RECYCLING OF MARBLE AND GRANITE WASTE IN THE PRODUCTION OF VITRIFIED CLAY PIPES

By

Manar Morsy Abd-Elmonam Madboly

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Chemical Engineering

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Under the Supervision of

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Title of Thesis:
Recycling of Marble and Granite Waste in the Production of Vitrified Clay Pipes

Key Words:
Marble Waste; Granite Waste; Vitrified Clay Pipe; Ceramics; Clay

Summary:
Marble and Granite industry powder wastes have high alkaline nature that causing serious damage to the environment. Recycling of these wastes into production of vitrified clay pipe as a partial replacement of the standard clay pipe mixture was investigated. Samples consisting of standard pipe mixture and waste content varying from 0-35% were formed using marble and granite powder waste individually. They were molded, dried and fired at temperatures of (1000, 1100, 1150, 1200 and 1250 °C) for 3 hour. Different tests were conducted on clay pipe combined wastes specimens so as to evaluate the suitability of addition of wastes in the production of vitrified clay pipes. Tests including plasticity, linear drying shrinkage and modulus of rupture were performed on green unfired bodies. While, for fired bodies; linear firing shrinkage, Loss on ignition, bulk density, apparent porosity, water absorption and bending strength were examined. The results concluded that firing at 1200°C for 3 hours was the ideal condition for incorporating marble and/or granite fine waste with certain composition into the clay pipe mixture. It was found that the addition of 20 wt. % of marble waste to the standard mix gave sample conforming to standard values. While, 35 wt. % of granite waste was the optimum addition into typical standard mixture.

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

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Signature:

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Nomenclature

$\overline{D_{Pi}}$: The average particle diameter, mm

$\overline{D_s}$ **:** Volume – surface mean diameter of particle, mm

D **:** Dry weight/mass of the specimen, g

$\boldsymbol{d_1}$: Inner diameter of the pipe, mm

$\mathbf{D_{50}}$: Median particle size, mm

DN : Nominal interior diameter, mm

DTA : Differential Thermal Analysis

E **:** Water absorption

$\boldsymbol{F_N}$ **:** Crushing strength, kN/m

GP : Granite Powder

$\mathbf{H_f}$ **:** Final height after compression, mm

$\mathbf{H_o}$ **:** Original height of the cylinder, mm

$\mathbf{H_o / H_f}$: Compaction ratio

L.F.S **:** Linear Firing Shrinkage

$\boldsymbol{L_d}$ **:** Tile length after drying (original length), mm

LDS : Linear drying shrinkage

$\boldsymbol{L_f}$ **:** Tile length after firing (final length), mm

$\boldsymbol{L_i}$ **:** Selected tile length (initial length), mm

LOI **:** Loss On Ignition

M **:** Saturated weight of the specimen after submersion in boiling water, g

$\boldsymbol{m_1}$ **:** Mass of liquid added to the solid in the pycnometer, g

MD : Marble Dust

MOR : Modulus of Rupture, N/mm^2

$\boldsymbol{m_s}$ **:** Mass of the solid powder in the pycnometer, g

m_w **:** Mass of water in the pycnometer, g

m_{w+s} **:** Combined mass of the solid with the liquid, g

NRC : National Research Centre

P **:** Apparent porosity

p **:** Fractional porosity

PSD : Particle size distribution

S **:** Summation of hook and wire weights, g

s_1 **:** Wall thickness of the pipe, mm

SEM : Scanning Electron Microscope

SMD : Sauter mean diameter, mm

TGA : Thermo–gravimetry Analysis

V **:** Exterior volume of specimen, cm^3

VCP : Vitrified Clay Pipe

V_P **:** Volume of the pycnometer, cm^3

V_s **:** Volume of the solid, cm^3

W_f **:** Tile re–weight after firing (final weight), g

W_i **:** Tile weight after drying and before firing (original weight), g

wt. %: Weight in percent

x **:** The percent marble or granite waste added

X_i : The differential fraction retained between two sieves (i) and (i – 1)

XRD : X-Ray Diffraction

XRF : X–Ray Fluorescence

α_k : Correction factor

ρ_B **:** Bulk Density, $g.cm^{-3}$

ρ_p **:** Powder (true) density of the body, $g.cm^{-3}$

ρ_s **:** Powder density of solid, $g.cm^{-3}$

σ_{bz} **:** Bending tensile strength, N/mm^2

Abstract

Marble and Granite sawing powder wastes impose a serious problem to the environment and human-being as well. These wastes are non-biodegradable materials with highly alkaline nature, dumping such wastes to surrounding causes threat to the environment and ecosystem. Recycling of these wastes in construction material industry has become more significant for sustainability development.

On the other hand, Vitrified clay sewer pipe has proved its capability to stand for hundreds of years because of its high durability and for its chemical and corrosion resistance. VCP production using different waste has been investigated lately in some researches as a part of economical and environmental benefits.

This thesis aims to use marble and granite powder waste as a partial replacement of standard raw materials by mass in the production of vitrified clay pipes. For that aim, samples consisting of standard raw materials mixture (85% clay and 15% grog) with content of waste, varying from 0-35% on a step of 5 %, was formed from marble and granite fine powder waste separately. Chemical, mineralogical, thermal and screen analyses, as well as powder density were identified for both standard raw materials and wastes used.

Samples were prepared, casted, pressed and dried. Plasticity was measured for free-waste specimens and specimens incorporated wastes. Dried samples were then fired at temperatures range from 1000 to 1250 °C for 3 hours soaking time.

Physical and mechanical tests were conducted on both green and fired wastes incorporated clay specimens in order to evaluate the suitable addition of wastes in the production of vitrified clay pipes. Linear drying shrinkage and modulus of rapture were measured for green bodies. Whilst examinations including; linear firing shrinkage, loss on ignition, bulk density, apparent porosity, water absorption and bending strength were conducted on fired bodies. Scanning electron microscope (SEM) was also done on selected fired bodies in order to determine their microstructure. The tests were compared to the standard requirements for clay sewer pipes technology. The recommended mixture were then produced in Sweillem Vitrified Clay Pipe Company's production line and were tested for acid and alkali resistant and other tests according to both International and National standards.

The results show positive significances in terms of strength by the substitution of the standard mixture of clay sewer pipes by both marble and granite fine wastes. It is possible to reach a modulus of rapture, water absorption and chemical resistance conforming to the standard requirements. It was found that substitution of 20 wt. % of the standard body mix by marble waste, and firing to 1200 °C for 3 hour gave samples that are conforming to standard values in both physical and mechanical properties. Granite waste showed a slightly better performance than marble ones. Thus, substitution by 35 wt. % of granite waste into typical standard mixture yielded samples that are compatible to the standard values when fired for 3 hour at 1200 °C.

Marble and granite can be induced in clay/grog mixture producing vitrified clay pipe at lower temperature; reducing energy, saving natural resources and protecting environment.