{3 \times 9.8 \times 500} = 6.9998$ kg.

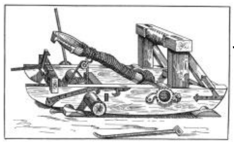
Here, the result shows that given beam can bear max. load of 6.9998 kg or it will break. & there is no discrepancy.

Q6 What do you observe from the plot of Q2?

(6) with the increase in span load the bearing capacity of simply supported beam decreases.

Q7 What do you observe from the plot of Q3?

(7) with the increase in cross-section, the load bearing capacity of beam increases.



NAME: Meharamt Singh Roll No: 102003241 Group: 2CO10

Q8 **Now let us address the Catapult.** Assume the length of the throwing arm of the Catapult is 240 mm from the axis of rotation to the D-ring. Select the optimum diameter and so that the arm does not fail in bending under static loading. The worst case of static loading is when the arm is fully pulled back and ready to release. You should use a peak static force of 120 N in your calculation. Note! The end conditions of the arm are different to those in class experiments, i.e. it is not simply supported! Refer to notes handout to determine which equation is appropriate for this cantilevered condition. Is the diameter of the throwing arm of 28 mm adequate? Comment.

(8) $L = 240$ mm

$P = 120N$

σ (Avg from Q 1) $= 94.07650917$ N/mm^2

We know that, $\frac{M}{I} = \frac{I}{\rho}$

$M = PL$

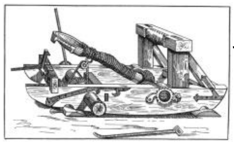
$I = \frac{\pi}{64} d^3$

$$\frac{PL}{\left(\frac{\pi d^4}{64}\right)} = \frac{11.7 \times 10^9}{500}$$

$$\frac{120 \times 280 \times 64}{\pi d^4} = \frac{11.7 \times 10^9}{500}$$

$d = 39.8$ mm

Hence, the req. diameter, so that the arm doesn't fail in bending under static condition is 39.8 (∴ 28 mm is not adequate :)



NAME: Meharamt Singh　　Roll No: 102003241　　Group: 2CO10

Q9 For the conditions in Q8:

a. Can the nylon cable holding the main arm in place, when cocked, resist the force without breaking? What is the FOS? You may assume that the axial failure stress of the cable is 65 MPa (i.e. N/mm^2) and that the cable has a circular cross section of diameter 2.4mm.

(9) (a) $F = 120 N$　　$d = 2.4 mm$　　Failure, stress $= 65 MPa$

$r = d/2 = 1.2 mm$

Allowable stress $= \frac{P}{A} = \frac{120}{3.14 \times 1.2 \times 1.2} = 26.539$ MPa

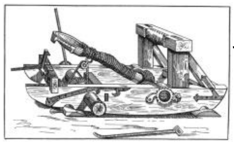
Factor of safety is ratio of failure stress to allowable stress

$FOS = \frac{65}{26.539} = 2.45.$　　$\sigma = \frac{4P}{\pi d^2}$

$P = \frac{65 \times 3.14 \times (2.45)^2}{4}$

$= 293.904 N$

Max. force that nylon is able to bear w/o breaking is 293.904 N, so it will be able to resist 120N of force.



b. The other end of the cable is attached to a timber dowel 20.5 mm diameter which is held in double shear by the base of the Catapult. Design the minimum diameter of dowel that is required to resist this force without it failing in shear. You may assume the shear stress capacity of the dowel is 15 MPa. What is the FOS of the dowel of your Catapult?

(b) Dowel diameter = 20.5 mm

Shear stress = 15 MPa

$FOS = \frac{\tau_s}{\tau_a}$

$\tau_s = \frac{P}{\left(\frac{\pi d^2}{4}\right)}$

$P = \frac{\pi d^2 \tau_s}{4}$

Putting values, we get.

$P = \frac{3.14 \times 20.5 \times 20.5 \times 15}{4}$

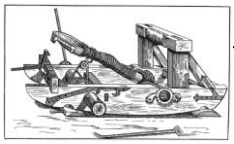
$= 4948.4437$ N

$\tau_a = \frac{P}{2\left(\frac{\pi}{4} d^2\right)}$

$= \frac{2 \times 4948.4437}{3.14 \times (20.5)^2}$

$= 7.5$ N

$\therefore FOS = \frac{\tau_s}{\tau_a} = \frac{15}{7.5} = 2$



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Q10 Using the library and /or the internet for referencing, compare the strength of timber in bending with a variety of other available materials. Produce a table of the relevant properties and comment on their suitability for use as the main arm in a Catapult. You will use this information as well as the analysis techniques above to help you redesign/optimise the throwing arm.

Sr No	Material	Strength in Bending	Comment
1.	Plastic		
2.	Acrylic		
3.	Glass		
4.	Aluminium		
5.	Stainless Steel		

(10)

Sr. No	Material	strength in Bending	Comment
1	Plastic	15	Plastics are very weak, in comparison to timber That is the reason due to which it can't be used to make a sustainable main ar in a catapult.
2	Acrylic	70	Acrylic is strong material in comparison to timber that is why we can use it to make the arm of catapult
3	Glass	7	Since, glass has the least strength is the weakest amongst all. Therefore. it can't be used.
4	Aluminium	90	It can be used as it's strength is greater than acrylic & also a decent value.
5	Stainless steel	505	Strength of stainless steel is highest but still it can not be used. Since, it is not a flexible material & thus, it cannot bend.

M Singh

Note!! The end conditions are different in Q1-Q7 (simply supported) from that of the Catapult (cantilever) in Q8 onwards. The equation for the bending stress will therefore be different!