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Testing the Effect of Building Materials on Carbon Footprint

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Abstract : *Architects are interested in using building materials that help save energy in buildings, without considering the impact of using these materials on carbon emissions. This study aims to use of simulation programs to measure the effect of materials (building materials, insulation and glass) on carbon emissions in buildings by measuring the Carbon Equivalent (kgCO2) in the laboratories building and laboratories at Fayoum University.*
By studying the definition of carbon footprint, and the impact of building materials on carbon emissions in buildings. By using the "DesignBuilder" program.to evaluate carbon emissions in building materials.
This study revealed that: The best insulation materials that reduce carbon emissions in the building are "XPS Extruded Polystyrene" – "CO2 Blowing". However, while "Polystyrene" is good insulation, it is one of the most carbon emissions materials.

Keywords *-Building Materials- insulation -carbon footprint- "Design Builder" program.*

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I. Introduction

As a result of increased urbanization and large communities, energy is produced in huge quantities, leading to air pollution and the production of huge quantities of carbon dioxide. this is one of the major contributors of global warming, so the world's countries are trying to cut carbon emissions, and in 2012 it decreased by 15% of the construction and transport associated compared to of 2008 levels. The goal is to reduce carbon emissions 80% by 20501. (fig.1)

in the emission gap report in 2018, it was found that the nationstheir efforts must be redoubled, if we are to aiming preserve our worldas global emissions reacheda new level of 53.5 gigatons of CO2 equivalentIn 20172.carbon footprint is the sum of all emissions of CO2 (carbon dioxide), which were induced by human activities in a given time frame. Usually a carbon footprint is calculated for the time period of a year.[3]

II. Carbon foot print

Demand for low carbon footprint can be a key factor in fostering innovation, while motivating policymakers to encourage sustainable consumption. Nevertheless, their efficient and widespread implementation is hampered by the range of methodological approaches and techniques used to measure life cycle emissions.[4]

The carbon footprint is measure of the total amount of carbon dioxide emissions caused directly and i ndirectly5by an activity or accumulated over the lifetime of a product[6]. Meanwhile, the carbon footprint is a me asure of carbon dioxide emissions[7].

Carbon footprint is a tool to guide emissions reductions and related emissions, so their standardization at the international level is essential[8]. The value of footprint is "tons of carbon dioxide equivalents".

It is an indicator of the impact of human activity on global warming.[9].[10].

III. Materials and carbon emissions (Global Studies)

Building operations contribute significantly to climate change, resulting in more than the third of global greenhouse gas emissions[11].

Emissions from buildings are produced over the building life cycle during the manufacture of materials.

In a study about emissions from production of construction materials in Australia, The use of concrete contributes to the emission of carbon by 42% and then followed by aluminum 37% and iron 9% while flooring cover 8% and affects both paints and glass by 0.1% And 0.9%, respectively[12]. (Fig.2)

In studying greenhouse gas emissions. In a low-energy building in Finland, emissions are estimated at 470 kg / m 2 in terms of building systems, roof emissions are estimated at 40%, while HVAC and the electrical system have a stake of about 20%, to add a share of about 10%.[13] (Fig.3)

In (King Abdullah University of Science and Technology) green concrete was used. It helps to absorb carbon dioxide, in addition to using wood to build and form external destinations, because it absorbs greenhouse gases. (Fig.4)

IV. Case Study

The case study is divided into the study of Methodology and inputs, then conclude the results

V. Methodology

The methodology of the study depends on three steps; (fig.5)

a) Inputs are specific to the basic case of the building, which is the location of the building, activities, building materials, lighting, openings and air conditioning systems.

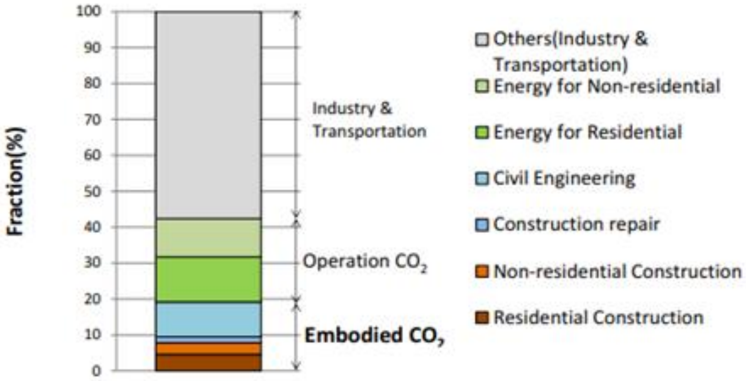

Fig. 1 embodied co_2 from construction, (1)

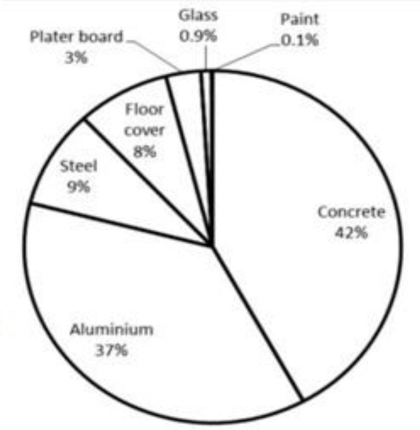

Fig. 2. emissions from production of construction materials (12)

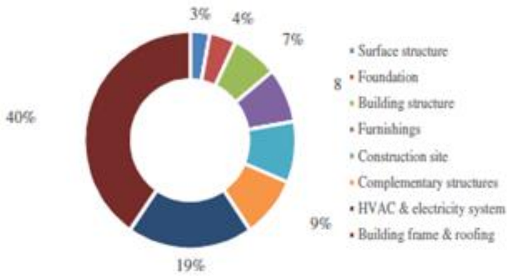

Fig.3. Embodied and construction phase greenhouse gas, (13)

Fig. 4 wood in the construction on the campus of KAUST

Fig.5 show the methodology of the study

b) Simulation process which is based on three cases: The first case is using of different materials in finishing floors, the second case is the using of different insulation materials on the roof of the last floor, and the third case is using different types of glass with openings. The following table shows a detailed explanation of the cases. (Tab. 1)

c) Results of Simulation process is a determination of the least carbon emission used in the study in (finishing floors materials, insulation materials, and glass in openings).

VI. Inputs

The program needs a set of inputs to be simulated

a- **Drawing building:**The building on which the study was based were built in workshop and laboratories at the Faculty of Engineering, Fayoum University. The building consists of workshop in the ground floor, one of which is special for the carpentry, and the other for mechanics and the concrete factory. This floor is a meter high and the upper floor is 4 meters high. It contains the physics and chemistry labs. (Fig.6)

b- **Location:**The project is located in Fayoum city, in North of Upper Egypt.(Fig. 7)

c- **Activities:** The building has a Miscellaneous of activities on the ground floor workshops and laboratories. in next floor Computer labs and drawing galleries.(Fig. 8)

d- **Building Materials:** building materials of The basiccase were input into the program model. As shown in the following (Table.1) then changed to apply the research methodology to measure the best carbon emissions. As shown in the following table (Table.1)

Table.1 a detailed explanation of the three cases of study

No. of case	Description	
The basiccase	Roof reinforced concrete 16 cm / Insulation moisture / sand and mortar 8 cm / tile 2 cm	
The first case	Use of different materials in finishing floors	ceramic/clay tiles - ceramic floor tiles dry -cork - tiles conditioned -wooden battons -wood wool roofing slabs -loose fill/powders – gravel -marble - stone - hard stone (unspecified- woods – softwood- tile bedding- ceramic glazed- gypsum insulating plaster- gypsum plasterboard- limestone- granite- rubber tiles- clay tile (roofing)
The second case	The use of different insulation	mw glass wool (rolls)- mineral fibre/wool – wool- eps expanded polystyrene (standard)- pur polyurethane board (diffusion tight)- polystyrene- xps extruded polystyrene - co2 blowing- r-19 glass-fiber batt insulation (compressed) low-density glass wool, high density glass wool, rock wool of two different densities, cork, foamed glass, and aerogel.
The third case	Use different types of glass with openings	sgl clr 6mm, sageglass climaplus grey no tint, dbl bronze 3mm/13mm arg, dbl clr low iron 3mm/13mm arg, dbl clr low iron 5mm/13mm air, dbl elec abs bleached 6mm/6mm air

VII. Result Of Study Case

The study simulated the four cases described by using (designbuilder program), and revealed the following results.

Fig. 6 plan and elevation of workshop and laboratories at the Faculty of Engineering, Fayoum University

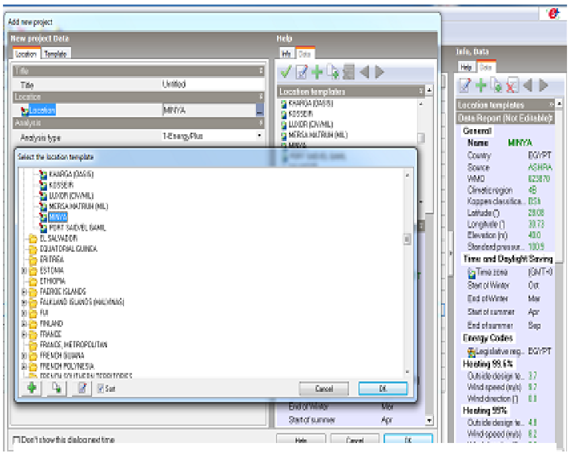

Fig 7show tool bar of location in the program

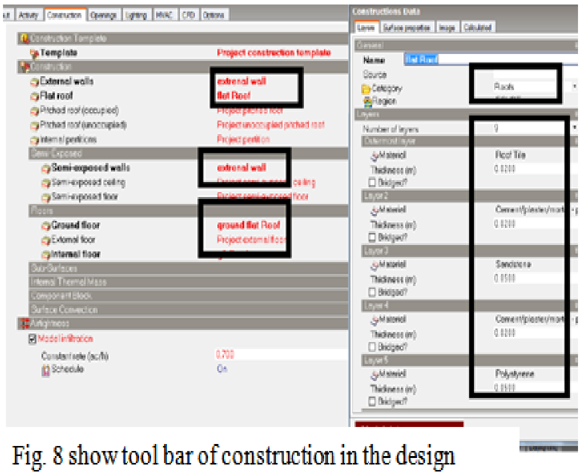

Fig. 8 show tool bar of construction in the design builder program

VIII. First case

In the first case of this study, the simulation was done by using different finishing materials for the floors.The use of "rubber tiles" in the floors is the most materials that emit carbon emissions, it increases carbon emissions by 87%. followed by "ceramic glazed" which increase carbon emissions by 20%, while "loose fill / powders – gravel", "tile bedding"," limestone" and "gypsum insulating plaster" are among the best low carbon materials, because they decrease carbon emissions by -1 to -2%. (table 2) (Fig 9)

Table 2 show the result of using different finishing materials for the floors, and the effects of change material percentage

material	Equivalent CO_2 (kgCO_2)	effects of change %	material	Equivalent CO_2 (kgCO_2)	effects of change %
Basic case	115496.3		Tile Bedding	111608.62	-2%
Ceramic/clay tiles - ceramic floor tiles Dry	123051.47	8%	Gypsum insulating plaster	112350.51	-1%
Cork - tiles Conditioned	120604.87	6%	Ceramic glazed	136850.2	20%
Wooden battons	130865.39	15%	Granite	121994.99	8%
Woodwool Roofing Slabs	118778.7	5%	Limestone	112023.32	-1%
Loose fill/powders - gravel	112147.11	-1%	Gypsum Plasterboard	113092.39	0.08%
Marble	116525.25	3%	Rubber Tiles	214389.41	87%
Stone - hard stone (unspecified)	123113.52	8%	Clay Tile (roofing)	125656.11	10%
Woods - softwood	115041.48	2%			

IX. Second case

In the Second case of this study, the simulation was done by using different types of insulation materials

It is clear from the simulation that the best insulation material that reduce carbon emissions in the building is "XPS Extruded Polystyrene - CO2 Blowing"-6%

Cork is the best insulation materials that reduce carbon emissions by -84.5%, followed by glass wool - high density, foam glass board by -76.8%,

While" R-19 Glass-fiber battulation (compressed) " gives no change from Basic case. While "Polystyrene" is one of the most carbon-emitting, it increases carbon emissions by 29%. (Table 3)(Fig 10)

Table 3 the result of using different insulation materials, and the effects of change percentage

material	Equivalent CO2 (kgCO2)	effects of change material %	material	Equivalent CO2 (kgCO2)	effects of change material %
Basic case	115496.3				
cork	17857.64	-84.5%	Polystyrene	149258.4	29%
EPS Expanded Polystyrene (Standard)	**117285.1**	2%	XPS Extruded Polystyrene - CO2 Blowing	109641.75	-6%
R-19 Glass-fiber batt insulation (compressed)	**115496.3**	No change	PUR Polyurethane Board (Diffusion TIGHT)	**119337.4**	3%
rock wool- high density	17750.2	-84.6%	glass wool - high density	26770.2	-76.8%
Mineral fibre/wool - wool	**121232.3**	5%	rock wool- low density	17857.64	-84.5%
foam glass board	26801.46	-76.8	aerogel	117285.1	1.5
glass wool - low density	26786.46	-76.8%	MW Glass Wool (rolls)	**116233.7**	1%

X. Third case

In the third case of this study, the simulation was done by using different types of glass in openings

In this case, the use of " DBL ELEC ABS bleached 6mm / 6mm air" gives the lowest carbon emissions in the building, its carbon emissions is-5% compared to basic case. followed by "dbl bronze 3mm / 13mmARG", and "DBL CLR" low iron 3mm / 13mm arg", which emissions are 0.08%, but the glass use of sage glass climaplus gray no tint gives larger emission of carbon dioxide in the building, its carbon emissions is 2.5%. (table 4)

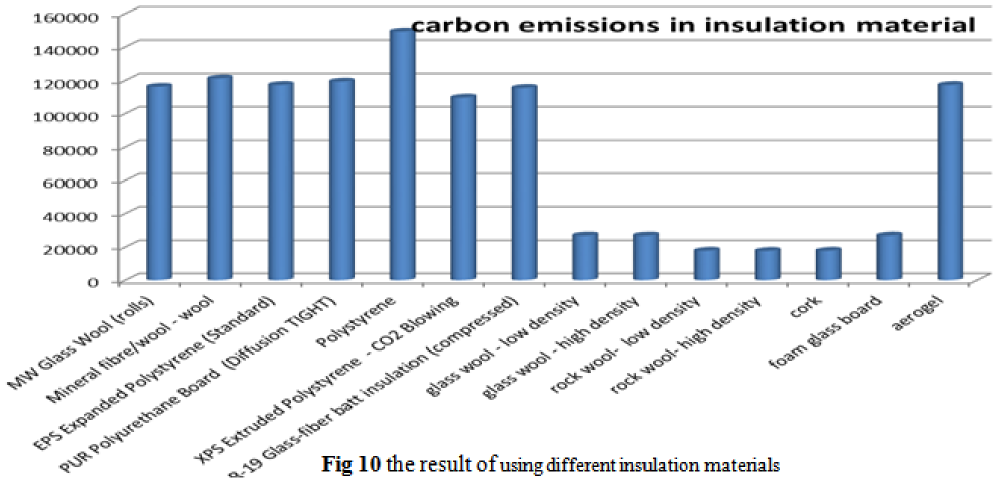

Fig 10 the result of using different insulation materials

Table 4 The result of using different types of glass in openings, and the effects of change percentage.

material	Equivalent CO2 (kgCO2)	effects of change material %
Sgl Clr 6mm	**115496.3**	Basic case
Sage Glass Climaplus Grey No Tint	**118382.9**	**2.5%**
Dbl Bronze 3mm/13mm Arg	**115590.8**	**0.08%**
Dbl clr low iron 3mm/13mm Arg	**115590**	**0.08%**
Dbl Clr Low Iron 5mm/13mm Air	**117117.2**	**1.4%**
Dbl Elec Abs Bleached 6mm/6mm Air	**110489.9**	**-5%**

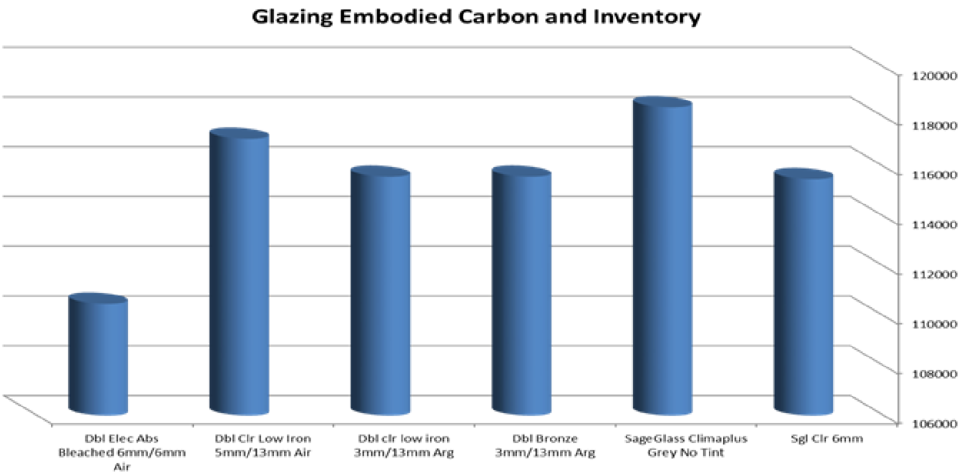

Fig. 12 show the result of using different types of glass in openings

XI. Discussion

In a study on emissions from building materials production in Australia, carbon emission from floors was studied 8% and affected both paints and glass by 0.1% and 0.9%, respectively. This study did not use different types of floor finishing materials. so this study made this case, then reached to some types of floors such as Rubber Tiles in the floors of is the most materials which increase carbon emissions by 87%. Followed by ceramic glazed which increase carbon emissions by 20%.

The using of some materials like: " Loose fill / powders – gravel", "Tile Bedding", "Limestone" and Gypsum insulating plaster in the floors are the best low carbon materials.

Therefore, the study concluded that the previous study did not take into account the effect of the different types of floor finishing materials, which could be less than and greater than the percentage reached by this study

In the same study, it is estimated that carbon emission from glass is about0.9%, and through this research paper it was found In the using of different types of glass with openings, the use of "Dbl Elec Abs Bleached 6mm / 6mm Air" gives the lowest carbon emissions (-5%) in the building, while the use of "Sage Glass Climaplus Gray No Tint" gives larger Emission of carbon dioxide (2.5%) in the building

In Finland, a study was conducted on greenhouse gas emissions from building systems, and emissions from HVAC are estimated at about 20%, and the study in this paper concerned emissions from insulation and thermal insulation from ways to reduce energy use for refrigeration purposes, but the study renewed that insulation produces carbon emissions that affect Building carbon footprint.

In using different types of insulation materials. The best insulation materials that reduce carbon emissions in the building are "XPS Extruded Polystyrene - CO2 Blowing" but. "Polystyrene" is one of the most carbon- emissions materials, while it is good insulation[14].

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