Investigating the potential of using an alternative finishing material for counter top construction as a cost-effective solution

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***Abstract**: Current economic situation, material price hikes and shortage of materials have directly and indirectly caused an unprecedented price increment in finishing materials and the total cost of construction specially in the finishes stage. Therefore, finding alternative materials that are cost effective without sacrificing quality and appearance has become a vital need. With the popularization of open kitchen and open pantry concepts countertop construction has gained more attention in terms of aesthetics and appearance as well as the function. Thus, a research series was initiated with the aim of investigating the feasibility of the ferrocement as an alternative material for countertop construction while maintaining the intended appearance and functional requirements. The paper presents the findings of the initial stage of the research conducted to assess the cost effectiveness of the proposed alternative material prior to further experimentation on material development. An onsite experiment was carried out to construct a prototype countertop and check the feasibility of construction. Ferrocement panel with a dimensions of 1200mm X 600mm X 20 mm was cast for the study. Epoxy coating was applied on ferrocement body to achieve desired water absorption rate and aesthetic appearance of the final product. Since the prototype construction was successful a cost comparison was conducted. The total production cost was calculated and compared with same size conventional granite countertop construction. Accordingly, sq.ft rate of ferrocement countertop was calculated to be Rs. 1536.08. Results showed that 41.7% cost saving could be achieved while keeping the desired aesthetical qualities and water absorption limits. This could be a feasible alternative for countertop construction in Sri Lanka.*

***Keywords**: Countertops, Ferrocement, Cost effective materials*

1. Introduction

Construction is one of the major industries in Sri Lanka which directly accounts for the overall economic development of the country while providing numerous direct and indirect job opportunities. However, due to the current economic crisis and depreciation of currency the construction industry has been heavily disturbed by the price hike as well as shortage of materials. Observations clearly depicts a sharp drop in projects and job opportunities due to the prevailing energy and fuel shortage, rise of raw material price as well. In such a context, it is vital to rethink how to approach the industry and find solutions to deal with such challenging shifts. Finding alternative cost-effective materials can be identified as a remedial action to overcome the material shortage and the price hike.

Opara (1999) defines a material as a blend of processed or un-processed materials or compounds utilized in engineering construction including timber, sand, cement, gravel, graniter etc. In construction, cost of these materials is identified as a major contributor to the total cost (Ayeni, 1986, Wahab, 1996 and Ene, 1997). Cost effectiveness in construction is a concept that is related to budgeting and aims to cut off construction costs by proper utilization of locally available materials, managing skills and technology better without giving up the quality or durability (Tiwari *et al.*, 1999). As Miles

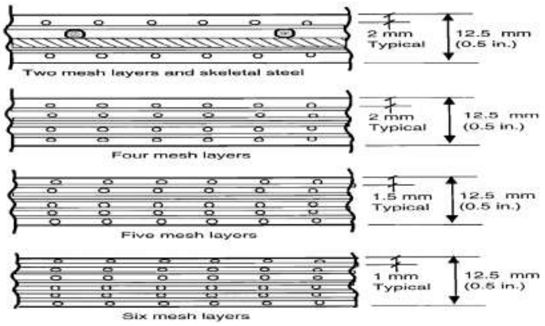

Figure 1: Typical cross section of ferrocement
Source: Naaman (2000)

(2000) states, effective use of locally available materials and techniques which are economical, durable, acceptable and low maintenance leads to achieving cost reduction in construction. Further, research findings highlight that effective budgeting, improved techniques and skills contribute to cost reduction without any damage to the material performance or life time of materials (Kumar, 1999; Civil Engineering Portal, 2008).

The finishes of a construction project costs a considerable percentage of the total costs. However, quality and the appearance of the finishes have a greater contribution to the overall end product. Therefore, designers as well the clients always have a high concern about the finishes of a building project. Finishes of a building ensure the aesthetics, taste and comfort and by utilizing different materials. In current context where construction costs have hiked in greater percentage reducing the costs for finishes while maintaining the quality and appearance is vital. Therefore, experimenting alternative finishes is needed.

Ferrocement construction technology is not a new concept in the industry. Commonly, ferrocement is used as a thin element in construction and also as a repair material. Apart from these common applications as structural and form making, architectural applications such as building elements with attractive and rich surface finishes have been put in to practice in different design applications as observed through magazines, case studies and etc. However, research evidence on such applications and their long term feasibility, cost, application process and development are not available.

With this need an experimental research was initiated with the aim of investigating ferrocement as an alternative material for countertop construction. As the first step, the cost of the proposed alternative material was investigated prior to further investigations. The paper presents the findings of the initial stage conducted to investigate the cost effectiveness of ferrocement as an alternative worktop construction material in the construction industry.

A. Ferrocement as a construction material

With the current need of finding materials that are fit for the purpose and cost effective, ferrocement is identified as such material which is slender and slim while the same time being elegant and strong (Divekar, 2011). Ferrocement is investigated as an alternative building material for prestressed concrete, RCC, stone, steel, brick, , timber and structural components such as slabs,columns, floors, roofs, water and soil retaining wall structures and roofs. Further, ferrocement is also used for applications such as shutters, doors and windows (Divekar, 2011, 2011a,b,c). Moreover, the studies on ferrocement reveal the possibility of the material being formed into different shapes or structural configuration which cannot be achieved with RCC, standard masonry or steel (RoblesAustriaco, 2006; Dongyen et al., 2006; Kondraivendhan & Pradhan, 2009).

There are numerous structures made out of ferrocement such as houses, shell roofs, water tanks, swimming pools, storage units for food, biogas digesters, silo, and etc. Also, in situations such as floating marine structures where RCC is heavy, ferrocement is used as an alternative (Hago et al., 2005; Naaman, 2000; Abasolo et al., 2009). Research conducted on ferrocement applications has proved that when compared to similar constructions using steel, reinforced cement concrete, steel or fiberglass use of ferrocement is cost effective (Sharma et al.

1979; Report JABE-ARC-07, 1976; Ferro 10 Information).

Being a thin construction element ferrocement thickness can be achieved to be 10-25mm. It consists of rich cement mortar with no coarse aggregate. One or several small diameter steel wire or mesh is used as reinforcement in ferrocement construction. As depicted in Ferro 7 (2001), ferrocement does not require high skilled labor for casting and require less or no formwork. Further, as the reinforcement which is below the surface takes over the cracking forces the cement matrix is resistant to cracking (Desai, 2011). Due to these properties and behavior and the uniqueness and versality ferrocement construction has become very popular in many countries like USA, UK, Canada, Australia, Mexico, New Zealand and etc. as well as in developing countries.

B. *Experimenting ferrocement as the worktop material*

Shortage of essential building construction materials such as ceramic tiles, granite, high increase in material cost has made an opportunity for sustainable and economical alternatives. Use of ferrocement for different architectural applications and elements can be experimented. However, countertops are a common feature in almost all the residential and commercial projects which is considered as a vital element in interiors in terms of functional purposes as well as aesthetical appearance. Therefore, the research scope was limited to application of ferrocement as countertop material for this specific study.

Granite, timber, ceramic tiles, timber, cut cement finished concrete are few of common materials used for worktop construction. Based on the current market trends and the opinion of designers as well as clients, granite is the most popular building material used for countertop construction in Sri Lankan residential building. Granite finish has replaced tiled surface of counter tops due to lower maintenance, ease of installation, high strength and durability, lower water absorption (0.05% to 0.40%), and scratch resistance. Resistance to stains and the excellent moisture repellent quality as well as the high heat resistance makes it more appropriate material for the countertop finish. The ability to create seamless counter tops with continuous surface is beneficial in avoiding staining and food seepage compared to tile surface which is hygienic than the tiled surfaces. Due to the rich outlook and the timeless appearance of the granite finish, the attraction towards granite as the finishing material has remained high. Granite can be well polished to achieve a rich surface texture due to its igneous property.

Due to its properties by today, granite has become one of the most preferred countertop finish materials which also depicts an ultimate status and style symbol in the kitchen. Further, granite facilitates creating beveled or bullnose finish on the horizontal edges if required. Among the available surface finish texture of granite countertops, polished finish is the most commonly used granite finish option. However, with the prevailing situation in the country granite has become a highly expensive countertop finishing material.

The research was initiated with the aim of investigating the potential of using ferrocement as the countertop finishing material as an alternative material which has the desired qualities and the aesthetical appearance of the highly preferred granite material. Therefore, the purpose was to find the feasibility of architectural applications of the proposed alternative material.

Since ferrocement technology facilitates the construction of complex curvatures, architects are given the freedom to try out different forms. However, apart from such form making options, the use of ferrocement as a finish material has been rarely explored. Based on the properties of ferrocement and its practical applications it was observed that this could be used as an alternative to replace the expensive granite material as the counter top finish material. The thickness, cracking behavior and specially the resistance to biological agents such as vermin or fungus makes ferrocement an ideal alternative for countertop finish material.

As discussed earlier the mural joints, rife and grains in granite enables the material to be finished as larger slabs with less thickness. Similarly homogeneous reinforce arrangement of the ferrocement
allows casting of precast slabs with small thicknes in an affordable price. Due to the nature of the mineral comprising of stone, granite is a highly polishable material which makes popular as countertop material with less maintenance requirement as the polished surface resist stain penetration. Eventhough ferrocement doesn't inherit superior polishing quality it can be improved by adding a cement rendering layer on top of the ferrocement body ultimately achieving the desired finish.

Granite naturally inherit variety of colours and patterns due to its hardening process which involves combining of various sources of molten lava.Alternatively, to achieve the desired architectural appearance when ferrocement is used, colour pigments can be added to the cement rendering layer. Granite has a significantly lower water absorption rate (0.1% - 0.4%). Though compared to granite ferrocement's water repellent quality is lower it is no exception as it is also used for construction of water tanks and boats due to its low water absorption. However, application of an epoxy sealer as the top coat of the finished product can heighten the water repellent quality of ferrocement while at the same time enhancing the glossy finish of the final product.

2. Methodology

The research was designed as an on-site investigation with field and lab testing to develop a worktop with the intended ferrocement finish. Titanium Oxide and Iron Oxide were added as colour pigments for the particular study. As the first step a cost comparison was done to identify the potential cost effectiveness of the proposed ferrocement counter top finish. A prototype model worktop in the size of 600mm X 600mm X 25mm was constructed on site to calculate the unit rates of the construction. The mortar composition was maintained as cement; sand: water proportion

WIRE-MESH REINFORCEMENT	• Wire Diameter:	• $0.5 \leq d_w$ 1.5 mm; ($0.020 \leq d_w \leq 0.062$ in.)
	• Type of Mesh:	• Square woven or welded galvanized wore mesh; aviary (chicken) wire mesh; or expanded metal mesh
	• Size of Mesh Openings:	• $6 \leq D \leq 25$mm ($1/4 \leq D \leq 1$ in.)
	• Number of Mesh Layers:	• Up to 6 layers per cm of thickness (Up to 14 layers per in. of thickness)
	• Volume Fraction of Reinforcement	• Up to 8% in both directions corresponding to up to 630 kg/m^3 (40 lb. per ft^3) of steel mesh reinforcement.
	• Specific Surface of Reinforcement	• Up to 4 cm^2/cm^3 in both directions (up to 10 in.^{2}/in.^{3} in both directions)
INTERMEDIATE SKELETAL REINFORCEMENT	• Type:	• Wires; wire fabric, rods; strands
	• Diameter:	• $3 \leq d_b \leq 10$ mm; (1/8 to 3/8 in.)
	• Grid Size:	• $5 \leq G \leq 15$ cm; ($2 \leq G \leq 8$ in.)
	Skeletal reinforcement not always present	
TYPICAL MORTAR COMPOSITION	• Portland cement:	• Any type depending on application
	• Sand -to-Cement Ratio:	• $1 \leq S/C \leq 2.5$ by weight
	• Water-to-Cement Ratio:	• $0.35 \leq W/C \leq 0.6$ by weight
	• Recommendations:	• Fine sand all passing U.S. sieve No. 16 (1.5 mm) and having 5% by weight passing No. 100 (0.25 mm), with a continuous grading curve in-between.
		• Additives: (Fly Ash / C) = 0.2 Air entraining agent; Corrosion inhibitor; Water reducing agent, or Superplasticizer, as needed.
COMPOSITE PROPERTIES	• Thickness:	• $6 \leq h \leq 50$ mm; ($1/4 \leq h \leq 2$ in.) [mostly < 30mm]
	• Steel Cover:	• $1.5 \leq$ cover ≤ 3 mm; ($1/16 \leq$ cover $\leq 1/8$ in.)
	• Ultimate Tensile Strength:	• Up to 35 MPa (5,000 psi)
	• Allowable Tensile Strength:	• Up to 14 MPa (2,000 psi)
	• Modulus of Rupture:	• Up to 70 MPa (10,000 psi)
	• Ratio	• From 2 to 2.5

Figure 2: Properties of ferrocement
Source: Naaman (2000)

in 1.5:2.5 ratio. Sand particles less than 2mm was used and a water proofing admixture was added.

Formwork was made with 12.5 mm thick Marein plywood sheets. Portland cement and sand were used as the cement-based Matrix. Sand cement were proportioned by weighting (1.5:2.5) for the dry mix and then it was mixed with water using mechanical mixing. Square type steel mesh with 3mm mesh opening size, was used as reinforce structure. Three layers of mesh reinforcement was placed in the cement matrix. The volume of the reinforcement (volume fraction) is 4- 8 % in both directions ensuring homogeneous reinforcing structure.

Compaction was done by beating the mortar with a trowel. Cement slab was kept for four days for curing prior to removing the formwork. After the curing time, Cement /titanium rendered finish with colour pigments were applied on all the faces and edges of the slab to get the desired architectural finish. Slab was for kept two days for drying after sanding. Finally, a clear epoxy coating was applied using a roller to get the final finish. Based on cost of the prototype countertop slab construction the cost analysis and the cost comparison were conducted considering a countertop finish of 600mm x 3000mm x 20mm counter top slab.

3. Reuslts and Discussion

Based on the costs incurred for the prototype ferrocement countertop slab construction, cost for a typical countertop and sq.ft rate for construction was calculated.Cost calculation is conducted according to the below Table 1. Since cost calculation was conducted to compare the construction cost of ferrocement countertop with the cost of typical granite counter top construction. Since both the material are pre-fabricated and transported the transportation costs were not considered for the comparison.

Based on the cost analysis, approximate cost for the construction of ferrocement countertop with the dimensions of 600x300x 20mm is Rs. 18,433.00. Therefore, the per square foot rate is calculated as Rs. 1536.08. As per the current market rate, granite countertop construction cost per sq. ft rate varies from Rs.3000 – 4000 upwards where local granite countertop cost varies between Rs. 3000 – 3400 and imported granite countertop cost varies from Rs. 3600-4000 upwards.

Accordingly if average cost of granite countertop is taken as Rs. 3500 and ferrocement countertop is taken as Rs. 1540, the cost saving percentage with the alternative material application is calculated as 41.7%. Therefore, based on the calculations it is evident that the developed ferrocement countertop construction cost is significantly lower than granite countertop construction.

Table 1: Ferrocement countertop construction – cost calculation

Concrete 1 1/2:2 1/2 (Cement: Sand)		**12 sq. Ft**			
	Cost type	**Qty**	**Unit of measure**	**Total cost (Rs)**	**Cost per sq. Ft (Rs)**
1.0	**MIXING Cost**				
a	Materials				
b	Cement	0.25	bags	3,200.00	800.00
c	Sand	0.007	Cube	23,000.00	161.00
d	Water	15.00	gal	1.00	15.00
e	Net (2-0" x 6'-0") X 4	36	sq. Ft.	170.00	6,200.00
f	formwork Plywood board (8'x4')	0.50	no	3,500.00	1750.00
					8926.00
2.0	**LABOUR Cost**				

a	Un / skilled Labour	1.00	day	2,500.00	3,000.00
					3000.00
	Cost 12Sqft (mixing only)				**11,926.00**
	Add				
b	3% of Cost for tools				357.00
3.0	**CURING**				
a	Water	100.00	gal.	0.50	50.00
b	Un / skilled Labour	0.04	day	2,500.00	100.00
					12283.00
4.0	**FINISH**				
a	Cement rendered Titanium finish	12.5	sq. Ft	300.00	3,750.00
b	Epoxy Finish	12.5	sq. Ft	200.00	2400.00
	Cost for 12 sq. Ft slab				18433.00
	Sq. Ft rate for finish product				**1536.08**

According to the market observations among the available countertop finishing materials, granite has obtained more popularity as a luxury finishing material in local market due to its appearance and high quality. Based on the observation in practical applications it has been identified that when using local granite, due to the iron contained in the stone, when contact with oxygen and water for longer time it generate iron oxide (rust) which causes scaling and discoloration. Therefore most countertop projects are done with imported granite slabs. In this regard, rather than importing finished products, introduced ferrocement precast slab can be easily manufactured locally with imported raw materials which is more cost effective and a good alternative for material shortage in sri lanka.

However, the imported granite slabs have a variety of color variations and patterns. Therefore, further experiments needed to be conducted with different pigment combinations to achieve colour and variation in the proposed ferrocement pre cast countertop construction. Further, comparatively to other raw materials steel price is high for ferrocement construction. Therefore, introducing natural fiber instead of steel reinforcement can be a good alternative. Further research can be conducted on natural fiber reinforcement as well.

Findings suggests ferrocement as an ideal alternative material to countertop construction in terms of cost effectiveness. However, further research is needed on the properties, structural feasibility and long term application to promote the proposed material as a feasible alternative countertop material. Also, experimental studies need to be conducted to get better aesthetical appearance (eg- Mixing of colour pigment powder and in a liquid form together).

4. Conclusion

At a time when solutions should be found to address the challenging situations in construction industry the research was initiated as an experimental study to find alternative finishing materials for countertop construction. The paper presented the results of the initial step of the research conducted to investigate the economic feasibility and the cost effectiveness of the proposed alternative material compared to the cost of the countertop material most preffered in the market as a luxury and high quality material.

Ferrocement was identified as a potential alternative and therefore an onsite experiment was carried out to construct a prototype countertop and check the feasibility of construction. Since the prototype construction was successful and demonstrated the potetial for further development it was decided to conduct a cost comparison to confirm the cost effectiveness prior to advancing with the research. The paper presented the outcome of the cost comparison which confirmed the cost effectiveness of the proposed material intervention. Therefore, it can be assumed that ferrocement can be used as an alternative material to countertop construction which is a cost effective approach. Further testing should be conducted to identify the properties, structural feasibility and long term application prior to promoting the proposed material as a feasible alternative countertop material.

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