Grade 10 – Semester 1

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THE MASONRY BEAM

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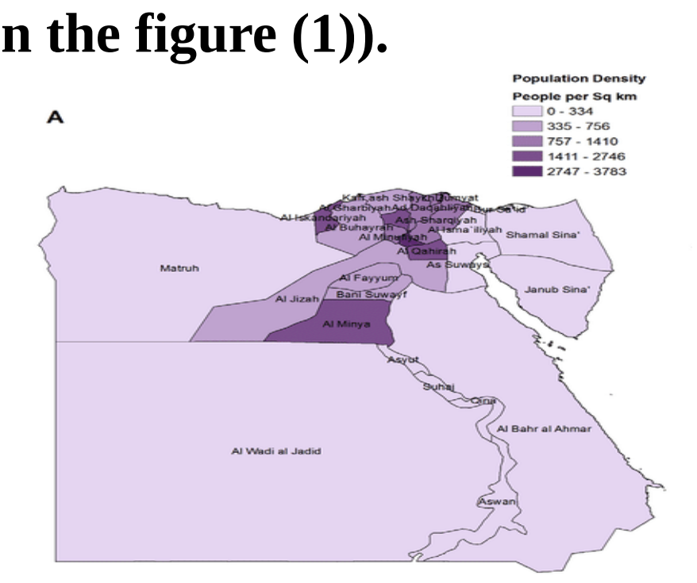
Abstract

It is well known that a leading country exploits every inch of its land. Egypt, on the other hand, did not do so. It is clear that Egypt suffers from arid areas problem despite its high population density. During research, it was discovered that arid areas cover approximately 96 percent of Egypt's land area, with only 1.7 percent of the population concentrated there, while the remaining part is concentrated around the Nile. That is to say, Egypt has two interconnected problems: arid areas and urban congestion. Egypt seeks to construct about 17 new cities in the western desert to deal with the increasing population concentrated in almost 4% of Egypt's area only. To support Egypt in solving these problems, a construction element using alternative building materials should be built, and the beam was chosen to be that element. On the beam's construction, certain requirements must be met. The beam must be made of a non-metallic material that can withstand a force of at least 50 newtons with a maximum deflection of 10mm. To meet these requirements, the idea of a prototype was born. A rectangular beam is made up of small cuboids of plywood that are glued together in a specific way known as the stretcher bond design, which helps distribute the load quickly along the beam. The test plan demonstrates how effective the beam is. Based on our findings, we believe that using various alternative building materials in construction is a viable solution to arid areas and urban congestion.

Introduction

Egypt is affected by plenty of problems which are called grand challenges, and as Egyptians, these grand challenges must be solved. Arid areas in Egypt are a grand challenge that we are attempting to solve. The western Sahara, the eastern Sahara, and the Sinai Peninsula are the three main desert zones. These areas cover around 96 percent of Egypt's land area and have a population of around 1,760,000 people (as shown in the figure (1)).

People are more likely to leave these arid areas and migrate to the Nile and delta regions due to a shortage of water and work opportunities, resulting in urban congestion, which is another grand challenge. To solve these major problems, the root of the problem has to be found which is the lack of alternative building materials.



figure(1): Population density in Egypt's governorate.

Building materials have been an important problem in Egypt. The construction field in Egypt depends on traditional building materials like cement and steel, but they have bad impacts like water pollution and increasing climate change.

For these reasons, A lot of searches had done to find other solutions that have already been tried attempting to solve such a problem. For example, insulated concrete forms (ICF) are a type of wall construction material that is considered an environmentally friendly technique of construction. One of its strengths is its resistance to fire. ICF walls can withstand four-hour fire exposure. However, it does have weaknesses, one of which is humidity. In an ICF home, humidity might be a challenge. The internal humidity has risen as the concrete continues to dry. The humidity level in the air should return to normal once the air has dried completely Another solution is using bamboo instead of steel for construction as Bamboo has higher tensile strength than steel, but Bamboo also suffers from the disadvantage of shrinking substantially more than any other wood species, particularly when water is lost

After problem has identified well, the design requirements as follow. The project requires a non-metallic constructed element that can withstand at least 50 newtons of force with a maximum deflection of 10mm. Within the test plan, Loads should be added gradually while the resulting deflection is measured until the element breaks to determine the load-to-weight ratio.

After a lot of researches have been done to find the best solution for the problem of lack of alternative building materials, we found out that building a beam with alternative building materials to replace steel beam is one of the most effective solutions. The beam will be made of wooden cuboids with dimensions that don't exceed 3 cm. This beam must be made of reliable materials and connected by scientific methods which discussed in the next part.

Materials & Methods

There are some materials and other methods that must be used to construct the prototype. Materials should be chosen based on their ability to fulfil the project's design requirements.

Material	Plywood	(PVA)White glue
Description	The prototype building material, we use a specific type of plywood which is Birch plywood	The binding agent of the prototype
Quantity	105 cubes (Not identical)	400gm
Picture		

Table(1):Table of Materials.

The prototype was constructed in a flat-shaped design as shown in figure (2) with the dimensions of 2.2±0.05cm x 7.45±0.05cm x 50cm and consisted of two identical layers of plywood pieces. Each layer had the dimensions of 1.1cm x 7.45cm x 50cm and was glued together with PVA.

Figure(2): Rectangular beam.

First, each layer was constructed by making the dimensions (where the height was set at 1.1 cm, the width at 7.45 cm, and the length at 50 cm), which was complemented by sticking the pieces of plywood together with PVA.

Second, each layer was constructed with a different number of pieces and with different dimensions of pieces according to the design which is called stretcher bond to make every block above 2 halves of another 2 blocks (as shown in figure (3))

Figure(3): The two surfaces of the beam.

Third, the two layers with different distributions of pieces were stacked together by PVA to achieve the stretcher bond style (as shown in figure (4)).

Figure(4): 1 Block above 2 halves of other blocks.

Test Plan

After the prototype has been installed, it is time to test it to see if it met the design requirements.

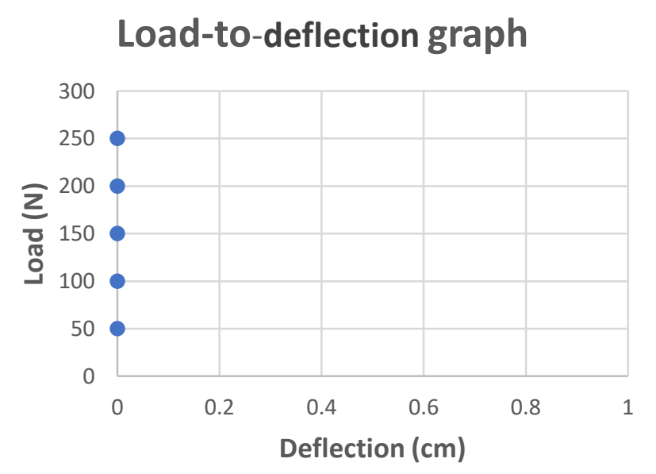
- **First**
  - The weight of the beam was measured to calculate the load-to-weight ratio later.
- **Second**
  - The beam was put above two supporting point according to 3-point flexural test (3cm of each end will be considered as a support point).
- **Third**
  - The loads were hanged on the beam from the middle with cord.
- **Fourth**
  - The loads were hung in sequence, 500 grams at a time, and the deflection was measured by using vernier caliper at each time.
- **Fifth**
  - The loads were hung sequentially until the beam broke to calculate the load-to-weight ratio.
- **Sixth**
  - The magnitude of loads which was hanged in the highest deflection point was taken to determine the load to weight ratio.

Results

Negative results

Our first test plan obtained negative results, as shown in (graph 1), the beam could withstand a 50N load without deflection.

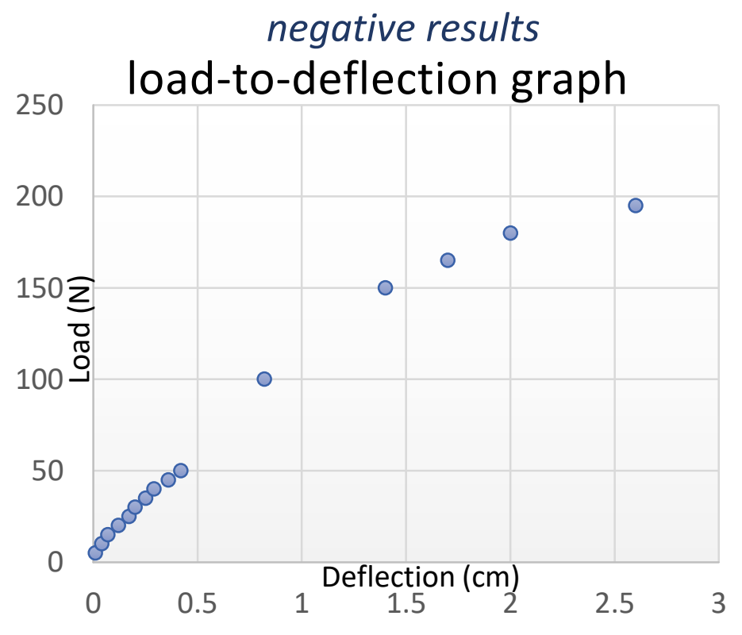
The negative results were analyzed (found in the Analysis section) and made changes until the positive results appeared, as shown in (graph 2).



Graph(1):load-to-deflection graph in negative results

Positive results

-The beam bears 50N with a deflection of.... and it can withstand 195N without being broken, and that meets the design requirements, so the beam is successful. The weight of the beam is 518g, so the load: weight ratio is 19.5:5.18= 37.6. This means that the beam can withstand 37. 6 times its weight.



Graph(2): Load-to-deflection graph.

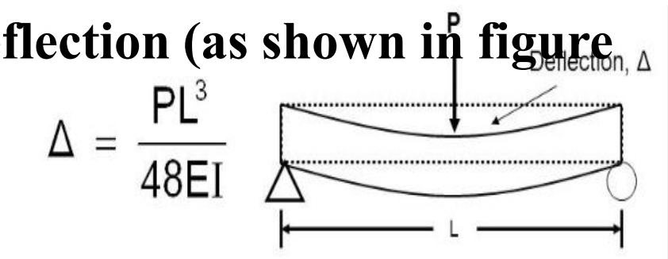
-The maximum stress of the beam is calculated by dividing the "maximum load" by the "surface area of the beam" which is equal to 195 ÷ (0.5×0.075) = 195÷0.375 which is equal to 5,200 Pa and the standard steel beam ranges from 36 to 50 ksi.

Analysis

Various materials and building designs were discovered during the research, so the correct strategy was to analyze each one to determine which one is suitable.

Building Material analysis:

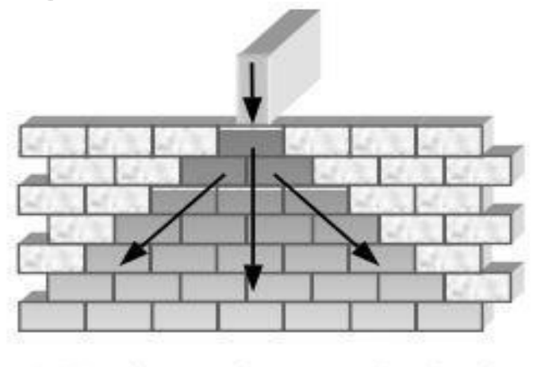
Plywood is used for a variety of reasons that can help us fulfil design requirements. First and foremost, it has a high strength-to-weight ratio. The second factor is its sustainability (The ability of a material to withstand external forces is referred to as sustainability).Thirdly, Plywood is corrosive-resistant due to its resistance to fungal attack. In comparison to other woods, it is a good building material. The significant factor of plywood to our project is its high elasticity (about 11901 $N.mm^{-2}$ parallel to the grain and 1200 $N.mm^{-2}$ across the grain) which is inversely proportional to beam's deflection (as shown in figure (5)).



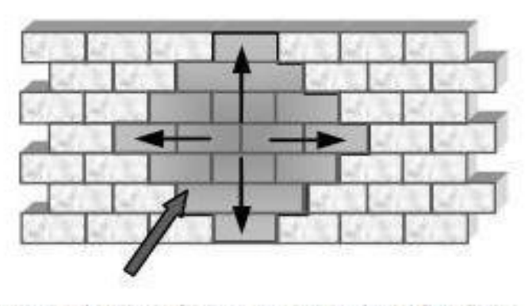
Figure(5): Deflection law.

Design analysis:

The beam design idea is inspired from the Masonry bonding system. The Masonry bonding is the arrangement of building units in a structure such as a wall or column. The building units can be laid as soldiers (standing upright), stretchers (laid lengthwise along the wall) or headers (laid width wise along the wall). The most widely used bond is a pattern that is made only using stretchers, which is called stretcher bond. It's the most used as it's the easiest to construct and reduces the used material for better results. It connects each course by half a brick above and below. The stretcher bond was used to manufacture the beam because when adding weight on the beam, distribution due to in-plane loading occurs in the shape of a triangle because 1 wooden block is above 2 so the load is distributed on the 3 blocks. (Shown in figure a) and distribution due to out-of-plane loading occurs in a rhombus shape. (Shown in figure b).



(a) Distribution due to in-plane loading



(b) Distribution due to out-of-plane loading

Negative results analysis

Negative results were obtained during the test plan as the beam didn't meet the design requirements. The beam could withstand more than 50N with no deflection. During research about the reasons, it was found that the second moment area plays an important role in deflection which resists bending. In order to minimize the second moment area, we should minimize the cross-section area because the cross-section area is directly proportional to second moment area (as shown in figure (6)).

$$I_x = \frac{bh^3}{12}$$

Figure (6): Law of second moment area.

Calculating the percentage of binding material:

The percentage of binding material will be calculated by the following steps: -

First: finding the density (applying what was learnt in CH.LO1) of wood by measuring the mass of a piece of wood (using the sensitive balance(applying what was learnt in CH.LO1) and taking and average 5.22+5.23+5.21/3 = 5.22g then calculating the volume 1.1×2.5×3 = 8.25cm^3 (by verniers caliper (according to what was learnt in PH.LO1) then dividing the mass by the Volume 5.22/8.25 = 0.633g/cm^3

Second: finding the volume of the beam 2.2±0.05×50×7.45±0.05 = 800±20cm^3 (by verniers caliper and a measuring tape).

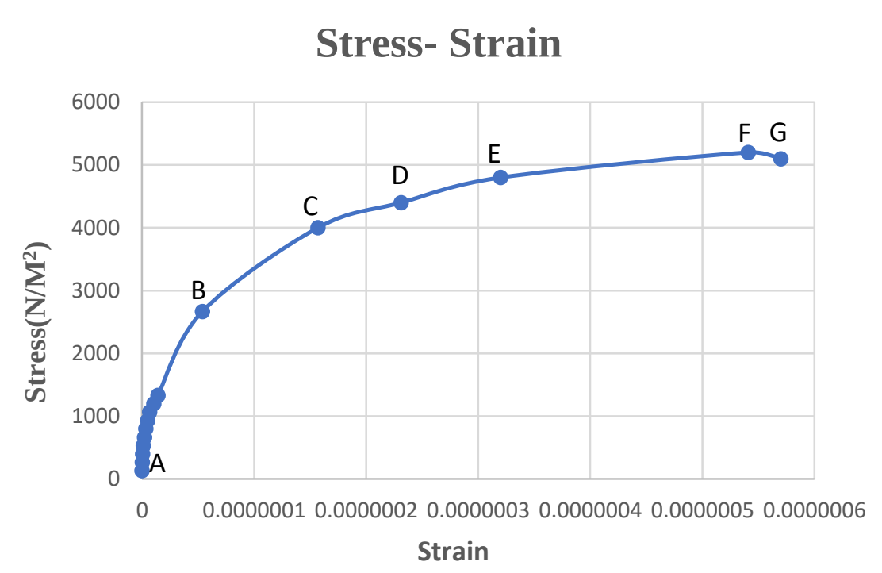
Third: converting the volume to mass by multiplying the density by the volume, 820±20×0.633 = 519±10g and this mass represents 100% of the beam.

Fourth: finding the mass of the binding material by measuring the real mass of the beam with the binding material 569g and subtracting the mass of the beam without the binding material 519g from it, 569-519±10 = 50±10g

Fifth: find the percentage of the binding material from the 100% of the mass by dividing the mass of the binding material by the mass of the beam without the binding material 50±10/519 = 0.0963±0.02then multiplying it by 100%, 0.0963±4×10^-3×100% = 10±2%, so the binding material meets the design requirements.

Stress- Strain beam analysis:

Stress-strain graph describes the mechanical properties of the beam. Graph (3) represents the stress-strain graph of the beam. The elastic region is represented by (AB). The elastic region is the region where the material hasn't been deformed. Point B is the elastic limit (yield strength point). The plastic region is represented by BG and it's the region where the beam is deformed and can't return back to its normal form after deflection. Point F is the ultimate strength, which means the maximum stress that a material can withstand. G represents the rupture point of the beam.



Graph(3): Stress-strain graph of the beam

Connections:

-According to MA.LO2, we used the scatter plot in representing the deflection-to-load graph to study the relation between the deflection of the beam when a load is applied on it.

- According to CH.LO1, uncertainty and errors were used to produce more accurate and correct measurements.

- According to PH.LO1, significant figures were used in approximating calculations.

Conclusion

From the research and identification of the problem to the analysis and test plan, there had been a lot of work done. The results of the test plan showed how effective the beam is. It fulfilled the design requirements and solved the problem of a lack of alternative building materials, allowing Egypt to construct in arid areas in a variety of ways in order to achieve population balance.

Recommendation

- It's recommended to use internal support system in real application to make the beam bear more load.
- It is recommended to use fiber glass (figure 1) in the internal support of the beam. Because it would be better to cover the regions in which stress is concentrated with. This would increase the strength and durability of the beam.
- It is recommended to use E-poxy (figure 2) as a binder in the internal support of the beam with the fiberglass because it is characterized by its resistance to acids and chemicals.
- It's recommended to use ply wood In construction because it's small hygroscopic and the small changing in its dimension comparing with other woods . The dimension movement of ply wood is very small .it's about .15 mm per Meter in the width or length in every 1% change in the moisture content and it's change in the thickness is in range between .3 % to .4% per 1% in moisture change

Figure(7):Fiber glass

Figure(8):E-poxy

Acknowledgement

At the end of this project, we'd like to point out that this project would not have been possible without Allah's guidance and support, as well as the support and assistance of some people such as Mohamed Morsy (academic deputy principal), Mrs. Phoebe Makram (capstone leader), and Mr. Mostafa Anany (capstone teacher) are all people we would like to thank.

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