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GROUP 113

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Dovetailed Acrylic Beam

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Dovitail joints
Acrylic

Abstract

Egypt's grand challenges are the problems that Egypt faces as the pollution, the useless of arid areas that cover 96% of Egypt and only 4% occupied by the population, the overpopulation (90% of people live in Nile basin), ... etc. The role of the project is to help solve these problems especially the arid areas and urban congestion by exploiting the arid areas and building on them, which will decrease the urban congestion. Of course, the build needs building materials. The building materials these days are conventional and harmful to the environment and humans, so instead of using these materials, there are alternative building materials or as they are been called green materials because they don't pollute the environment. The acrylic was the chosen material to use and build the project's prototype which is a beam as it is one of the most common building constructions. The beam is made from small pieces in the shape of a puzzle and gathered together with the cyanoacrylate as adhesive. To measure the rate of the beam successfully there are some design requirements that must be achieved by the beam like it is must be 50 cm in length and lift 50 N with a maximum deflection of 10mm. After testing the beam achieved the design requirement and record 50 N weight with 2.3 mm deflection.

Introduction

The Grand Challenge is a term applied to the problems and challenges of the countries. Each country has grand challenges including Egypt as increases the industrial base, reduces pollution, improves the usage of arid areas, decreases the urban congestion, ... etc. The capstone challenge focuses on improving the usage of arid areas and reducing urban congestion by using the arid areas that cover 96% of Egypt with different types and percentages, as shown in fig (1), to decrease the urban congestion at the Nile basin. The arid areas can be used by building on them, but the building needs building materials. The common building materials that are already being used cause pollution and human health problems as it emits harmful gasses and materials either while manufacturing or after building.

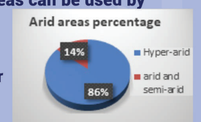


Figure "1" (Percentage of the aridity in Egypt)

Egypt is full of materials that could provide innovative alternatives for building materials as rammed earth, polycarbonate, and acrylic. The prior solutions that have been tried by the alternative building materials helped us in chosen of the right material and gain experience and learn from the previous mitakes. From the prior solution, they have been hired the Bamboo sports hall that was a hall in Thailand built by Chiangmai life architects in 2018.
It belongs to Panyaden International School. The design was made of bamboo trusses with spans of over 17 meters without steel. The strength points of the hall are that the hall is made from ecofriendly material (bamboo) that made carbon footprint zero, the hall can handle natural problems like earthquakes and high wind speed. From disadvantages of the hall are that the bamboo needs to be chemically treated before using in buildings. The second one is the observation tower that was a tower made from rammed earth between Belgium and Netherlands. It was built by De goueden liniaal architect. from the strong points of the tower that it was made from green material that was crafted from materials that don't emit carbon dioxide or other pollutants. From disadvantage of the tower was that it was not water-resistant. The acrylic is the chosen material to build our prototype that is a beam as it is one of the essential building constructions. The acrylic characterizes by its durability and strength, in addition to its being eco-friendly which makes it the suitable material to be used. Some design requirements have been determined to select the prototype succussed or failed as it is must be 50 cm that doesn't short or long and lift 50 N which is a suitable weight compared to its length and envelop that it is maximum of 10 × 10 cm. The prototype makes needed materials and it is done in steps.

Materials & Method

Name	Quantity	Image
Acrylic	240 pieces	
Selsil	1 package (400 mL)	

Acrylic is the material that is used to build the prototype or the beam. The beam passed with steps while it's making. The steps represent in:

- Cut the acrylic sheets into puzzle pieces using the laser cutter as shown in fig (2).
- Remove the layer of paper that is cover the pieces, as shown in fig (3)
- Gather the pieces together making two flange sheets and a web sheet, as shown in fig (4), and splice them using cyanoacrylate
- Let the sheets dry for an hour.
- Installation of sheets together using also cyanoacrylate making the beam.
- Let the beam dry for an hour.

The total used amount of the cyanoacrylate less than 28 g. By this way the beam constructed and started to be tested.

figure "2" (pieces shape)

figure "3" (the removed paper piece)

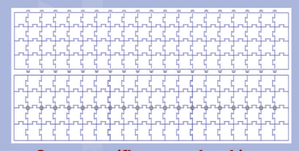


figure "4" (flange and web)

Test Plan

After building the beam we tested it, the test followed some steps that are:

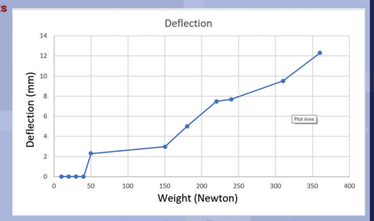
- o Put the beam between two support points with 3 cm on each side
- o Rotate a bag around the center of the beam
- o Start to put the loads one with one inside the bag
- o Taking the measurement

Results

"All life is an Experiment. The more experiment you make the better" Waldo Emerson. This quote summarizes the prototype's trails. The first trial has been tried for testing the way of connecting the pieces (Dovetail way) and the adhesive. This experiment failed due to the unsuitability of the adhesive and an error while attaching and gluing the pieces. In the second trial, the adhesive was changed and the way of gluing and attaching the pieces was edited but this time the design of the beam doesn't succeed in lifting the required weight and failed. In the third and last trial, we have benefited from the previous experiment, and all the causes of the failure and the errors had been detected and treated and the design has been edited. Finally, the beam succussed and achieved the design requirements, the result of the experiment is shown in Table (1) and represented in Graph (1.1).

Table "1": Weight & deflection measurments

Weight (Newton)	Deflection (mm)
10-40	0
50	2.3
150	3
180	5
220	7.5
240	7.7
310	9.5
360	12.3

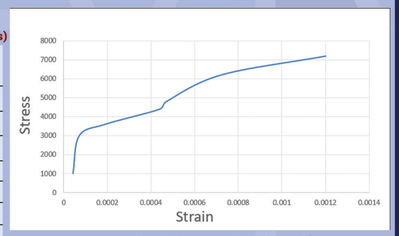


Graph "1.1" (Deflection - load graph)

The beam weight ratio reached to 10 N and it lifted 390 N as a maximum load, so the load-weight ratio= maximum load ÷ weight = 39.
The Stress and the strain are two properties that characterize the beam which Stress is defined as force per unit area within materials that arise from externally applied forces. While the strain is the amount of deformation experienced by the body in the direction of force applied, divided by the initial dimensions of the body. The stress and strain measurment of the beam are shown in table (2) and represented in the graph (2.1).

Table 2 (stress and strain measurments)

weight	Strain	Stress
50	0.000042	1000
150	0.000071	3000
180	0.00019	3600
220	0.00044	4400
240	0.00047	4800
310	0.00072	6200
360	0.0012	7200



Graph "2.1" (Stress and Strain graph)

Analysis

The urban congestion comes due to the small size of the country compared to its population, however, Egypt owned large areas it suffers from the urban congestion. This is the challenge of the capstone on how to solve the urban congestion problem using the arid areas that cover 96% of Egypt. Solving these problems can be achieved by building on arid areas and decreasing the population at the Nile basin governorates. The choices in the project like the choice of the H-Beam, the choice of material, The choice of the adhesive and other thing based on scientific search like:

-Acrylic is a transparent thermoplastic homopolymer with chemical formula $C_5H_8O_2$ as shown in figure 5 known more commonly by the trade name "plexiglass." The material is similar to polycarbonate in that it is suitable for use as an impact resistant. The Acrylic is the chosen material for the prototype for its great properties like the low weight, the weight of acrylic sheet with thickness 6mm and 1m^2 area is 7.2kg, so it will help improving the load to weight ratio. From other strength points of acrylic is the high melting point that is 130c and heat deflection temperature equal 95c. From the best advantages of the acrylic is the tensile strength of 65MPa and flexural strength 90 MPa which make the acrylic able to face pressure and deflection with a good rate.

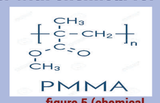


figure 5 (chemical formula of Acrylic)

-While choosing the design of the beam the conflict was about I and H beam so after searching, the difference between the two beams is the thickness of the flange and its length as shown in figure 6. The flange of the H beam has more thickness than I beam so this property makes the weight of H beam heavier, but it makes it extremely stronger and makes the H beam has more load bearing capacity. The thick web of the H beam is from its strength points that makes it strong. The H shape give the beam advantage that it increases the distance between the neutral axis and the flange, so the bending moment resistance increase because bending moment resistance=force × distance, so by increasing the distance the deflection decrease. One other advantage of the shape is that the yield strength remains the same under load opposite to other shapes that its yield strength increases under the same load and this advantage is important in increasing the beam compressive force.

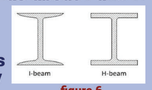


figure 6 (I-beam & H-beam comparisons)

-Dovetail joints technique is the chosen for our prototype according to its strength points like its tensile strength. Dovetail joints is usually used to join the sides drawer to front. Series of pins cut to extend from the end of one board interlock with series of tails cut into the end of another board to make a trapezoidal shape as shown in figure 7. Once glued the dovetail require no mechanical asteners. This technique is very strong because of its tail and pin shape which make it difficult to pull the joint apart and it becomes impossible with adding glue. From the advantage of this method is its ability to transfer tensile force and binding moment. The acrylic-based Selsil Rainbow Spray Paint was created to satisfy the demands of industrial applications such as painting engine parts, tools, all types of cars, steel furniture, and DIY. Acrylic binder of excellent quality with RAL standard colors. An adhesive is consisting of two things: the cyanoacrylate and instant. The cyanoacrylate is used to glue the pieces together, then the instant used to increase the rate of gluing and make it stronger and get dry quickly.

figure 7(dovetail joints)

-The chemical formula of the Cyanoacrylate is $C_6H_7NO_2$ as shown in the figure 8
Fast adhesive offers a wide range of applications in almost every part of life. One cyanoacrylate and one aerosol activator make up this mixture. It has a strong adhesion strength and a quick initial bonding time, so we used the Cyanoacrylate to affix the beam.

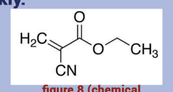


figure 8 (chemical formula of Cyanoacrylate)

-The deflection was calculated with very steps first by calculating the young's modulus then by calculating the moment of inertia. Strain will be calculated by the law, strain=F/A=390/0. 05=7800PA.stress calculated by the law /l=l final-l initial=0.2503023-0.25=0003023m/0.50=0.0012m and use them in the law. The young's modulus will equal=stress/strain=7800/0.0012=6500000pa. The second thing to calculate is the moment of inertia will be done by the law, I=1/12bh³ of flange +area of flange× distance between center of flange and web+ 1/12bh³ of web × distance between two centers (0)+1/12bh³ another flange+ distance between center of flange and web
=1/12×10×0.6³+10×0.6×4.7²+1/12×0.6×8.8³+1/12×10×0.6³+10×0.6×4.7²
=299.5136cm=2.995m

LEARING TRANSFER

LO2 physics: free body diagram concept helped to draw the beam with a simple shape to determine the forces effect on it
LO6 physic: concept of stress and strain helped to determine the stiffness of the beam and helped to calculate young's modulus
L06 physics: concept of young's modulus helped determining the stretch and deform of the beam.
Lo1 chemistry: SI units concept helped choosing right units to get right measurements.
Lo1 math: concept of trig functions helped calculating the final length of the beam after deflection to calculate the strength strain.

Conclusion

Defining the problem, conducting research, developing the prototype, and determining if the prototype met the design requirements took a significant amount of time. Egypt has a large number of arid areas and urban congestion. The project targets beam work to help reduce arid areas, and urban congestion by build in the arid areas with this beam or build by it in the areas that has urban congestion. After comparing by our beam and other beams that built before, there are many advantages in the beam makes it better than other projects.
The beam provides the design requirements that make it special, which are durability, and eco-friendly. The cost of the prototype is less than 350L.E. In addition, The process' efficiency was preserved to the greatest extent possible.

Recommendation

The way of fitting the cutting:
The way of fitting the pieces can be improved. The pieces in our project are complex as a (Dovetail way) as shown in Fig (9). The thickness of each piece is 6 mm. Instead of cutting the whole 6mm from the thickness of pins pieces. We can cut only 3 mm and let the other 3mm of thickness in the tails piece. To make the shape like the shape shown also in fig (9) In this way, we make a supporter to the tailpiece by making a flat plane in the case that a force is applied to it. Due to the complexity of this way it wasn't able to be implemented in the prototype.

figure 9 (Dovetail way)

Scratch resistance:
There is some solution that gives the acrylic resistance for the scratching which it is easily stretchable, like the anti-scratch coating, it is a very thin layer of microscopic substance. This substance wasn't be used in the prototype because there isn't a need for it and it is expensive compared to the budget.

Putting trusses:
putting trusses will increase the load that the beam can carry and will not increase the weight very much so it will improve our load to weight ratio but it will need more pieces so the price limit might be exceeded and the design of the I beam will not be the same

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