Influence of cement and glass powder on the compressive strength of ultra-high performance concrete

Karim, F.R.[#1], Abu Bakar, B.H.[#2], Kok Keong, Choong [#3], Aziz, O.Q. [#4]

[#1] PhD Candidate, School of Civil Engineering, Universiti Sains Malaysia, Pulau Pinang, Malaysia
[#2] Professor, School of Civil Engineering, Universiti Sains Malaysia, Pulau Pinang, Malaysia
[#3] Associated Professor, School of Civil Engineering, Universiti Sains Malaysia, Pulau Pinang, Malaysia
[#4] Professor, Civil Engineering Department, College of Engineering, Salahaddin University, Erbil, Iraq

Abstract *— this investigation highlights the influence of glass powder and cement content on the compressive strength in ultra-high performance concrete. The cement content and replacement of cement by glass powder were selected as the parameters in this research. To study the influence of cement content and replacement of cement by glass powder, 117 cubes were cast and tested under compression. The test results were claimed that the compressive strength was enhanced by including extra cement content to the mix and replacement of cement by glass powder up to 14% and 5%, respectively. The SPSS software package was used to proposed equation to predict compressive strength includes mix proportion of UHPC using nonlinear multiple regression. The proposed model was showed that it has a good agreement with test results.*

Keywords— *Compressive strength, Glass powder, Ultra-high performance concrete.*

I. Introduction

The glass powder positioned as cement which has been improved the strength of concrete while it has located as fine aggregate, the strength of concrete has been reduced.

In fact, the mean particle size of glass powder has been influenced on the strength which behaves positively on the strength if the mean particle size less and equal to 75µm [1, 2]. The presence of glass powder in the concrete has been effected on the properties of concrete based on the presence of coarse aggregate.

A. *Concrete with coarse aggregate*

The replacement of cement by glass powder in the concrete included course aggregate has improved the slump in fresh concrete [3, 4] because of the water requirement of mix has increase as the ratio of glass powder increase [5].

In addition, the compressive strength of concrete has been improved in the range of (20-52.6%) due to replacement of cement by glass powder from 10% to 30% [3, 4, 6, 7].

B. *Concrete without coarse aggregate*

The replacement of cement by glass powder has been decreased the workability of the fresh concrete because of the demand of water has been found to increase with the presence of glass powder [8]. Beside this, the replacement of cement by glass powder has been decreased the compressive strength at early age, however, the decrease has become less with prolonged curing time[8, 9]. While it has been found that the inclusion silica fume with replacement of cement or quartz sand by glass powder has improved the compressive strength of the concrete[10, 11] even though it has not been influenced on the density of the concrete with or without heat treatment [10].

II. Research Significance

This paper highlights the influence of cement content and glass powder on the compressive strength of UHPC. Even though in the previous researches have been applied on UHPC and they found that there is no effect on the compressive strength by replacement of cement by glass powder disregard the presence of silica fume, the high content of cement is going to change the effect of glass powder for working as a pozzolanic material in the concrete mix. In addition, the model was proposed to predict the compressive strength of UHPC include glass powder, silica fume as a pozzolanic material in the mix.

III. Experimental procedure

An experimental programme was designed to examine the influence of cement replacement by glass powder and the cement content in UHPC on the compressive strength. Two target strengths 90 and 100 MPa were used to study the influence of glass powder and cement content in UHPC. The cement content was varied between 752.2 and 1565 kg/m^3 while glass powder was varied between 65.79 and 320.54 kg/m^3. The compressive strength and flow value of fresh UHPC were measured to evaluate the influence of parameters.

A. Materials

The materials were used in ultra high performance concrete are Ordinary Portland Cement (Type I), Quartz sands (0.6mm) average sieve size, silica fume, glass powder 11.9 µm median particle size, filtered water, HRWR Sika VC2055 , and retarder Sika Plastiment-R.

B. Mix proportion

The proportion of the mix was chosen to involve the parameters in this investigation. The control mix proportion for 90 and 100 MPa target strength are shown in Table I. The details of the mixes are presented in Table II and III.

TABLE I

DETAIL OF CONTROL MIXES

Materials, Kg/m^3	Mix U-B (90 MPa)	Mix U-C (100 MPa)
Cement	752.2	815
Silica sand	188	163
Quartz sand	904	945
Glass powder	165.2	241
HRWR	26.43	32.9
Retarder	3.761	4
Water	291.3	283

TABLE II

DETAILS OF CONTROL MIXES U-B

Mix denotation	W_t/B	Ad/B	R/B	SF/(C+SF)	GP/(C+GP)
U-B-1	0.291	0.023	0.004	0.200	0.180
U-B-2	0.283			0.111	0.099
U-B-3	0.276			0.131	0.117
U-B-4	0.282			0.158	0.142
U-B-5	0.276			0.131	0.150
U-B-6	0.276			0.131	0.050

C. Specimen preparation

The ultra-high performance concrete was mixed in a 0.05 m^3 laboratory pan mixer using the following sequences: Quartz sand and silica fume were blended for five minutes. Then, the cement and glass powder were mixed for another five minutes. After that, entire water contained whole super-plasticizer and retarder were added and blended for another 8 minutes for activating the admixture in the blended materials. After that, the mixing process was continued for another 2 minutes to improve the uniformity of blending materials.

TABLE III

DETAILS OF CONTROL MIXES U-C

Mix denotation	W_t/B	Ad/B	R/B	SF/(C+SF)	GP/(C+GP)
U-C-1	0.262	0.025	0.004	0.167	0.228
U-C-2	0.246			0.114	0.160
U-C-3	0.244			0.103	0.146
U-C-4	0.242			0.094	0.133
U-C-5	0.241			0.094	0.170
U-C-6	0.243			0.094	0.097
U-C-7	0.244			0.094	0.060

After casting of ultra-high performance concrete in the 100 mm side length of cube steel moulds, the fresh concrete was vibrated for 45 seconds in one layer using vibrating table in order to reduce the voids between surface of steel moulds and concrete. Afterwards, they were left in the moulds for 24±2 hours. Nine 100 mm steel moulds were made to check the compressive strength at 7, 14 and 28 days.

IV. TEST RESULTS AND DISCUSSIONS

A. *Influence of cement content*

Fig. 1 and 2 show the influence of cement content for improving compressive strength in ultra-high performance concrete with 90 MPa and 100 MPa as target strengths, respectively. The maximum improvement in compressive strength happened at U-B-3 and U-C-3 which contain 1250 and 1415 kg/m^3 of cement, respectively.

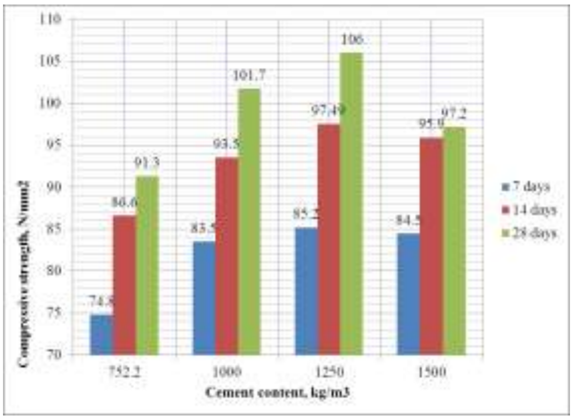

Fig. 1 Influence of cement content on the compressive strength of UHPC U-B mixes at different ages

B. *Influence of glass powder*

The optimum percentage of glass powder in ultra-high performance concrete was found that it was happened at 5% and 9.7% for concrete strength 90 and 100 MPa, respectively. It was found that the improvement of compressive strength of UHPC reached to 6% at early age (7 days) and the improvement of strength decreased with prolong of curing time as shown in Fig. 3 and 4.

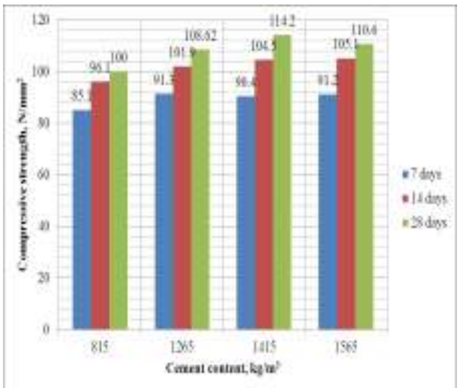

Fig. 2 Influence of cement content on the compressive strength of UHPC U-C mixes at different ages

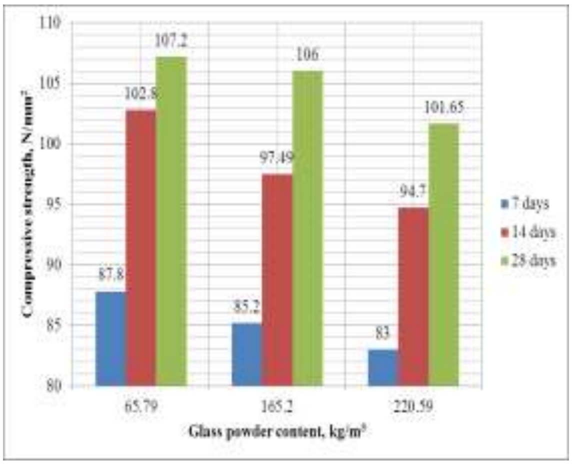

Fig. 3 Influence of glass powder content on the compressive strength of UHPC U-B mixes at different ages

C. *Influence of curing time on the compressive strength in UHPC*

The compressive strength of concrete was slowly grew and reached 13% at 14 days while beyond this age the progress of gaining strength was dropped slightly with respect to 14 days curing time and the improvement of strength was reached to 20%.

V. Theoretical Model

In this study, model to predict the compressive strength from the mix proportion was proposed. The SPSS software package version 19 was used to predict the compressive strength of ultra-high performance concrete considering the percentage of materials in the mix such as water to binder ratio, glass powder to binder ratio, silica fume to binder ratio, GP/(C+GP) and SF/(C+SF).

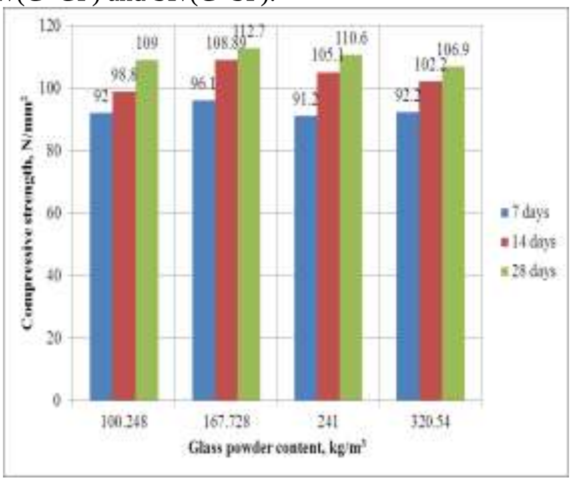

Fig. 4 Influence of glass powder content on the compressive strength of UHPC U-C mixes at different ages

The non-linear multiple regression was used to develop equation which based on the 13 data in this research. The following proposed model has a coefficient of determination 89.2% and the model expressed as follows:

$$f'_{c28} = \frac{174.9\left(\frac{SF}{B}\right)^{2.16}\left(\frac{GP}{B}\right)^{2.49}}{\left(\frac{W_t}{B}\right)^{0.89}\left(\frac{SF}{C+SF}\right)^{1.77}\left(\frac{GP}{C+GP}\right)^{2.34}}$$

Where,

B: binder content in the mix includes cement, glass powder and silica fume, kg/m3
C: cement content, kg/m3
GP: glass powder content, kg/m3
SF: silica fume content, kg/m3
Wt: water content in the mix includes liquid admixtures, kg/m3

VI. Conclusions

Based on the outcomes and the model proposed in this study for predicting the compressive strength in ultra-high performance concrete, the following conclusions could be carried out:

1. The compressive strength is found to be improved up to 14% due to addition of extra cement to the mix up to 70% from the control mix.
2. The early strength of the ultra-high performance concrete is improved up to 5% . However, the amount of improvement is reduced with prolong of curing time to reach 1 to 2%.
3. The growth of strength of ultra high performance concrete is reached 13% and 20% at 14 and 28 days age with respect to 7 days age strength.
4. The proposed model has a good agreement with the results in this research.

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