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A Study on Reuse of waste clay bricks

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Abstract - *Waste clay brick (WCB) is silicate solid waste, its recycling process has played a great significant role in our environment and construction. The application of WCB as recyclable coarse and fine aggregate in concrete and mortar, wall materials, as well as raw material or addition in the production of recyclable cement, has been momentarily introduced. The subsequent aspects were highlight: the study progress of the impact of waste clay bricks as supplementary cementitious material on physical mechanics, deformation and toughness of cementitious materials; the development of the function of Waste clay bricks as environmental materials on removing fluorine, ammonia nitrogen and phosphate in waste water; the current status of waste clay bricks as filler in decorative paints, as filler in rubber plastic materials after being organically modified, as well as in the production of recyclable prehistoric architectural brick in recent years. The problems in recycling of waste clay bricks has also been summarized.*

Key Words: **waste clay brick, recycling, research progress;**

1. INTRODUCTION

Clay brickis a product of a brick dough, which consists of clayey soil and water. It is formed primitively, naturally dried, and fired in the kilns in the workshop Clay brick is the oldest and most used building material, has been manufactured at the water fronts where suitable soil could be found. Soilisa cheap, environmentally friendly, and abundantly available building material. People always seek for accessible building materials to build a shelter.

Fast growth of urban construction and improvement, a large amount of Waste Clay Brick (WCB) from the destruction of old buildings has been produced. According to statistics, WCB account for 50%-70% of the construction waste produced by urban redevelopment, and 30%-50% by building operations. Quite a lot of brick not up to standard were also produced through the production of clay brick. In the past, WCB were often transported to suburban areas and landscape, and were treated with open-air piling up or being buried underground, which spent a large sum of request fees, and the issues like disperse rubbish also caused serious second environmental pollution. According to the past five decades, at least 20 billion meters cubed of clay brick products have been produced in India, which will mostly be transformed into solid waste in the next five decades, approximately accounting for 50% of the total amount of construction garbage. Whether WCB surface with cement mortar or not, they're typical silicate solid waste, consisting of SiO2 and AI2O3 in mass, the amount of the two accounting for no less than 80% of the total, other compounds are Fe2O3, TiO2, CaO, MgO and so on. The mineral components are mainly quartz, feldspar and hematite, but clay mines and carbonate will also exist if not fully sintered. Since the surface of WCB is rough, porous, and there are lots of corner angles and the micro cracks caused by collapse and crush on it, WCB aggregate possess characters as low strength and high hygroscopicity compared to natural aggregate. Though it's critical for working capability and strength of concrete and mortar, the character of rough surface and high hygroscopicity will form a microtubule or micropore system similar to light aggregate, which is beneficial for improving the cohesiveness between aggregate and cement, as well as increasing the compactness of hardened cement near the surface of aggregate, and also improving the interface structure of aggregate and cement paste thus, the properties of concrete will be improved. Through adjust the parts, adding admixture and modifying the aggregate with organic compound, the strength, dry-shrinkage, freezing and thawing resistance, and chloride ion penetration resistance of recyclable concrete and mortar will be improved in different extents with WCB as coarse or fine aggregate. With small apparent density than dinas aggregate, and sharing some characters of lightweight aggregate, WCB aggregate were often used to produce wall materials, the influence on physical mechanics, durability and thermal insulation of wall materials were researched with WCB as coarce or fine aggregate partly or totally, or complementary cementitious materials. In order to improve one or several characters mentioned above, the meatures often being taken is to add admixture (like fly ash), lightweight aggregate (like waste polystyrene particles), foamer, activator and so on, in those ways, products meeting the demands of some standard could be produced, the thermal insulation effect of produced lightweight wall materials has yet to be improved due to relevant high thermal conductivity of WCB itself. As silicon-aluminum materials, WCB has the character of pozzolanic activity, there was documents recording masonry cement without clinker produced by WCB in the early 1970s. When WCB was used to produce cement, it mainly serve as raw materials or admixture, and via activated technology or proper proportion of different raw materials, cement meeting a certain demand of strength grade could be produced. Since there are already comprehensive regarding application research of WCB in concrete, mortar, wall materials, road materials as well as recycle cement, an elaborate account will not be given in the text. The applications of WCB in the following aspects are summarized: 1) as supplementary cementitious materials, with particle size less than cement, WCB was used in

cementitious materials directly or after being grinded or alkali activated; 2) Used in environmental materials; 3) Used in GRC materials, decorative materials, as filler in rubber plastic materials, as well as in recyclable ancient architectural brick.

Fig-1 Waste clay bricks

2. WCB used as a additional supplementary cementitious materials

2.1 The influence of WCB on physical mechanics, mechanical property and workability

According to the physicochemical property of cement mortar specimen were researched ,which cement clinker partly replaced by WCB accounting for 0%,5%,10%,15 and 20% respectively of the total mass, as well as mechanical property in 7days, 28days and 90days. The microscopic structure of mortar was examined via SEM, while mineral components with XRD, and particle distribution analyzed with LG., the results show that WCB, an artificial pozzolanic material, could increase the time of grinding and setting of cement. When cement was replaced 10% by WCB, the strength of mortar could be increased. According to the relationship between the mixing amount (0-50%) of WCB powder, which pozzolanic activity index is 107%, and the pozzolanic reaction was researched. The results show that when cement was replaced with 10%,20%,30%,40%,50% by WCB powder respectively, the setting time of the mixing system increased and the compressive strength accelerated more slowly in the early stage, but the strength increased sharply in the later stage. According to microscopic analysis, Ca(OH)2 (CH) and CSH gel of the mixed phase have the same hydration phase with ordinary portland cement at first, but in the later stage of curing, the pozzolanic activity of WCB powder could consume CH and generate CSH, CAH and CASH, which could fill the gel holes, thus , the proportion of gel and gel holes could be increased. The strength change of cement mortar was also researched, while cement was replaced by WCB powder, with the same fineness of cement, in different replacement rate. The results show that when the replacement ratio is 5%-10%, the strength of mortar was higher than that of pure cement mortar. The results also show that WCB can be further activated with hydrated lime added in a certain amount. The application of Ground WCB Powder (GWCBP) in self-compacting concrete was researched, the results show that the strength of self-compacting concrete would be decreased without admixture, but 28d compressive strength could be improved with admixture. When the mixing amount of GWCBP was 62.5%, the strength of concrete could still increase, the reason was that more CSH generated from the pozzolanic reaction between GWCBP and CH could fill in the open pores of cement phase. The influence on the characters of concrete was researched when cement was replaced in different replacement ratio by different finenesses of WCB powder. The results show that the compressive strength of concrete could be reduced to some extent while adding WCB powder, however, if the mix proportion was proper, the 28d compressive strength of concrete with WCB would be more than 50MPa. With the increasing of the curing time, the strength of concrete with 10% or 20% WCB was similar to ordinary one, especially the strength at 90d could reach to 55 MPa, and shrinking value could be reduced obviously. The influence of waste concrete and brick powder from construction waste, with partical size less than 0.16mm, on concrete were researched in comparison. The results show that the strength of cement mortar could not be affected while replacement amount of recycle micro powder was less than 10%, in contrast, the strength could be enhanced. The finer the recycle micro powder was, the higher the compressive strength of cement mortar specimen was. After being activated with alkali activator, WCB could replace 20% cement to produce concrete meeting the demands of workability and mechanical property. It's thought that the activity of WCB powder was stronger than inert quartz powder, but poor than active fly ash, and the activity of mixing waste brick and concrete powder was stronger than that if only one of the two was added one by one. The manipulate of WCB powder, as recycle binding material, on cement standard consistency water(CSCW), setting time and compressive strength of cement was researched. The results show that the CSCW would be increased and setting time be shortened while WCB powder is added. Comprehensively in view of the relationship between the character of cement and the content of WCB powder, when the replacement of WCB powder was 30%, the character of 32.7 pozzolanic portland cement can be met. WCB has the similar characters with pozzolanic material. There were dried out kaolinite and amorphous silica while calcinated to 700. The compressive strength at 28d and 90d, water absorption ratio, surface porosity and capillary suction of cement, with the replacement ratio of 10%, 25% or 40% by sintered clay brick, particle size less than 45μm and specific surface area 0.38m2/g, were researched. The results show that the strength and density of mortar containing WCB could increased, however, the mortar without WCB has good fluidity, and the compressive strength was high and enhanced to 130% in all curing time with 40% WCB compared to the one without WCB. The influence of waste

brick powder combined with flyash and slag powder on fluidity and strength of mortar were researched. The results show that waste brick powder could replace grade II of fly ash as mineral admixture of concret

2.2 The inhibition to alkali-aggregate reaction in cementitious material

The influence on Alkali Aggregate Reaction(AAR) in cementitious material was researched with the replacement ratio 0-30% to cement, and analyzed using SEM. The results show that the expansion caused by AAR could be inhibited, and the more the WCB admixture ratio was, the weaker the expansion was. Cement mortar specimen were produced with 25% of cement replaced by ground WCB with a specific surface area of 372 m2/kg, and then soaked into 80 NaOH solution so as to examine the AAR. The results show that the spreading out of mortar could be declined by WCB. With replacement ratio 15%-25% of cement, the AAR expansion of cement could be effectively controlled. Under the condition of AAR, the loss of flexural strength and elastic modulus could be decreased by WCB, thus the loss brought by AAR of related mechanical character could be declined, since the gel produced by AAR could be decreased for the subsistence of WCB. Cement partly replaced with 45μm WCB, the delaying extent to AAR was researched. The results show that when the replacement ratio is 10% ,25% and 50%, 28d AAR expansion rate would be declined by 31%,67% and 95% respectively. The smaller the particle size was, the more the expansion rate decreased. The gel component produced by AAR could be changed obviously and its viscosity be reduced, so as to reduce the pressure on the surrounding phase.

2.3 The influence on the properties of anti-corrosion, anti-freezing, and Anti-carbonation of cementitious material

Cement mortar specimen were produced with 0%-15% of cement replaced by ground fine WCB, and then soaked in saturated lime solution, 5% sodium sulfate solution and 5% ammonium nitrate respectively, conserved at 20±3°C for 7d ,28d, 90d and 180d, so as the character of anti-corrosion was researched. The results show that the 180d swelling value would be declined while the replacement ratio of WCB powder was 2.5%-10%, and the 180d compressive strength is maximum when the replacement ratio is 10% in the three solutions. The strength of concrete did not decline after freezing and thawing recycle for 300 times, when the cement is replaced between 10-30% by WCB powder with particle size of 0.04-0.3 mm. The anti-penetration of CI- of recycle concrete with 10-20% WCB powder was similar to ordinary concrete, but the penetration of CI-get bigger when WCB powder was 30%. According to the result of replacement ratio of WCB increasing, the CI-penetration ability of mortar declined. The CI- penetration, carbonation depth and sulfate corrosion resistance were researched while the replacement of sintered clay brick to cement were 10%,25% and 40%, and particle size<45μm. The results show that the strength and density of mortar could be increased due to the filling effect on pores by physical and pozzolanic activities, but the sulfate corrosion resistance ability is not as good as mortar without WCB, The CI-impermeability was strong. After curing for 28d, the carbonation resistance changes little, but for 90d and with 10% and 25% of WCB, the carbonation resistance became good.

3. Operation with WCB used in environmental materials as adsorption

With porous honeycomb structure, larger particular surface area, and simply processed into fine particles or powder, WCB has the basis of adsorption material, in recent years, the applicational research of WCB as environmental material are mainly concentrated in the following aspects

3.1 WCB used to treat waste water containing fluorine

WCB powder, with particle size less than 0.3mm, was used to reduce fluorine in surface water as sorbent. The results show that when the feed quantity of WCB was 0.01 g/mL, absorbing for 60 min, and pH=6-8, the removal rate of WCB powder to the fluorine contained in a solution with a concentration of 5mg/L could reach to 56.8%. However, the absorption ability of WCB with particle size 0.5 mm -1mm to fluorine was researched. The results show that the effect of absorption and eliminating fluorine was not quite ideal. for the target of purifying the waste water greatly containing fluorine, the absorption capability of WCB after modified with different methods to fluorine was researched. The results show that WCB modified with AICI3 had stronger ability to eliminate fluorine. At 25,PH=2, and the proportion of sorbent and fluorine at 110:1, the absorption capacity of modified WCB to fluorine was 9.735mg/g.

3.2 WCB used to treated waste water containing ammonia, nitrogen and phosphorus

The exclusion effect of modified WCB on ammonia nitrogen (NH3-N) was researched with WCB supply as substrate in artificial wetland. The results show that being modified with 10% NaCI, the absorption value of modified WCB on NH3-N was 5.05mg/g, at 24, PH=9.5, the proportion of sorbent and NH3-N at 200:1, and the oscillation time for 1h, the elimination ratio of WCB on NH3-N reached to 97.8%, and the absorption pattern of solution complies with isothermal absorption model. The elimination effect of WCB on NH3-N was researched with WCB serving as substrate in artificial wetland. The results show that WCB could effectively remove and remove N and phosphorus stably, and it was not easy to get clogged, but the content of NH3-N and Total Phosphorus (TP) in seepage water were still high, thus it is still unable to serve as replacement technology for the secondary treatment of waste water. As such, in reality, it was advised that WCB should be properly combined with

other substrate material, which has good absorption effect, such as zeolite and steel slag. The absorption ability of WCB, gravel and pebbles as artificial filling, to N and P in artificial wetland was researched in the results show that the absorption per unit mass at 36 on N and P was greater than the one at 24 , but with the temperature going up, the cycle of absorption increment of fillings on NH3-N was WCB gravel ≈pebbles, and the sequence of theoretical saturate absorption of fillings on NH3-N and P was WCB ,gravel, pebbles.

WCB, waste ceramics and mold bricks from construction wastes with the characters of good permeability, large specific surface areas and abundant resources, serving as fillings for artificial wetland system, the operating characters of Medium Scale Plot were researched for the purpose of choosing proper fillings for artificial wetland treatment system. The results show that the reproduction wetland system built by mixed fillings consisting of same volumes of WCB and waste earthenware could effectively eliminate the waste in rivers containing both high and low concentration of organic wastes. Using WCB as filling for artificial wetland, a new type of tide artificial wetland treatment system was developed, using the system to treat the effluent from sewage treatment plant, the removal effect on TP, NH3-N, total nitrogen(TN) and COD were examined. The results show that the inclusion ability of WCB was better, and the absorption and elimination on TP were strengthened. Compared with class A standard of GB18918-2002, the control rates of NH3-N, TN and COD in the effluent were 96.97%,38.68% and 100% When the inlet water temperature was less than 10.5, the TP in outlet water was 0.50-0.88mb/L. When the inlet water temperature was over 10.5, the concentration of TP in outlet water could reach class A standard. Therefore, WCB could be regarded as very suitable for filling for artificial everglade. The more amount of total Ca, water-soluble Ca, Colloidal Te2O3 and Colloidal AI2O3 inside filling, the better the absorption ability to phosphorus. The mass fractions of calcium, iron and aluminum inside the WCB are 42.7 mg/g, 33.9mg/g and 50.4mg/g respectively, the elimination rate to phosphorus was 99%. Aiming at the characteristic of waste water quality in livestock and poultry farms, the phosphorus elimination ability of four fillings including WCB was examined. The results show that the micro structure on the surfaces of WCB and zeolite was in favor of the growth of biomembrane, while the oyster shells and WCB pieces have higher potential to eliminate phosphorus. The absorption of oyster shells on phosphorus was chemical, while that of WCB was both physical and chemical. The absorption behavior of red brick to relatively comply to the Langmuir absorption characteristic, and its absorption volume was 35.54 mg/g. As fillings for multi-level vertical underflow artificial wetlands, red brick, with particle size 0.4cm -2.6cm, not only perform good capability to remove phosphorus (the average removal ratio to TP was 84.8%), but also guarantee that the pH of outlet water meet the discharge demand of. WCB chosen as wetland filling, with the design theory of wetland modularizing, the development of artificial wetland treatment was researched. After the treatment, the waste matter water quality was stable, and meeting the standard of urban afforestation water. Being chosen as fillings in an equal amount, the absorption effect of WCB, gravel and pebble, on phosphorus at 25 were researched, and the influence of different sorts of fillings on the operation of outdoor underflow artificial wetlands were also analyzed. The results show that WCB had the best absorption

ability, during the process of the outside underflow artificial wetland operation, With the extension of hydraulic retention time, the elimination effect of WCB filling to wetland TP was better than combined filling, thus WCB filling could be used for small town underflow artificial wetland systems. As media, hollow brick powder, coarse sand, fly ash, fine coal cinder and activated carbon were mixed in proper proportions to make different filling treatment columns, which were used to treat low concentration domestic sewage water. The results show that fly ash and hollow brick powder combined could effectively removed NH3-N and TP best, and removal rate could reach to 87% and 82% correspondingly.

4 The application of WCB in other fields

4.1 The function of WCB in decorative materials

WCB attached with mortar from masonry-concrete structure (waste brick pieces accounts for 75%, waste mortar accounts for 25%) were washed, dried, cracked and divided. Parts of natural colored sand were replaced by WCB with the particles size of 2.5 mm-0.075mm as filling to create sand wall paint. The test results show: the water resistance and alkali resistance both surpass the standard value greatly, while other factors like temperature resistance and drying time all meet demands. However, since the color is single, the decorative effects were limited

4.2 The function of WCB as fillings in rubber and plastic materials

To reduce construction solid wastes and preserve natural mineral resources, samples of pulverized and sieved waste brick (0.5-12.0μm) were modified by silane coupling and other agents and then employed as the filler in preparing styrene-butadiene rubber (SBR) samples. an additional SBR sample was prepared using light calcium carbonate and the same other filler ingredients. The modified waste brick based SBR samples are equivalent or better than the light calcium carbonate based SBR in terms of important technical performance dimensions and mechanical properties; such results suggest that the waste brick may replace light calcium carbonate as the major filler ingredient in prepare rubber materials.

4.3 The application of WCB to produce ancient architectural bricks

WCB pieces were used to produce prehistoric architectural bricks. It was authorized with rights for utility models in 2016 and put into use in 2017. It's applied to old town

redevelopment in greater noida area in Delhi NCR, and the project of new rural demonstrated building in the Gautam Buddh Nagar District.

5. CONCLUSION

In these days, the recyclable usage of waste clay brick has concerned more and more care, the enlargement of its ways of recyclable usage has laid a solid foundation for improving its function value. But there are also some problems:

(I)The sources of WCB are different, and the components vary greatly, especially the difference of the amount of SiO2 and AI2O3 affects the pozzolanic active.

(II) When serving as environmental absorption material, since the source and the particle status after cracking vary, the absorption effect of WCB will be different. At present, most of the research content are physical absorption of WCB, the relationship between chemical compound and absorption effect is still not commonly seen.

(III) The new application technologies of WCB currently are still not very mature, mostly in the stage of laboratory research without significant industrial application experiments, let alone standardized, industrial production process, which is dissonant with the discharge amount of WCB both currently and in the future.

(IV)The evaluation on economical and environmental benefits of recycle usage of WCB is insufficient.

(V)Since currently the policy concerning classified discharge of construction waste are not strong sufficient,

there is no obvious profit on the expense of recycle, cracking and processing compared to directly using natural sand or other admixture, like fly ash and mineral slag.

But we trust that with great support from governments and unrelieved efforts from scientific and technical worker , those problems will sooner or later be solved.

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