THE EFFECT OF PROPERTIES OF FLY ASH ON STRENGTH AND MICROSTRUCTURE DEVELOPMENT OF MORTARS

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THE EFFECT OF PROPERTIES OF FLY ASH ON STRENGTH AND MICROSTRUCTURE DEVELOPMENT OF MORTARS

by

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Dedicated to my parents…

CERTIFICATE

This is to certify that the thesis entitled **"THE EFFECT OF PROPERTIES OF FLY ASH ON STRENGTH AND MICROSTRUCTURE DEVELOPMENT OF MORTAR"**, being submitted by **Ms. Amarpreet Kaur**, to the **Indian Institute of Technology Delhi**, for the award of **'Doctor of Philosophy'** in Department of Civil Engineering is a record of the bonafide research work carried out by her under our supervision and guidance. She has fulfilled the requirements for submission of this thesis, which to the best of our knowledge has reached the requisite standard.

The material contained in the thesis has not been submitted in part or full to any other University or Institute for the award of any other degree or diploma.

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ABSTRACT

Supplementary cementitious materials such as fly ash are currently used as clinker replacement to reduce costs and environmental pollution associated with the production of cement. The objective of this study was to understand the effect of physical and chemical properties of fly ash on strength development and hydration kinetics of mortars and cement pastes. Ten different fly ashes, collected from northern and central parts of India, were used. All the fly ashes and cements were characterised using X-ray diffraction (XRD) and X-ray fluorescence (XRF). The chemical composition of fly ashes shows that all the fly ashes fall under category Class F as per ASTM C-618 that have pozzolanic properties and react with water and calcium hydroxide produced by cement hydration. Two cements, obtained from two different cement plants, were used to eliminate effects that may be associated with one particular cement. The mortar mixes were prepared by replacing 25% of cement with fly ash, using three different water to binder ratios viz. 0.4, 0.45, 0.5, which were cured under water at a temperature of 27°C. The compressive strength of mortars was measured at 1, 3, 7, 28 and 90 days. The hydration kinetics were measured using isothermal calorimetry and chemical shrinkage. Sorptivity was measured on mortar discs after 90 days of hydration to study the effect of fly ash on the pore-structure. Advanced techniques such as scanning electron microscopy (SEM) were used to understand the effect of fly ash on the morphology of the cement paste.

The results from experiments show that the early strength of mortars with fly ash is lower than cement mortar but most of the mortars recover strength by 28 days. Finer fly ashes show higher or equal strength as compared to OPC after 28 days. It is also observed from sorptivity and SEM (Scanning electron microscopy) images that the finer fly ashes improve the microstructure and porosity. A linear correlation was found between degree of hydration and strength. Modelling of the strength development on the basis of the particle size distribution was carried out. It was found that it is possible to predict the strength development of the mortars using only the particle size distribution of the fly ash as the input. It was found that for the fly ashes studied, there is little effect of the chemical composition of the fly ash on hydration and strength development. It was also found that the existing test for reactive silica in the Indian standard is not suitable to assess the reactivity of a fly ash.

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NOTATIONS

A	Aluminium oxide Al_2O_3
AFt	Ettringite
AFm	Monosulphate
α_c	degree of hydration of cement
BSE	Backscattered Electron Microscopy
C	calcium oxide CaO
C_3S	Tricalcium Silicate
C_2S	Dicalcium Silicate
C_3A	Tricalcium aluminate
C_4AF	Tricalcium aluminoferrite
C-S-H	Calcium silicate hydrate
CH	Calcium hydroxide
DOH	Degree of Hydration
DTG	Differential Thermogravemetry
EDS	Energy Dispersive X-Ray Spectroscopy
F	Iron oxide Fe_2O_3
f_{fw}	fraction of OPC replaced by fly ash
GGBS	Ground granulated blast furnace slag
H	Water H_2O
IR	Insoluble Residue
k_v	volume efficiency
LOI	Loss on ignition
mW	milliwatt
OPC	Ordinary Portland cement
PSD	Particle size distribution
ρ_c	Specific gravity of cement
ρ_f	Specific gravity of fly ash
r_d	Dissolved thickness
RHA	Rice Husk Ash
S	Silicon dioxide SiO_2
$	Sulfate SO_3

SCM	Supplementary cementitious material
SEM	Scanning Electron Microscopy
TGA	Thermo gravimetric Analysis
v_w	Volume fraction of water phase
v_c	volume fraction of cement phase
v_{gel}	volume fraction of hydration products
v_s	volume fraction of space
v_f	volume fraction of fly ash
w/b	water to binder ratio
w/c	water to cement ratio
w_c	water to cement ratio for OPC
XRD	X-Ray Diffraction
XRF	X-Ray Florescence
X_c	Gel-Space ratio for cement