MODULATION OF α COEFFICIENT BY ADDITION OF GROUND BLAST FURNACE GRANULATED SLAG

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Introduction

Granulated Blast Furnace Slags (GBFS) are common products used in road construction as binder (sand 0/2) in hydraulically bound mixtures. In pavement construction, the reactivity of the GBFS is defined by the alpha coefficient (α), which is the product (EN 13286-44 standard) of the specific surface of the elements lower than 80 µm by the sand friability. Higher is α, better is the reactivity of the slag[1]. This paper deals with the variation of this coefficient based on a study of physico-chemical properties of twenty height GBFS coming from a same production unit. In order to modulate the coefficient and to control the mechanical performances of road granular mixtures, addition of different proportion of Ground Granulated Blast Furnace Slags (GGBFS) has also been investigated during one year.

Materials and Characterisation

Twenty height GBFS were used for this study. They come from a same production unit, from 2 blast-furnaces (14 samples by blast furnace). They correspond to two periods of production of two weeks in the year. The maximal and minimal values, the average and the standard deviation of the physico-chemical characteristics (main oxides contents, specific surface (S), friability (F), alpha coefficient (α), water content (w)) are reported in Table 1. The water content and the oxides contents are relatively regular; the standard deviation is below or close to 1.0 for all these parameters. The main variation is observed for the alpha coefficient: it varies from 13 to 26 with an average of 18.6 and a standard deviation of 3.0. This variation is essentially due to the evolution of the specific surface of the fines particles whereas the friability values show small variations.

Table 1: Physico-chemical characterisation of the GBFS

	Blast furnace	CaO %	SiO_2 %	Fe %	S %	Al_2O_3 %	MgO %	S (<80 µm) cm^2/g	F	α Coeff.	w %
Max	BF1+ BF2	43.84	38.14	0.45	1.21	12.43	7.39	2535	12.5	26	10.3
Min		39.89	35.59	0.01	0.56	10.40	5.78	1457	8	13	5.1
Max	BF1	43.60	38.14	0.34	1.21	12.43	7.16	2002	12.1	22	10.0
Min		39.89	35.98	0.01	0.56	10.78	5.78	1457	8	13	5.4
Max	BF2	43.84	38.11	0.45	1.03	11.69	7.39	2535	12.5	26	10.3
Min		40.07	35.59	0.06	0.56	10.40	6.23	1489	9	14	5.1
Average	BF1+BF2	42.02	37.15	0.25	0.89	11.25	6.77	1775	10.5	18.6	7.2
	BF1	42.07	37.16	0.22	0.90	11.38	6.64	1633	10.4	17.1	7.5
	BF2	41.96	37.15	0.27	0.88	11.13	6.89	1916	10.5	20.2	6.9
Standard deviation	BF1+BF2	0.82	0.49	0.08	0.10	0.36	0.29	227	0.7	3.0	1.1
	BF1	0.79	0.42	0.06	0.11	0.41	0.32	116	0.5	1.3	1.2
	BF2	0.73	0.55	0.10	0.09	0.33	0.26	245	0.9	3.5	0.8

The granularity of all the GBFS is similar (not given here). The fines content (< 80 µm) is always about 0.8% and the chemical analysis by XRF of the fines and the coarse particles are also similar. Thus, the variation of the alpha coefficient depends only on the specific surface of the fines, which depends essentially on the granulation process (water flow, water pressure…)[2]. The variations observed for the alpha coefficient will lead to a difference in the mechanical performances of hydraulically bound mixtures. In order to control the mechanical performances of road granular mixtures, addition of ground granulated blast furnace slags was investigated.

Formulation of hydraulically bound mixtures

The study deals with the formulation of hydraulically bound mixtures composed of 80% in weight of crystallised blast furnace slag CBFS (0/22.4 mm), and a mixture of various proportions of granulated blast furnace slag (GBFS) and ground granulated blast furnace slag (GGBFS). The specific surface of the GGBFS is about 4000 cm^2/g. The various formulations are reported in Table 2.

Table 2: Formulation of hydraulically bound mixtures

	Formula 1	Formula 2	Formula 3	Formula 4
CBFS	80	80	80	80
GBFS	20	19	17.5	15
GGBFS	0	1	2.5	5

The manufacture of test specimens was realised using vibrocompression according to the NF EN 13286-2 standard. This test allows the determination of a paired value: optimum water content (w_{opn} (%)) and optimum dry density (Ds_{opn} (t/m^3)). This paired value corresponds to the coordinates of the optimum proctor point for a given compacting energy. In this study, the test was carried out on the material with

“modified” energy as defined in the standard (use in pavement layers). The obtained values are an optimum dry bulk density of 2.03 t/m^3 for optimum water content (W_{opn}) of about 9%. They were then kept one year in a conservation room until the determination of the mechanical performances: the splitting tensile strength Rtb in MPa (NF EN 13286-42) and elastic modulus E in MPa (NF EN 13286-41). The compaction reference was determined according to the NF EN 13286-50. In accordance with French practice, the tensile strength value (Rt, MPa) is calculated by the following formula (1):

$$Rt=0.8*Rtb \quad (1)$$

The specimens were prepared at the optimum water content and with a target density of 98.5% of the reference value (2.03 t/m^3). For a better comparison between the different formulae, the relative values of Rt and modulus E (average of 3 measurements) are calculated according to the formulae (2, 3). The results are reported in Table 3 and drawn on Figure 1.

$$Rt \text{ relative value} = Rt / Rt_{F1\ 28d} \quad (2)$$

$$E \text{ relative value} = E / E_{F1\ 28d} \quad (3)$$

Table 3: Relative values of R_t and E modulus of the hydraulic bound mixtures according to time

	Formula 1		Formula 2		Formula 3		Formula 4	
Days	$Rt/Rt_{F1\ 28d}$	$E/E_{F1\ 28d}$	$Rt/Rt_{F1\ 28d}$	$E/E_{F1\ 28d}$	$Rt/Rt_{F1\ 28d}$	$E/E_{F1\ 28d}$	$Rt/Rt_{F1\ 28d}$	$E/E_{F1\ 28d}$
28	1.0	1.0	1.33	4.29	2.58	5.93	8.75	13.62
90	2.17	7.38	2.33	6.86	4.25	9.34	12.00	14.46
270	2.42	8.46	2.92	8.13	5.25	9.99	10.83	17.02
360	2.50	8.00	3.08	8.16	5.83	11.34	16.08	16.07

The mechanical strengths increase until 90 days and then stagnate. The highest increase in mechanical strengths compare to the reference (without GGBFS) is observed at 28 days, which shows the influence of the slag’s fineness on the reactivity. The characteristics of the formulae 1 and 2 are close to each other and their performances do not change even for a period of cure of one year.

The formula 3 has mechanical properties higher than those of formulas 1 and 2 (factor of 2) and increase in time even after one year. Those of the formula 4 are much higher (up to a factor of 10 for short curing times) and increase over time including a curing delay of one year. These results show that the addition of 2.5 or 5% of GGBFS to the mixture can improve the hydraulic activity and the mechanical performances of the hydraulically bound mixture.

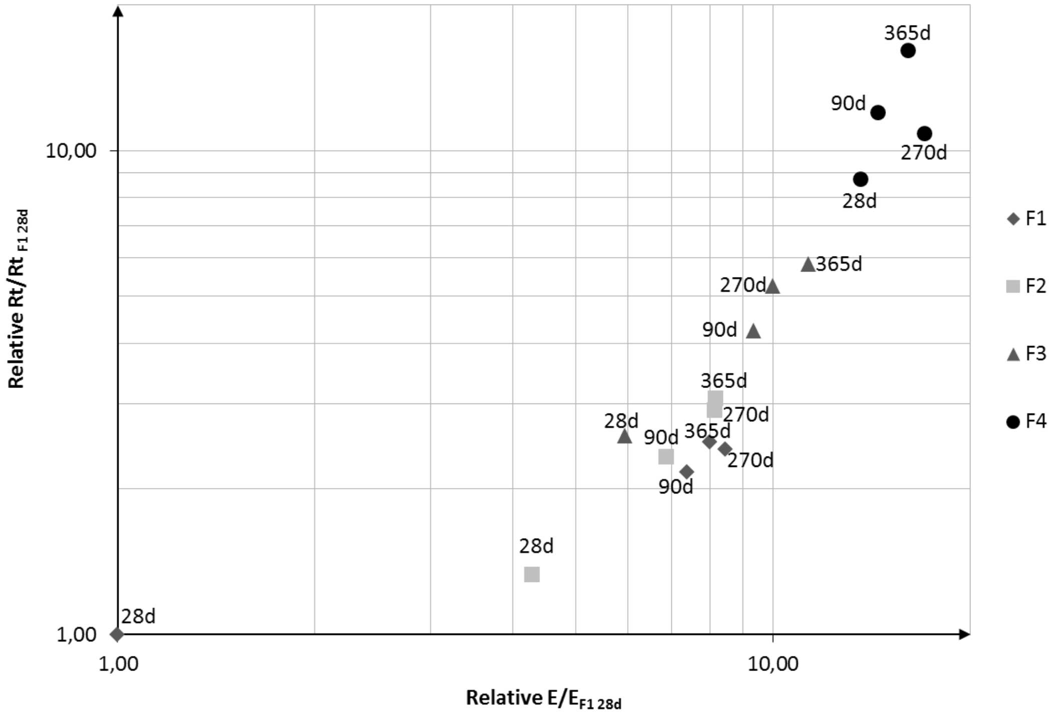

Figure 1: Representation of the relative values of tensile strength as a function of the elastic modulus

Conclusions

The reactivity of the GBFS is governed by the value of the α coefficient, whose variation is essentially due the specific surface of the fines. The addition of GGBFS to hydraulically bound mixtures (*i.e.* increase of α coefficient) allows an increase of the mechanical performances of road granular mixtures. It is so possible to compensate the variation or a minor reactivity of the GBFS by addition of GGBFS. These results show also that the α coefficient is not relevant enough to evaluate the reactivity of hydraulically bound mixtures, because it does not take into account the quantity of fines in the mixture.

References

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