RECYCLING OF MARINE CLAY FOR USEFUL BUILDING PRODUCTS

Y.M. CHENG, S.S. FANG
Department of Civil and Structural Engineering, The Hong Kong Polytechnic University

ABSTRACT: With the rapid economic growth and pressure for redevelopment, the management of marine clay waste is becoming a major problem in Hong Kong. With the upcoming 10 major construction projects in Hong Kong, vast amount of marine clay has to be removed. Direct dumping of marine clay is harmful to the marine ecology while stabilization with cement is expensive and dumping can still generate disturbance to the marine ecology is unavoidable. In the present study, the author has carried out a pilot trial in mixing marine clay with recycled aggregate and sand, and the mix is hydraulically pressed to form building blocks. The experience in the trial and the various practical problems will be discussed.

INTRODUCTION

Type area

Marine clay is one of the predominant geological materials covering seashore along the coastlines of Hong Kong and many other major cities in China, and large quantities of marine mud are excavated at different construction sites each year. Marine clay is well known to have the long term problem of consolidation, and significant settlement after reclamation if there is no treatment to the marine clay. The severe settlement problem at Tseung Kwan O in Hong Kong has created various cracking of minor structures a decade ago. Relevant news and reports on these issues has also aroused the concern of the public. In the Chek Lap Kok airport project in Hong Kong, in order to avoid the settlement problem arising from marine clay, majority of the marine clay is removed by dredging, which actually contribute to the 110 billion dollars construction cost (for the first runway) and the airport is actually the most expensive one in the world.

Marine clay creates various problems to dumping areas which will not be developed for a long time. Some of the sea dumping areas has also been disturbed environmentally. With the recent awareness of environmental protection, various government departments are facing increasing difficulties in finding suitable dumping areas and to comply with the increasingly stringent environmental protection regulations. With the recent plans for the construction of several major construction projects in Hong Kong, the problems caused by marine clay can be further amplified.

For the large scale Hong Kong – Zhuhai – Macao Bridge (HZMB) project, for instance, reclamation of the foreshore and sea-bed will be carried out to form approximately 6 hectares of land at southeast of the Hong Kong International Airport (HKIA) for the proposed carriageways and the road tunnel connecting the proposed Hong Kong Boundary Crossing Facilities (HKBCF) for HZMB with HKIA, together with the ancillary works. The reclamation works (including associated dredging works) are more than 5 hectares in size while the dredging of the marine clay will possibly exceed 500,000m³ in volume.

In view of severe situation mentioned above, the disposal of the marine clay wastes has become a severe environmental problem in the territory. Currently, this natural resource is treated as a waste and is dumped at different dumping area. Legislation in Hong Kong sets aside many restrictions in disposing marine clay as landfills, which has then created an urgent need to exploit them. On the other hand, government sources indicated no sufficient public filling area or landfill space in Hong Kong. Our landfill areas are expected to be full within 10 years' time. The possibility of recycling the marine mud is thus becoming an increasing important issue in Hong Kong. In addition to the environmental benefits in reducing the demand for land to dispose the waste, the recycling of marine clay can also help to conserve natural materials.

In literature, marine clay is usually stabilized with cement and is then used as marine backfill. This "passive" approach will still affect the ecology system at the seabed as well as the marine environment. To achieve an "active" approach in conserving the environment, marine clay deposits is recycled for the production of construction materials in the present proposal. If marine clay deposits can be used as raw materials for making

bricks, concrete filler, concrete aggregates and cement-like materials, the impact to the environment and eco-system will be greatly relieved.

Pilot studies has been conducted by the authors in recycling marine clay between 2006 to 2007, and subsequently a consultancy study in investigating the possibility of large scale recycling of marine clay has been awarded by the Housing Authority for the Kai Tak public housing project. The aims of the present study is to develop a marine clay recycling method which will not generate any gas emission or require artificial heating which is environmentally unfriendly. Furthermore, the method of recycling must be suitable for large scale production with a low production cost and simple production plant, and the method of production cannot be too complicated in operation.

MARINE BLOCK PRODUCTION

For the site formation for Kai Tak Cruise Terminal commissioned by Civil Engineering and Development Department, dredging and disposal of about 1380000 m^3 of marine sediments at designated marine dumping areas has now been processed to allow manoeuvring and berthing of mega cruise vessels with deep drafts. For the foundation works associated with the development of public housing at the Kai Tak Development Sites by Housing Authority, about 10000 m^3 of clay (private development is not included) will be removed from the sites during the construction. The marine mud was delivered to paving block manufacturing plant for the production of eco-paving blocks. The wet marine mud as shown in Figure 1 is sticky and difficult to be broken down into smaller pieces. Since the wet marine mud was too sticky for mixing, some marine mud was dried under sunlight for subsequent trial mixes as shown in Fig.2, with a view to improving the mixing of the marine mud with the aggregates.

The marine mud was weighed, and then fed into the bucket at the bottom of the production line. The bucket was carried by a conveyor to the top of the production plant. The marine mud, cement and the recycled aggregates were mixed in the mixer at the top of the production unit with a final, manual adjustment of water to be added as illustrated in Figure 1.

Since the marine mud was naturally in a plastic state and sticky, even the marine mud had been cut into pieces before mixing. Difficulties in mixing were still found in mixing the marine mud with the other ingredients evenly and thoroughly. The marine mud which had been dried before mixing still faced the difficulty of mixing, as the outside of the marine clay was dry while the inside of the marine clay was still wet and sticky. Several mixing and

Figure 1 Wet marine mud and mixing
(lumps of marine clay are seen, poor mixing)

preparation methods had been tried in this study, and finally it is found that the marine clay must be cut to a lump size of less than 100mm before a good mixing can be achieved, and a longer mixing time is required before all the ingredients can mixed well.

After mixing thoroughly, the mixed materials were fed to a hopper which was then delivered to the hydraulic press to form the eco-paving blocks in the mould. The quality of blocks produced also varied with different trial mixes.

Figure 2 Marine mud dried under sunlight

Figure 3 Production of satisfactory eco-paving blocks

Final criterion to evaluate the product comprises the mixing effect, the yield rate of block production, the quality of blocks, difficulties during mixing etc. It was actually not easy to produce a uniform mixture for either relatively dry or wet marine mud if a large piece of

Figure 4 Production of eco-paving blocks of poor yield rate and quality

marine mud was used, in that the aggregates could not be pressed into the marine mud and broke the marine mud into smaller pieces. The lumps of marine mud present in the blocks were due to the difficulty in mixing evenly and thoroughly. The percentage yields of the first 5 trial mixes were as low as from 50% to 70%.

It was observed that the well mixing of the ingredients with the marine mud in plastic state is one of the key issues which affect the quality, consistency and yield rate

(a) Very poor mixing within whole matrix

(b) Non-uniform mixing with poor edge

Figure 5 Close-up views of poor eco-paving blocks

of blocks produced. The additional pre-mixing process adopted in the last trial mix seemed to be able to improve overall mixing process and hence the quality and yield rate of blocks in certain extent. For the last mix, the relatively wet marine mud was cut into small pieces (<50mm) and mixed with recycled aggregates in a smaller pre-mixer first, in which the aggregates were pressed into the marine mud, and could mix wet marine mud and aggregates quite well. The yield rate of this mix was also high (above 90%). From visual observation, the quality of paving blocks appeared to be quite uniform and good. The compressive strength were further proved to be comparatively higher and consistent though they still could not reach the required strength of 30MPa in the HA Specification.

BASIC PHYSICAL TESTS

The basic properties of the marine clay were determined as: liquid limit 48% (range from 42 to 50%), Plasticity index 24% (range from 23 to 25%). Once the fabrication was completed, the 7 and 14 days compressive strengths were measured for monitoring purpose in the laboratory. Besides the compressive strength tests, water absorption tests had also been carried out in accordance with AS/NZ 4456.14 1997 and 2003 which required the water absorption to be less than 6.0%. Based on a series of tests on the samples, the water absorption was found to be 8% in average which exceeded the limit as specified in the standard. For the skid resistance, the test results passed the standard BS6717, 2001.

It should be noted that some fluctuating results occurred in the compressive strength of the samples, which was a clear indication that the consistency of the mix was not satisfactory due to the presence of lumps of marine mud. These lumps formed weak points in the blocks.

ENVIRONMENTAL TESTS AND DISCUSSIONS

Since the use of marine mud to form paving blocks has never been tried before, environmental tests are carried out to assess the acceptability of the blocks from an environmental point of view. Six Eco-paving blocks and the two normal blocks in total supplied by the Housing Authority were tested. Basically a comparison approach was applied to evaluate the Eco-paving block product for its environmental concerns. Four groups of tests relevant to (a) toxicity, (b) potential water pollution, (c) biomass emission and (d) potential odor problem were conducted for the Eco-paving block samples and normal block samples with the same experimental procedures.

Test results in terms of toxicity, water pollution, biomass emission and odor problems had been carried out. It was found that there was no significant difference of toxicity release between the normal block and Eco-paving block samples. Also no obvious difference could be obtained on organic factors between the normal paving blocks and the marine clay paving blocks. Further results regarding the heavy metal pollution indicated no major difference of heavy metal release between the normal block and the Eco-paving block samples. However in term of the biomass emission, the marine clay paving block demonstrated a significantly higher release of volatile organics than the normal block. Similar situation also happened for the odor emission test results. From these results, it was recommended that a profile of the TVOC emission vs. time should be conducted to determine a half-life time.

CONCLUSIONS AND RECOMMENDATIONS

In this study, the innovative Eco-paving block made from marine clay is introduced and assessed in terms of production, physical behaviors and environmental impacts. Relevant results are discussed and compared with ones from ordinary blocks. Conclusions could be drawn as follows:

a. The last trial mix for which the marine clay was broken to lump size less than 100mm had demonstrated the viability of production of eco-paving blocks with marine mud (yield rate above 90%)

b. There was great variation and inconsistency in the compressive strength of the eco-paving blocks produced. This was a strong indication of uneven mixing resulted in significant variation in the quality of the paving block with marine mud.

c. Since satisfactory mixing process was crucial to the production of good quality paving blocks, it was suggested that mechanical cutter should be used to cut the marine mud, in natural plastic state, to a size not greater than a fist for each piece. The marine mud should then be mixed with the 10mm recycled aggregates in a pre-mixer with press, roll and blend operation until a relatively uniform mix has been produced before delivery to the main mixer for finally mixing with cement and water.

d. All six trial mixes produced in this study could not achieve the required compressive strength of 30MPa. Yet, with the improved mixing process as mentioned above and further refinements in the mix proportions, production of satisfactory eco-paving blocks with marine mud should be achievable.

e. Due to the nature of marine mud, the blocks could not pass testing requirements of water absorption. The actual water absorption is slightly higher than that as specified in AS/NZ 4456.14 1997 and 2003. This could affect the performance of the eco-paving block with marine mud when the paving blocks were subjected to cyclic wetting and drying. It is possible that the blocks may deteriorate with time subjected to cyclic swelling and shrinkage of the blocks. It is suggested that long term durability test should be carried to assess the durability of the eco-paving blocks.

f. With reference to the environmental test, it is noticed that the marine clay from Kai Tak does not contain much contamination. The amounts of toxic and organic materials are low, and the results of these two tests for the eco-paving blocks are comparable to the normal paving blocks.

g. For the biomass and odor emissions, if the blocks are used about 4 months after casting, the levels of the emissions are comparable to the normal paving blocks. In this respect, there should be a control about the time before the eco-paving blocks can be used for actual construction.

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