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SUSTAINABILITY PERSPECTIVE OF SAW-GANG GRANITE WASTE IN CONCRETE MIXES

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ABSTRACT

This paper highlights the sustainability benefit of using saw-gang granite waste with various proportions to substitute cement and fine aggregate in concrete with an aim to prevent the environmental pollution especially in the regions of excessive granite production.

Three concrete mixes of 5%, 10%, and 15% partially replacing cement by granite waste, and three mixes of 10%, 17.5% and 25% partially replacing fine aggregate by granite waste were studied for sustainability measures using the Sustainable Decision Support System (SDSS).

The study revealed that there is a directly proportional relationship between the percentage of granite waste added to the mixes and the sustainability measures as compared to the control mix. In general, sand replacement by 25% of saw-gang granite waste showed the highest sustainability measures when considering all SDSS factors. Whereas, cement replacement mixes showed more significant effect on sustainability measures when considering climate change, pollution, energy consumption and cost factors.

KEYWORDS: Granite Waste, Environmental Pollution, Recyclability of Construction Materials, Green Concrete, Low Consumption of Raw Materials

INTRODUCTION AND GENERAL REVIEW

Sustainability is ascertained by making a balance for the natural resources with the environmental, social and economic requirements of the human society. Sustainable development related to the construction industry involves the efficient allocation and use of natural resources, reduction in consumed embodied energy, minimize pollution, reuse and recycling materials, creating healthy and safe working environment, facilitating employment creation, developing human resources and uplifting financial benefits [1,2].

Granite and marble sawing powder wastes is a widespread by-product of industrial process in many countries rich with ornamental stone. Generally these wastes pollute and damage the environment due to sawing and polishing processes [3].

Green Concrete as the name suggests is eco friendly and saves the environment by using waste products generated by industries in various forms like rice husk ash, micro silica, etc to make resource-saving concrete structures. Green concrete is very often also cheap to produce as it uses waste products directly as a partial substitute for cement, thus saving energy consumption in production of per unit of cement. It is realistic to assume that the technology can be developed, which can reduce the CO_2 emission related to concrete production. Marble and granite sludge powder can be used as filler and helps to reduce the total voids content in concrete [4].

Garas G. L et al., 2014 observed that studies on red granite revealed that concrete mixes containing 30% red granite dust showed comparable compressive strength using natural or recycled aggregates, good workability, and excellent reddish coloured surface finish. Therefore, it was recommended to re-use these wastes in concrete to move towards sustainable development in the construction industry and produce green concrete [5].

Mamta R. and Jayeshkumar P., 2013 studied the economical benefits of using the sludge generated from natural marble manufacturing processes as raw material or as a by – product instead of being a waste material. The study revealed that the use of stone waste in brick manufacturing can solve the disposal problem; reduce the cost and produce a greener eco-friendly brick for construction [6].

Bacarji et al., 2013 investigated the applicability of marble and granite residues as a sustainable alternative for cement replacement in Brazil. In this study Compressive strength, elastic modulus and water absorption tests were conducted to examine the mechanical performance of concrete containing marble and granite residues [7].

A similar study was conducted by Bahar D., 2010, in order to study, the effects of using waste marble dust as a fine material on the mechanical properties of the concrete. It was observed that the addition of waste marble dust replacing the fine material passing through a 0.25 mm sieve at particular proportions has displayed an enhancing effect on the concrete compressive strength [8].

OBJECTIVES

The main aim of this research was to study the sustainability measures of the green concrete produced by using saw-gang granite waste as a partial replacement of sand and cement in concrete mixes.

METHODOLOGY

Sustainable decision support system (SDSS) [9] was used in order to assess the sustainability of alternative mixes (green concrete mixes SGC5, SGC10, SGC15, SGF10, SGF17.5, and SGF25) and compare them to the traditional concrete (control mix CM).

Table (1) presents the components and weights of the alternative mixes under the sustainability study: Control mix, three mixes of partially replacing cement by granite waste (5%, 10%, and 15% for cement replacement by weight), and three mixes of partially replacing fine aggregate by granite waste (10%, 17.5% and 25% for sand replacement by weight). All concrete mixes were prepared with the constant W/C ratio (0.45%). Selection of alternatives was based on a previous technical evaluation in an earlier stage, where those mixes were technically studied by conducting experimental tests to evaluate their mechanical properties [10].

Table 1: Alternative Mixes' Weights and Percentages

Concrete Design Mixes			Components	Cement	Fine Aggregate	Coarse Aggregate	Granite Waste
1	Control mix	CM	Weight (kg)	350	450	900	0
			Percentage	20.59%	26.47%	52.94%	0.00%
2	Saw-gang Granite 5% Cement Replacement	SGC 5	Weight (kg)	332.5	450	900	17.5
			Percentage	19.56%	26.47%	52.94%	1.03%
3	Saw-gang Granite 10% Cement Replacement	SGC 10	Weight (kg)	315	450	900	35
			Percentage	18.53%	26.47%	52.94%	2.06%
4	Saw-gang Granite 15% Cement Replacement	SGC 15	Weight (kg)	297.5	450	900	52.5
			Percentage	17.50%	26.47%	52.94%	3.09%

Table 1: Contd.,

5	Saw-gang Granite 10% Sand Replacement	SGF 10	Weight (kg)	350	405	900	45
			Percentage	20.59%	23.82%	52.94%	2.65%
6	Saw-gang Granite 17.5% Sand Replacement	SGF 17.5	Weight (kg)	350	371.25	900	78.75
			Percentage	20.59%	21.84%	52.94%	4.63%
7	Saw-gang Granite 25% Sand Replacement	SGF 25	Weight (kg)	350	337.5	900	112.5
			Percentage	20.59%	19.85%	52.94%	6.62%

SUSTAINABILITY FACTORS & ASSUMPTIONS

Sustainable decision support system (SDSS) is a life cycle assessment method that can be used to compare between different alternatives on a sustainability basis. It is a software tool based on multi-criteria decision analysis technique that used to rank alternatives depending on a developed sustainable scoring system [11,12].

Actually, life cycle of the alternative mixes can be considered through manufacturing, construction and demolition phases through the SDSS. However, in this study the produced concrete have similar sustainable behaviour during construction and demolition phases, therefore; only manufacturing phase was considered.

Two groups of total ten factors – and their indicators - present the flowchart of the SDSS factors. The ten sustainable factors cover the environmental, economical, social and technological areas of sustainability through the alternative life. Each group includes five sustainable factors [9].

First Group: ***Includes Five Sustainable Factors Related To Structural Element Design***

- Climate Change includes global warming (embodied CO_2 is an indicator to measure it)
- Pollution includes air pollution and acidification (DALY index and acidification index are indicators to measure them respectively)
- Energy Consumption (initial embodied energy is an indicator to measure it)
- Resources & Waste includes raw materials consumption and solid waste (weight of raw materials consumption and solid waste generated through manufacturing are indicators to measure them respectively)
- Cost (market price is an indicator to measure it)

Life cycle inventory (LCI) data for alternatives' components (cement, aggregate, granite waste) were collected from different sources to be integrated in the SDSS in order to fulfil the required input data of the first group of SDSS factors for manufacturing phase. Table (2) presents the collected LCI data of CO_2, SO_x, NO_x, particulates, embodied energy, raw material consumption and solid waste for used materials.

The collected data were based on the results of different published reports and papers such as reports of Portland Cement Association (PCA), Athena Sustainable Materials Institute, and concrete centre [13,14,15], Fact Sheet of National Ready Mixed Concrete Association [16], BEES Technical Manual and User Guide of National Institute of Standards and Technology [17], Published paper by Baird, et al [18], and SPINE database [19]. Average values were considered for the different sources' values of the same indicator.

Saw-gang granite waste is a waste material; therefore, it was assumed that it had no emissions, embodied energy, raw material or waste for manufacturing phase. Cost of all materials was based on actual market price in Egypt.

Table 2: Life Cycle Inventory (LCI) Data for Used Materials

	Climate Change	Pollution			Energy Consumption	Resource & Waste	
Indicator	**CO_2**	**SO_x**	**NO_x**	**Particulates**		**Raw Material Consumption**	**Solid Waste**
Unit	Kg/ton	g/ton	g/ton	g/ton	MJ/ton	Kg/ton	Kg/ton
Cement	852	635	2069	2152	4641	1602	17
Aggregate	3	1	8	101	41	1000	0

Second Group: ***Includes Five Sustainable Factors Related To General Material Properties***

- Recyclability includes recycled content is an indicator to measure it.
- Local Economic Development includes locality and employment (local material/equipment and contribution to employment & skills improvement are indicators to measure them respectively)
- Health/Safety includes health and safety (environmental quality and safety against labours accidents are indicators to measure them)
- Human Satisfaction includes climate/culture and noise/vibration (appropriateness for climate “habitability” and level of noise & vibration insulation are indicators to measure them)
- Practicability includes constructability and resource depletion (degree of off-site manufacture and renewability of resources are indicators to measure them)

In order to fulfil the required input data of the second group of SDSS factors for manufacturing phase, data for alternatives’ components (cement, aggregate, granite waste) were collected or assumed. Saw-gang granite waste is a waste material; therefore, it was assumed it has 100% recycled contents. The recycled content of aggregate or cement was considered as 0% because virgin aggregate was used and there were no recycled components in the used cement.

All used materials are local materials, local labours, non-renewable resources and same degree of safety, off-site manufacturing, constructability, and appropriateness of culture/climate. Therefore, local economic development, health and safety, human satisfaction, and practicability factors for all used materials were assumed to be100% due to similarity in their indicators.

RESULTS AND DISCUSSIONS

The SDSS software was used to evaluate and compare the sustainability of the alternative mixes under study (CM, SGC5, SGC10, SGC15, SGF10, SGF17.5, and SGF25). Moreover, the study was performed on four divisions (a, b, c, and d) to develop a deep and reliable analysis for the sustainability of alternatives.

Division (a): Overall Evaluation

Sustainability analysis was performed taking into consideration the ten sustainable factors (i.e., all SDSS factors) using the system default weights of factors

Division (b): First Group Evaluation

Sustainability analysis was performed taking into consideration only the first group of SDSS factors (i.e., five factors related to the element design) using equal weights of factors.

Division (c): Second Group Evaluation

Sustainability analysis was performed taking into consideration only the second group of SDSS factors (i.e., five factors related to general material properties) using equal weights of factors.

Division (d): Individual Evaluation

Sustainability analysis was performed taking into consideration each factor separately. Only the first six factors are selected to be analysed for this step because the other four factors are similar for all alternatives as described before. In each process, weight of considered factor 100% was used.

Tables (3) and (4) present the results of sustainability evaluation of alternatives considering the four divisions (a), (b), (c) and (d). The tables show the sustainability ranks based on the SDSS measurement scale. The results were based on materials' quantities and percentages of concrete mixes as well as collected/assumed data for the system factors and indicators.

Table 3: Sustainability Results of Alternatives (Divisions a, b and c)

Concrete Mix	Sustainability Rank (R^+)		
	Division (a)	Division (b)	Division (c)
	Considering all SDSS Factors	Considering First Group of SDSS Factors	Considering Second Group of SDSS Factors
CM	54.93%	88.67%	50.00%
SGC5	55.47%	88.97%	50.52%
SGC10	56.02%	89.27%	51.04%
SGC15	56.56%	89.57%	51.56%
SGF10	56.24%	88.84%	51.33%
SGF17.5	57.22%	88.96%	52.34%
SGF25	58.20%	89.09%	53.36%

Table 4: Sustainability Results of Alternatives (Division d)

Concrete Mix	Sustainability Rank (R^+)					
	Division (d): Considering Each Factor of SDSS Factors					
	Climate Change	Pollution	Energy	Resource & Waste	Cost	Recyclability
CM	93.16%	91.90%	96.91%	80.83%	88.32%	0.00%
SGC5	93.50%	92.28%	97.06%	81.13%	88.80%	1.03%
SGC10	93.84%	92.66%	97.21%	81.42%	89.28%	2.06%
SGC15	94.17%	93.05%	97.36%	81.72%	89.76%	3.09%
SGF10	93.17%	91.91%	96.92%	81.27%	88.35%	2.65%
SGF17.5	93.17%	91.92%	96.92%	81.60%	88.38%	4.63%
SGF25	93.17%	91.93%	96.92%	81.93%	88.40%	6.62%

Division (a): Overall Evaluation

Sustainability Analysis Considering all SDSS Factors

The results revealed that SGF25 mix had the best sustainability rank of all alternatives with an increase of 3.27% than CM. In addition, SGC15 had the best sustainability value of cement replacement mixes increasing than CM by 1.63% as presented on Figure (1). SGC5 gave the worst sustainability value of all alternatives as it increased only by 0.54% than CM. In general, sand replacement mixes were more sustainable than cement replacement mixes.

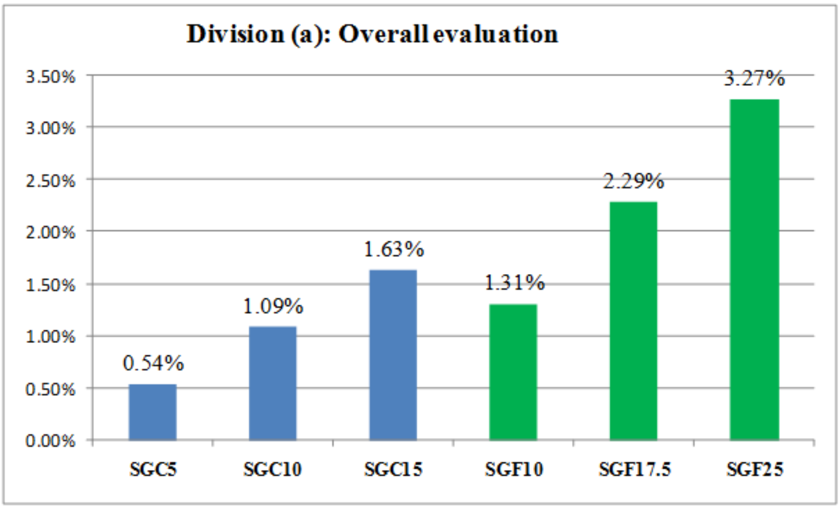

Figure 1: Increase of Samples' Sustainability Than Control Mix Considering all SDSS Factors

Division (b): First Group Evaluation

Sustainability Analysis Considering the First Group of SDSS Factors

The results showed that SGC15 mix had the best sustainability rank of all alternatives. An increase of 0.90% than CM was recorded. In addition, SGF25 had the best sustainability evaluation of sand replacement mixes as it increased by 0.42% than CM as shown in figure (2). SGF10 had the worst sustainability measures of all alternatives showing a slight increase of 0.17% than CM. In this division of evaluation, cement replacement mixes showed more significant effect on sustainability measures than sand replacement mixes. This was because reducing cement content in the mixes of cement replacement means reducing cost, negative emissions (i.e. CO_2, SO_x, NO_x, ...), consumed resources and consumed energy. While, sand has no negative emissions (i.e. CO_2, SO_x, NO_x, ...) or consuming energy during the manufacturing phase or expensive material; therefore, replacing sand by granite waste in the mixes of sand replacement cannot increase the sustainability rank of the produce concrete mix.

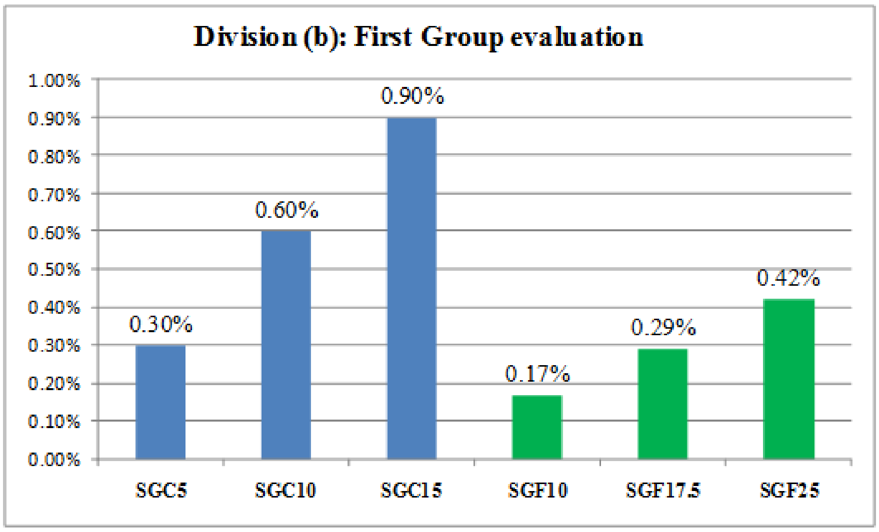

Figure 2: Increase of Samples' Sustainability than Control Mix Considering First Group of SDSS Factors

Division (c): Second Group Evaluation

Sustainability Analysis Considering the Second Group of SDSS Factors

The results showed that SGF25 mix had the best sustainability rank of all alternatives with an increase of 3.36% than CM. In addition, SGC15 had the best sustainability evaluation of cement replacement mixes increasing than CM by 1.56% as presented in figure (3). SGC5 recorded the worst sustainability measures of all alternatives increasing than CM only by 0.52%. In this division of evaluation, sand replacement mixes were more sustainable than cement replacement mixes due to the bigger percentages of recyclability in sand replacement mixes.

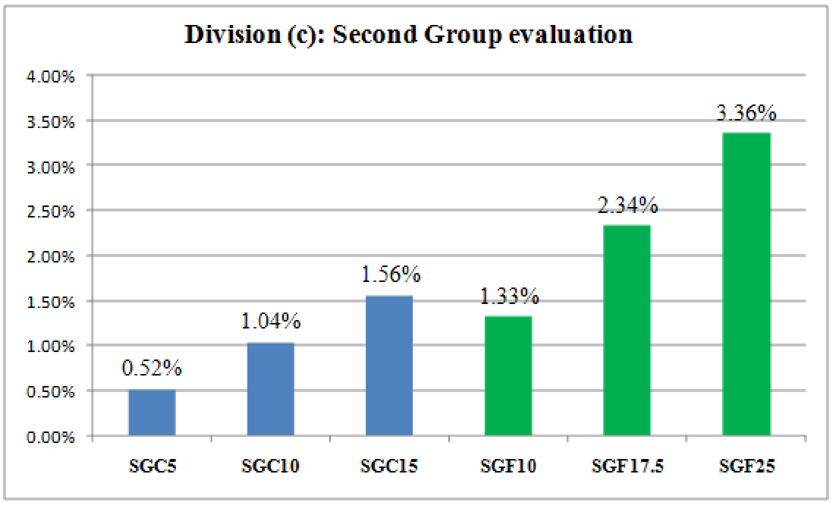

Figure 3: Increase of Samples' Sustainability than Control Mix Considering Second Group of SDSS Factors

Division (d): Individual Evaluation

Sustainability Analysis Considering each Factor Separately

When considering Climate Change, Pollution, Energy Consumption or Cost factor separately, the results showed that SGC15 mix had the best sustainability rank of alternatives with increases of 1.01%, 1.15%, 0.45%, and 1.44% than CM respectively as presented in Figure (4). On the other hand, all sand replacement mixes had similar sustainability ranks with no significant increase than CM (less than 0.08%) as presented in Figure (4). Consequently, cement replacement mixes were better than sand replacement mixes for these factors.

The results showed that SGF25 mix had the best sustainability rank of alternatives when considering Resources/Waste factor or Recyclability factor with increases of 1.1% and 6.62% than CM respectively. In addition, SGC15 had the best sustainability rank of cement replacement mixes with increases of 0.89% and 3.09% than CM respectively as presented in figure (4). Therefore, sand replacement mixes were more sustainable than cement replacement mixes for these factors.

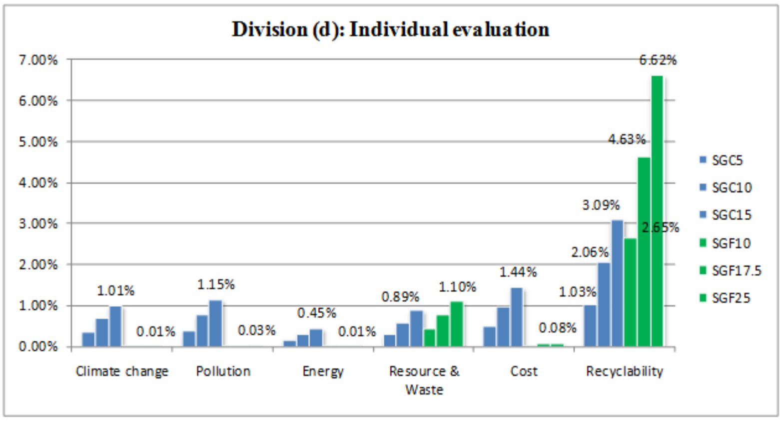

Figure 4: Increase of Samples' Sustainability than Control Mix Considering Each Factor of SDSS Factors

CONCLUSIONS

This paper presented a comparative study between different concrete mixes using various percentages of granite waste in order to evaluate the sustainability of each design mix. Seven design mixes were selected - after testing their mechanical properties in a previous stage – to study their sustainability: One control mix with no granite waste contents, Three mixes of cement replacement by granite waste (SGC5, SGC10, SGC15), and three mixes of sand replacement by granite waste (SGF10, SGF17.5, SGF25)

A sustainable decision support system (SDSS) software was used to compare between the alternatives using sustainability measurements. Results showed that the design mixes with granite waste contents had better overall sustainability rank than the traditional mix (control mix) by 0.54% to 3.27% on the SDSS measurement scale.

Based on the results of SDSS, there was a directly proportional relationship between the percentage of granite waste in the concrete mix and the sustainability rank of the mix. However, this relation was not significant in case of sand replacement (SGF10, SGF17.5 and SGF25) when considering one factor separately such as climate change, pollution, energy, and cost.

It can be noticed that the higher increase of sustainability evaluation than control mix can be referred to the recyclability factor especially for sand replacement mixes with increases ranging from 2.65% to 6.62%. In addition, when considering the first group of SDSS "division b", the increasing values in sustainability than control mix were ranging from 0.17% to 0.90%. These values were less than the increasing values when considering the second group of SDSS "division c" which were ranging from 0.52% to 3.36%.

In division (b) when considering the first group of SDSS factors including climate change, pollution, energy, resource & waste and cost; it can be noticed that the increase in sustainability in cement replacement mixes (SGC5, SGC10, SGC15) was better than the increase of sustainability in sand replacement mixes (SGF10, SGF17.5, SGF25). While, in division (c) when considering the second group of SDSS factors; it can be noticed that the increase in sustainability rank in cement replacement mixes (SGC5, SGC10, SGC15) was less than the increase of sustainability in sand replacement mixes (SGF10, SGF17.5, SGF25) due to the bigger percentages of recyclability in sand replacement mixes. It was the same reason of why sand replacement mixes were better than cement replacement mixes in overall sustainable evaluation in division (a) when considering all SDSS factors.

REFERENCES

1. Ding, G.K., 2008. Sustainable construction: the role of environmental assessment tools. Journal of Environmental Management, 86, 451–464.
2. Yang, J., Brandon, P.S., and Sidwell, A.C., 2005. Smart and sustainable built environments. Oxford: Blackwell
3. Dhanapandian, S. and Gnanavel, B., 2010. "Using Granite and Marble Sawing Power Wastes in the Production of Bricks: Spectroscopic and Mechanical Analysis". Research Journal of Applied Sciences, Engineering and Technology ; vol. 2, issue (1), p73 – 86.
4. Desai1, D.B., Gupta1, A.K. and Pradeep Kumar, 2013. "Green Concrete: Need of Environment". International Journal of Advanced Science, Engineering and Technology, Vol 2, Issue 2, pp134-137.
5. Garas G. L., Allam M. E. and Bakhoum E. S., 2014. "Studies undertaken to incorporate marble and granite wastes in green concrete production". ARPN Journal of Engineering and Applied Sciences VOL. 9, NO. 9
6. Mamta R. and Jayeshkumar P., 2013. "Stone Sludge: Economical Solution for Manufacturing of Bricks", International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume-2, Issue-5, April 2013
7. Bacarji, E., Toledo, R.D., Koenders, E.A.B, Figueiredo, E.P., and Lopes, J.L.M.P., 2013. "Sustainability perspective of marble and granite residues as concrete Fillers". Construction and Building Materials, pp 1–10.
8. Bahar D., 2010, "The effect of the using waste marble dust as fine sand on the mechanical properties of the concrete". International Journal of the Physical Sciences Vol. 5(9), pp. 1372-1380.
9. Bakhoum, E. & Brown, D., 2014. An automated decision support system for sustainable selection of structural materials. International Journal of Sustainable Engineering, pp.1-13. Taylor & Francis.
10. Allam M. E., Bakhoum E. S. and Garas G. L., 2014. "Re-use of granite sludge in producing green concrete". ARPN Journal of Engineering and Applied Sciences VOL. 9, NO. 12,
11. Bakhoum, E. & Brown, D, 2012. "A Developed Sustainable Scoring System for Structural Materials Evaluation.", Journal of Construction Engineering and Management (ASCE), (138), pp.110-119.
12. Bakhoum, E. & Brown, D., 2012. A hybrid approach using AHP–TOPSIS–entropy methods for sustainable ranking of structural materials. International Journal of Sustainable Engineering, 6 (3), pp 212-224. Taylor & Francis
13. Marceau, M.L., Nisbet, M.A. & VanGeem, M.G., 2007. Life Cycle Inventory of Portland Cement Concrete. Portland Cement Association (PCA).
14. Athena, 2005. Cement and Structural Concrete Products: Life Cycle Inventory Update 2. Ottawa, Canada: Athena Sustainable Materials Institute.
15. Porritt, J., 2009. The concrete industry sustainability performance report. First report. The concrete centre.
16. NRMCA, 2008. Concrete CO_2 Fact Sheet. National Ready Mixed Concrete Association.

17. Lippiatt, B.C., 2007. Building for Environmental and Economic Sustainability (BEES 4): Technical Manual and User Guide. USA: National Institute of Standards and Technology, Building and Fire Research Laboratory.

18. Baird, G., Alcorn, A. & Haslam, P., 1997. The energy embodied in building materials - updated New Zealand coefficients and their significance. IPENZ Transactions, I(24), pp.46-54.

19. SPINE database. CPM LCA DATABASE. [Online] Available at: www.lifecyclecenter.se