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Effect of ultrafine mineral powder on the charge passed of the concrete

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Abstract

The effect of different ultrafine mineral powders (UFMP) and water–binder ratio (W/B) on the charge passed of concrete under 28 days standard curing was investigated in accordance with ASTM C1202-97. The results show that the charge passed of concrete with UFMP is obviously lower than that of the concrete without UFMP, and the order of reducing the charge passed is silica fume (SF) > fly ash (FA) > natural zeolite (NZ) > ground blast furnace slag (GBFS). The charge passed of concrete decreased with W/B reduced and the dosage of the UFMP increased.

Keywords: Ultrafine mineral powder; Charge passed; Water–binder ratio

1. Introduction

The durability of concrete is determined by its impermeability [1–3], and it can be explicated by the electrical conductivity in accordance with ASTM C1202-97. If the 6-h period charge passed of concrete is lower than 1000 C, the concrete has very high impermeability and durability [4]. The charge passed is determined by the microstructure and the conductance of liquid in holes of the concrete [5]. The microstructure can be improved and the charge passed can be decreased by mixing ultrafine mineral powder (UFMP), so that the impermeability and durability of the concrete can be increased efficiently [6,7].

The concrete with different water–binder ratio (W/B) was prepared in the experiment by replacing a part of the cement with silica fume (SF), fly ash (FA), ground blast furnace slag (GBFS), and natural zeolite powder (NZ) separately. The charge passed through the concrete under 28 days standard curing was measured in accordance with ASTM C1202-97, and the effect of the replacement level of UFMP and the W/B on the charge passed will be presented in the paper.

2. Materials

2.1. Cement

525R Ordinary Portland Cement (OPC) was used. The main properties and chemical composition of the cement are shown in Tables 1 and 2, respectively.

2.2. UFMPs

SF, FA, NZ, and GBFS were used. The chemical composition and specific surface area are also shown in Table 2.

2.3. Water reducer

Sulfonated naphthalene formaldehyde condensate was used. The water-reducing ratio is about 20%.

Table 1
The main properties of the cement

	Bending strength (MPa)		Compressive strength (MPa)		The amount of water required for normal consistency (%)	Setting time (min)		Specific surface area (m^2/kg)
	3 days	28 days	3 days	28 days		Initial	Final	
Cement	6.5	9.2	38.6	64.3	28.00	170	245	345

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Table 2
The chemical composition and the specific surface area of the cement and the UFMPs

Materials	Chemical composition (%) SiO$_2$	Al$_2$O$_3$	Fe$_2$O$_3$	CaO	MgO	SO$_3$	LOI	Specific surface area (m^2/kg)
Cement[a]	20.41	4.81	2.88	63.86	1.52	2.03	3.77	340–350 (Blaine)
FA	58.09	20.62	9.55	2.65	1.14	0.56	4.62	400 (Blaine)
SF	92.45	0.63	1.16	0.45	1.84	–	3.61	18000–20000 (BET, N$_2$)
NZ	66.24	12.82	1.42	2.40	1.08	–	14.60	550 (Blaine)
GBFS	30.25	12.50	1.20	42.51	3.42	5.20	4.16	500~550 (Blaine)

[a] The f-CaO of cement is 0.97%.

Table 3
The list of experimental conditions

Series	No.	W/B	Mixture proportion (kg/m^3) Cement	UFMP	Sand	Crushed stone	Water	Water reducer
1	1	0.42	400		700	1150	168	2.4
	2		380	SF 20	700	1150	168	2.4
	3		360	SF 40	700	1150	168	2.4
	4		360	NZ 40	700	1150	168	2.4
	5		340	NZ 60	700	1150	168	2.4
	6		360	FA 40	700	1150	168	2.4
	7		320	FA 80	700	1150	168	2.4
	8		280	FA 120	700	1150	168	2.4
	9		340	GBFS 60	700	1150	168	2.4
	10		300	GBFS 100	700	1150	168	2.4
	11		260	GBFS 140	700	1150	168	2.4
2	12	0.36	450		690	1100	162	3.6
	13		427.5	SF 22.5	690	1100	162	3.6
	14		405	SF 45	690	1100	162	3.6
	15		405	NZ 45	690	1100	162	3.6
	16		382.5	NZ 67.5	690	1100	162	3.6
	17		405	FA 45	690	1100	162	3.6
	18		360	FA 90	690	1100	162	3.6
	19		315	FA 135	690	1100	162	3.6
	20		382.5	GBFS 67.5	690	1100	162	3.6
	21		337.5	GBFS 112.5	690	1100	162	3.6
	22		292.5	GBFS 157.5	690	1100	162	3.6
3	23	0.32	500		680	1060	160	6.0
	24		475	SF 25	680	1060	160	6.0
	25		450	SF 50	680	1060	160	6.0
	26		450	NZ 50	680	1060	160	6.0
	27		425	NZ 75	680	1060	160	6.0
	28		450	FA 50	680	1060	160	6.0
	29		400	FA 100	680	1060	160	6.0
	30		350	FA 150	680	1060	160	6.0
	31		425	GBFS 75	680	1060	160	6.0
	32		375	GBFS 125	680	1060	160	6.0
	33		325	GBFS 175	680	1060	160	6.0
4	34	0.28	550		660	1050	154	8.8
	35		522.5	SF 27.5	660	1050	154	8.8
	36		495	SF 55	660	1050	154	8.8
	37		495	NZ 55	660	1050	154	8.8
	38		467.5	NZ 82.5	660	1050	154	8.8
	39		495	FA 55	660	1050	154	8.8
	40		440	FA 110	660	1050	154	8.8
	41		385	FA 165	660	1050	154	8.8
	42		467.5	GBFS 82.5	660	1050	154	8.8
	43		412.5	GBFS 137.5	660	1050	154	8.8
	44		357.5	GBFS 192.5	660	1050	154	8.8

Table 4
The charge passed of concrete (28 days)

Series	No.	Mixture type	W/B	Charge passed Coulombs	Relative value
1	1	OPC	0.42	2869	100
	2	SF 20		1043	36.3
	3	SF 40		393	13.6
	4	NZ 40		2337	81.4
	5	NZ 60		1976	68.8
	6	FA 40		1880	65.5
	7	FA 80		1748	60.9
	8	FA 120		1581	55.1
	9	GBFS 60		3039	105.9
	10	GBFS 100		1895	66.0
	11	GBFS 140		1671	58.2
2	12	OPC	0.36	2659	100
	13	SF 22.5		794	29.8
	14	SF 45		293	11.0
	15	NZ 45		2103	79.0
	16	NZ 67.5		1786	67.1
	17	FA 45		1844	69.3
	18	FA 90		1495	56.2
	19	FA 135		828	31.1
	20	GBFS 67.5		2759	103.7
	21	GBFS 112.5		1797	67.5
	22	GBFS 157.5		812	30.5
3	23	OPC	0.32	2524	100
	24	SF 25		583	23.1
	25	SF 50		276	10.9
	26	NZ 50		1935	76.6
	27	NZ 75		1698	67.2
	28	FA 50		1795	71.1
	29	FA 100		1353	53.6
	30	FA 150		598	23.6
	31	GBFS 75		2629	104.1
	32	GBFS 125		1679	66.5
	33	GBFS 175		495	19.6
4	34	OPC	0.28	2361	100
	35	SF 27.5		483	20.4
	36	SF 55		224	9.5
	37	NZ 55		1770	74.9
	38	NZ 82.5		1459	61.7
	39	FA 55		1732	73.3
	40	FA 110		1083	45.8
	41	FA 165		459	19.4
	42	GBFS 82.5		2352	99.6
	43	GBFS 137.5		1535	65.0
	44	GBFS 192.5		335	14.1

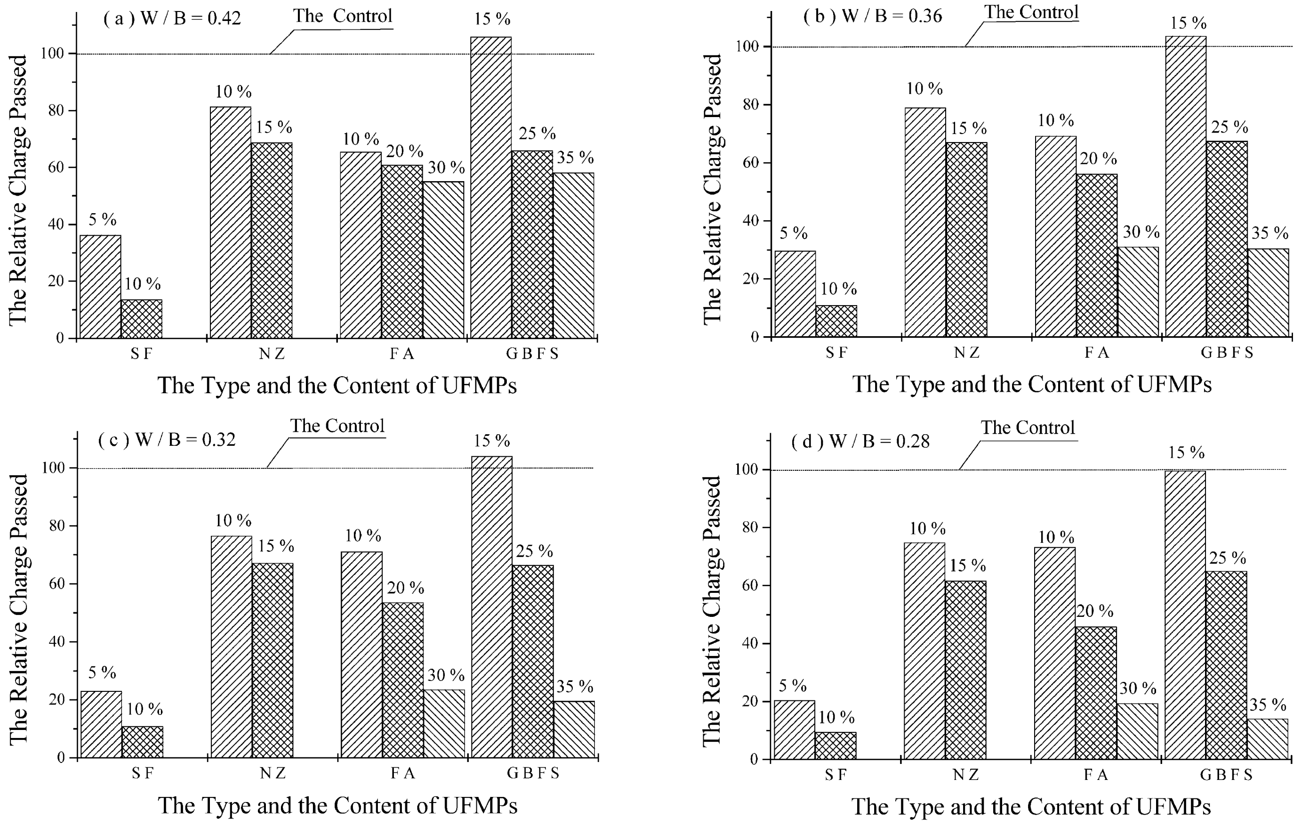

Fig. 1. The effect of UFMP on the charge passed.

2.4. Fine aggregate

River sand with middle size was used. The fineness modulus is 2.7, packing density is 1503 kg/m^3, apparent density is 2678 kg/m^3, and grading is qualified.

2.5. Coarse aggregate

Crushed stone of diabase was used. The maximum size is 20 mm, packing density is 1440 kg/m^3, and apparent density is 2740 kg/m^3.

3. Experiment

Four series of concrete have been tested both with and without UFMP. The aim of the experiment is to see how the charge passed of concrete is influenced by various factors. The experimental conditions are listed in Table 3. In total, four series of concrete with different W/B and UFMP were tested.

4. Results and discussion

The charge passed of each concrete in series is shown in Table 4. The effect of different UFMP on charge passed is shown in Fig. 1. The relationship between W/B and charge passed of the concrete with and without different UFMP is shown in Fig. 2.

From Table 4 and Figs. 1 and 2, it can be seen that:

(1) For the same W/B, when the cement was replaced by different type and different content of UFMPs, the charge passed of concrete can be reduced, and with the increase of replacement level, the charge passed was reduced further. Among the UFMPs, SF is the most effective on reducing the charge passed. For the concrete with W/B = 0.42, when the replacement level of cement with SF is 5% and 10%, the charge passed is 36% and 13% of the control concrete, respectively; when the replacement level of cement with FA is 10%, 20%, and 30%, the charge passed is 65%, 61%, and 55% of the control, respectively; and when the replacement level of cement with GBFS is 15%, 25%, and 35%, the charge passed is 106%, 66%, and 58% of the control. It is special that when the replacement of cement with 15% of GBFS, the charge passed is higher than that of the control by 6%. For NZ, when the replacement level is 10% and 15%, the charge passed is 81% and 61% of the control, respectively.

For the concrete with W/B = 0.36, 0.32, and 0.28, the rule of the effect of UFMPs on the charge passed is similar to that of the concrete with W/B = 0.42.

(2) The charge passed is reduced with lowering W/B. However, the effectiveness of different type and different content of UFMPs on the charge passed is different.

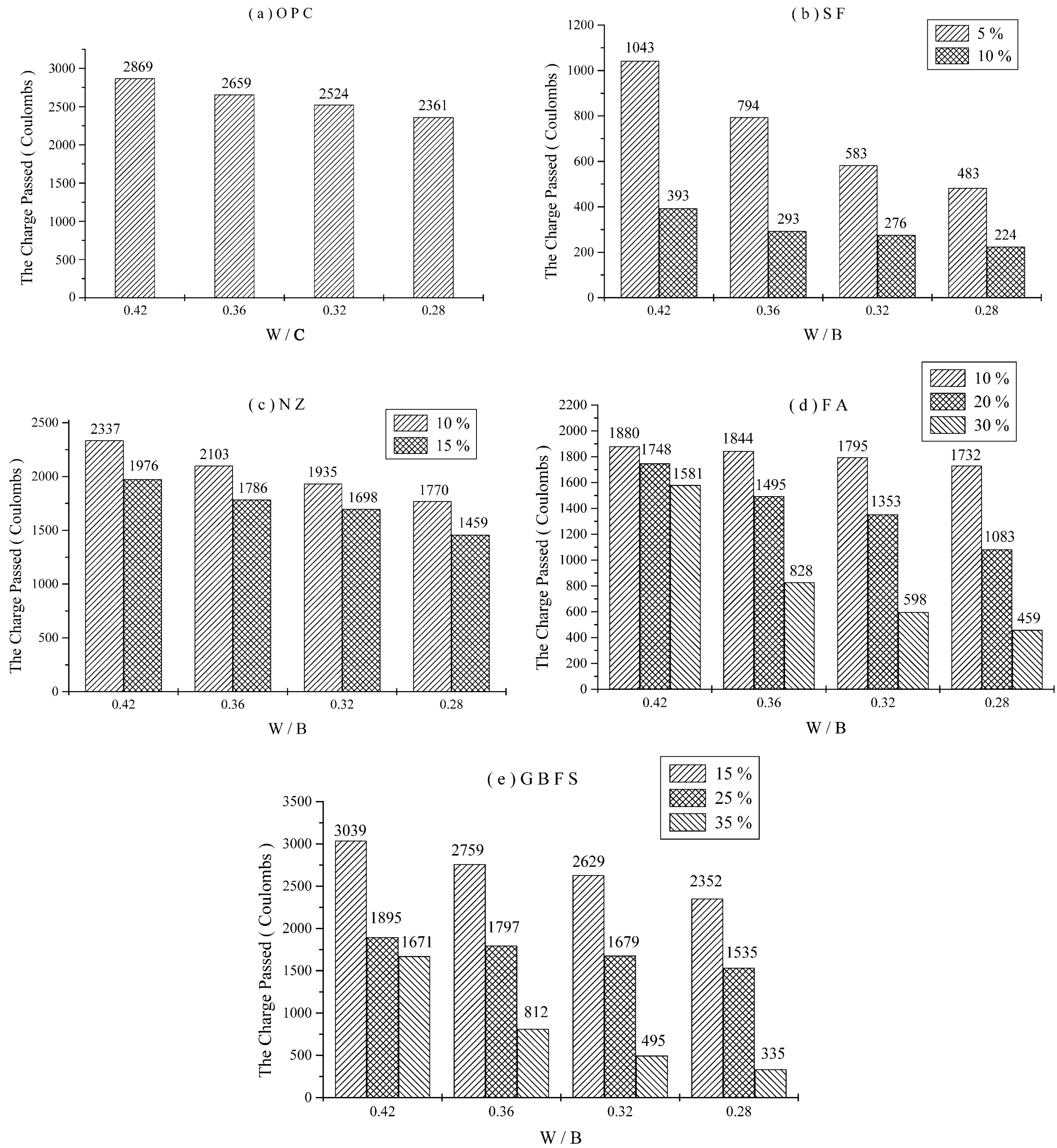

Fig. 2. The relationship between W/B and charge passed of concrete.

For SF, when the replacement level of cement is 5%, the charge passed is reduced obviously along with the lowering of W/B; however, when up to 10%, the tendency to reduce the charge passed is not obvious. It can be deduced that the best replacement level for SF to reduce the charge passed is approximately 10%.

For FA, when the replacement level of cement is up to 30%, the charge passed of concrete with different W/B can be reduced effectively.

For NZ, when the replacement level of cement is 10% and 15%, the tendency is not obvious that the charge passed of concrete is reduced with the lowering of W/B.

For GBFS, when the replacement level of cement is ⩽15%, there is no effectiveness on reducing the charge passed of concrete. Only when the replacement level is ⩾35% can the charge passed be reduced effectively.

It can be seen from the above that the order of reducing the charge passed for different UFMP is SF > PFA > NZ > GBFS.

(3) According to the ASTM C1202-97, when the charge passed during a 6-h period is <1000 C, the chloride ion penetrability is very low. It can be seen from the data in the Table 4 that for SF, when W/B $\leqslant 0.42$ and the replacement level is $\geqslant 5\%$, almost all the charge passed is less than 1000 C, and when the replacement level is 10%, the charge passed can even be less than 500 C; for FA, only when W/B $\leqslant 0.36$ and the replacement level is 30%, the charge passed is less than 1000 C; for GBFS, only when W/B $\leqslant 0.36$ and the replacement level is 35%, the charge passed is less than 1000 C; and for NZ, when W/B $= 0.28 \sim 0.42$ and the replacement level is 10% or 15%, all the charge passed is more than 1000 C.

From the above experimental results, it may be deduced that in order to reduce the 6-h charge passed of concrete to less than 1000 C and make the concrete possess low Cl^- permeability, when proportioning the mixture of concrete, W/B should be $\leqslant 0.36$, the UFMP should be used, and the replacement level of SF, PFA, and GBFS should be $\geqslant 5\%$, $\geqslant 30\%$, and $\geqslant 35\%$, respectively.

5. Conclusions

- For the concrete with W/B = 0.42, 0.36, 0.32, and 0.28, when the cement is replaced with SF by 5%, the total charge passed during a 6-h period is almost all less than 1000 C; when replaced by 10%, it can be lowered to less than 500 C. Among the UFMPs, the charge passed of concrete can be reduced most effectively by replacing cement with SF.
- When the replacement level of cement with NZ is 10–15%, the charge passed is not reduced obviously.
- When the replacement level of cement with FA is $\geqslant 30\%$, and the W/B of concrete is $\leqslant 0.36$, the charge passed during a 6-h period is all less than 1000 C, and with lowering W/B, the charge passed is lowered further.
- Only when both the replacement level of cement with GBFS is $\geqslant 35\%$ and the W/B is $\leqslant 0.36$ is the charge passed less than 1000 C, and with the reduction of W/B, the charge passed is lowered further.
- In order to reduce the 6-h charge passed of concrete to less than 1000 C and make the concrete have high durability, when proportioning the mixture of concrete, W/B should be $\leqslant 0.36$, the UFMP should be used, and the replacement level of SF, FA, and GBFS should be $\geqslant 5\%$, $\geqslant 30\%$, and $\geqslant 35\%$, respectively.

References

[1] N.Q. Feng, F. Xing, High Performance Concrete Technology, Nuclear Energy Press, Beijing, China, 2000.

[2] M. Regourd, Microstructure of high strength cement paste systems, Mater. Res. Soc. Symp. Proc., Pennsylvania, vol. 42, 1985, pp. 3–17.

[3] L. Hjorth, Development and application of high density cement based materials, Philos. Trans. R. Soc., London, vol. A310, 1983, 167–173.

[4] ASTM C1202-97, Standard test method for electrical indication of concrete's ability to resist chloride ion penetration. Annual Book of ASTM Standards, vol. 04.02.

[5] T.H. Wee, A.K. Suryavanshi, S.S. Tin, Evaluation of rapid chloride permeability test (RCPT) results for concrete containing mineral admixtures, ACI Mater. J. 97 (2) (2000) 221–232.

[6] A. Bentur, Microstructure of high strength concrete, Proc. Darmstadter Massivbau-Seminar, Darmstadt, vol. 6, Paper 1V, 1991.

[7] T.J. Zhao, Z.H. Zhou, J.Q. Zhu, N.Q. Feng, An alternating test method for concrete permeability, Cem. Concr. Res. 28 (1998) 7–12.