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Development the Construction Materials Sustainable Performance via Value Approaches Techniques

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Abstract : This paper attempts to enhance the sustainable performance of the construction materials in order to raise the forceful of the sustainable aspects by applying value approaches techniques. On the International side, All the construction materials research and the manufactures realization of sustainability approach have increased in different terms. Thermal comfort is the main sustainable aspect that effect the end-users. This paper aims to present the thermal comfort analysis for Glass Fiber Reinforced Gypsum GFRG system in Egypt as a case study for one of the new construction materials. It will present and compare with traditional systems which are used with the GFRG system. It also aims to apply new creative value ideas or value solutions in order to increase sustainability aspects.

Therefore, the study tries to correct the development of the construction materials by applying value solutions. The research applies a scientific methodology with the materials and methods as theoretical studies. Then, results and discussions in each term. Results gained during the analysis of the case study, which is based on the value ideas, can be used as new solutions for the development of GFRG as a construction material.

KEYWORDS: Construction Materials; sustainable performance; value solutions; GFRG

1. MATERIALS and METHODS

1.1. GLASS FIBER REINFORCED GYPSUM (GFRG) SYSTEM DEFINITION

GFRG is a very important solution, there is a need for repetitive projects such as housing projects. The product has many advantages green material, resistance to fire, and water. GFRG is manufactured to a length of 12m, a thickness of 124 minimum and a height of 3mas shown in figure 1. In spite of its main application being in the vatical walls, it can also be used in the construction of horizontal floors and roofs slabs by filling reinforced concrete in the cavities as shown in figure 2.(GFRG design manual,2011).

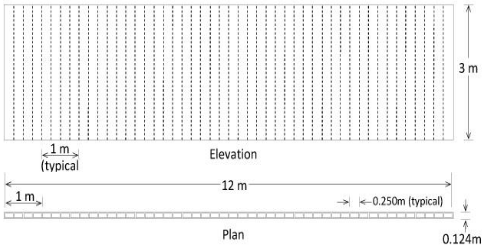


Fig 1: Dimensions of GFRG Panel

Source: GFRG/RAPIDWALL BUILDING STRUCTURAL DESIGN MANUAL

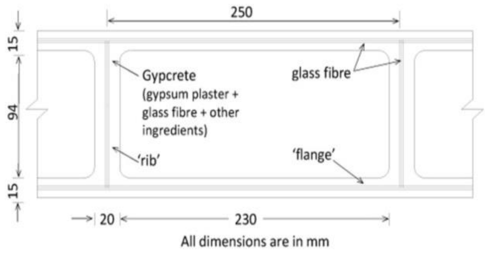


Fig 2: Enlarged View of a Typical Cell

Source: GFRG/RAPIDWALL BUILDING STRUCTURAL DESIGN MANUAL

1.2. GLASS FIBER REINFORCED GYPSUM (GFRG) SYSTEM USES

The panel uses at the intermediate roof slab or floor slab in filling with RC. The strength of the slabs can be enhanced by hidden reinforced concrete micro or small beams. For providing hidden micro beams, the top flange of the cavity is removed in such a way that a minimum 25-millimeter flange on both ends is protruded as shown in figure 3. (Rapid wall inst. manual,2011).

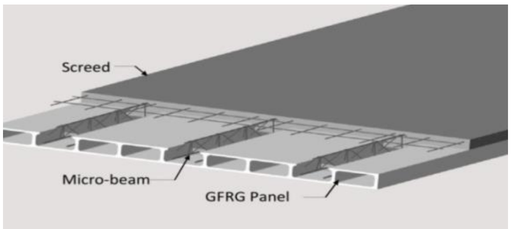


Fig 3: GFRG floor slab with micro beam and screed

Source: GFRG/RAPIDWALL BUILDING STRUCTURAL DESIGN MANUAL

2. RESULTS AND DISCUSSIONS

The research will propose the value idea step by step to analyze each one to follow the main important factors of the value techniques which are quality performance and economic strategies. The steps will be as follow:

1-Thermal analysis for GFRG.

2-Propose a new treatment by adding new mixtures.

3-Thermal analysis for GFRG after treatment.

4-Comparing U-values for the two cases.

5-Development of the ideas based on the results and provide real creative value ideas based on the value perspective.

2.1. THERMAL ANALYSIS For GFRG

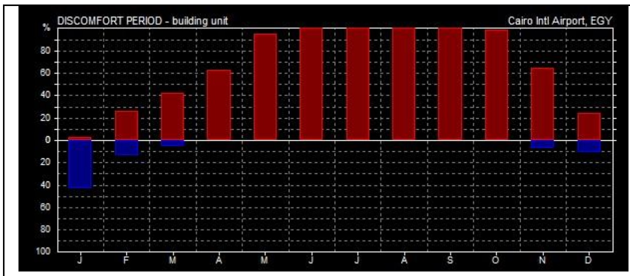
This research will analyze the thermal performance as a sustainable aspect of the GFRG system as the table below, using the U-Value equations. The analysis was achieved and generated the model using the software "Design Builder"; the dimensions for this model are 3m*3m *3m in width, length, and height. (Meselhy,2016). Design Builder is software used to check the energy of building lighting, carbon, and comfort performance. It was developed to simplify the simulation of the building process .It is a tool to quakily compare the function and the performance of building designs to provide the results related to time and budget. **U-Value Calculations**

Table 1. Thermal Analysis for GFRG

Source: Analysis by Author

U = 1/ Rt U = U-Value (W/m2.C) Rt = Overall Thermal Resistance (m2.C/W)	Rt = Ro + Σ R + Ri Ro = Outer Air-Film Resistance = 0.055 m2.C/W Ri = Inner Air-Film Resistance = 0.123 m2.C/W
R = L / K L = Material Width (m) K = Thermal Conductivity (W/m.C)	Rt = Ro + ∑ R + Ri = 0.055+ L1/K1+ L2/K2+ …… + Ln/Kn+0.123

Wall	Material Layers	L (m)	K (W/m.C)	R=L/K	Rt (m2.C/W)	U-Value (W/m2.C)
GFRG Panel System	Outer air-film			0.055	0.312	3.20
	Gypsum plaster	0.0145	0.42	0.0345		
	Concrete	0.094	1.44	0.065		
	Gypsum plaster	0.0145	0.42	0.0345		
	Inner air-film			0.123		



	Month	discomfort		comfort
		hot	cold	
1	January	2%	41%	57%
2	February	28%	14%	58%
3	March	41%	5%	54%
4	April	62%	0%	38%
5	May	95%	0%	5%
6	June	100%	0%	0%
7	July	100%	0%	0%
8	August	100%	0%	0%
9	September	100%	0%	0%
10	October	99%	0%	1%
11	November	65%	8%	27%
12	December	25%	10%	65%

GFRG System

2.2. PROPOSE NEW TREATMENT BY ADDING NEW MIXTURES

Nano technology materials and techniques are now having more impact on the building construction and design phase, one of these mixtures is Aerogel. (Edson,2010). It is one of the nanotechnology materials used in building and construction (Michel,2022). Aerogels are highly solid materials and porous which can consist of 99% air. As highly efficient insulators and extremely fine filters, it has made contributions to space research for years. It can be used in many cases as aerogel tiles and aerogel granulate (Sabu, 2019).

2.3. THERMAL ANALYSIS FOR GFRG AFTER TREATMENT

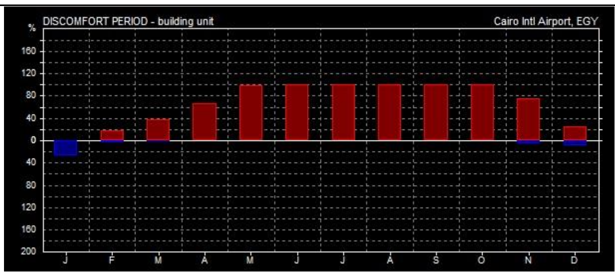
This term will analyze the thermal performance of the GFRG system after adding Aerogel mixtures as the table below, using also the following U-Value equations. The analysis was applied and generated also at the same dimension panels 3m width, 3m length and 3m height by software "Design Builder". The Analysis will consider two types for the Aerogel uses tiles and granulate.

Table 2. Thermal Analysis for GFRG after treatment.
Source: Analysis by Author

Wall	Material Layers	L (m)	K (W/m.C)	R=L/K	Rt (m2.C/W)	U-Value (W/m2.C)
Aerogel tiles	Outer air-film			0.055	0.65	1.522
	Aerogel tiles	0.0254	0.021	1.21		
	Gypsum plaster	0.0145	0.42	0.0345		
	Concrete	0.094	1.44	0.065		
	Gypsum plaster	0.0145	0.42	0.0345		
	Inner air-film			0.123		
Aerogel granulate	Outer air-film			0.055	0.532	1.87
	Aerogel granulate	0.004	0.018	0.22		
	Gypsum plaster	0.0145	0.42	0.0345		
	Concrete	0.094	1.44	0.065		
	Gypsum plaster	0.0145	0.42	0.0345		

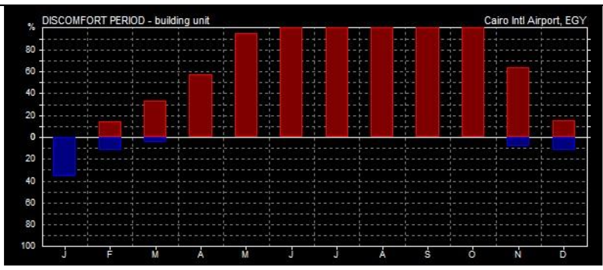
	Inner air-film			0.123		

Aerogel tiles



Month		discomfort hot	discomfort cold	comfort
1	January	0%	28%	72%
2	February	19%	1%	80%
3	March	39%	1%	60%
4	April	64%	0%	36%
5	May	94%	0%	6%
6	June	100%	0%	0%
7	July	100%	0%	0%
8	August	100%	0%	0%
9	September	100%	0%	0%
10	October	100%	0%	0%
11	November	75%	4%	21%
12	December	22%	8%	70%

Aerogel granulate



Month		discomfort hot	discomfort cold	comfort
1	January	0%	35%	65%
2	February	15%	11%	74%
3	March	34%	5%	61%
4	April	58%	0%	42%
5	May	94%	0%	6%
6	June	100%	0%	0%
7	July	100%	0%	0%
8	August	100%	0%	0%
9	September	100%	0%	0%
10	October	100%	0%	0%
11	November	63%	8%	29%
12	December	16%	11%	73%

2.4. COMPAREING BETWEEN U-VALUES for TWO CASES

After adding new nano mixture aerogel materials, the thermal comfort performance is slightly improved from month no. 11 to no. 4. The other months are typically the same conditions. This results improvement was below the research expectations for the sustainable term mainly on the thermal comfort performance. When we compared GFRG before the nano treatment with after treatment, the thermal comfort performance was almost the same as shown in figure 4.

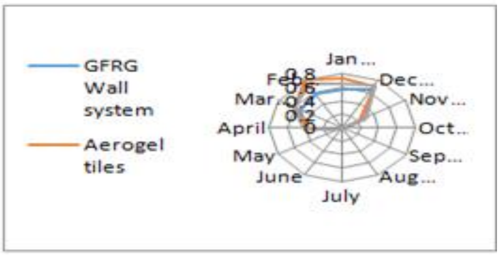


Fig 4: Comparing between U-Values for case study
Source: Analysis by Author

2.5. DEVELOPMENT THE VALUE IDEA

The milestone in the value methodologies is a creative value idea. On the other hand, the study area is not only concerned with new technologies to get more thermal comfort and raise the quality and effective results but also the economic term is a most important factor in value idea. Value techniques are playing by two factors, to improve the quality performance for GFRG and reduce the cost (initial and running cost) by eliminating any unnecessary costs (Anderson, 2014).

The additional cost in front of that slight effect is not equal or not enough for improving the quality requirements in the valuation techniques.

Table 3. Thermal Analysis for GFRG.
Source: Analysis by Author

	Month		discomfort hot	discomfort cold	comfort
More void cavity	1	January	0%	20%	80%
	2	February	15%	9%	76%
	3	March	30%	5%	65%
	4	April	45%	0%	55%
	5	May	80%	0%	20%
	6	June	85%	0%	15%
	7	July	90%	0%	10%
	8	August	90%	0%	10%
	9	September	85%	0%	15%
	10	October	85%	0%	15%
	11	November	60%	8%	32%
	12	December	10%	11%	79%

The main reason for the thermal comfort performance was almost the same as filling and adding more concrete to the cavity in external walls especially.

On the other hand, the value solution recommends increasing the void cavity. This void will play a natural insulator without adding any unnecessary cost (Laurie, 2017).

Structural wise, Concrete by nature is too weak to resist tensile stress while it has a quite strong compressive strength, the tensile strength of concrete is only about 10 % of its compressive strength. This is where the idea of prestressing in "How to make use of concrete high compressive strength overcome its nature weakness in tension" (Bijan, 2014).

The post tension technique is a clever technique to reinforce the concrete, by applying, external stresses opposite in direction and equal in magnitude to the original stresses of concrete as shown in figure 5.

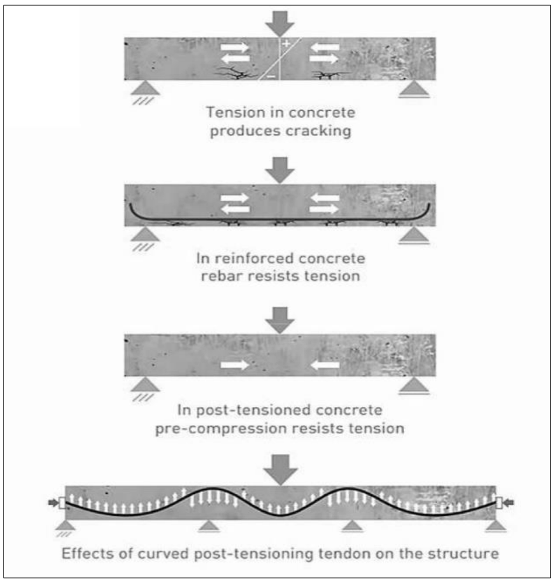


Fig 2: Effect of post tensioning on the structure
Source: Post-Tensioned Buildings Design and Construction, 2014

Table 4. Thermal Analysis for GFRG after more void cavities.
Source: Analysis by Author

Row Labels	GFRG Wall system Rt (m2.C/W)	Aerogel tiles Rt (m2.C/W)	Aerogel granulate Rt (m2.C/W)	More void cavities Rt (m2.C/W)
January	0.57	0.72	0.65	0.8
February	0.58	0.8	0.74	0.76
March	0.54	0.6	0.61	0.65
April	0.38	0.36	0.42	0.55
May	0.05	0.06	0.06	0.2
June	0	0	0	0.15
July	0	0	0	0.1
August	0	0	0	0.1

September	0	0	0	0.15
October	0.01	0	0	0.15
November	0.27	0.21	0.29	0.32
December	0.65	0.7	0.73	0.79
Grand Total	**3.05**	**3.45**	**3.5**	**4.72**

The economics of the pre-stressing concrete is playing with many factors. The individual requirements of each case by using specific accessories. The quantities of materials included all items like ordinary concrete, reinforced concrete, formwork, and post tensioning tools. Other factors such as speed of construction, foundation cost, etc., must also be given into consideration as shown in figure 6,7.

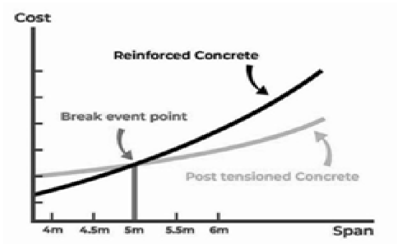


Fig 6: Exponential saving for span < 5 m

Source: Post-Tensioned Buildings Design and Construction, 2014

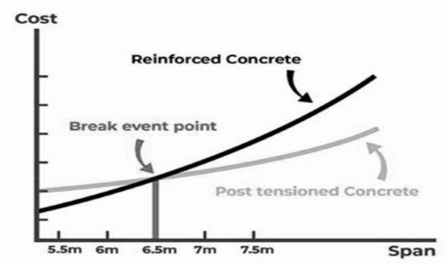


Figure 7: Exponential saving for span 6.5> **m**

Source: Post-Tensioned Buildings Design and Construction, 2014

III . CONCLUSION

The study is built on the theoretical part shown in materials and methods and the applied part shown in dissections and results. The developed new framework needs more valuable tools to be able to improve the quality related to thermal comfort and reduce the unnecessary cost. The study believes that the value solutions and framework have shown valuable tools for construction materials developments.

The research has concluded that the assessment using value engineering tools as follows:

- After adding new materials such as aerogel materials (tiles and granulate), the quality performances at the thermal comfort are slightly improved during the period from month no.11 to no.4. This improvement was below our expectations for its performance mainly when considering the cost factor.
- When the study compared the traditional system with the panel system, the thermal comfort performance was almost the same. That means, this alternative is out of value engineering approach, we increase the cost without improving the quality level.
- After the analysis Thermal conductivity factor was more than expected. the main reason for that is the filling of concrete to the cavity in external walls especially.
- The study uses the creativity idea based on value strategies, by applying the opposite direction, post-tensioning techniques which will achieve the positive effects. These positive factors are reducing the thermal conductivity by getting the concrete more properties for reducing the filling cavities.
- The study recommends applying the value engineering and its solution process not only in the contraction process but also in the materials.
- The study recommends other disciplines in the construction industry must apply value solutions to get more valuables ideas.

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