Feasibility of Using Dredged Mud for Prepared the Permeable Brick

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Abstract. Through experimental analysis found that the chemical composition of the dredged mud is similar to clay and the dredged mud does not leach heavy metals. Using the dredged mud in the preparation of permeable bricks reduced the quantity of incineration dredged mud buried in landfills, and the exploitation and consumption of natural sandstone. The dredged mud needs to be checked by the validation criteria when the second use, so we used the TCLP test to identify hazardous materials. Its leaching of heavy metals was in line with industry standard. And the basic formula of permeable brick were prepared, its performance was in line with national standards. The use of dredged mud preparing eco-friendly permeable bricks, not only solves the problem of environmental pollution, but also gets some economic and social profit.

1. Introduction

In recent years, the harbor waterway expansion and the coastal dredging engineering maintenance result in dredged mud increased gradually. Proper handling of dredged mud has become a top priority. At present, the treatment of dredged mud is mainly in landfill, marine dumping, filling and so on.

Over the past decades, extensive studies dealing with characterization and stabilization of dredged marine soils have been reported, and dredged material has been recognized as a promising marine resource for the back-fills used for land reclamation [1]. In China, dredged materials have always been treated as geo-waste and directly dumped into the ocean, resulting in unforeseen large volume of dredged materials accumulated in the ocean[2]. It is statistically reported that the annual production of dredged materials in Shanghai region alone exceeds 70 million m³, and so far more than 2.5 billion m³ of dredged materials had been already dumped into the surrounding ocean [3, 4]; In South Korea, about 729 million cubic meters of coastal dredging has occurred between 2001 and 2008 with some 31 million cubic meters of dredged sediment dumped in the open sea [5]; Annually, 5.9 million cubic meters of dredged sediments is excavated and placed in several disposal areas in Jasper County, South Carolina [6]. In addition to marine landfill, the dredged mud also can use in the other way. Over the past decade, most people are vigorously promoting green and environmentally friendly energy materials. The dredged mud has a huge output annually, and the second use of materials bear the brunt of a large number of researchers attracted attention. For distance, the preparation of lightweight aggregates used the dredged mud as aggregates [7]; the preparation of fired brick sediment used the harbor river as the primary raw material [8]. In China, many cities are calling the concept of sponge city, permeable brick meets this concept. For ordinary bricks, it has good strength, but poor water permeability leads to a series of problems, such as urban waterlogging, heat island effect, ground subsidence and etc. The permeable brick with light and porous features is different from other ordinary brick. The porosity of permeable brick is between 10% and 20%, so that the permeable brick have good water permeability. The permeable brick has many advantages: alleviate the city waterlogging and heat island effect, replenishment of groundwater timely and absorb the noise. Based on the rough
surface, it can increase the wear resistance to increase the safety of the road. In recent years, many researchers used various materials to prepare permeable bricks and achieved good results. Such as: preparation of water permeable brick using fly ash as main raw material. The compressive strength and coefficient of water permeability of the fly ash water permeable brick was 30.6 MPa and $1.08 \times 10^{-2} \text{ cms}^{-1}$ [9]. The prepared water permeable brick by discarded ceramics has a compression strength of 48.9 MPa, a bending strength of 7.8 MPa and a permeation coefficient of 0.0312 cm$^{-1}$ [10]. And the water permeable brick from red mud has the compressive strength of 35.32 MPa with permeability coefficient of 0.028 cm$^{-1}$ and wear length of 27.35 mm [11].

2. The Characteristics of Dredged Mud

The dredged mud was obtained from the river near Cencun, Guangzhou. And the dredged mud was sampled in three different places, to avoid the difference of the dredged mud composition in the same river. The dredged mud was pretreated firstly. The dredged mud was placed on the tray, then was oven-dried at 105°C for 2 hours. Then the dry dredged mud was grinded for 2h in the ball mill machine, the obtained powder sieved to a granular size $<0.546$ mm to removed other impurities.

2.1 XRD and XRF Analysis of Dredged Mud Composition

Table 1 shows the X-ray fluorescence (XRF) analysis of the dredged mud. The main ingredients of the dredged mud are SiO$_2$, Al$_2$O$_3$, and Fe$_2$O$_3$ similar to natural clay. All materials present a significant loss of ignition which is likely associated to carbonate and sulphate decomposition and also to burn-off of organic matter that is usually adsorbed in three kinds of materials [12]. Therefore, dredged mud was used instead of natural clay as a low temperature binder to prepare the permeable brick. Figure 1 shows the X-ray diffraction (XRD) patterns of the dredged mud, it demonstrated that the dredged mud mainly contains quartz, kaolin and silica phase.

| Sample | SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | K$_2$O | TiO$_2$ | CaO | P$_2$O$_5$ | Na$_2$O | Total | LOI |
|--------|--------|-------------|-------------|------|--------|-----|---------|-------|-------|-----|
| P1     | 61.12  | 21.19       | 4.76        | 2.63 | 0.84   | 0.58| 0.27    | 0.24  | 99.72 | 8.09 |
| P2     | 54.54  | 20.34       | 5.58        | 3.01 | 1.07   | 1.05| 0.21    | 0.22  | 99.75 | 13.73|
| P3     | 59.34  | 22.02       | 4.34        | 2.52 | 1.02   | 0.87| 0.19    | 0.27  | 99.6  | 9.03 |

2.2. The Analysis of the Ash of Dredged Mud

The ash of dredged mud refers to the percentage of inorganic solid oxide in the dredged mud. The organic matter residue completely was burned, and water was completely discharged (including structured water).

A certain amount of dry dredged mud ($D_1$ = the weight of dry dredged mud and the crucible) was weighed into the crucible, then put into the muffle furnace for 30 min from room temperature slowly heated to 500 °C, and then 30 min to 815 °C and 815 °C for 1 h. Then the crucible removed to the asbestos plate and cooled to room temperature. And the above procedure was repeated until the difference in mass between the two measurements was less than 0.002 g, meanwhile the mass ($D_3$) was
recorded. $D_2$ is the weight of the crucible. The content of ash in the dredged mud was calculated according to equation (1).

$$A_{ash} = \frac{D_3 - D_2}{D_1 - D_2} \times 100\%$$  \hspace{1cm} (1)

Where $A_{ash}$ is the content of ash in the dredged mud ($\%$), $D_3$ is the weight of ash and crucible (g), $D_2$ is the weight of crucible (g), $D_1$ is the weight of dry dredged mud and crucible (g).

The test results are shown in Table 2. It can be seen from the Table 2 that dredged mud was mainly ash. Three points of dredged mud’s $A_{ash}$ were more than 94%. The dredged mud has high content of organic matter.

| Sample | $D_1$(g) | $D_2$(g) | $D_3$(g) | $A_{ash}$(%) |
|--------|---------|---------|---------|-------------|
| N1     | 135.19  | 84.77   | 132.72  | 95.10       |
| N2     | 141.43  | 88.15   | 138.55  | 94.59       |
| N3     | 163.30  | 109.28  | 160.63  | 95.06       |

2.3. TCLP Leaching

Many countries use TCLP leaching test to identify hazardous materials. If the concentration of leached heavy metals exceeds the regulatory standard, the dredged mud is considered hazardous waste, and must be further treated to reduce the risk of leaching of heavy metals into the environment. The dredged mud leaching test was carried out according to the Taiwan EPA standard testing method for solid waste. The dredged mud and a leaching solution (CH₃COOH) at a weight/volume ratio of 1/20 were mixed and agitated at 30rpm for 18h. The leachate was then filtered. The heavy metal concentration was analyzed by atomic absorption [13, 14]. The experiment of this study was conducted dredged mud whose heavy metal dissolution met the regulatory standard.

| Sample | $P_1$ | $P_2$ | $P_3$ | Taiwan limits |
|--------|-------|-------|-------|---------------|
| Cu     | 0.031~7.86 | 0.012~0.21 | 0.017~3.9 | 15            |
| Cr     | 0.8~1.83  | 0.19~0.24 | 0.18~1.03 | 5             |
| Pb     | 0.01~0.047 | 0.005~0.05 | 0.032~0.14 | 5             |
| Cd     | 0.0005~0.0023 | <0.0005 | <0.0005 | 1             |

Table 3 lists the result of TCLP analysis for the dredged mud from three sampling points and all samples met the QA/QC requirements that generated the data ranges. So the dredged mud in place of clay to prepare the permeable brick met the required regulations and standards, and it can not to leave a negative heritage to future generations [15].

2.4 Preparation of Permeable Bricks with Dredged Mud

The dredged mud powder sieved to a granular size <0.546 mm, the particle size of glass powder was 0.154 ~ 0.197 mm, and the particle size of waste porcelain was 2.675 ~ 3.53 mm. The permeable brick was prepared according to the proportions of the samples in Table 4. In the laboratory, the permeable brick was prepared according the flowed chart (figure 2.a) and the samples were fired according the firing systems (figure 2.b).
Figure 2.a The preparation of process flow chart. 2.b The firing systems.

Table 4 The composition of the permeable brick

| Sample | MG(mud to glass) | Waste ceramics (%) | Density (g/cm^3) | Porosity (%) | Strength (MPa) | Permeability (cm/s) |
|--------|------------------|--------------------|------------------|--------------|---------------|---------------------|
| 1#     | 1:3              |                    | 1.866            | 5.92         | 159.37        | 0.00205             |
| 2#     | 2:2              | 60                 | 1.885            | 7.25         | 94.46         | 0.0294              |
| 3#     | 3:1              |                    | 1.859            | 23.48        | 75.84         | 0.0405              |
| 4#     | 4:0              |                    | 1.857            | 24.41        | 64.44         | 0.0532              |

Figure 3. The permeable bricks under different MG ratios.

As can be seen from figure 3, the surface color of the permeable bricks is very different. With the content of the dredged mud increases, the sample gradually deepened the color. Because the dredged mud contains Fe₂O₃, the sample's color is brighter with the increasing of the dredged mud. In life, the color of the permeable bricks can be changed by controlling the content of dredged mud. The four samples of the body density and porosity can be seen from the Table 4. Increasing the content of the dredged mud causes increases in the porosity, due to the combustion of organic matter in the dredged mud. And the density of the permeable brick is greater than 1.8 ~ 1.9 g/cm³. The water permeability of re-prepared permeable brick are greater than the national standard 1×10⁻² cm/s.

3. Conclusion
The possibility of using dredged mud as the primary material making permeable bricks was
investigated in this study. Through the composition analysis, the ash analysis and heavy metal
dissolution analysis of dredged mud, it determined that the dredged mud could to prepare the
permeable brick and the performance of the permeable bricks was better. The TCLP testing shown that
the heavy metal concentration of the dredged mud were fully in line with industry standards. Based on
these preliminary analyses, it can be concluded that studied the dredged mud can be used as secondary
raw materials for the production of permeable bricks. In the preparation of permeable bricks, the
content of heavy metal is in line with industry standards and can also contribute to the construction of
sponge city. The experiment using the dredged mud to prepare permeable bricks will be carried out in the
follow-up study.

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5. References
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