5C2. Effective Use of Ash in Cement/Concrete

Technology overview

1. Technology overview

Research has been conducted on utilizing fly ash in the cement sector as an alternative for pozzolana. Enhanced research on the use of fly ash as a good-quality alternative to pozzolana led to its first application as a concrete admixture in the late-1940's, when it was used for structures like dams in the United States. This process was subsequently disseminated to other countries. In Japan, following its commercialization as a cement admixture early in the 1950's, standards were established for fly ash in 1958 and then for fly ash cement in 1960, encouraging its widespread application in general concrete structures.

In the meantime, fly ash came to be used as a clay-alternative raw material in cement in 1978 and by 2003, 70.1% of all the effectively used fly ash was used in this manner.

2. Utilization in the cement sector

1) Utilization as a clay-alternative raw material in cement

The raw materials for cement are limestone, clay, silica, and ferric oxide, with clay accounting for 15% of the total composition. Coal ash containing silica (SiO_2) and alumina (Al_2O_3) is also used as an alternative to clay. However, coal ash contains less SiO_2 and more Al_2O_3 than clay, which requires that more silica be used to offset the shortage of SiO_2. This deficiency limits the substitutability of coal ash for clay. At present, coal ash can constitute approximately 5% of the raw materials for cement but theoretically its use could be as high as around 10%.

2) Utilization as cement mixture

Japanese Industrial Standards (JIS) specify standards for fly ash cement[2], allowing the mixture to range from 5-30%. In general, fly ash can also be used as a Portland cement mixture, blended at 5% or less.

3. Utilization in the concrete sector

1) Utilization as a concrete admixture

1. Dam concrete

In Japan, research on fly ash as a concrete admixture started around 1950, with favorable results and economics through the first commercial use at a dam site in 1953.

Roller compacted dam-concrete (RCD) is a concrete product finished by compacting concrete of ultra-thick consistency with a vibration roller. The then Ministry of Construction led independent technology development to utilize this in a concrete dam, successfully systematizing the trial into the RCD construction method, which was commercialized for dam construction in 1978.

In order to prevent cracks, dam concrete is generally not allowed to reach high temperatures.

Due to this restriction for RCD, only a portion of the cement can be replaced by fly ash in order to limit temperature increases. Generally, the replacement ratio is 20-30%. As many as some 30 dams have thus far been built employing this construction method, making it a well-established engineering method, justifying the development efforts.

2. Pre-packed concrete

Pre-packed concrete is a concrete product fabricated by casting coarse aggregate of a designated grain size into a mold or place of application beforehand and injecting mortar into voids at an appropriate pressure. The mortar used must be one of high fluidity, with little material separation, and of moderate expansibility. For this purpose, fly ash is generally mixed at a rate of 25-50%.

Applications include underwater concrete, mass concrete, and the repair/reinforcement of existing concrete work. The substructure work for the Honshu-Shikoku Bridge also employed this construction method.

3. High-fluidity concrete

Fly ash enriched concrete (FEC) is a two component-type, high-fluidity concrete product using cement and fly ash as powder materials. It can contain 40% or more fly ash, providing such characteristics as excellent self-filling capability requiring no compaction after casting, minimal cracking due to heat of hydration, which increases its long-term strength, as well as higher durability against alkali aggregate reactions and salt/acid damage.

Fly ash and slag concrete (FS), using steel slag and coal ash as aggregates, is a plain concrete product developed for wave-breaker superstructure works and fixation blocks/tetrapods that do not require great strength.

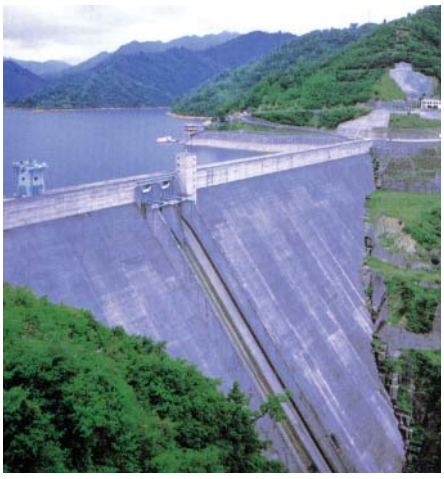
4. Industrial standards for concrete-purpose fly ash

After evaluating fly ash as a concrete admixture it was determined that it performed well due to its ultra-fineness and the limited quantity of unburned carbon. Subsequently, ultra-fine items produced by an advanced analyzer were commercialized. In addition, items with higher-performance qualities, or qualities likely to prove effective as admixture despite their substandard state, were added to the JIS standards[3] and classified as grade 4 materials, thereby designating them with a quality suitable for utilization. Grade 1 fine fly ash is used as an admixture for concrete products used as water/moisture barriers. It must be durable, among other characteristics. Uses include ocean concrete and specially-reinforced shielding material used for long-distanced pumping.

Table 1 Quality of fly ash (JIS-A 6201)

Class		Class I fly ash	Class II fly ash	Class III fly ash	Class IV fly ash
Silica dioxide (%)		45.0 or higher			
Moisture content (%)		1.0 or less			
Ignition loss[1](%)		3.0 or less	5.0 or less	8.0 or less	5.0 or less
Density (g/cm^3)		1.95 or higher			
Fineness[2]	Residue on 45μm sieve (screen sieve method) [3] (%)	10 or less	40 or less	40 or less	70 or less
	Specific surface area (Blaine method) (cm^2/g)	5000 or higher	2500 or higher	2500 or higher	1500 or higher
Flow value ratio (%)		105 or higher	95 or higher	85 or higher	75 or higher
Activity index (%)	Material age: 28 days	90 or higher	80 or higher	80 or higher	60 or higher
	Material age: 91 days	100 or higher	90 or higher	90 or higher	70 or higher

1. In place of ignition loss, the unburned carbon content ratio may be measured by the method specified in JIS M 8819 or JIS R 1603 to apply to the result a stipulated value of ignition loss.
2. Fineness based on the screen sieve method or the Blaine method.
3. Regarding fineness, the results of the Blaine method are provided as a reference value for the screen sieve method.



Application for dams

Application for buildings

References

1) The Japan Cement Association: Common Cement Practices, 2000.
2) JIS R 5213-1997, 1997.
3) JIS A 6201-1999, 1999.