LIFE CYCLE COST ANALYSIS OF MICRO CONCRETE ROOFING TILES WITH WASTE GLASS

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Although glass is recycled on a large scale, it still ends up in landfills due to inefficiencies in the recycling process. This study investigates the applicability, cost-effectiveness, and energy efficiency of incorporating waste glass into the production of Micro Concrete Roofing (MCR) tiles, as well as the evaluation of the product over its lifecycle. MCR tiles are conventionally manufactured using a chip concrete mix with a 1:1:1.5 mix ratio of cement, fine aggregates, and coarse aggregates at the commercial manufacturing plants. The transverse strength test conducted on MCR tiles incorporating 5%, 10%, 15%, and 20% waste glass as partial fine aggregate replacement was used to identify the most suitable mix proportion of waste glass to the conventional mixture in accordance with the standards for concrete roofing tiles. At the initial stage, the manufacturing cost was evaluated by considering the raw material quantities per one batch of tiles at the manufacturing plant and the prices mentioned in the Building Schedule of Rates (BSR), 2024. The energy consumption and labour requirement were measured by conducting a work study there. The installation cost of MCR tiles was evaluated according to the standard norms published by the Department of Buildings, Sri Lanka. According to the published data on roofing tiles on water tightness and replacement periods and the experience of users, the maintenance cost was evaluated. An energy simulation model for a selected house model was utilised to quantify the energy performance of the MCR tiles with waste glass through the design life, compared with the other roofing materials by considering annual cooling loads. At this stage, an exceptional difference was experienced with the asbestos sheets, which is the most common roofing material in Sri Lanka at present, due to the better thermal properties of MCR tiles with waste glass aggregates and their short usable life span of 30 years. At the end of the life span of 60 years, MCR tiles have a significant salvage value, which is similar to that of concrete, while asbestos sheets are omitted from reuse.

With the integration of cost parameters related to each stage, the Net Present Value of the Life Cycle Cost (LLC) of MCR tiles with waste glass aggregate was calculated, using an annual inflation rate of 5% and a discount rate of 3% for the study. With the superior energy-efficient performance of MCR tiles with waste glass aggregate, the total LCC can be reduced by up to 22% compared to asbestos sheets and showed an approximately similar performance to clay tiles. These findings highlight the potential of waste glass-based MCR tiles in advancing the circular economy and sustainability in roofing applications for mid-scale housing projects, incorporating the waste portion that would otherwise be scheduled for landfilling.

Keywords: Alternative roofing materials, Life Cycle Cost, Micro concrete roofing tiles, Operational energy, Waste glass aggregate

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LIFE CYCLE COST ANALYSIS (LCC) OF MICRO CONCRETE ROOFING TILES WITH WASTE GLASS AGGREGATE

Aim: Determination of the **Total Life Cycle Cost of Micro Concrete Roofing (MCR) Tiles Incorporating Waste Glass** (WG) as a partial replacement for fine aggregates with a **comparative analysis with conventional roofing materials** available in Sri Lanka.

1. Optimum Mix Proportion with waste glass for MCR tiles

→ Transverse Strength Test on sample MCR tiles of 5%, 10%, 15% & 20% of WG replacement of fine aggregates

2. Identification of Costs at each stage of lifecycle

- ◊ **Manufacturing Stage** - Work Study at Commercial Manufacturing Plant, Building Schedule of Rates (BSR)
- ◊ **Installation Stage** - Standard Norms of Building Construction Works, Published Literature
- ◊ **Maintenance & Operational Stage** - Literature Survey, Interviews of Users, Energy Simulation Modeling with DesignBuilder Software
- ◊ **End-of-Life Stage** - Published Literature

3. Comprehensive LCC Analysis Model

Life Span - **60 years for affordable houses** (British Standards Institution [BSI], 2015)

Financial Parameters - Inflation Rate (d) , Policy Interest Rate (i)

Accordance with Central Bank of Sri Lanka

Discount Rate, $r = d - i$

Conventional Chip Concrete Mixture of MCR Tiles

Cement: Quarry Dust: Chips = 1: 1.5: 1

Landfilling of the rejected portion of glass particles after recycling process (Particle size < 12 mm) at PGP Glass Ceylon, Horana, Sri Lanka

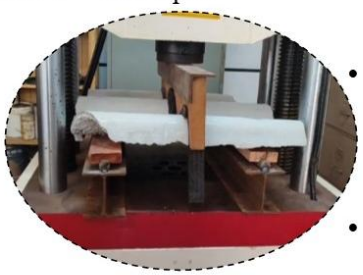
Total cost at the end of each year,

- C_t = ***Initial Cost + Maintenance & Operational Cost - Residual Value***

Net Present Value of LCC,

When T = Life Span

$$LCC = \sum_{t=0}^{T} \frac{C_t}{(1+r)^t}$$



Transverse Strength Test on MCR Tiles (Accordance with SLS 1189: Part 1 and 2)

- **22% of total LCC reduction** due to the significant energy reduction of MCR tiles with WG at the operational stage
- **Contribution to Circular Economy** with the incorporation of WG