PORTFOLIO

GROUP 112

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Chapter I

Egypt grand challenges

Arid areas

Arid areas are areas characterized by low annual rainfall of less than 250 mm. They have an evaporation rate exceeding the rate of precipitation (any liquid that forms in the atmosphere and then falls back to Earth). This has made agriculture hard to be applied in these areas as a result of the lack of water leading to lowering the population density in these areas.

There are three types of arid areas in the world according to the aridity index. The first type is hyper-arid areas. They are drylands in which the rains are irregular and low scarcely exceeding 100 millimeters per year. The second type is arid areas. they are areas with rainfall ranging between 100 and 300 millimeters per year. The third type is semi-arid areas that can support agriculture that depends on rain. The rain in these areas ranges between 300-600 to 700-800 millimeters per year.

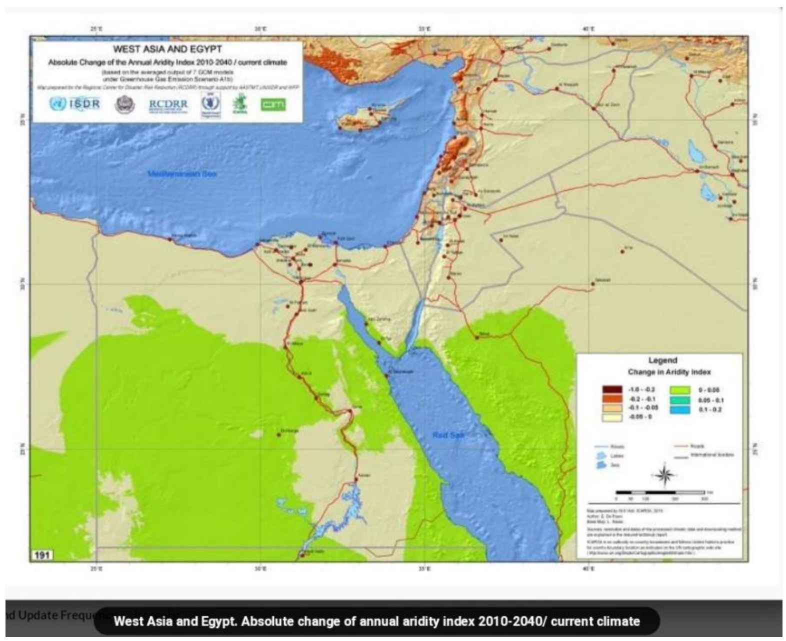


FIGURE (1): dryland in Egypt

According to FAO, about 95% of Egypt’s area is hyper-arid. The western desert itself is considered 100% hyper-arid. There are three main arid areas in Egypt Western Sahara, Eastern Sahara, and the Sinai Peninsula. these areas represent about 96% of Egypt's area (according to figure 1). They are distinguished by a low population of about 1760000 people. These areas contain many resources despite their harsh environment like gravel, gold, copper, sandstone, limestone and granite. These resources are worth hundreds of billions of dollars.

Causes of arid areas

1. Moisture reduction:

When the water is evaporated from the sea, the lands closer to the sea receive much of the water in the shape of rain. As the wind moves further in the land, the amount of moisture it carries decreases. That makes the amount of rain falling decrease. Areas that lie deep inland may become deserts simply because the air currents which reached them have lost the moisture they once had.

2. The limited water resources:

One of the reasons for arid areas in Egypt is the limited water resources. the limited water resources have put Egypt under the line of water poverty (about 1000 cubic meters per person) with about 700 cubic meters per person. Egypt suffers from a water deficit of 30 billion cubic meters because it uses 110 billion cubic meters. Even so, it has only 80 billion cubic meters. According to the water resources Egypt already uses about 100% of its water resources and 27% above them. resources are represented in the opposite figure (figure 2).

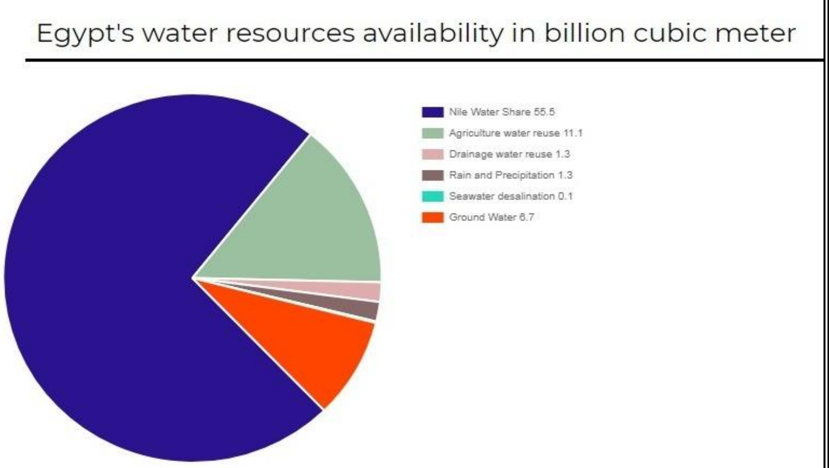


figure (2): Egypt water resources

The Nile is the main resource that provides Egypt with freshwater it provides residents with about 55 BCM per year which represent about 69% of its water requirements this deficiency in water resources makes up a barrier in reclamation or even protection the farmland from aridity protection the farmland from aridity.

The impacts of arid areas

1. Relying on importing from other countries:

Arid areas cover a huge percentage of Egypt's land. As known, the arid areas are not suitable for implantation without water resources. This makes Egypt imports most of its needs of crops. Food and agricultural goods represent about 40% of Egypt's imports. Egypt remains one of the world's largest importers of wheat. The importation of wheat between July 2018 and June 2019 is estimated at 12.5 million metric tons.

2. Urban congestion:

The arid areas are regions that lack water and jobs chances. All these factors make people leave these regions and go to live around the Nile and delta. One example of this is the new valley governorate, the biggest governorate in Egypt (in the area). It represents about 44% of Egypt's whole area but it only has about 25.3 thousand people that makes it have a low population density equals 1 person per 2 kilometers; mainly due to not having enough water resources.

Urban congestion

FIGURE (3): CONCENTRATION OF PEOPLE

Urban congestion is the high concentration of people in certain areas (as shown in figure 3). As a result of this concentration, the land is being transformed for residential, commercial, industrial, and transportation needs. It can include densely inhabited areas as well as the peri-urban or suburban edges surrounding them. Because of its bad impacts, urban congestion is considered one of the biggest grand challenges that Egypt faces in many areas specifically in the greater Cairo metropolitan area. The Greater Cairo Metropolitan Area

(GCMA), with more than 19 million inhabitants, is host to more than one-fifth of Egypt's population. The population of the GCMA is expected to further increase to 24 million by 2027. a lot of people migrate from villages in upper Egypt and delta to the capital "Cairo ".

Causes of urban congestion

1.Bad services in the south:

Cairo population increases by 1.34% every year, in addition to people from inside the country itself either they are from villages or remote areas, they come looking for a better life and jobs by internal migration. For example, the public services like public health care, education, clean water, and electricity have low quality compared with Cairo and Alexandria. makes a lot of Egyptian prefer to live in Cairo and Alexandria looking for better services as Cairo has many developed hospitals with highly skilled doctors and better medical equipment.

2.The rise of ride-hailing services:

The researchers constructed a model that supported 44 cities in the United States where Uber and Lyft operate, according to an MIT publication. They discovered that ride-hailing vehicles cause a 1% increase in congestion volume and a 4.8 percent increase in congestion duration.

Impact of Urban congestion

1. The spread of slums and poverty:

According to Sherif El-Gohary, a technical support manager at the Ministry of Urban Renewal and Informal Settlements, the "eradication" of Egypt's slums, which account for 40% of the country's urban regions, will cost roughly LE250 billion.

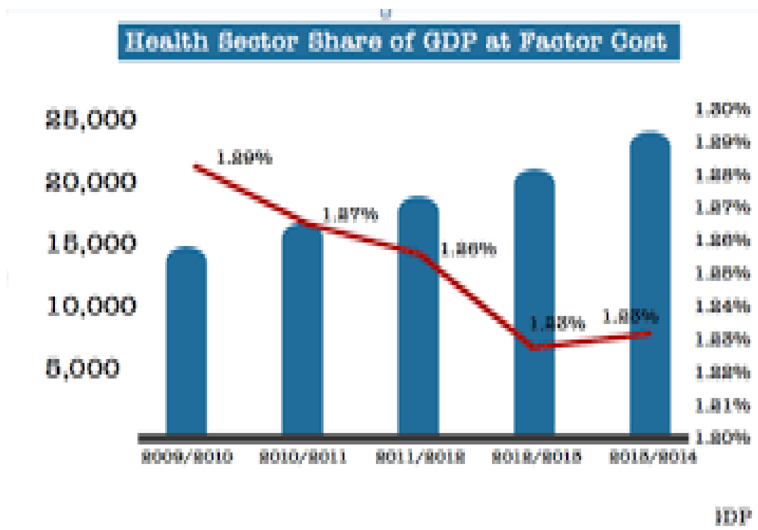
In an interview with the Aswat Masriya website, El-Gohary stated that informal settlements account for 37% of urban space in Egypt, while "unsafe slums" account for just 1% of urban areas. There are 364 slum zones in the United States.

2. Traffic congestion:

Logically the urban congestion leads to traffic congestion. According to a recent World Bank report titled "Cairo Traffic Congestion," at least 4,000 Egyptians are injured, and 1,000 Egyptians die each year in traffic-related accidents. According to the same report, Cairo's traffic congestion costs the country EGP50 billion (US$8 billion) per year, approximately 4% of Egypt's Gross Domestic Product (GDP). It’s four times the quantity lost by cities of the same size.

public health

Urban congestion in the crowded regions in Egypt as in Cairo exhausts the health care system and makes it very weak to absorb these huge numbers of people. This collapse in the health care system helps the diseases to spread and become more active or may even develop and become more lethal. For instance, virus C.



GRAPH (1): Egypt spending on health care

In the year 2008 statistics -as shown in figure (4)- had shown that 14.7% of Egypt population had virus-c, the infection was high in Egypt especially in upper Egypt it reached 28% or about 6 per 1000 people every year, that mean about 170,000 persons every year. In 2016 about 40,000 people died due to virus-c and another 4.5-5 million people were infected.

Causes of health care issues:

1. Low funding:

Health care issues could be summed in one thing which is low funding. Egypt spends about 1.23% of the country's GDP on public health care which is low considering Egypt's GDP is about 363.1 billion USD, while the EU nations spend about 9.9% of the country's GDP. The low arbitrage of health care makes building new hospitals or even developing the old ones is a hard thing.

2.Brain drains:

Brian drain is one of the reasons that cause issues to Egypt health care system as many talented people travel to European countries for better education and jobs, so it prevents Egypt from benefiting these brains to develop its health care system

Impacts:

1. High rates of disease:

One of the results of urban congestion is deteriorating public health.in 2016 reports determine that there is 1.5 available bed for every 1000 Egyptian. In addition to speedreading of many diseases. one of these diseases is hepatitis c. It was an epidemic that was increasing for about three decades and it affect about 6.2% of people in Egypt. Also, this deterioration in public health helps in the spreading of covid-19.

2. Low average human life span:

The deterioration of public health in Egypt caused a low average human life span. the life expectancy in Egypt is 72.54, the life expectancy of females is 74.95 and the life expectancy is 70.23.

Problem to be solved

Lack of alternative building materials

Building materials have been an important problem in Egypt. 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. Egypt depends mainly on steel and concrete in the construction of its mega projects and produces about 80-85 million tons of cement every year. In 2019, Egypt consumed about 44 million tons of cement, and studies have shown that cement has bad effects on people and the environment. People who work in factories that make cement usually suffer from blindness, breathing problem, and chemical burns. Cement also increases the rate of CO_2 in the atmosphere during its manufacturing process causing the increased rate of global warming. Egypt must look for alternative building materials that are cheap, useful, eco-friendly, and can be easily found to solve urban congestion and arid areas.

Positive consequences (If solved)

1.Environmental protection

Our climate and the natural environment are two of the most essential sorts of benefits that green buildings provide. Green buildings can benefit the environment (at the building or city scales) by generating their energy or supporting biodiversity, as well as decreasing or eliminating negative environmental consequences by consuming less water, energy, or natural resources.

2. Financial benefits

Using alternative building materials provides several economic or financial advantages that help a variety of people. Cost savings on utility bills for tenants or families (due to energy and water efficiency); lower construction costs and higher property value for building developers; and increased occupancy rates or operating costs for building owners are just a few examples.

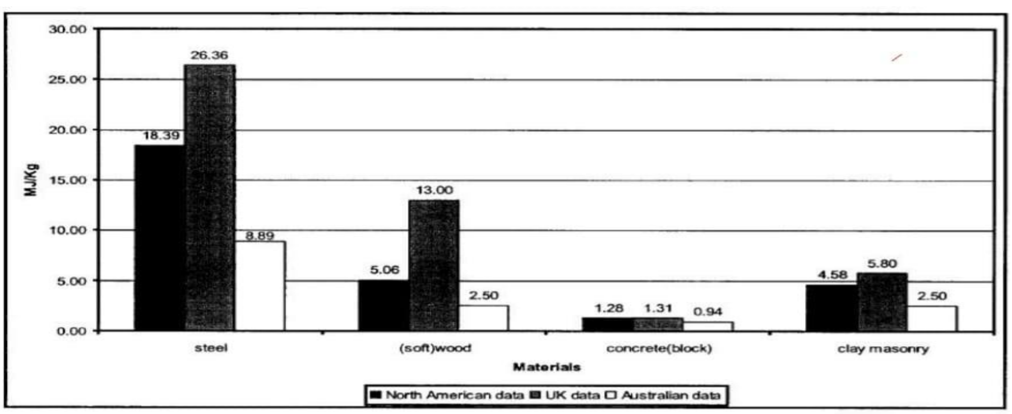
Negative consequences (if not solved)

1. Increase in water pollution:

One of the most important water pollution reasons is the water that is used to cool the coal which was used in steel production after it has been used up. Water pollution occurs when harmful substances which are often chemicals pollute a stream, river, lake, ocean aquifer, or any other body of water, deteriorating the water quality and making it toxic to humans and the environment. Water pollution can also cause illness. Every year, polluted water sickens about 1 billion people and low-income communities are disproportionately at risk because their homes are often closest to the most polluting industries. It caused 1,8 million deaths in 2015, according to a study published in The Lancet.

2. Increase the consumption of energy:

The production of steel consumes a big quantity of energy it cost about 26.36 MJ (in the United States) for every kilogram of steel. This figure (figure 5) compares different building materials to see which has less or which has the highest consumption of energy per unit watt.



GRAPH (2): COMPARISON BETWEEN DIFFERENT BUILDING MATERIALS IN THEIR CONSUMPTION OF ENERGY

Research

Topic related to the problem

1.Cost & abundance of alternative building materials

Because alternative building materials are not always widely available, they can be costly. A country, for example, could be constructing with alternate building materials. However, it is not widely known within the country who may be importing it from another country, or it is difficult to harvest or collect it, for example, if it is a specific type of wood, this wood may only grow in a specific location and at a specific time of year, or the wood may be planted on a mountain or in a valley. The cost changes depending on the sort of alternative building material used, which could be environmentally friendly but expensive, or require chemical modification.

2.The environmental effect of the production of the steal

the production of steel has many bad effects on the environment. first, the dust or the particular matter that volatilizes leaving the reactors during the steel production. this dust comes from ore piles, coke ovens, or blast furnaces. this dust leads to air pollution. especially in the regions that are in the range of steel industrial areas. second, the emission of green gases. the steel production requires large inputs of coke. coke is made by heating cool at high temperature for a very long time which causes a lot of emissions of green gases. the main emission greenhouse gas is carbon hydroxide (co2). the carbon hydroxide emission causes a lot of climate changes as global warming.

Topic related to the solution

1. T-beam

A T-beam (shown in figure 4) is a load-bearing structure made of reinforced concrete, wood, or metal with a T-shaped cross-section that is used in construction. To resist compressive loads, the top of the T-shaped cross-section acts as a flange or compression member. Below the compression flange, the web (vertical section) of the beam resists shear stress and provides greater separation for the paired bending forces. Because it lacks a bottom flange to deal with tension, the T-beam has a huge disadvantage over an I-beam (with I form). Using an inverted T-beam with a floor slab or bridge deck linking the tops of the beams is one method to develop a T-beam more structurally efficient.

FIGURE (4): T-BEAM

2. 3D printer in construction

While using the 3D printers (shown in figure 5) in construction it is referred to 3D construction, which is basically printing entire building, offices and houses.

Reducing their cost and time taking in construction. Using 3D printers in construction will reduce the cost by far, as it almost wastes no material, less material wasted would also means it have less impact on the environment and it does not need any additional worker for it to function, also the printed housed are characterized with low cost as a printed house may only cost 4000$ (in US dollars) which is approximately 63000 Egyptian pounds.

Also, 3D construction does not require workers in the construction site except for some type of 3D construction. The 3D construction mainly depends on software to lay out the building layer by layer in whatever shape does the civil engineer want.

Type of material used:

3D printer usually uses a mixed of building materials most commonly concrete, fibre, sand, and geopolymers, the materials are mixed in a hopper and then they are layered into the building.

FIGURE (5):3D PRINTING

Prior Solutions

1.ICF wall system

Overview:

Insulated Concrete Forms (ICF) are a form of wall construction material used in residential construction (shown in figure 6). It's a different type of construction than standard wood-frame construction. Lightweight concrete material with built-in insulation and a self-anchoring stay-in-place mechanism, the ICF Wall System ensures straightforward and quick installation.

figure (6): ICF wall system

The First ICF home in Yazoo County, Mississippi built using Build Block ICFs On April 10, 2015.

Mechanism:

Instead of using screws to frame the walls, Styrofoam blocks are used to construct the walls, and concrete is poured into those forms. The Styrofoam blocks are insulated concrete forms (ICFs). They're light, simple, and simple to assemble– they just snap together like Lego. They're permanent forms

FIGURE (7): ZONT & ZUCKLE METHOD

that stay in place after the concrete is poured and help insulate the house after it dries. The forms can be layered and interconnected to create concrete-filled walls, ceilings, roofs, and pool walls. Consider that there is a process known as the Zont and Zuckle process that must be followed as shown in (figure 7). It involves a vertical bar connected to a horizontal bar to support the wall. The process of fixing the wall takes time.

Strength points

1. Fire resistance:

In comparison to most other building materials, ICF walls are more fire-resistant. The protection of occupants from fire is dependent on fire resistance. ICF walls can withstand up to for hours of intense fire exposure, whereas normal wood-frame house walls are only rated for one hour of fire exposure.

2- Saving time in the building:

builders benefit greatly from the speed with which ICFs are installed because they can simply pour and just go with the forms. Although this method costs a little more than typical concrete building methods, the amount of work saved usually makes up for the difference – especially when compared to the cost of other alternative insulation methods used.

Weakness points

1. Humidity

An ICF home is susceptible to humidity. The rise in interior humidity is since the concrete is still drying. The humidity level in the air should return to normal once it has completely dried. Until then, using a dehumidifier or air conditioner is important to reduce humidity.

2. Remodeling

Another issue with ICF homes is that remodeling them is difficult. Users should carefully consider the design of their home, as well as any future changes that may be required. Adding a window or door, for example, requires cutting into solid concrete walls, which can be difficult and time-consuming. It's also crucial to account for all the electrical and plumbing chases they'll need, as installing them after the fact may necessitate cutting into the concrete.

2.Engineered wood

Overview:

Engineered wood is also known as composite wood because it includes a range of derivative wood products (as shown in figure 8) that are made by joining together two or more pieces of wood, or fixing strands, particles, fibers, veneers, or boards wood and adhesives, or other ways of attachment fixing to create composite materials.

FIGURE (8): ENGINEERED WOOD

T3 becomes the first modern tall wood building in the U.S (as shown in figure 9). T3 is seven-story office skyscraper in downtown Minneapolis, designed by Michael Green

FIGURE (9): T3 BUILDING

Architecture and DLR Group. It is consisted of 6 stories nail-laminated and glulam timber above 1 story concrete podium and completed in 2016.

Composite wood products can be applied in a range of applications, including both residential and commercial construction, and are frequently used to replace steel in building projects for joists and beams.

Mechanism:

The wood I beams are designed wood structural components with an "I" shape that are strong, lightweight, follow strict performance requirements, and sometimes are called I-joists. I-joists are made up of top and bottom flanges that resist bending and webs that offer excellent shear resistance. The web is often made of plywood or Oriented strand board (OSB), while the flange is typically made of laminated veneer lumber (LVL), or solid sawn lumber (as shown in figure 10). The adaptable, cost-effective framing member is easy to install in residential and light commercial applications because of the solid mix of structural features.

Figure (10): I wooden beam

Strengths points

1. The flexibility in designing:

The wood composite is man-made, so it can be designed for specific performance requirements. It can be made into different thicknesses, grades, sizes, as well as manufactured to take advantage of the native strength characteristics of wood (and sometimes results in greater structural strength and stability than regular wood).

2. Resistance to rot and marine borer attack:

Composite wood is also less likely to fade or warp when exposed to moisture, humidity, and temperature fluctuations over time and far more resistant to rot, decay, and marine borer attack than solid wood. Wood composites are also less expensive than high-quality solid wood because of the affordability of wood scrap material and the production method.

Weakness points

1. Difficulty in maintenance:

Some types of engineered wood used in flooring, such as engineered hardwood, can't be mopped with steam mops. This is because engineered hardwoods are bonded by adhesives that could be affected by steam mopping. So, they require a specially engineered wood cleaner.

2. Toxicity:

The wood layers of some types of engineered wood, like plywood, are bonded together using adhesives. These adhesives are usually made from formaldehyde. Formaldehyde is a colorless gas that can enter the body through inhalation. Materials containing formaldehyde can release it as a gas or vapor into the air. Formaldehyde may cause amyloid leukemia and pharyngeal cancer.

3.Bamboo

Bamboo has a long and distinguished history as a building material in tropical and sub-tropical areas all over the world. It is widely used in a variety of structures, especially in rural areas for housing.

There are a lot of constructions that are made of beam one of the most famous of them is a bamboo sports hall (as shown in figure 11). The carbon footprint of Pany Aden's Sports Hall is zero. The bamboo used in the structure absorbed far more carbon than was emitted during treatment, transportation, and construction.

It was constructed in Thailand in 2017.

Figure (11): Bamboo sports hall

Strengths points

1. Tensile strength:

Because bamboo strands run axially, it has a higher tensile strength than steel

2. Fire Resistance:

Bamboo has great fire resistance and can sustain temperatures up to 4000 degrees Celsius. This is due to the presence of silicate acid and water with a high value.

3. Elasticity:

Due to its elastic properties, bamboo is often used in earthquake-prone areas. Bamboos are readily relocated or installed due to their lightweight, making transportation and building much easier unlike other construction materials, such as bricks and concrete.

Weakness points

1. Shrinkage

Bamboo shrinks substantially more than any other species of wood, particularly when water is lost.

2. Durability

Before being used for construction, bamboo should be appropriately treated against insect or fungal attacks.

Chapter II

Generating and defending a solution

1. Solution requirements

Sustainability:

The material used in building our project should be sustainable to be resistant to erosion, have a long life-span, and be resistant to rooting. Also, it must be unaffected by being immersed in water.

Availability:

The alternative building materials of the project should be widely available in Egypt and accessible throughout the country.

Cost-efficient:

One of the most important conditions for any project's success is its low cost. The project material must be inexpensive, as this will support our project's expansion throughout Egypt. Long-term maintenance costs should be low.
In summary, our project must produce a perfect result without costing a lot of money.

Eco-friendly:

One of the most significant factors to consider when selecting a material is its environmental impact. To increase the efficiency of energy consumed and reduce the impact on human well-being and the environment, the project must be made from environmentally friendly materials.

Efficiency:

The project should use a strong material with high quality to make the best project that can be able to endure the highest weights with the lowest mass and the lowest deflection and make the best use of this beam in a building.

2. Design requirements

The design which is the beam should meet certain criteria so it could be an efficient beam. The beam must withstand 50 newtons at least with deflection no more than 10mm. Loads should be added while measuring the resulting deflection until the beam breaks. the weight of the beam can be minimized to maximize the load-to-weight ratio. The load-to-weight ratio explains the ability of the beam to withstand a load. These criteria were chosen so the beam could achieve durability.

3. Selection of solution

To deal with the lack of alternative building materials, it is important to find a solution that makes Egypt depend more on these materials and this solution is making a beam from alternative building material. The beam is a horizontal structure that withstands vertical loads and bending moments. The beam transfers the loads that are applied along its length to its endpoints like walls, constructions, and columns. to make this beam the plywood was used as an alternative building material. plywood is a sheet of material that is made of combining layers of wood veneer that are glued together. these layers increase the separation between the outer layers where stress is at its highest, meaning its ability to fight back against bending is raised. the plywood has several properties that make it one of the best building materials to be used in the beam. it has a high strength to weight ratio, low density with density in the range of 400kg/m^3 to 700kg/m^3, resistance to fungal attack which give it resistance to corrode counter to other woods, a small hygroscopic and a small changing in dimensions which make the corresponding change in thickness is likely to be in the range of 0.3% to 0.4 , and high elasticity (about 11901 N.mm^{-2}parallel to the grain and across the grain 1200 N.mm^{-2})

4. Selection of prototype

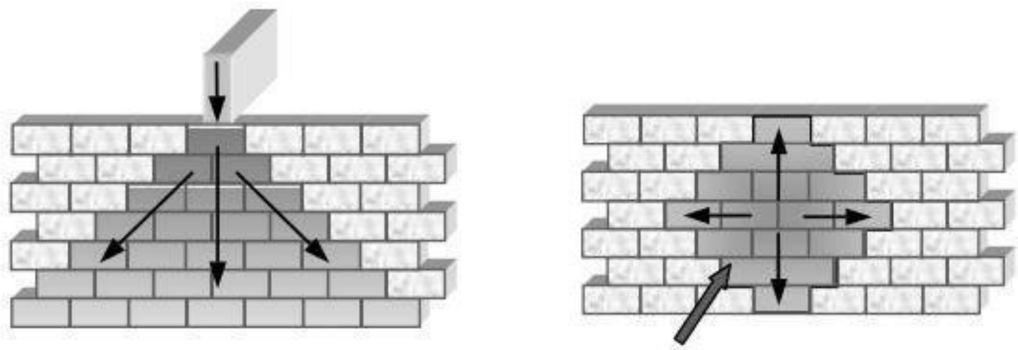
After a lot of searches to find a good beam suitable for our materials to resist bending, flat bar beam has chosen. It has also a cross section of rectangle so it is called also a rectangular beam. Its maximum shear stress force which

$$\tau_{max} = \frac{1.5V}{bh}$$

FIGURE (12): LAW OF MAX SHEAR FORCE

occurs at the neutral axis, becomes equal to 1.5 shear force divided width of section multiplied by the height (as shown in the figure 12).

The beam consists of two layers, each layer consists of wooden cubes put together by a specific design called stretcher bond design. The stretcher bond was used in the structure of 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. (As shown in figure 13.a) and distribution due to out-of-plane loading occurs in a rhombus shape. (As shown in figure 13.b).



(a) Distribution due to in-plane loading **(b)** Distribution due to out-of-plane loading

Figure(13): distribution of load

III. Constructing and testing the prototype

Materials and methods

Materials

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

Item	Plywood	PVA (White glue)
Description	It is the prototype building material; we used a specific type of plywood which is birch plywood.	It is the bending agent of the prototype.
Quantity	105 cubes (Not identical)	400 gm
Picture		
Price	125 L. E	15 L. E
Source of purchase	Building supplies shop	

Safety precautions

A lot of safety precautions were taken in consideration while constructing our prototype:

1) clothes were worn that provide maximum body coverage (lab coat - gloves – face mask) to protect ourselves from any glue drops.

(2) When carrying out experimental work a lab coat was worn (as shown in figure 14) to be safe from any accidents like glue dropping.

FIGURE (14): LAB COAT

(3) long trousers or jeans were worn to cover all of our legs.

(5) There was no eating or drinking during working on the prototype to make sure the prototype will be fine.

(7) The work area was kept tidy and Any spills was cleaned up.

(8) Washing hands carefully was a necessity to get rid of glue.

Methods

The prototype was constructed in a flat-shaped design as shown in figure (15) 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 (15): 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 16).

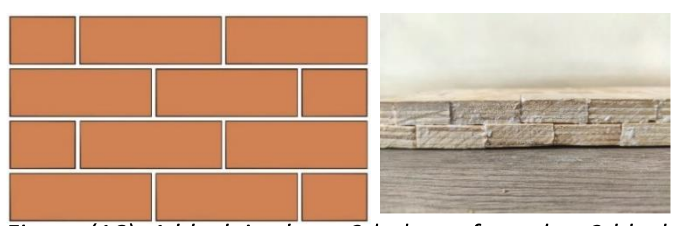


Figure (16): 1 block is above 2 halves of another 2 blocks

Third, the two layers with different distributions of pieces were stacked together by PVA to achieve the stretcher bond style (as shown in figure 17).

Figure (17): surface of the beam.

Test plan

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

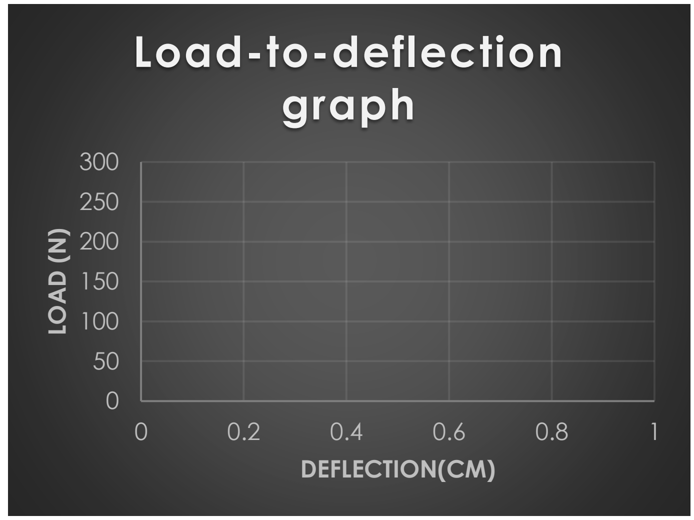
- The weight of the beam was measured to calculate the load-to-weight ratio later.
- The beam was put above two supporting point according to 3-point flexural test (3cm of each end will be considered as a support point).
- The loads were hanged on the beam from the middle with cord.
- The loads were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

Data collection

Negative results:

The first test plan obtained negative results, as shown in (graph 3), because 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 4).

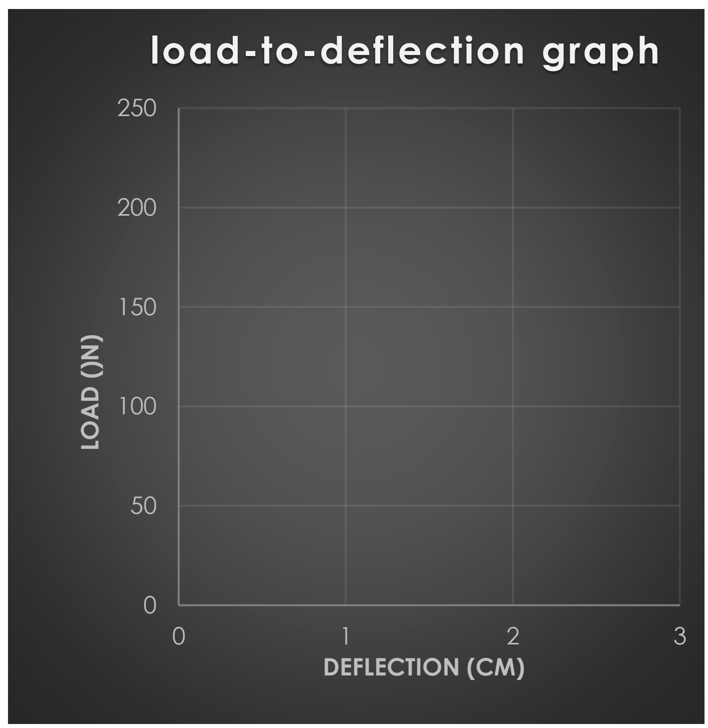


Graph (3): Load-to-deflection in negative results graph

Positive results:

-The beam bears 50N with a deflection of 0.42 cm 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 51,90N, so the load: weight ratio = 195:5.19 = 37.6

-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 beam ranges from 36 to 50 ksi.



Graph (4): Load-to-deflection graph

IV. EVALUATION, REFLECTION AND RECOMMENDATION

Analysis & Discussion

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 third factor is its sustainability. The ability of a material to withstand external forces is referred to as sustainability. 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 18).

$$\Delta = \frac{PL^3}{48EI}$$

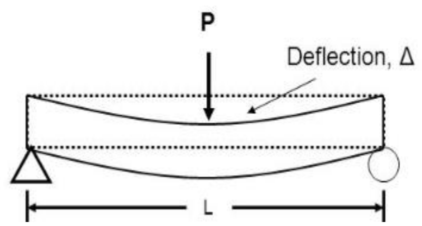
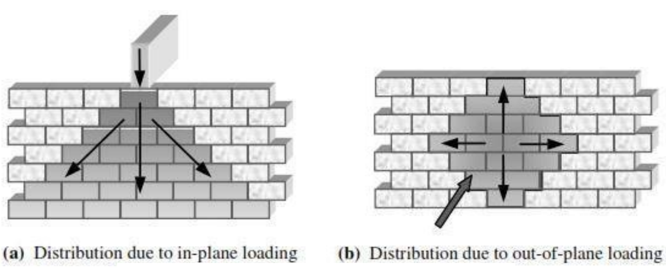


FIGURE (18): LAW OF DEFLECTION.

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 in the structure of 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. (As shown in figure 13.a) and distribution due to out-of-plane loading occurs in a rhombus shape. (As shown in figure 13.b).



Figure(13): load distribution

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 found that the second moment area plays an important role in deflection which resists bending. In order to minimize the second moment area, the cross-section area should be minimized because the cross-section area is directly proportional to second moment area (as shown in figure 19).

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

FIGURE (19): 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 (according to CH.LO1) of wood by measuring the mass of a piece of wood (using the sensitive balance (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 (PH.LO1)) then dividing the mass by the Volume 5.22/8.25=0.633g/cm^3.

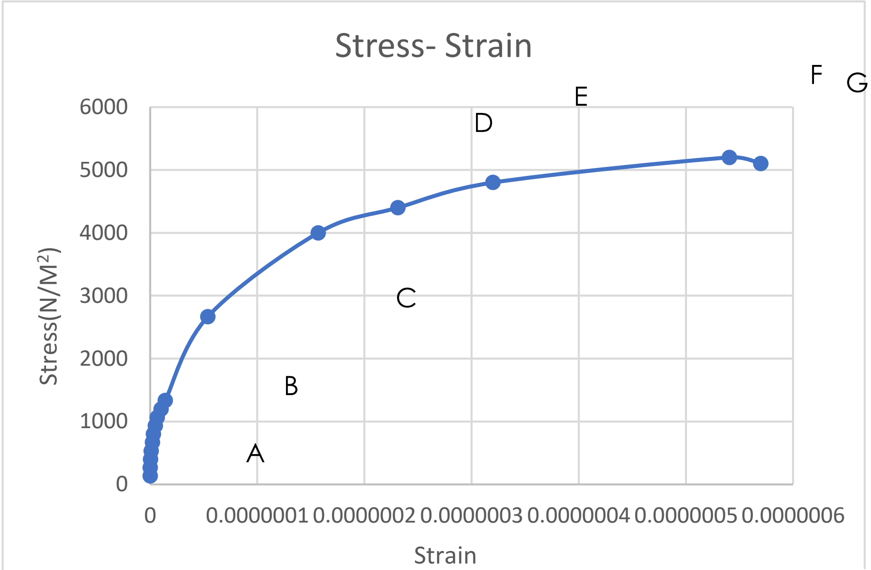
Second, finding the volume of the beam 2.2±0.05×50×7.45±0.05= 800±20cm^3 (by verniers caliper and a measuring tape). Third, converting the volume to mass by multiplying the density by the volume, 820±20×0.633=519±10g and this mass represents 100% of the beam.

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 of the beam analysis:

Stress-strain graph describes the mechanical properties of the beam



GRAPH (5): STRESS-STRAIN GRAPH OF THE BEAM.

graph (5) 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.

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 in the internal support of the beam. Because it would be better to cover the regions where stress is concentrated with fiber glass (as shown in figure 20) This would increase the strength and durability of the beam.

FIGURE(20): FIBERGLASS

It is recommended to use E-poxy (as shown in figure (21) as a binder in the internal support of the beam with the fiberglass because it is characterized by its resistance to acids and chemicals.

FIGURE (21): E-POXY

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 0.15 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 0.3 % to 0.4% per 1% in moisture change.

Learning out comes

Learning outcomes	Concepts used	Description
PH.1.01 physics	-Si units -Uncertainty and errors	it was used in calculating the uncertainty and errors of the measurement and in making a precise and an accurate calculation.
PH.1.02 physics	-Free body diagram	It was used to visualize all the forces acting on the beam to calculate the net force.
PH.1.05 physics	-Torque	It was used to determine the direction of the torque as well as the amount of torque delivered to the beam.
PH.1.06	-Stress-Strain	It was used to calculate the elastic modules of the beam by making Stress-Strain graph.
MA.1.01	-six trig functions	It was used in calculating the deflection of the beam by tan trig function.
MA.1.02	-Scatter plot -Correlation -Regression line	It was used in representing the data in a scatter plot, calculating the best-fit line by regression and correlation.
CS.1.01	-Sketchup tools	It was used in designing a 3d model for the prototype.
Geo.1.03	-Building materials	It was used in learning the required properties of the building material.
Ch.1.03	-Absorption and emission	It was used to learn the absorpiton rate of building materials to determine which one can transfer heat to building or not
MA.1.03	-Cross-section	It was used in drawing 2-D cross-sections of representation of the beam

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