AN EXPERIMENTAL STUDY ON MITIGATING ALKALI SILICA REACTION BY USING EXPANDED PERLITE POWDER

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1. Introduction

Perlite is a pozzolan due to its glassy structure and high SiO_2 and Al_2O_3 contents[1)]. It is interesting to use perlite in blended cement, specially for mitigating alkali silica reaction (ASR). The previous studies showed that as a cement replacement expanded perlite powder (EPP) could be used as a cement replacement in small quantities due to its high water absorption capacity. The previous studies showed that when perlite powder incorporated into mortar bars, perlite powder has potential to suppress expansion induced by ASR[2)]. In those programs, the mineral was added to mortar as mass replacement of the OPC. However, further investigation is needed to determine the adequate replacement ratio to suppress ASR in pessimum condition. This paper discusses the effect of EPP to mitigate ASR.

2. Experimental Program

2.1 Material and Mixture proportion

Chemical compositions of cement and EPP, physical properties of material and mixture proportions of concrete are shown in **Table 1**, **Table 2** and **Table 3**. It can be looked at **Tabel 1** that the content of Na_2O and K_2O in EPP are high compare to OPC. Mortar mixtures were prepared according to JIS A1146. Aggregate combination (in ratio 30:70) between reactive and non-reactive were prepared. Andesite coarse aggregate was crushed into sand that meet particle requirement based on JIS A1146. Alkali content in mortar was set such that Na_2O_{eq} of cement 1.2 wt% by pouring NaOH solution to mixing water. In concrete mixtures, aggregate combination (in ratio 30:70) between reactive and non-reactive were also prepared. Concrete with water binder ratio 0.5 were prepared by using tap water, details as follow : Mixture 1 was made without mineral (P0), Mixture 2 and 3 used EPP at level 10% and 15%. Mixture 4 used EPP at level 20%. Total alkali in concrete is 6.0 kg/m^3, 6.4 kg/m^3, 6.6 kg/m^3, 6.8 kg/m^3.

Table 1. Chemical compositions of cement and EPP

Constituents	OPC	EPP
SiO_2, %	20.89	65.85
MgO, %	0.92	0.14
SO_3, %	2.02	-
Na_2O, %	0.35	4.68
K_2O, %	0.36	4.07
Al_2O_3, %	-	9.96
LoI	1.87	-

Table 2. Physical properties of material

Material	Discription
Cement, OPC	Density = 3.16 g/cm^3, SSA = 3330 cm^2/g
EPP	Pass sieve No. 200 (0.075 mm), Density = 2.30 g/cm^3
Fine aggregates (Limestone)	Density (SSD) = 2.70 g/cm^3, Water absorption = 0.61%, Rc = 8 mmol/l. Sc = 1 mmol/l.
Coarse aggregates (Andesite)	Density (SSD) = 2.60 g/cm^3, Water absorption = 2.75%, Rc = 185 mmol/l. Sc = 620 mmol/l.
Coarse aggregates (Limestone)	Density (SSD) = 2.70 g/cm^3, Water absorption = 0.55%, Rc = 8 mmol/l.Sc = 1 mmol/l.

Table 3. Mixture proportions of concrete

Mixtures	Mixture 1 (P0)	Mixture 2 (P10)	Mixture 3 (P15)	Mixture 4 (P20)
w/b, %	50	50	50	50
s/a, %	45	45	45	45
Water, kg/m^3	160	160	160	160
OPC, kg/m^3	320	288	272	256
EPP, kg/m^3	-	32	48	64
Sand, kg/m^3	843	838	836	833
Gravel, kg/m^3	992	987	984	981
NaOH, kg/m^3	5.347	3.080	1.947	0.813
(AE+WR), gr	1000	1400	1400	1400
AE, gr	9.6	17.6	17.6	17.6
Temp, ^{o}C	19	24	25	22
Slump, mm	80	57	65	55
Air content, %	5.0	4.0	2.9	3.9

WRA= water reducer and air entraining agent (AE+WR), AE= air entraining agent

2.2 Testing method

The size of mortar was 40x40x160 mm (JIS A1146). The size of concrete, prisms was 75x75x250 mm (RILEM AAR-3), and cylinder Ø 100x200mm. After 24 hours, specimens were demoulded, wrapped with wet paper and plastic sheet. Mortar placed vertically in a polyethylene container. Concrete prisms placed vertically in stainless container. Then mortar and concrete prisms were stored in a 40^{o}C and 100% R.H. controlled room. Concrete cylinder for compressive test were stored in a 40^{o}C and 100% R.H. and 20^{o}C and 60% R.H. controlled room. Compressive test were conducted in accordance with JIS A1108 and JIS A1149. The length change was measured periodically. Before measuring, specimens were cooled at 20^{o}C for 24 hours.

3. Results and Discussion

3.1 Expansion test

Expansion behavior of mortar is shown in **Fig.1.** In the case of P0, expansion increased slowly until eight weeks, then enlarged until the end of the observation.

P10 increased remarkably, but became lower than P0 at the end. It might because of the alkali content in EPP. However, when EPP is increased there are expansion reduction. One of pozzolanic effect in suppressing the ASR is binding of alkalis into pozzolanic C-S-H[2)]. Mortar bars containing 15% and 20% EPP show expansion reduction. Mortar bars containing 20% EPP are under 0.1% which is classified innocuous. Furthermore, **Fig.2.** shows expansion behavior of concrete. In the case of P0, expansion was large and fast after 50 days. It can be observed that there is expansion reduction due to usage of EPP. P10 did little to inhibit expansion. However, increasing EPP levels decreased expansion. Concrete prisms containing 15% and 20% EPP show expansion reduction. Concrete prisms containing 20% EPP under 0.05% which is classified as non-reactive. The effectiveness of EPP in mitigating ASR can be attributed to pozzolanic activity possessed by the material. Pozzolanicity may be due to the binding of alkalis onto perlite[2)].

3.2 Compressive strength and elastic modulus

The compressive strength and relationship between compressive strength and elastic modulus in 28 days are presented in **Fig.3.** and **Fig.4.** It could be noticed that the usage of EPP would influence to enhance the compressive strength values in 20°C and 40°C. The compressive strength of concrete with EPP 15% and EPP 20% are greater than P0. Adding EPP to concrete mixture would bring small particles to fill in the spaces between cement grains. It would affect toward significant improvement of the concrete. Finer pozzolans are also sufficient in increasing strength. Urhan[3)] mentioned that the enhancement of bond strength between lightweight expanded perlite aggregate and cement matrix is due to pozzolanic activity of perlite. Demirbŏga et al.[4)] attributed the strength improvement of expanded perlite aggregate concrete to both the self-curing property and pozzolanic of perlite. The strength increase because of the increasing of EPP replacement level. It can be observed that when the expansion has just been started in the 40°C, the strength of P0 is low, and relation of elastic modulus to compressive srength is under of JSCE's standar line. However, for concrete with EPP 10%, EPP 15% and EPP 20%, a good relation are achieved.

4.Conclusion

From the above description, it can be concluded that EPP with the level of 15%, and 20% have potential to mitigate ASR when aggregate was used in pessimum proportion. In the case of fresh concrete workmanship, degree of difficulty of concrete with EPP is higher than control concrete.

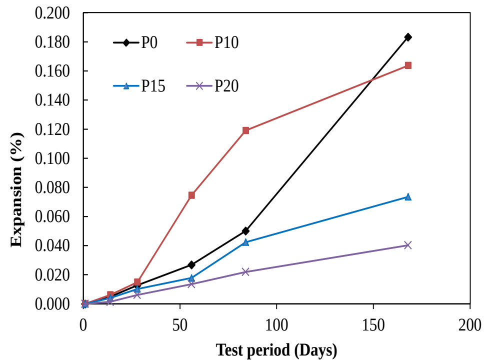

Fig.1. Test results of mortar bar test JIS A 1146

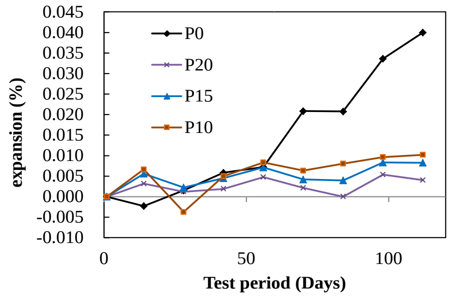

Fig.2. Concrete expansion

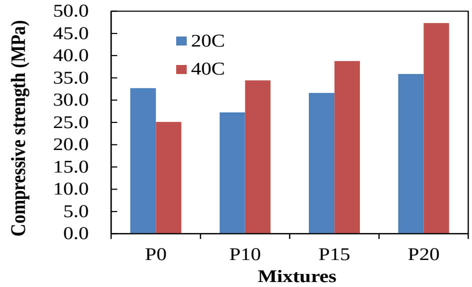

Fig.3. Compressive Strength of concrete at 28 days

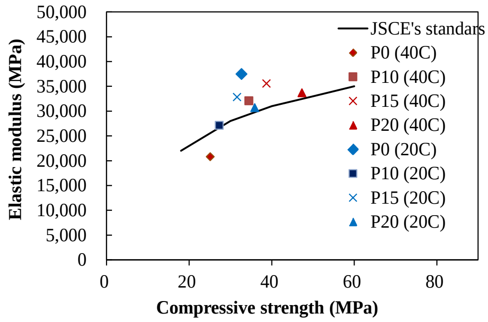

Fig.4: Relationship between compressive strength and elastic modulus

References

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