Poly Concrete

Group 101

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جمهورية مصر العربية
وزارة التربية والتعليم

Abstract

Egypt faces lots of major **grand challenges** including urban congestion, arid areas, overpopulation, pollution problem, a poor public health and lack of interests in recycling. Most of these challenges result from the total dependency in life on the River Nile, causing a problem of urban congestion in an area of land and leaving the rest as arid areas. Thus, affecting national facilities and causing the problems mentioned before. Solving these grand challenges is our purpose of study and is solved using our major finding by offering new practical housing units. The **prototype** was chosen to be an eco-friendly and cheap building block with dimensions of 30×10×2 cm³, and to be valid for real life it must have a **design requirement** of static strength. To test the prototype validity, the block was held with its two terminals upon two rigid standing bodies with axial load applied downward to dry and wetted samples. Our chosen solution achieved promising results and met the **design requirement** and it could be applicated to solve our capstone semester challenge and the formerly addressed problems.

Introduction

It's important to mention how most of Egypt's **grand challenges** are deeply interconnected. In other words, solving a one helps to solve the others. Starting from arid areas, that result in an urban congestion as Egyptians live on only 4% of the whole land *(shown in Figure 1)*, overpopulation, pollution, lack of recycling and public health. These problems could be treated by solving Egypt housing problem. And that problem could be solved by offering cheap housing that includes recycled wastes. Solving housing would expand urban land, on the other hand, reduce arid areas.

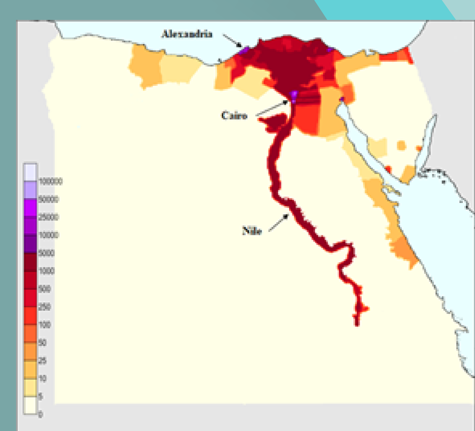


Figure 1. Congestion map of Egypt showing a massive urban congestion in the Valley and

An **attempt** was done to take a look into how other countries tried to solve similar problems and it was taken as **prior solutions**. One of these solutions was using plastic bottles filled with sand in Nigeria. As a point of **strength**, it was stronger than usual bricks. But, in the other hand, as a **weakness**, no more than 3 floors could be built using this method. Another **prior solution/attempt** was rammed earth, compressed sand and clay *(shown in figure 2)*. As **strength**, it was suitable for both warm and cold climates. Though, **for weaknesses**, relatively expensive and also time consuming.

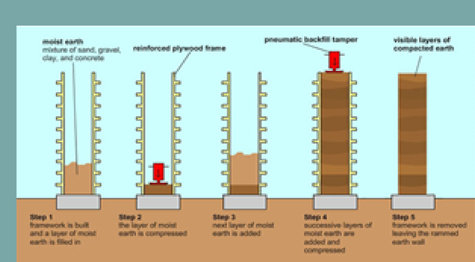


Figure2: showing the process of rammed earth formation

Seeing, studying and analyzing those prior solutions, **the prototype was chosen** to be a block that is durable, ECO-friendly, light weighted and has a relatively high static strength to solve the problem of **housing**. To achieve most of these requirements, the main **design requirement** should be the static strength. The prototype would be tested with load applied horizontally pulling down on the block, calculating binding angle for each applied weight, fracture point and weight-to-body ratio.

The block was made and tested according to the requirement and method of testing mentioned before. The results turned out to be impressive compared to normal bricks. These amusing results came from following the specific methods needed to make the block for using the materials.

Materials and Methods

Materials (Table 1):

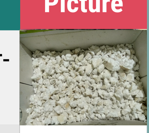
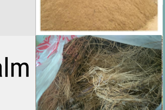
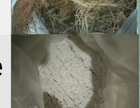
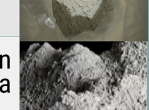
	Approximate Weight	Description	Picture
Foam Boards	200 grams	Formed from Polystyrene (C_8H_8), a light, thermoplastic polymerized monomer.	
Clean Sand	200 grams	A naturally occurring rough material composed of finely divided rock.	
Palm Fibers	20 grams	An organic, light fibers. Taken from palm trees.	
Marble Powder	400 grams	Crushed marble. By-product of cutting marble for industrial purposes.	
Portland Cement	400 grams	A hydraulic binder from the chemical reaction of an inorganic material with water creating a mortar.	

Table 1: Showing used materials, briefly described, mentioning used mass and illustrative picture(s).

Used Materials:

- Marble Powder - **400 g**
- Portland Cement - **400 g**
- Sand - **200 g**
- Fire-crushed Polystyrene - **200 g**
- Palm Fibers - **20 g**

Methods:

1. A mixture of Portland cement, marble powder and sand was made.
2. Polystyrene was subjected indirectly (in container) to fire for about 15 minutes, forming solid particles *(melted from 200 g of foam)*.
3. Solid particles *(formed in step 2)* were crushed using hammer to the size of gravel
4. Heated and crushed polystyrene was then put in a container and mixed with the mixture formed in step 1.
5. Water was put on the mixture for around 3 minutes.
6. The mixture was poured to fill half of the mold.
7. Palm fibers were used to fill the remaining space.
8. A wooden platform was put on the mold *(shown in figure 3)* with a weight of no less than 40 kilograms applied on it and left for seven days, watered every 12 hours.

The design requirement is static strength and highest weight-to-body ratio.

Figure 3 showing a wooden platform being applied to the sample.

Test Plan:

Dry Testing: -

1. Prototype was stranded over two rigid bodies, with its terminals 1cm on each.
2. A load was applied perpendicularly by attaching a rope at the middle point of the prototype.
3. For each applied weight, binding angle was calculated.
4. Repeat steps 2&3 until the block fracture.

Wet Testing: -

5. 5 blocks were immersed in water for varying time intervals.
6. Blocks were tested each 2 hours, with the first one two hours after the initial immersion.
7. Steps 2,3&4 (mentioned above) were repeated for each block.

Results

The block showed very promising results that assured its validity. The prototype has achieved the design requirement and was able to outstandingly withstand (45-50 ± 1) kilograms (See Figure 4), being of mass of 0.962 – 1022 grams (with an error of ± 10 gram).

Figure 4 showing the block withstanding a mass of 45kg

The results (detailed in Table 2 below) have also shown that the block is able to solve the problem of housing and well contribute to solving the other grand challenges.

The correlation and regression line equation between angle of binding and weight could be seen in Figure 5. No or micro-scaled angle of binding was noticed. Thus, no correlation was found on macroscale, and regression line equation is Y= 0.

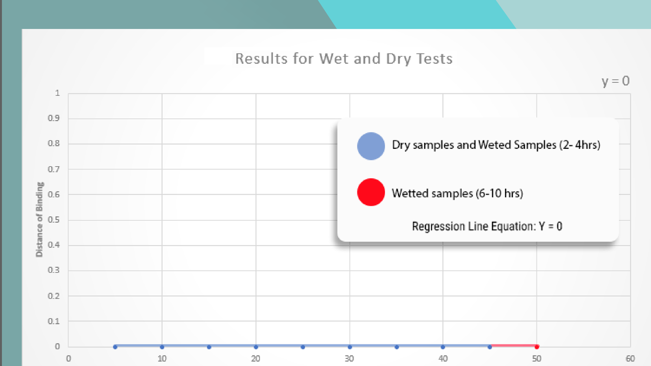


Figure 5: Correlation graph and regression line equation for binding angle at macroscale (>1mm). Blue line indicates graph of dry and wetted samples (2-4hrs) tolerating 45 kilograms. Red line indicating wetted samples (6-10hrs) tolerating 50 kilograms.

Condition	Mass	Mass Tolerance	Weight-to-body ratio
Dry	962±10 grams	45±1 kg	46.8 : 1
Wet - 2hrs.	1018±10 grams	45±1 kg	44.2 : 1
Wet - 4hrs.	1020±10 grams	45±1 kg	44.1 : 1
Wet - 6hrs.	1022±10 grams	50±1 kg	48.9 : 1
Wet - 8hrs.	1025±10 grams	50±1 kg	48.8 : 1
Wet - 10hrs.	1025±10 grams	50±1 kg	48.8 :1

Table 2: Numerical results of the test plan. Indicating weight-to-body ratios.

Analysis

Prototype composition:

Polymers are large molecules of repeated subunits formed from polymerization and acquire new unique properties. Polystyrene (C8H8), in the prototype: taken from 200 grams of packaging foam boards, is originally a hydrocarbon polymer, polymerized from styrene monomers through free radical vinyl polymerization as in Figure 6.

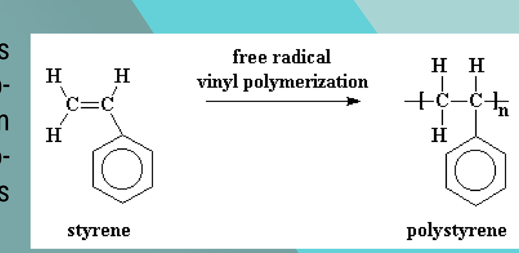


Figure 6 showing styrene monomer and polystyrene chemical composition

Polystyrene is characterized by being inexpensive, good thermal insulator, and a flexural strength of 70MPa. It also counts as a cheaper and lighter alternative for Gravel with a density of 0.96-1.04g/cm³.

Polystyrene (in form of foams) could be melted at room temperature to form expanded polystyrene using one of various possible solvents (all known commercially as paint solvents) like ketone-based solvents (solvents with carbonyl groups attached to their hydrocarbon molecules).

Such method would require about a week for polystyrene to solidify, aside, used solvents are highly flammable with a flash point of around 40 °C (104 °F; 313.15K), and causes samples to expand continuously, destroying block edges as in *Figure 7.* Instead, in the prototype, polystyrene foams were indirectly subjected to fire (with flame of heat 60-160 °C), resulting in faster solidification, harder and inflammable resultants.

Figure 7: expanding polystyrene destroys edges of the block.

Portland Cement (400g) is a hydraulic cement (a cement that hardens when in contact with water forming a water-resistant product) consisting mainly of lime (CaCO3), silica (SiO3), alumina oxide (Al2O3), magnesium oxide (MgO) and iron oxide (Fe2O).

Portland cement (Type I), commonly resorted for general building, was used in the prototype. Portland cement is put to react chemically with water (Hydration) to form Calcium Hydroxide, Calcium Silicates and other neglectable compounds.

$$2Ca_3SiO_3 + 7H_2O \rightarrow 3CaO \cdot 2SiO_2 \cdot 4H_2O + 3Ca(OH)_2$$

Figure 8: Chemical formula of Tricalcium Silicate hydration forming Calcium Silicate and Calclium Hydroxide

Calcium silicate is the only compound to contribute to the strength of the final product, rising from hydrating tricalcium silicate that forms most of the early strength, and dicalcium silicates contributing to late strength. (See detailed formula in *Figure 8*.)

Marble Powder (400g) is a by-product of Marble industry when cut to pieces, used for its light density of around 1.3-1.5g/cm³. Sand is a water-absorption medium, with a rate of more than 2 inches per hour, continuously supplies water for cement hydration.

Palm fibers are used as an organic inexpensive and light fibers, with a density of 1.24g/cm³. It is also eco-friendly and has low water absorption (as in table 3). Palm fibers are used to strengthen out the prototype, with it arbitrary arranged into the mold, mixture poured over and finally stirred, then left to physically bond.

Fiber properties	Quantity
Average fiber length, mm	30
Average fiber width, microne	21.13
Tensile strength (MPa)	21.2
Elongation at break (%)	0.04
Specific gravity	1.24
Water absorption %, 24/48 hrs	0.6

Table 3: Characteristic properties of palm fibers

A compression of no less than 400N should be applied to formed samples (isolating samples from moist air) and be left for 28 days, to ensure it gaining the most obtainable strength. Cement commonly achieve various strengths before achieving the highest possible at 28 days. (see Figure 9.)

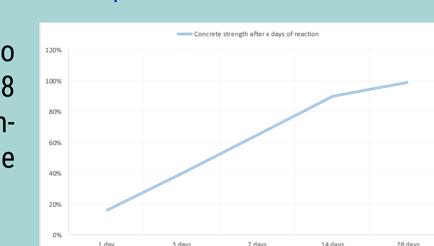


Figure 9: Concrete strength after X days of hydration reaction

Calculations and Statistical Relations (Correlation and Regression Line):

Using results obtained from the test plan, numerical data could be obtained to calculate weight-to-body ratio and correlation and regression line equation between applied weight and angle of binding (both concepts of correlation and regression line equation were explained in the fifth learning outcome of the mathematics syllabus).

Weight-to-body ratio defines the maximum possible amount of weight that a sample of one kilogram could tolerate before complete fracture. Weight-to-body ratio is calculated using the equation in Figure 10.

$$Ratio = \frac{Applied\ mass\ (in\ kg)}{Mass\ of\ sample\ (in\ kg)}$$

Figure 10: Weight-to-body ratio formu-

Linear correlation is a quantitative value, expressing the strength and direction of relation between two variables. Correlation is calculated by the formula in Figure 11, where **X** resembles applied weight and **Y** representing a coefficient of binding angle. Results should range between 1 (perfect correlation - direct proportionality), 0 (no correlation) and -1 (inverse perfect correlation - inverse proportionality) to indicate how much connected the variables are.

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$$

Figure 11: Correlation formula.

Regression line equation is a function variable **Y** in terms of variable **X** changes. Yielded equation could be used to predict the binding angle of a wide range of possible applied weights with high accuracy. Its calculation could be easily done by substituting in the equation shown in Figure 12.

Linear regression equation
(without error)

$$\hat{Y} = bX + a$$

$$b = \frac{n\sum xy - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2}$$

$$a = \frac{\sum y - b\sum x}{n}$$

Figure 12: Linear Regression equation.

Learning Transfer:

Chemistry (L.O.1): The scientific method in this learning outcome had been used thought the project. Thus, forming an organized research which ends up by yielding a solution to a definite problem. That research included looking into prior solutions, making hypotheses and making tests and experiments.

Geology (L.O.3): Building materials were discussed in details in this learning outcome. That included: Cement physical strength and the reasons behind it, Marble in industry and Sand as a component of concrete.

Physics (L.O.1): Errors and measurement concepts were used to come up with highly accurate calculations and expressing errors properly. These calculations included applied weight, weigh of sample and weight of materials.

Technology (L.O.2): Our research was much aided by modern technological application, including Microsoft Word (used in writing research), PowerPoint (used in sketching poster layout), Excel Spreadsheets (used in collecting data and making calculations) and Google SketchUp (used in constructing 3D sketches for the prototype).

Conclusion

At last, based on the analysis, the results, and former research, promising and impressive results were achieved. Thus, it could be concluded that this solution has the standards to stand best as a solution for housing problem.

It could also be confirmed that the prototype meets and exceed the design requirement, as it was able to hold a significant amount of weight applied to it downward for enough time.

Adding to that, it was deduced that this very block could be the solution in the future to the problem of housing, contributing to solving all of its arising problems like the urban congestion, arid areas, pollution, public health and over population.

Recomendations

1. Luffa

Luffa was noticed to minimize in density after a certain process of treatment using Methacrylamide compound with concentration of 3% and left for 3 hours. This process reduces the sample density from 1160(kg.m³) to 1070(kg.m³).

A sample of compressed Luffa to 40% of the mold volume obtains the highest results in a tensile strength of around 2800psi compared to the lowest at 50% of total volume with a tensile strength of 1740psi. While its flexural strength reaches its peak when the mixture is compressed to 30% of total volume, reaching a tensile strength of 9572.49psi compared to only 5801.51psi when its compressed down to 10% volume of fraction. (As shown in both figures 13).

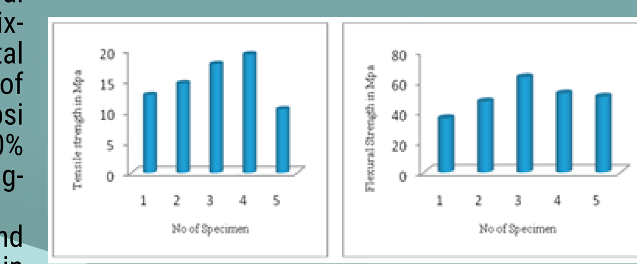


Figure 13. Showing tensile and flexural strength for compressed luffa at different volumes of fraction

Due to a lack in materials and equipment, it couldn't be implemented in the prototype despite being notably higher in flexural strength compared to palm fibers. Luffa is highly recommended to be used when improved instead of palm fibers.

2. Gauged Mortar

Mortar is a material used for binding between multiple objects (building blocks in a building). Gauged mortar was determined to be the best possible mortar, with widely abundant materials and low cost. Gauged mortar is composed from cement (for increasing strength) and lime (for plasticity). These elements, when used together, could make quite a good mortar. The usual proportion of cement, lime and sand are 1:1:6, 1:2:9 and 1:3:12. This mortar is to be used within half an hour after mixing cement.

Gauged mortar is preferred to be used as a binding material between samples of the prototype.

3. Aluminum-Steel Alloy

Aluminum could be used to reinforce concrete when added to iron. Though, their atoms don't always fuse together. Nickel could be used to react with Aluminum forming sheer-resisting B2 crystals. Making it incredibly strong, as strong as titanium, lighter in weight by 13% and 10 times cheaper. Formed mixture is formed as rods and put in the vertical center of the building block.

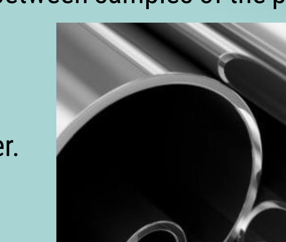


Figure 14. aluminum -nickel alloy

There was no available equipment to melt neither iron nor aluminum, and thus, these rods could not be made.

Though it iss essentially suggested to be used instead of normal steel.

4. Poly Concrete in Real Life

To applicate Poly Concrete in real life for building houses or factories, it is better to have dimensions of 30×20×20cm³ (like conventional concrete blocks).

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