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Properties of self-compacting concrete "SCC" containing potable water treatment sludge ash

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Abstract— The aim of this research is to study the effect of using potable water treatment sludge ash (PWTS) on some mechanical properties of self-compacting concrete (SCC), namely, compressive strength, density, porosity, ultra-sonic pulse velocity and Schmidt hummer readings. PWTS was used as partial replacement of 5, 10 and 15% by weight of cement. Same quantities were used as partial replacement with 30% fly ash (class C) to produce different mixes. In this research, super-plasticizers were used to achieve the required slump of concrete. A comparison was made between the test results of the different types of concretes. Results of this research revealed that, in case of partial replacement of cement, 5% and 10% has a different positive effect on different mechanical properties than 15%. Similar conclusion has been reached at in case of using WTS as partial replacement of cement no/with 30% fly ash. Effect of potable WTS inclusion on slump flow, V-funnel and L-box in concrete has been also studied and presented.

Index Terms— Self-compacting concrete; SCC; partial replacement of cement; fly ash

1 Introduction

Nowadays, one of the most popular concrete types is the Self Compacting Concrete (SCC). SCC is a concrete which has little resistance to flow so that it can be placed and compacted under its own weight with no vibration effort, yet possesses enough viscosity to be handled without segregation or bleeding [1]. Also, [5] stated that, the use of self-compacting concrete (SCC) is nowadays common for projects of structures and infrastructures
The aesthetic quality of casts is appreciated very much in architecture and the aspects related to workability and durability increased its popularity. On the other hand the peculiarities of this material lead to problems in finding the optimal mix design for the requested application as well as in-site complications for casting, like special formworks due to the fluidity in the fresh state. Moreover the extreme variability of mixtures has direct consequences on the properties of concrete in fresh and hardened states, especially on the final mechanical properties. The design of the self-stressing and self-compacting concretes under consideration implies an extensive understanding of the influence of different parameters in their performance, during both the fresh and hardened states [6].In recent years, there has been an increasing interest in using high quantities of fillers as a partial replacement for cement in self-compacting concrete (SCC). This helps to make SCC a more sustainable material. Incorporation of high quantities of super-plasticizer (SP) and a large volume of filler material is essential to achieve high flow ability and sufficient resistance to segregation. There are many types of filler that have been used successfully in SCC but the most common fillers are fly ash, limestone and silica fumes. Moreover, the use of mineral admixtures and micro-fillers as a partial replacement for cement may also reduce the high cost of SCC but the durability of such additives needs to be studied further [4].

Sustainable waste management has been incorporated as a core principle in European (EU Directive 2008/98/EC on waste) and worldwide (United Nations Framework Convention on climate change, 1992) legislation. A more environmental friendly hierarchy of waste treatment options, of which recycling and incineration rank above disposal is now prescribed by law. Potable water treatment sludge is a by-product of waste water treatment. [3] Past disposal methods of this waste are no longer readily acceptable, for example, in Europe, disposal at sea has been banned since 1998 (EU Urban Waste Water Directive 91/271/EC), spreading on farmland has been restricted due to cautious approaches adopted by countries for health reasons and mandatory targets have been set to reduce the biodegradable waste landfilled fractions (EU Landfill Directive 1999/31/EC). Per annum in the 28 European member states, of which, 22% is incinerated [8].

It is often the case that water suppliers criticize the quality of untreated water. However, some POTABLE WTPs end up discharging their waste in water courses, which runs contrary to their own interests. POTABLE WTP sludge is a type of solid waste and must be processed and disposed of accordingly to prevent environmental damage. [2] POTABLE WTP sludge is rich in pathogens and metals. When discharged in water-courses, it increases the amount of suspended solids, eventually causing the water body to silt up Several researchers have attested the viability of using untreated sludge as a partial substitution for fine aggregate or cement or as a partial substitution for the siliceous material in the manufacture of cement. [2] Also mentioned that, POTABLE WTP sludge has also been used as lightweight coarse aggregate (water treatment sludge and softwood sawdust composite) and in the production of heavy clay however, there are few studies on the possibility of using POTABLE WTP sludge ash as a pozzolanic agent in concrete and Portland cement mortars. The present study thus

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aims to determine the optimal temperature and residence time to yield a material with pozzolanic activity that can be used as a partial substitution for cement without compromising mechanical strength and production cycles and that can improve the sustainability of construction sites and reduce concrete costs.

2 Experimental Program

2.1 Materials

Ordinary Portland cement (CEM - 42.5 N) was used. The sand used was local siliceous natural sand with a specific gravity of 2.56 and a fineness modulus of 2.60, the coarse aggregate was dolomite with a nominal maximum size of 20 mm and a specific gravity of 2.61, POTABLE WTPS materials were added as partial replacement of 0, 5, 10 and 15% by weight of cement. Same quantities of POTABLE WTPS were used as partial replacement with 30% fly ash to produce different mixes. A summary of POTABLE WTPS chemical composition is presented in Table 1.Sika ViscoCrete - 5930 (super-plasticizer according to ASTM C-494 types G and F and BS EN 934 part 2:2001) was added with (0.8-2) % by weight of cement for SCC. An X-ray diffraction (XRD) diagram for major POTABLE WTPS components is provided in Fig.1

TABLE 1
Chemical Composition Of Water Treatment Planet Sludge Ash

Oxides Cont.	
SiO_2	51.95
Al_2O_3	22.19
Fe_2O_3	11.87
CaO	4.71
MgO	2.66
Na_2O	0.43
K_2O	0.98
SO_3	0.43
TiO_2	1.68
P_2O_5	1.27
L.O.I.	0.83

2.2 Concrete Mixes

These materials were used for the production of eight concrete mixes. The first was control concrete. Three mixes was with 5, 10 and 15% for POTABLE WTPS/SA (Sludge ash) material used as partial replacement of cement. Three mixes were made with same POTABLE WTPS/SA quantities addition to 30% fly ash used as partial replacement of cement. One mix was with 30% fly ash only which also used as partial replacement of cement.

Quantities required to produce one cubic meter of concrete are given in table 2. Where, in partial cement replacement stage, the absolute volume of each mix was 1m^3 assuming 2% entrapped air.

TABLE 2
Concrete mix proportions

Mix.	Cem.	Water	Sand	C. Agg.	SA - FA	SP	W/C
	kg/m^3	L/m^3	kg/m^3	kg/m^3	kg/m^3	gm	
CC	520	225	835	850	0 - 0	7.8	0.37
FA-30	364	225	835	850	0 - 156	7.8	0.53
SA-5	494	225	835	850	26 - 0	7.8	0.41
SA-10	468	225	835	850	52 - 0	7.8	0.46
SA-15	442	225	835	850	78 - 0	10.4	0.53
F30-S5	338	225	835	850	26 - 156	7.8	0.62
F30-S10	312	225	835	850	52 - 156	7.8	0.74
F30-S15	286	225	835	850	78 - 156	9.4	0.93

2.3 Pozzolanic activity index of POTABLE WTPS

Chemical activity of POTABLE WTPS material is determined according to the Chapelle test. The results obtained are presented in table 3. The comparison of the determined free lime for POTABLE WTPS that, POTABLE WTPS showed accepted and good pozzolanic activity according to technology of building materials (R&D Unit).

TABLE 3
Chapelle test Results

Time (hours)	Free lime (Cao) % of POTABLE WTPS				
	2	6	24	72	168
	14.59	10.17	9.42	9.17	7.29

3 Fresh properties

For POTABLE WTPS mixes, the only fresh property measured was the slump using the standard slump cone test which led to a slump value of 120 mm. Fresh properties of POTABLE WTPS were assessed using the slump-flow, L-Box and V-funnel tests. The results of L-Box and V-funnel test as well as their typical acceptable ranges are shown in Table 4, 5

TABLE 4
V- Funnel Test Results

	V- Funnel							
Mix Code	OPC	FA-30	SA-5	SA-10	SA-15	F30-S5	F30-S10	F30-S15
T_o min.	10.12	7.2	9.47	7.8	7.45	8.62	7.73	6.9
T_5 min.	13.54	10.18	12.9	11.15	12.11	11.9	10.61	10.75

Where:
Acceptable range of To is (6-12) sec.
Acceptable range of T5 is (To –To+3) sec.

From table 4 it could be seen that, at partial replacement of cement stage, SA – 15 and F30-S15 concrete mixes had the lowest time among different replacement levels concrete mixes at T_o which means that workability had been increased with increasing of partial cement replacement percentage. SA – 10 and F30-S10 concrete mixes had the lowest time among different replacement levels concrete mixes at T5.

TABLE 5
L- BOX TEST RESULTS

	L- Box							
Mix Code	OPC	FA-30	SA-5	SA-10	SA-15	F30-S5	F30-S10	F30-S15
T_{200}	2.1	1.71	1.82	1.93	1.63	1.72	1.58	1.38
T_{400}	4.21	3.51	3.72	4.03	3.43	3.52	3.31	3.06
Ratio	0.85	0.92	0.84	0.86	0.86	0.9	0.9	0.88

4 MECHANICAL PROPERTIES

The mechanical properties were measured using cubes of 150 x 150 x 150 mm for compression test. Three specimens were used for each type of test as well as each type of concrete, namely, CC, FA-30, SA-5, SA-10, SA-15, F30-S5, F30-S10 and F30-S15. That resulted in a total of 144 specimens.

5 RESULTS & DISCUSSION

5.1 COMPRESSIVE STRENGTH

Table 6, shows the experimental results at POTABLE WTPS partial replacement of cement stage with/without 30% fly ash of the compressive strength ($f$cu) at the age of 7 and 28 days. Compressive strength at 28 days was measured after burning each cube for 12 hours in 100º C to can observe the temperature effect.

TABLE 6
AVERAGE COMPRESSIVE STRENGTH (KG/CM^2) RESULTS

Mix Code	OPC	FA-30	SA-5	SA-10	SA-15	F30-S5	F30-S10	F30-S15
7 days	316	282	304	299	287	253	212	194
28 days	335	310	308	322	282	279	268	252

From table 6 it could be seen that, at partial replacement of cement stage, SA - 10 concrete mixes had the highest compressive strength among different replacement levels concrete mixes at ages 28 days. The compressive strength increased with the increase of replacement percentage up to max. value of 10% partial replacement. The max. Increase at the optimum dose of replacement was about 7.7%.; our results are in contradiction with the results of A.L.G. Gastaldini et, Al [5]. Fig. 1 shows effect of POTABLE WTPS/SA as partial cement replacement on compressive strength.

5.2 SCHMIDT HAMMER

Table 8, shows the experimental results at POTABLE WTPS partial replacement of cement stage with/without 30% fly ash of Schmidt hammer values at 28 days after burning each cube for 12 hours in 100º C.

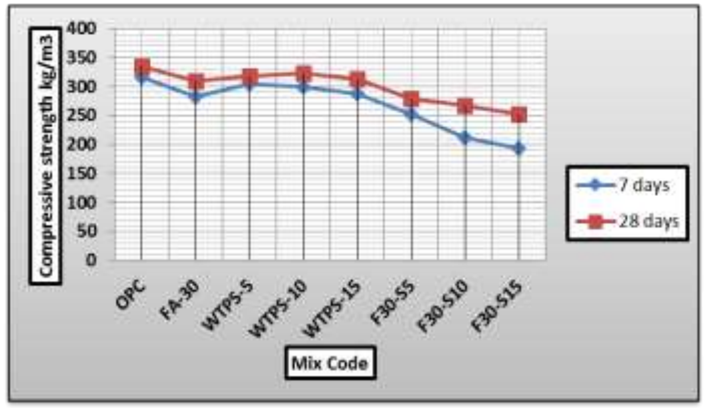

Fig. 1. Effect of POTABLE WTPS as partial cement replacement on compressive strength

Table 7, shows the experimental results at POTABLE WTPS partial replacement of cement stage with/without 30% fly ash of the compressive strength ($f$cu) at 40 days after burning each cube for 12 hours in 200º C, 400º C, 600º C and 800º C to can observe the temperature effect.

TABLE 7
AVERAGE COMPRESSIVE STRENGTH (KG/CM^2) RESULTS AT DIFFERENT TEMP. DEGREE

	Mix Code	OPC	FA-30	SA-5	SA-10	SA-15	F30-S5	F30-S10	F30-S15
200º C	40 days	471	284	339	311	296	309	301	272
400º C	40 days	324	260	204	274	201	218	218	199
600º C	40 days	23	217	187	134	179	189	195	160
800º C	40 days	158	166	168	140	130	137	168	123

From table 7 it could be seen that, at partial replacement of cement stage, compressive strength decrease directly proportional with increasing of burning temperature. SA - 5 concrete mixes had the highest value of burning resistance among different replacement levels concrete mixes at ages 40 days with 49.5%. Fig. 2 shows effect of burning temperature on compressive strength.

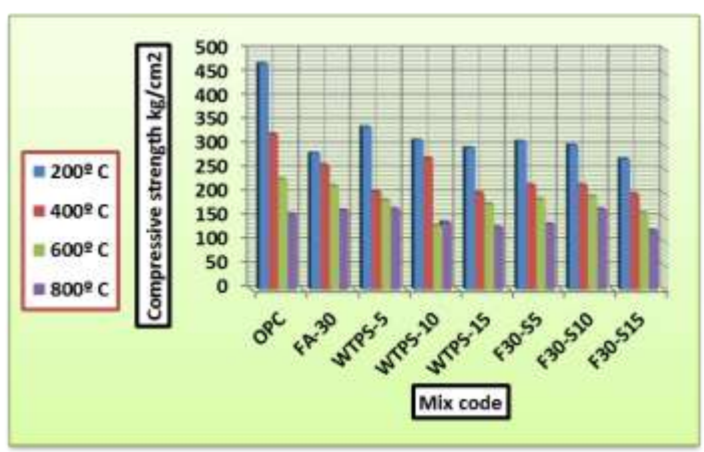

Fig. 2. Effect of burning temperature on compressive strength

TABLE 8
AVERAGE SCHMIDT HAMMER RESULTS AT 100°C

	At 100º C – kg/cm²				
Mix Code	OPC	FA-30	WTPS-5	WTPS-10	WTPS-15
Sch. H. Value	284	272	274	273	264
Mix Code	F30-S5	F30-S10	F30-S15		
Sch. H. Value	263	259	258		

6 CONCLUSION

Based on the experimental results the following conclusions could be drawn:

1. As a cementitious component, POTABLE WTPS satisfies the standard pozzolanic activity measures in the majority of cases and in this regard is comparable to fly ash. In mortar and concrete mixes, using POTABLE WTPS as a direct cement replacement results in lower strength and workability, though at low contents, performance on par with the control can be achieved by adjusting the cement content or using super-plasticizer to lower the w/c ratio of the mix.
2. At replacement stage, 10% cement replacement (POTABLE WTPS-5 and POTABLE WTPS-10) values of schmdit hammer are the maximum for all types of replacement.
3. POTABLE WTPS - 5 concrete mixes had the highest value of burning resistance among different replacement levels concrete mixes at ages 40 days with 49.5%.
4. The compressive strength increased with the increase of replacement percentage up to max. Value of 10% partial replacement. The max. Increase at the optimum dose of replacement was about 7.7%

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