ABSTRACT

Title	Studies on development of water-retentive interlocking block (WR-ILB) mixed with fresh volcanic ashes, and on function of temperature-rise-restraint of surface of WR-ILB paving road

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The applicability to concrete fine aggregate of the volcanic ashes, i.e. the ash from Mt. Shinmoedake erupted recently and one from Mt. Sakurajima erupted sometimes, was studied by the physical and chemical tests and the investigation in ash-falling sites. The former ash, sampled from wide ash-falling sites, had physical properties of 4-7% absorption, 2.1-2.3 g/cm^3 density in saturated surface-dry condition, and 2.0-3.2 fine modulus occupied with smaller particles in a range of JSCE standard fine aggregate grading. Mortar specimen mixed with high-absorption ash tended to raise their water retention. As the chemical properties, firstly ash's pH was about 4.60, strong acid, due to SO_2 volcanic gas, and secondary the ash, being packed in plastic bag for one year and one month, changed from the acid side to near the neutrality one, and then the density of SO_2 volcanic gas could not detect in the ash layer for 3.5 years. As it could not deny residual possibility of a very small amount of SO_2 gas inside fresh ash, mixing fresh ash into reinforced concrete could be difficult. Shinmoedake ash (T) was newly prepared large quantity for concrete product examinations from the sedimentation place of volcanic ash as indicating 2.15-2.27 fine modulus. On the other hand, Sakurajima ash (S) was very fine with 0.61 fine modulus, 0.93% absorption and 2.67 g/cm^3 density in saturated surface-dry condition.

Chemical compositions of T and S were composed by both 56% SiO_2 and 17% Al_2O_3 mainly, being natural pozzolan material. Both ashes were judged to be harmless from the ASR test's results indicating be less than 0.100% of JIS 26-week-mortar-bar expansion standard, although containing ASR properties in both ashes by a XRD analyzing. Therefore, both ashes were confirmed to be able to utilize into precast unreinforced concrete products as fine aggregate by mixing with high quality fine aggregate, although both ashes were not satisfied JIS standard for fine aggregate of concrete.

Water-retentive interlocking block (WR-ILB) must be satisfied the bending strength (for sidewalk block): more than 3.0 N/mm^2, the capacity of water-retention: more than 0.15g/cm^3 and the height absorbed water: more than 70%, as JIS standard for WR-ILB, being just established in March, 2010 to contribute to heat island effect relaxation. The JIS authorization factory plant of concrete block produced WR-ILB without volcanic ash and WR-ILB with each T and S of 10, 20, 30, 50% (vol.), being fine aggregate replacement ratio. All WR-ILB was experimented on the above three tests adding the water permeability test. As the results, the maximum mixing volume rate was 30% for T and 20% for S to be satisfied JIS standard for WR-ILB. Mixing with very fine S a lot into concrete could increase

water retention but extremely reduce a water permeability. The heavy metal leaching test for the grain of each piece of WR-ILB, mixed with 50% T and S, were not found numerical values to exceed its standard values.

Then, the concrete block plant produced 10 types of WR-ILB, which was mixed without volcanic ash and with 9 combined ash of 3-volume ratio blended with T of S, i.e. 3:7, 5:5 and 7:3, and 3-mixing-volume rate of 20, 30 and 40% being a fine aggregate replacement ratio. The maximum mixing volume rate of volcanic ashes for WR-ILB was clearly recommended 30% with 5:5 of T:S volume ratio blending both ashes, while thinking about reduction of volcanic ash accumulation volume, keeping JIS standard for WR-ILB, and keeping more water retention. Therefore, WR-ILB with most suitable concrete mix proportion to utilize fresh volcanic ash was developed.

The field test was done to measure temperature comparing the function of temperature-rise-restraint of surface in a test sidewalk composed with 5 materials, i.e. two types of WR-ILB (Ash-WR-ILB and No-Ash-WR-ILB mixed with and without volcanic ashes), normal ILB, loan and asphalt road, in the summer heat period from last of July to first of August in 2013. The changes of temperature in 20, 50, and 100cm heights above each test sidewalk surfaces was almost same as the change of the outside temperature. The higher temperature on surface and in 3cm-depth indicated as the order of asphalt road, normal ILB, No-Ash-WR-ILB, Ash-WR-ILB and loan. An effect of temperature-rise-restraint of Ash-WR-ILB was, however, recognized with a small different of temperature than No-Ash-WR-ILB.

Using ILB graft to make clear the reason of its small different of temperature between both WR-ILB, several tests were done, and their results were shown below; 1) Ash-WR-ILB could reduce 1.0 degree Celsius centigrade (℃) than No-Ash-WR-ILB. 2) When warming the surfaces of WR-ILB forcibly, the surface temperature of both WR-ILB increased gradually and then after warming the neighbor ILB graft, the joint of Ash-WR-ILB was warmed to increase its temperature. The joint could be influenced to temperature-rise-restraint effectively. 3) Ash-WR-ILB had a higher water retention because its quantity of evaporation was smaller than No-Ash-WR-ILB. 4) Unit weight of upper layer of ILB tended slightly heavy, and it indicated the upper layer of ILB is surely formed minute organization by producing ILB. 5) When infiltrating water into the surface of ILB, Ash-WR-ILB was infiltrated slowly than No-Ash-WR-ILB. Therefore, it is suggested that Ash-WR-ILB increase water retention by very fine S but a restrain evaporation and/or vaporization from upper layer forming by minute organization, and the joint contributed to a temperature reduction effect in ILB paving road.

Based upon the foregoing, on the function of temperature-rise-restraint of Ash-WR-ILB sidewalk, an original mechanism was elucidated as capillary phenomenon and water evaporation, from inside to upper layer and then from upper layer to surface, were restrained by forming minute organization in upper layer of Ash-WR-ILB, and as then inside water of ILB move to flank and neighborhood and then evaporate from the joint, being a free face for ILB. Thus was supported the joint contribution for a temperature reduction effect because the joint's temperature was remarkably low by 0.4-1.3℃ than the ILB surface one in thermograph figures of sidewalk ILB.

Accordingly the joint contribute to a temperature reduction effect, and it must evaluate a heat island effect relaxation by measuring the surface temperature including joints in ILB paving road. At present, a temperature reduction effect in ILB paving road is evaluated by an indoor irradiation examination measuring method (the indoor method) in center point of surface of one ILB, a plate block with 30×30×5cm size, and φ100mm-block core. Instead of that method, the author suggested newly the method of measuring temperature by using a low price radiation thermometer, as a temperature measuring tool with light weight, small size and simple working. Using a radiation thermometer is the merit that anyone can easily and quickly measure temperature of circle of a diameter same as a height from paving surface in ILB paving road, and it is easy to be understood as a method to compare the paving surface temperature on the site. After measuring temperatures of about 60-cm-diameter-circle surfaces (the mean temperature), ILB surfaces and joints in one sidewalk with 3-color-normal ILB in Miyazaki and in two sidewalks with 2-color-WR-ILB in Tokyo, temperatures of joints were significantly low than ILB surface temperatures ($P<0.05$ and $P<0.01$), and the mean temperature indicated effectively sidewalk surface temperature rather than ILB surface one. These results showed clearly to elucidate the mechanism of temperature-rise-restraint of WR-ILB sidewalk and also to reproduce indicating low temperatures of the joints in the thermograph figures of surface on sidewalk paved ILB. Furthermore, measuring the mean temperature including the joint temperature on ILB sidewalk was reasonable naturally and practically to evaluate a temperature reduction effect rather than the indoor method.

Finally, in view of a volcanic eruption to occur frequently these days, as countermeasure to utilize fresh volcanic ashes, WR-ILB production technologies were built as a volcanic ashes mixture type with the versatility. On the premise that can recruit fresh volcanic ashes, sediment old volcanic ashes (for example, Shirasu) as a fine aggregate, powder from tuff repository as a pozzolan, near a volcanic eruption area, the menu utilizing fresh volcanic ash was suggested for public works projects to store concrete blocks and environmental product mixed with volcanic ashes in the disaster prevention spot, including the flow to take first priority.

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