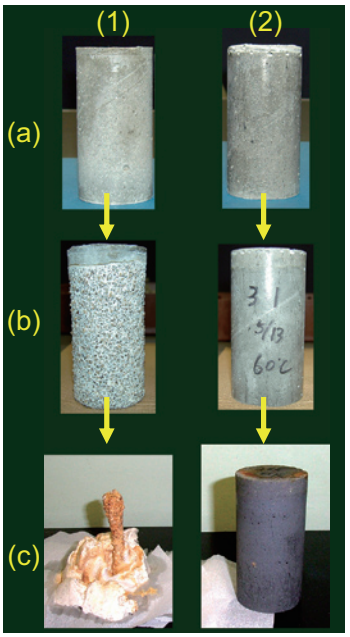
Research Regarding New Environmental Load-Reducing Concrete Using Coal Ash by Employing Geopolymer Method

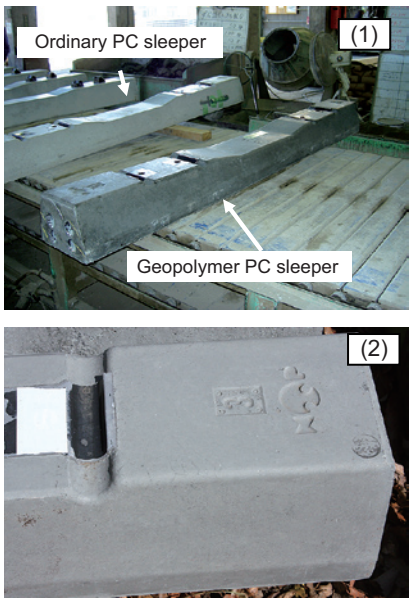
Motoki UEHARA
Senior Researcher, Concrete Materials, Materials Technology Division

Global warming has developed rapidly in recent years, and the reduction in carbon dioxide emissions has become an important theme in all sectors of industry. In particular, Portland cement is known to discharge a huge amount of carbon dioxide of approximately 750 kg when one ton is manufactured, and the reduction in carbon dioxide emissions has been studied actively. Recently, geopolymer cement, which does not use Portland cement, has drawn attention as new material to suppress the generation of carbon dioxide. This is a technology to react active powder with the alkali silicate solution in a polymerization and curing process with respect to the alkali such as coal fly ash, sewage calcined sludge and calcined kaolin, and can reduce carbon dioxide by approximately 80% compared to ordinary cement. Furthermore, the geopolymer concrete is material superior in reducing the environmental load in that a large amount of industrial by-products such as coal fly ash can be used. This geopolymer concrete has characteristics of superior durability compared with ordinary concrete as shown in Fig.1 and various applications are studied. In order to utilize this geopolymer concrete for the railway, we manufactured geopolymer PC sleepers made mainly from coal fly ash on a trial base by mix proportions in Table 1 in conformity with the standard of the post-tensioning type No. 3 PC sleeper specified in JIS E 1202. Figure 2 shows photos of the manufactured geopolymer PC sleeper. In comparison with sleepers made using ordinary cement, the geopolymer PC sleeper shows a slightly dark color reflecting the color of unburnt carbon in the coal ash fly, and a dark gray color in a water-wet state ((1) in Fig.2), and a gray white color in a dry condition ((2) in Fig.2). Generally, in the PC sleeper production cycle in a Japanese sleeper factory, hardening treatment is performed by steam curing in the nighttime and after a sleeper is demolded from the form the following day, prestress is applied. The compressive strength of geopolymer concrete manufactured on a trial base was 69.3 N/mm^2 at the age of one day, which is higher than the basis value of 14.7 N/mm^2 at the point of demolding and higher than that of 39.2 N/mm^2 at the point of prestress application. This means that geopolymer PC concrete can be manufactured in an ordinary production cycle of a sleeper factory in Japan. In addition, no problems with PC steel rod elongation were recognized at the point of prestress application, which clarified that geopolymer PC sleepers can be manufactured in a process similar to that for ordinary sleepers. Table 2 shows the results of performance confirmation testing for the sleeper conducted in accordance with required performance specified in JIS E 1202. All tests showed no cracks a the guarantee load level, and produced a larger breaking load than the basis value, thereby confirming that the load-bearing capacity of the manufactured No. 3 geopolymer sleeper satisfied the required level of performance in JIS E 1202. Currently, we are proposing an improvement method of workability and proceeding with its practical application so that sodium silicate solution, which is inferior to potassium silicate solution in workability but is low in price and from which cost reduction can be expected, can be used.



(1) Ordinary cement mortar, (2) geopolymer mortar, (a) Before soaking test, (b) one week later, (c) four months later

Fig.1 Geopolymer mortar and ordinary cement mortar exposed to 10% H_2SO_4 solution



(1) Immediately after completion (damp)
(2) One month later (dry)

Fig.2 Photos of the geopolymer PC sleeper

Table 1 Mix proportions of geopolymer PC sleepers

Unit weight (kg/m^3)						
FA	BS	KOH	SiO_2	Water	C	S
456	24	140	47	109	850	659
		Water glass*1 = 296				

FA: JIS Grade 1 fly ash; BS: blast furnace slag (Blaine specific surface area = 4,000 cm^2/g) *1 : water glass was manufactured by mixing and dissolving KOH, SiO_2 and water; C: coarse aggregate; S: fine aggregate

Table 2 Results of sleeper performance confirmation tests conducted in accordance with JIS E 1202 (Prestressed concrete sleepers-Post-tensioning type)

	Bending test at rail position		Bending test at center of sleeper		Pull-out test of fastening insert	
	Guarantee load	Destruction load	Guarantee load	Destruction load	Guarantee load	Destruction load
Acceptance value	77 kN	159 kN	45 kN	92 kN	30 kN	50 kN
Geopolymer PC sleeper	127 kN (No cracks*)	193 kN	66 kN (No cracks*)	142 kN	No cracks*	108 kN

* No cracks occurred at the guarantee load.
Numerical values in parentheses show loads at which cracking occurred.