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Mechanical Properties of Ultra High Performance Concrete Containing Silica Fume

Field of Study: Concrete Technology

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ABSTRACT

This thesis presents an investigation to produce ultra-high performance concrete (UHPC) incorporating silica fume with or without steel fibers. The study was carried out to develop UHPC mixes to achieve the targeted strength of 120 MPa at the age of 28 days. The early stage of this study is to determine appropriate materials and cement content to achieve not only the targeted strength of 120 MPa but as well the workability of concrete of 150-300 mm slump flow. Several factors such as method of curing, selected materials and production cost were put into consideration during the investigations in order to develop economical and green concrete. Various UHPCs were produced using Sherbrooke design method with some modification since no coarse aggregates were used. UHPC mixtures were designed with fixed water-binder (W/B) ratio of 0.22, two series of cement content i.e. 875 and 900 kg/m^3 and silica fume content in the range of 0 to 30% of cement by weight. Other materials used to produce UHPC of 120 MPa were silica sand with two sizes i.e. 70% of 600µm size and 30% of 0.6-2.0 mm size and superplasticizer of 2% of binder content. The fresh UHPCs were tested for workability with respect to slump flow. Test results for fresh properties showed that the slump flow increased with higher amount of total binder. The hardened UHPCs were tested for compressive strength, flexural strength, splitting tensile strength, ultrasonic pulse velocity, static modulus of elasticity, surface hardness, the rebound number and initial surface absorption test. In general, UHPC indicated good durability. From the studies carried out, it can be concluded that UHPC can be produced by incorporating silica fume and suitable to be used in precast industry, thus supporting the Governments initiatives in promoting industrialized building systems (IBS) usage in the local construction industry.

ABSTRAK

Tesis ini membentangkan hasil penyelidikan untuk menghasilkan konkrit perlakuan ultratinggi (UHPC) dengan menggunakan wasap silika serta menggunakan gentian besi atau tidak. Penyelidikan ini dijalankan untuk mencapai kekuatan sebanyak 120 MPa pada usia 28 hari. Tahap awal penyelidikan adalah untuk menentukan bahan-bahan dan kandungan simen yang sesuai untuk mendapat kekuatan konkrit sebanyak 120 MPa beserta kebolehkerjaan turun sebanyak 150-300 mm. Beberapa faktor seperti jenis pengawetan, pilihan bahan-bahan dan kos produksi turut diambil kira semasa penyelidikan dijalankan bagi menghasilkan konkrit yang ekonomikal dan mesra alam. UHPC dihasilkan dengan menggunakan kaedah rekabentuk Sherbrooke tetapi dengan beberapa perubahan oleh kerana tidak menggunakan batuan kasar. UHPC direkakan dengan menggunakan nisbah air-bahan pengikat (W/B) sebanyak 0.22 yang telah ditetapkan, serta dua kumpulan kandungan simen iaitu 875 dan 900 kg/m^3 dan juga kandungan wasap silika sebanyak 0 – 30% dari kandungan simen. Bahan-bahan lain yang turut digunakan ialah pasir silika dengan dua saiz iaitu 70% dari saiz 600µm dan 30% dari saiz 0.6-2.0 mm, turut digunakan ialah 2% superplasticizer dari bahan pengikat. Kebolehkerjaan UHPC ditentukan dengan menggunakan ujian alir turun. Hasil ujian menunjukkan aliran slump meningkat dengan kenaikan jumlah bahan pengikat. Konkrit terkeras ditentukan dengan kekuatan mampatan, kekuatan lenturan, kekuatan tegangan pemecahan, ultrabunyi halaju denyut, keanjalan moduls statik, kekuatan permukaan, ujian tukul pantulan dan ujian penyerapan mula permukaan. Secara keseluruhannya, UHPC memberikan hasil ketahanlasakan yang baik serta dapat dihasilkan dengan menggunakan wasap silika dan sesuai digunakan di dalam industri pra tuang, yang mana menyokong inisiatif kerajaan dalam menggunakan sistem binaan berindustri (IBS) dalam industri pembinaan tempatan.

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LIST OF ABBREVIATION AND SYMBOLS

Notation	Meaning
b	Width of cross section (mm)
d	Depth of cross section (mm)
σ_b	Basic stress
σ_a	Upper loading
ρ	Density
f_{cyl}	Cylinder compressive strength
E_c	Static modulus of elasticity in compression
f_{sp}	Splitting tensile strength
f_r	Modulus of rupture
ACI	American concrete institute
BET	Nitrogen absorption method test
C	Celcius
d	Diameter
ELE	Engineering Laboratory Equipment
F	Load
f_{cu}	Compressive strength of cube
FRC	Fiber reinforced concrete
G	Specific gravity of cement or pozzolanic material
G_{sp}	Specific gravity of material
G_{ssd}	Specific gravity of aggregates in saturated state
H_2O	Water
HPC	High performance concrete
HSC	High strength concrete
ISAT	Initial surface absorption test
ITZ	Interfacial transition zone
L	Length
LOI	Loss on ignition
M	Metal
m	Mass
MOR	Modulus of rupture

M_{sol}	Normal strength concrete
OPC	Ordinary Portland cement
RH	Relative humidity
RN	Rebound number
RPC	Reactive powder concrete
SCC	Self compacting concrete
Sp	Superplasticizer
SF	Silica fume
t	Time
UHPC	Ultra high performance concrete
UHPdC	Ultra high performance ductile concrete
UPV	Ultrasonic pulse velocity
v	Velocity
V_{liq}	Volume of water and superplasticizer
V_{sol}	Volume of superplasticizer
V_w	Water correction for superplasticizer
w/b	Water to cementitious ratio
W_{abs}	Water absorption
W_c	Water correction for aggregates
W_{tot}	Moisture content
XRD	X-ray diffraction
XRF	X-ray flourescence
ε_a	Strain under upper loading stress