A Review on Characterization of Sediments for Green Bricks Production

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Abstract

Accumulation of dredged sediment has raised environmental concern in various countries. Recycling of sediment into bricks is a viable solution to the environmental pollution. Concerning to the utilization of sediment in bricks, this study reviews the needs of characterization on sediment and methods of producing sediment bricks. Particle size distribution was found to be the key criteria for characterization of sediment. Sizes of particles determined the function of the sediments in the bricks. In spite of that, leachability of heavy metals is another important aspect for contaminated sediment. Cementing bricks used cementing materials as the stabilization agent to the heavy metals. It is necessary to conduct leaching test for the end-product of the sediment to ensure the heavy metals leached are within the regulatory limits. In conclusion, method of producing sediment bricks may vary due to the various characteristics of sediment for a promising environmental friendly production.

Keywords: sediment; characterization; environmental; brick.

1. Introduction

Reservoir sediment poses an environmental concern for all reservoirs worldwide. Accumulation of sediment in the reservoirs leads to reduction in its capacity. Mitigation measures such as dredging and erosion controls have been a common practice. Some regards dredging as a priority within the environmental recovery. However, dredged sediment can also become secondary pollution when it accumulated in landfill area. Researchers have taken several approaches in dealing with dredged sediment problems to reduce pollution. Dredged sediment has different properties depending on the source. Sediments from seaports contain majority of sandy particles [1]; dam sediment contains greater amount of silty particles [2]; harbour sediment contains more of clayey particles [3]; lagoon sediment contains predominance of clayey particles [4] and others. Properties of sediment may vary across the locations. Unlike silty sediment from Bakhada dam in western Algeria [2], Shihmen dam in Taiwan has predominantly clayey particles [5]. Differences in the physical and chemical properties of sediment and some that were contaminated with heavy metals emerged to the needs of adding other waste or raw materials such as gypsum [6], steel-manufacturing slag [7], clay [8] and others [9,10] in order to produce safe construction materials such as bricks [11].

2. Review of Research

2.1. The Importance of Characterization of Sediment

Characterization of sediment is important in order to compare its properties to the natural clay and sand as replacement of primary material in brick production. The characterizations mainly focus on physical properties, mineralogical composition and elemental analysis.

Sediments obtained from rivers are normally characterized and compared to natural sand in terms of particle size distribution and specific gravity. In addition, plasticity is tested for sediment to replace natural clay. River sediments are normally coarser as compared to lagoon and lake sediments, dominated by sand size fraction that is angular and light in colour [12]. Dredged river sediments are predominantly sand because of its greater flow velocity while dredged lagoon and reservoir sediments are sludgy and contained high percentage of fines [5]. Mezencevova et. al. [3] reported that dredged sediments extracted from lower and upper reaches of harbour are predominately by sandy particles while clay and silt particles are extracted from middle harbour and sediment basin. For sediments extracted from middle harbour, 38% of weight are found to be of silt, that is slightly higher than silt content in natural clay (34%); clay particles is 47%, which is higher than natural clay soil (40%); sand particles is 15%, which is lower than sand content in natural clay (26%). Silt exhibited non-plastic or slightly plastic behaviour that leads to lesser or no strength
when subjected to air dried, while high fraction of clay demonstrated higher surface area that requires higher amount of water to achieve the plastic state. In fact, higher ratio of silt to clay fraction in material resulted to weak and porous brick. On the other hand, insufficient sand content in the dredged sediment as compared to natural clay (26%) can be revamped by adding natural sand to the mix. This is important as the coarse fraction is significant in brick production to reduce shrinkage in firing. Moreover, sand is generally stronger than clay, that prompted to increase the compressive strength of the product [14]. Higher clay particles have indeed increased the plasticity behaviour and vice versa. For instance, sediment that has lower plasticity index such as that obtained from Dampremy-Charleroi (Belgium) lowers the plasticity nature of the mixture and decrease the bonding ability [15].

Mineralogical analysis conducted using X-ray diffraction (XRD) is important for the sediment to achieve the similar role as natural sand and clay. Sediments of Dampremy-Charleroi region (Belgium) deposited from several industrial activities areas such as coal mining, steel industry, glassworks, chemicals and electrical engineering composed mainly of quartz and marked the presence of iron oxide, calcite,feldspar, mica and sulphates. This indicated a possibility of replacing natural sand in brick production [15]. Similar to river sediment from Qinhuai River in Nanjing, China [16] and main rivers near Jacarepagua lagoon, Brazil [4] has quartz as its main mineral with lower contents of other minerals such as kaolinite. Iron and feldspars act as fluxes that promote the fusion of the particles at lower temperature and possess good fluxing properties. In addition, Quartz and kaolin group (such as kaolinite, dickite, and nacrite) maintain the shape of the product during the firing process of bricks [3].

Mezencevova et al. [5] mentioned that the presence of water soluble salts are related to the formation of whitish scum or efflorescence during the drying of bricks. The soluble salts such as sulfates of magnesium, sodium and potassium reacted with silicates during firing except for calcium sulfate (CaSO₄) that persisted through the firing process. Subsequently, sulfuric acid formed when SO₂ gaseous adsorbed at internal silicate surfaces tend to dissolve magnesium, sodium and potassium from crystalline phases. Salt deposition occurred when these solutions migrated to the brick surface. Furthermore, chlorides and sulphates that are present in the sediments such as SO₄, SO₃ and HCl can cause gaseous pollution during firing process.

Loss of ignition (LOI) is associated to the dehydroxylation of clay minerals, oxidation of the organic matter, decomposition of carbonates, sulphides, hydroxide and etc. [3]. Appropriate amount of organic matter contributed to the plasticity and act as pore during firing process. Nevertheless excessive amount of it will cause uneven surface texture of bricks and attraction of pollutants [15,17].

2.1.2 Heavy Metals in Sediment

Heavy metals pollution is another concern in sediments. The problematic cationic metals (positively charged cations in soil) include mercury, cadmium, lead, nickel, copper, zinc, chromium, and manganese. In addition, anionic metals (negatively charged anion in soil that combined with oxygen, e.g: MoO₄²⁻) include arsenic, molybdenum, selenium, and boron [3]. It is essential to investigate the characterization and contamination assessment of sediments in order to maximize the use of sediments as primary materials in bricks production [18–20].

Geotechnical properties and metals concentrations are mostly correlated to the distinct particle size distribution of the sediments. In finer sediments, metal concentrations are higher and plately clay materials are present in particles fraction at less than 75 μm [4,13]. Usually, coarser sediments are deposited at the rivers banks while fine sediments are transported to the reservoirs or lagoons and suspended in the water causing siltation. [3]. For these reasons, heavy metals pollution in reservoirs or lagoon sediments is found to be higher than river sediments.

Locally, Khairiah et. al. [21] have studied several soil samples at Cameron Highlands in the state of Pahang and found that the soil samples are contaminated with heavy metals such as Iron (Fe), Zinc (Zn), Cadmium (Cd), Manganese (Mn), Copper (Cu) and chromium (Cr) as a result of active agricultural activities. It was also found that there are lower organic content because of the long term farming activities and use of fertilizers and farmyard manure. Organic materials formed complexes with the metals in the soil. Hence, the lower the organic matters in the soil, the higher the rate of leachable metals. Abdullah et. al. [22] found that phosphate level at Ringlet river is eight (8) times higher than the allowable standard, while nitrate is six (6) times higher due to the heavy usage of fertilizers. Besides that, soils in Brinchang and Tanah Rata, Cameron Highlands contained Cu and Cd at above level of background values [23]. Chemical control is the main approach for crops pest and diseases control in Cameron Highlands. Use of fertilizers such as phosphate fertilizers contributed to Cd content in the soils while pesticides such as fungicidal sprays contained copper sulphate and copper oxychloride contributed to Arsenic (As), Copper (Cu), and Plumbum (Pb) in the soils [21,23]. High concentration of heavy metals in the soil of Cameron Highlands has contributed to heavy metals concentration in the rivers and reservoirs sediments. Huge sizes of open farming in the areas have accelerated soil erosion due to rain splashing practises. Higher concentration of metals in the reservoir sediments was attributed by finer grain particles with higher surface area to particles size ratio [21].

Characterization on granulometry, mineralogy, and concentration of heavy metals are always the priority while contamination indexes are being used to evaluate the anthropogenic contamination of the sediment. Several metal pollution assessment tools were used to evaluate the sediment’s contamination status. Geoaccumulation (Igeo), contamination factor (CF) and degree of contamination (DC) are frequently used indexes that compare the total concentration of metals with background concentrations. Geoaccumulation (Igeo) and contamination factor (CF) are using single metal approach. Degree of contamination (DC) considers the sum of all contamination factors (CF) [18,19,24]. The contamination indexes are commonly used for classification of heavy metals pollution but they do not have the exact adverse effects on the contaminated sediments. Indeed, contamination indexes were not design for that purpose. The biological effects are usually estimated using the sediment quality guidelines (SQGs) [18]. Total concentration of heavy metals in the contamination indexes calculation can be determined by various procedures. Pena-Icart et. al. [18] calculated Igeo for the sediment using total concentration of metals from digestion method by HNO₃, HF and HCl solutions, while Ruiz et. al. [25] and El-Sayed et. at. [19] used concentration of metals from X-Ray Fluorescence. The contamination levels are determined by referring to the natural background values in earth’s crust sedimentary rocks (regional of local) or the pre-industrial background values. The common regional background metal values in average shale by Turekian and Wedepohl [26] have been adopted for regions with no established local background metal values. These values have been adopted in various sediment contamination investigations [19,27,28].

Management of dredged sediment disposal has become an environmental and financial issue [29]. The dredged sediment may be polluted when it is associated with toxic industrial areas. It cannot be used as a direct geo-material in the construction and building sectors [10,16]. Contaminated sediments were treated before used, such as utilizing method of Novosol® process that stabilizes the heavy metals in solid matrix through phosphatation and destruction of organic matters by calcination [30]. The available fractions from anthropic sources are leached easily upon disposal where it is usually lower than the total concentration. This is due to the fraction of metals originated from rock producing sediments that are not easily leached with weak acids [4]. In addition, various treat-
ment methods have been used on contaminated soils, such as re-
moval technique and immobilization technique. Removal tech-
nique removed metals from the soils by separation of contami-
nated particulates in hydrocyclones, phytoextraction or leaching
methods, while immobilization technique changed the metals fra-
tication in the soils thus minimize its mobility. Immobilization
 technique includes increase of soil PH by soil liming, introducing
absorbents such as clays or organoclays, addition of phosphates
that formed insoluble salts with metals and soil solidification by
using various hydraulic binders to stabilize metals within the soils
[31].

2.2. Pozzolonic Materials in Bricks

Pozzolanic materials served as source of alumina and silica in
addition to cement or lime hydration in reactions to strength de-
velopment. 16-20% of calcium hydroxide (CaOH) or sometimes
called portlandite is produced from Ordinary Portland Cement
(OPC) during hydration process. Addition of pozzolanic materials
to the mixture produced additional cementitious gels when reacted
with CaOH [32]. Used of pozzolanic materials from waste is one
of the alternatives in reducing usage of cement for sustainable
and green manufacturing.

Alternative materials to replace cement must contain siliceous and
aluminous materials. Clays are commonly used as pozzolanic
materials to substitute cement in the construction materials [33].
Nurchasah [34] has substituted cement by 10%-20% of Tulakan
soil and found that it increased the concrete compressive strength
at about 3%. In addition, thermally activated kaolinitic clay is
found to be optimized to 30% of the blended cement [35].

In spite of evaluating alternative materials for its pozzolanic char-
teristics, performance of construction materials such as mortar,
concrete or bricks have been tested. Some researchers showed
contradictions between performance of the pozzolan in products
with the specifications of the standards in order to evaluate the
natural pozzolans (ASTM C618) [36]. Therefore, performances of
natural pozzolans have to be tested in construction materials in
addition to characterization as in accordance to the standards.

2.3. Method of Producing Brick

Development of bricks started with moulded adobe in Mesopot-
mia since 5000 BCE and later with fired bricks at around 3500
BCE. The use of bricks spread to Greeks, Rome, across northern
Africa and later to Europe by the early thirteenth century. It be-
came relatively inexpensive and was used by all levels of societies
in the seventeenth century. Later, it was produced in large scale,
shipped across long distances and was widely used as building
material since the nineteenth century [37].

Firing method has been used as the traditional way for making
bricks. Clays are mainly used in conjunction with Kiln firing of
temperature of more than 1000°C. Before the firing process, ho-
ogeneous clays were mixed with 14%-20% of water and were
then shaped by either pressing, extrusion or moulding. Later, dry-
ing of the shaped bricks was conducted progressively to remove
moisture from the clay matrix until constant weight is achieved.

The drying process could be air, oven or tunnel dried. The final
stage is the firing and cooling process. In firing process, manufac-
turer used either tunnel kiln or combustion chamber. The firing
and cooling were conducted progressively. Firing temperature
were found to produce huge impacts to brick’s properties [9,38].
Commonly, the brick manufacturers used traditional big ovens or
chambers that are not able to control air distribution and fire con-
ditions [39]. Researchers have conducted tests on firing tempera-
ture of up to 1200°C despite of the energy consumption. It was
found that kaolinites and ilite or montmorillonite formed mullite at
temperature 950°C and 1050°C respectively. This has increased
the mechanical resistance of the bricks. However, mullite dis-
olved after 1200°C thus decreases the mechanical resistance of
the bricks. On the other hand, the bricks showed high density upon
melting of the mullite, hence at low porosity. In fact, many re-
searchers have conducted tests on the potential use of waste ma-
terials in fired clay bricks. The temperature gradient of the firing
has highly effected the brick porosity since various minerals in the
waste materials and clays dissolved at different temperatures [39–
41]. Subsequently, firing temperature of higher than 850 degree
cause speedy and irreversible decay of the clay bricks [37].

An alternative to fired brick is by using pressurized vessel and
elevated curing temperature at less than 100°C for alkalai activated
aluminosilicate brick [42-44]. This method does not produce pol-
lution like firing method. Villagers in Senegal, Africa used sea-
water instead of commercially produced silicates. Curing of bricks
is conducted under a heavy tarp in the sun. Optimum molarity of
8M Sodium Hydroxide (NaOH) produced durable bricks that
compromised between strength and cost [45]. Nevertheless,
this method is limited to raw materials or wastes containing alumi-
nosilicate materials such as red mud, coal ashes, metal processing
slag and others. On the contrary, fuel wastes such as biomass,
petroleum residues, paper mill sludge and others are not suitable
for geopolymer bricks [46].

Carbon dioxide emissions from firing processes of natural gas
combustion released 248-271 kg CO2/ t of fired products. It is one
of the main energy consumptions [9,47]. For geopolymers bricks,
heating chambers or electric ovens that consumed energy are re-
quired when space for curing under hot sun is not available. Hence,
compressed earth brick technology is another alternative to clay
fired bricks or geopolymer bricks that has the advantage of not
requiring high temperature curing and compaction that can be
achieved by using hydraulic rams or levers [14]. In the com-
pressed brick technology, cement is normally used as the binder
and water is added for cement hydration. It is also frequently used
as plasticizer to aid the particle flow, rearrangement and defor-
mation. Compaction is essential to enhance cement stabilization
and improves the strength development at minimum cement con-
tent. Study has found that 3 to 7 MPa pressure is sufficient to pro-
duce cemented soil blocks [48]. However, increasing pressure
upon compaction of soil blocks leads to increase of soil density,
decrease of void ratio, reduce of soil porosity and water permea-
bility, increase of water resistance and thus enhance its durability
[49]. Watanaasriwech et. al [48] used pressure of up to 75 MPa
and it was found that by increasing the degree of compaction, the
bricks met the required compressive strength within 14 days in
stead of 28 days for bricks that were compressed by 25 MPa pres-
sure.

In short, the aforementioned methods have its drawbacks regard-
less of pollution caused by the firing, large carbon footprint associ-
ated to the usage of cement and restriction of raw materials con-
taining solid aluminosilicate for geopolymerization. As far as the
energy consumption is concerned, many studies have been con-
ducted to reduce the energy consumption [46]. For example,
Saikia et. al. [50] found that the use of dried sludge with calcifi-
cation of 18,213 kJ/kg could reduce energy consumption for fired
ceramic. Therefore, it can be concluded that there is no best met-
hood of producing bricks but rather subjected to the availability of
raw materials and facilities in the area.

2.4. Sediment in Bricks

Many studies were conducted on contaminated sediments that are
mixed with clay to form bricks by firing or pressing method
[6,8,10,16,30,40,46,51]. The following sub-sections described the
use of sediment in bricks using both manufacturing methods.

2.4.1. Sediments in Fired Bricks

Fired bricks are commonly used as building materials for decades.
Many researchers have been working on utilization of waste ma-
terials in fired bricks. Reviews of studies on this subject matter have
been conducted by several researchers such as Ruat et. al [52],
Zhang [40] and Monteiro and Vieira [46]. However, limited stud-
ies were found on utilizing sediment in fired bricks [3,5–8,15,16,53]. Relatively high chloride content in the sediment such as harbor sediment poses concern to the environment where it causes dioxi


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Sediments that comprised of fine sands and silty clay were utilized at 50-80% of amount in fired clay bricks [8,54] where some are mixture of gypsum instead of clay [6]. The bricks were mostly heated at temperature 105°C to evaporate the moisture, then sintered at 1000°C [3,15], 1100°C [6,7,53,54] or up to 1150°C [8]. Wei et. al. [53] found that the new crystalline phase formed at the sintering temperature of 1050°C. High temperature leads to loss in crystalline composition, at the same time it also formed a new phase of crystalline composition. These newly formed glassy phases could provide envelope capturing the blowing gases that leads to formation of pores in the specimens’ core regions. Thus, lighter specimens were formed. The formation of glassy phases then covered the surface pores and connects the surface pores with the inner pores, thus impeded the water absorption [7,53].

In addition, densification is found to occur at the temperature range of 1000-1050°C, thus this increased the compressive strength, bulk density and thermal conductivity. Moreover, sediment melts at high temperature and has considerable viscosity properties (thermoplastic glass-phase) [6]. Although Xu. et. al. [54] reported that thermal conductivity of the brick decreased by 40% with addition of river sediment, but the total porosity of the brick has increased. Macro pores are formed during the combustion of the organic matter in the sediment at earlier stage of firing temperature below 1000°C, which is responsible for the significant decrease of the thermal conductivity and compressive strength. The specimen was further improved by firing with temperature of up to 1050°C and resulted in higher bulk density and modified micro structure.

Sediment was found feasible to be used as sand or clay replacement in fired bricks depending on the properties of the sediment. Efforts to maximize the utilization of sediment are not limited to partial replacement in fired brick. Studies have also been conducted in using 100% sediment in producing lightweight aggregate pellet by preheating at 500-700°C followed by expansion at 1100-1200°C. The sintering process produced a significant vitreous phase that resulted in porous synthetic aggregates containing isolated and irregular pores. The lightweight aggregates were used to produce concrete masonry units [5].

2.4.2. Sediments in Unfired Bricks

Unfired bricks rely on the degree of compaction to densify the bricks and cementing materials to bind and solidify the materials. A review has been conducted by Zhang [40] on the production of bricks through cementing using waste materials. Waste materials such as fly ash, sludge, recycle paper mill, gold mill tailings, etc were mixed with cementing materials such as OPC, hydrated lime, alumina cement, slag cement and etc, moulded in conjunction with certain degree of compaction or some were heated in ventilated oven. However, none of the dredged sediments were discussed in this review on the production of blocks through cementing. This review [40] covered only on the use of river sediments in brick production through firing up to 1000°C by Samara [15] and Mezencevova [3] as aforementioned sub-section.

Method through cementing is basically establishing hydration reactions forming Calcium Silicate Hydrate (C-S-H) and Calcium Aluminate Sulphate Hydrate (C-A-S-H) phases that contributed to the strength [40]. Table 1 shows studies conducted on bricks made of sediment through cementing method. The sediments’ sources are either from water dam, harbors, reservoirs or water channels. Cementing materials such as cement or lime production waste were used together with compaction and some in conjunction with vibration. These bricks do not need to be sintered, steamed or water cured. This method is energy conserved and reduced CO₂ footprint [54]. Solidification or stabilization using cement immobilized the heavy metals within the sediment through fixation and physical retention, which limits the availability and mobility of the contaminants by forming monolithic products [31]. Serbah et. al. [2] amended the highly plastic sediments from Bakhada water dam in western Algeria with 30% of natural sand to produce compressed earth blocks by using modified optimum proctor with increasing compacting energy by 25 blows. It was found that decreasing water content at about 11% showed increased in unconfined compressive strength by three times. Mymrin et. al. [1] utilized small sandy particles of seaport sediments from Paranaugu Port, Brazil with construction and demolition debris, and lime production waste that cured in open air to produce a composite civil construction material. The experiment showed that up to 60% sediments can be used in combination with 20-35% construction and demolition debris and 15-30% lime production waste. Lei Wang et. al. [56] combined 15% of harbor and water channel sediments with binary cement which contained magnesium oxide cement and ordinary Portland cement, later curing with CO₂ for one day and subsequently at 7 days of air curing were conducted. The binary cement provided sufficient magnesium hydrates for metal sequestration but the used of magnesium oxide cement has weakened the compressive strength and increased the water absorption of sediment bricks. Therefore, the authors introduced curing by CO₂ to transform the soluble magnesium hydrate into stable carbonates and densify the microstructure. It also reduced the porosity that enabled a substantial enhancement in strength as well as carbon sequestration. The subsequent air curing resumed the carbonation and hydration of the binary cement, thus increase the strength.

Cheng et. al [57] proposed to use hydropower plant reservoir sediment and cement to produce non-sintered cured brick by high pressure and 28 days of natural conservancy curing. It was observed that the bricks produced have higher density and lower water absorption than clay bricks. It was also found that the higher

<table>
<thead>
<tr>
<th>Sediment source</th>
<th>Cementing materials</th>
<th>Type of samples</th>
<th>Compaction method</th>
<th>Curing method</th>
<th>Various test conducted</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1] Seaports</td>
<td>Lime production waste</td>
<td>Composite civil construction material</td>
<td>10 MPa compaction</td>
<td>Open air</td>
<td>Uniaxial compression strength, linear expansion, water absorption and density, XRD, SEM, EDS, and LAMMA.</td>
</tr>
<tr>
<td>[56] Harbors and</td>
<td>Binary cement</td>
<td>Paving blocks</td>
<td>30 MPa compac-</td>
<td>1 day CO₂</td>
<td>Compressive strength, water</td>
</tr>
</tbody>
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Table 1: Studies on production of bricks using sediment through cementing method.
the moisture content in the brick, the more shrinkage can occur. Said et al. [17] utilized marine sediments from Rades Harbor which are characterized as sandy silty clay (semi-spread distribution) with high plastic silt and soft consistency as partial replacement of quartz sand. It was mixed with cement and was applied with high frequency vibration and compaction of 120 bars pressure simultaneously to produce paving blocks. The blocks were cured in open area for one (1) day before being transported for storage. The authors found that the early strength (initial setting) of blocks was delayed due to the presence of organic matter in the sediment. Water absorption is lower in the blocks due to the well compacted particles when sediment is added. This is also due to the mineralogical composition of the sediment that is comparable to the material used as fillers. Furthermore, carbonation increases the impermeability of the blocks due to blockage of some pores by carbonate, thus the capillary absorption is reduced. Incorporation of sediment has improved the abrasive performance of blocks due to the presence of fines that enhanced the compaction of granular particles. Besides that, metal concentrations in blocks have remarkably decrease as compared to gross sediment metal concentrations. This is justified by the trapping of sediments in mortar matrix due to stabilization of cement.

3. Discussions

In general, characterization of sediments emphasized on the heavy metals assessment and organic pollution [24,27,28,58–63]. Nevertheless, particle size distribution of the sediments is the significant characteristic and certainly an important criterion for utilization of sediment in brick production [2], with heavy metals assessment that focused on the leachability of the heavy metals [17].

<table>
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<th>Table 2: Sediment characterization outcome for cementing bricks</th>
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<tr>
<td>Sediment source</td>
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<td>Water dam</td>
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<td>Seaports</td>
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<td>Harbors and water channels</td>
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<tr>
<td>Harbor</td>
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</table>
4. Conclusion

The importance of sediment characterization, method of producing bricks using sediment and utilization of sediment in fired and unfired bricks has been reviewed. Characterization of the sediment is one of the fundamental aspects in brick production since the source of the sedimentation could be from various backgrounds due to the overwhelmed development. This includes heavy metals assessment that is essential to determine suitable pozzolan or treatment that could stabilize the heavy metals. Cementing and geopolymeration are other options as compared to firing method in producing sediment bricks. The advantages include lower embodied energy method that evade carbon dioxide and dioxin/furan emission and densification issues due to minerals in sediment and clay that dissolve at different temperatures. However, methods to produce bricks are very much dependent on the resources of primary material which include wastes and local facilities. As a result, this will incur high impacts on the local economic and environmental aspects.

Acknowledgement

This study is sponsored by MyBrain scholarship 2012. The authors would like to thank TNB Research Sdn. Bhd and TNB Sultan Yussuf Jor Power Generation Station for granting the project under code U-SENR-13-21.

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