DEVELOPMENT OF THERMAL INSULATING AND LIGHT WEIGHT ROOFING MATERIALS USING FLY ASH-CEMENT COMPOSITES

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Degree of Master of Science

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Thesis submitted in partial fulfillment of the requirements for the degree Master of Science in Materials Science & Engineering

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DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Abstract

This thesis is focused on developing an alternative roofing material for asbestos fibre cement sheets. Coal Fly ash (CFA) was selcted as the main matrix modifier, which was collected from the electrostatic precipitator in Lakvijaya power plant, Norochcholai, Sri Lanka. The study is aimed at extracting low-density particles from CFA, called “cenospheres”. Dry sieving and sink-float methods were adopted to take low-density fractions. Four types of CFA fractions were used in the study which were the unprocessed CFA, the CFA below 75 µm particle size, the CFA below 45µm particle size and the CFA particles extracted from wet separation method. CFA fractions were characterized with respect to morphology, particle size, particle density and chemical composition. The flexural strength and density variations were determined by casting mortar prisms, replacing 10-50% (by weight) of CFA from Ordinary Portland cement (OPC). Glass fibre reinforced fly ash cement (GFFC) roofing tiles were fabricated using size fractionated coal fly ash (CFA) which are the unprocessed CFA, the CFA particle sizes below 75µm and below 45µm. OPC was replaced by 30% (by weight) of each CFA fractions and those matrices were reinforced by Alkali Resistant glass fibres as 1% and 2% by weight. Physical, mechanical, durability and thermal properties were determined and those properties and the costs were compared with Calicut clay tiles, asbestos fibre cement corrugated sheet and non-asbestos fibre cement corrugated sheets. The spherical particle concentration increased with decreasing CFA particle size indicating those spherical particles in the finer fraction could be cenospheres due the relatively bigger spherical particle diameter and the low ratio of Si/Al compared to the unprocessed CFA. Sink-float method yielded the lowest density particles and it could be due to the presence of cenospheres and unburned carbon. The transverse strength was reduced with the decreasing CFA particle size .This could be due to the presence of cenospheres, low Ca content or less amorphous silica amount. All the compositions GFFC roofing tiles complied with the transverse strength requirements (230 N) as specified in the standard SLS 1189 Part 2. Highest value was observed in tile including 2% AR fibres with the unprocessed CFA (1650 N) and the lowest from tile incorporated with the CFA below 45µm (1470 N). The characteristic transverse strengths of GFFC roofing tiles is in comparable with Calicut clay tiles (1000-2000N) in Sri Lanka. The water absorption of GFFC roofing tiles did not comply with the requirement (maximum 10%) whereas the observed maximum value was 20%. Nevertheless, asbestos and non-asbestos roofing sheets have much higher values, which are 23% and 29%, respectively. The dry density of GFFC roofing tiles (1.63-1.68 g/cm^3) is comparable with the dry density of asbestos sheet, which is ≈1.65 g/cm^3. The long term durability of the GFCC roofing tile is in satisfactory level, it could due to the inclusion of CFA and AR glass fibres. GFFC roofing tiles can be considered as a good thermal insulator due to the high specific heat (1296 J/kg.K), low thermal (0.278 W/m.K) conductivity and diffusivity (1.31×10^{-7}m^2/s) compared with the asbestos, non-asbestos roofing sheets and Calicut clay tiles. However, Calicut clay tiles also offer good thermal comfort to dwellings, even though the thermal insulation is not depicted by k.c and α. This is because clay tiles have this natural system to gradually lower the air temperature through the process of evaporation. Hence, GFFC roofing tiles is a promising substitute for asbestos fibre cement roofing sheets using CFA in both unprocessed and sieved form due to the comparable strength, density, water absorption and durability. The cost for GFFC can be reduced by lowering the fibre content and replacing cement by ultrafine crushed rock particles.

Key words: coal fly ash, roofing tiles, thermal insulating, cement composites, glass fibres

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PVC	: Polyvinyl chloride
CFA	: Coal fly ash
C-S-H	: Calcium Silcate Hydrates
PVA	: Polyvinyl alcohol
MCR	: Micro concrete roofing
NERD	: National Engineering Research and Development
XRF	: X-ray fluorescence
ICP-AES	: Inductively coupled plasma atomic emission spectroscopy
LOI	: Loss on ignition
XRD	: X-Ray diffraction
SEM	: Scanning electron microscopy
IFA	: Improved fly ash
ND	: Not detected
B	: Bituminous
SB	: Sub-bituminous
L	: Lignite
BDL	: Below detection level
BET	: Brunauer–Emmett–Teller
FACC	: Fly ash cenosphere containing cement composites
LWA	: Lightweight aggregate
SCM	: Supplementary cementitious materials
ULCC	: Ultra-lightweight cement composites
LWC	: Lightweight concrete
PE	: Polyethylene
AR	: Alkali resistant
OPC	: Ordinary Portland cement
ICP-MS	: Inductively coupled plasma mass spectrometry
FRC	: Fibre reinforced composites
SRI	: Solar refractive index
HVAC	: Heating, ventilation and air conditioning
EPA	: Environment protection authority