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SUMMARY OF DOCTORAL THESIS

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Title: Agricultural Bio Wastes as Potential Source of Pozzolan and Supplementary Cementitious Material
(ポゾラン及びセメント補助材料としての農業生物廃棄物の利用可能性)

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In the recent past a tremendous progress has been made to convert waste management into resource management. Cement which is the chief construction material has the potential to be substituted by alternate binders that are developed out of industrial or agricultural wastes. Some studies have been done to develop pozzolanic or cementitious material from agricultural waste products like rice husk, wheat straw, coconut fiber etc. Plants and trees uptake various minerals and contain significant amount of silica. If processed scientifically, it is the major element that imparts the pozzolanic activity which helps in enhancing the durability of cement based components. In view of the above scenario, series of experiments were carried out on various kinds of agricultural and bio-wastes; in a quest for developing alternate binders or supplementary cementitious materials (SCM), which are environment friendly, would contribute to achieve sustainable development goals and impart more durability and strength to the properties of cement based products. The primary objective of the current research was to replace conventional cement, partially by some alternate cementitious materials obtained from bio-wastes.

Experimental work was started with the identification and collection of various kinds of agricultural bio-wastes such as dead dry leaves of different plants, waste cut grass (Japanese shiba, Korai grass, and American Tifton grass), peanut shell, wheat straw, and sugarcane bagasse procured from different sources with in Japan and also from India. All the materials were dried and burned under controlled conditions to obtain reactive ash. In the first phase, many trials were made to define the optimum burning temperature and the time to obtain the ashes with amorphous mineral contents. To verify these parameters, all the ashes were subjected to various physical (density, color, particle size, specific surface area), chemical (water absorption, chemical composition, loss on Ignition, ash percentage), mineralogical (XRD examination, Thermo-gravimetric Analysis) and morphological testing (Scanning Electron Microscopy) using the facilities at Tottori and Shimane Universities.

Second experiment was based upon the results of first phase, and ashes were obtained from dry tree leaves (AML), Korai grass (KRI), and Tifton grass (TFT) by burning these materials at 600ºC for 5 hours under control conditions. Pozzolanic character of these ash materials was studied by evaluating the strength development values of ash substituted mortar specimens; prepared by substituting ordinary Portland cement by 10, 20, 30% ash. Destructive (compressive and flexural strength), as well as non-destructive tests were conducted at 3, 7, 14, 28, 56, and 91 days and results were compared with the control specimen. Strength activity index of all AML-blended and KRI- blended specimens was above 75%, whereas TFT-blended specimens did not show a significant reactivity. Mineralogical

(X-ray diffraction), morphological (scanning electron microscopy), and thermo-gravimetric (TGA) analyses were also carried out to analyze the reactivity and nature of hydration products influenced by the ash substitution. All ash materials exhibited pozzolanic property but with varying degree. It was noted that and up to 20% substitution of cement in the mortar by AML and KRI-ash gave as good strength properties as the control specimen.

Third experiment was conducted to investigate the potential of sugarcane bagasse (SCB) waste, an industrial cum agricultural waste available in huge quantities. The material was procured from India and experiment was conducted on the same guide lines as adopted in the second experiment. Pozzolanic reactivity of bagasse ash was evaluated by conducting destructive and non-destructive tests on ash-blended cement mortars. To verify the hydration reaction of SCB ash, blended pastes were examined by X-ray diffraction, thermo-gravimetry and scanning electron microscopy. Results showed a very good prospect for up to 15% replacement of cement with bagasse ash in mortar.

Fourth experiment was conducted to investigate the synergic effect of rice-husk ash (RHA) and wheat straw ash (WSA) on the strength properties of blended mortar. In this study, abundantly available wheat straw ash (WSA) which is a less reactive and scarcely used pozzolan was employed in ternary blends with rice-husk ash (RHA), which relatively is a more reactive pozzolan. Ash materials were obtained after burning the wastes at 600^{o}C for 5 hours at a control rate of 2^{o}C/minute. Two binary blends of mortar by substituting 15% cement with WSA and RHA and three combinations of ternary blends with (10+5)%, (5+10)% and (7.5+7.5)% combination of WSA and RHA, were prepared along with the control specimen. Standard rectangular prisms (40 × 40 × 160 mm) prepared with above mix ratios were subjected to destructive (compressive and flexural strength) as well as non-destructive (ultrasonic pulse velocity) tests till 180 days of curing. Ternary blends with (7.5 + 7.5)% combination of WSA and RHA showed better strength results than control and other blends. This proved to be the optimum combination for achieving maximum synergic effect.

It is generally recognized that the behavior of pozzolans or other supplementary cementitious materials can be different in concrete than in mortar applications. Therefore, to verify the behavior of different ash materials tried in blended mortars; blended concrete specimens (cylinder of size 200 mm × 100 mm ϕ) were prepared replacing Portland cement with 10%, 15% and 20% AML-ash. These were analyzed for the strength properties by conducting destructive, non-destructive and durability tests. The results indicated that ashes obtained under control processing conditions improved the strength characteristics of blended concrete specimens. Using leaf ash up to 20% replacement, concrete produced highly encouraging properties, which would be beneficial for economical as well as environmental perspectives.

The whole research work was an adoption of recycling concept and our effort through these experiments was a little contribution towards establishing a more sustainable society, assurance of environmental protection, better quality of life for present and future generations and; as a long term goal, for social benefits to be gained through collaborative action.