CSCanada
Management Science and Engineering
Vol. 5, No. 3, 2011, pp. 120-125
DOI:10.3968/j.mse.1913035X20110503.1z678

ISSN 1913-0341[Print]
ISSN 1913-035X[Online]
www.cscanada.net
www.cscanada.org

Silt Resource Utilization and Benefit Analysis of Silt Fired Perforated Brick Production: Take Nantong, China for Example

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Supported by "Jiangsu Provincial Economic and Information Technology Commission project" (No: 2010-927-2; 2009-343-6), and supported by "Nantong Applied Research Program" (No: S10907).

Received 20 June 2011; accepted 26 July 2011

Abstract
Resource utilization of silt dredging from rivers and other lake is an important issue that related to many government departments like water conservancy, shipping, land resources, construction management and other industries. It involves social, economic and environmental effects. With the encouragement of national policy of protecting arable land, make use of dredging silt to producing clay wall material is a higher value-added resource utilization than used for fill material and land use. Combined with the practice of producing fired perforated brick in Jiangsu Nantong, the economic, social and environmental benefits were analyzed based on the Summary of all these resource utilization. And the recommendation of regional development of the industry was presented at last.

Key words: Silt; Resource utilization; Fired perforated brick; Benefit analysis; Water dredging

LIU Hongmei, WU Kun, HONG Weimin, & ZHU Aidong (2011). Silt Resource Utilization and Benefit Analysis of Silt Fired Perforated Brick Production: Take Nantong, China for Example. *Management Science and Engineering, 5*(3), 120-125. Available from: URL: http://www.cscanada.net/index.php/mse/article/view/j.mse.1913035X20110503.1z678
DOI: http://dx.doi.org/10.3968/j.mse.1913035X20110503.1z678.

INTRODUCTION
There are lots of rivers, lakes and seas in our vast land area, in China. Each year, a very large amount of sludge generated from this water area. In order to improve the water quality of these rivers, lakes, coastal waters and to ensure a normal flood, navigation capabilities, a regular large-scale dredging and desalting works are implemented for many of these rivers, lakes, reservoirs and bays and other waters[1-4], generate a lot of dredged sludge need to be handled properly.

Dredging silt has high moisture content, low dry density, high compressibility and very low strength, and sometimes has toxic and hazardous substances in it, so, its handling and use reasonably become more and more concerned. Over the years, method of silt abandoning is the main way in most of our dredging engineering. The sludge was dumped into the sea, abandoned land areas or low-lying areas. Silt abandoning way is simple and low cost, but it impact the surrounding environment, take up a lot of land resources, and is incompatible with direction of economic and social development in protecting the environment, improving the efficient use of land resources[5].

On the other hand, China has been in the construction of the rapid development period, a large number of new buildings rise abruptly out of the ground at a cost of damage to farmland acres. Traditional clay bricks production needs to dig field, it is contrary to the national policy of protecting cultivated land. National policy has expressly provide, the use of solid clay bricks in all cities was prohibited by the end of 2010. And the use of river silt from dredging to produce clay wall materials was encouraged. This will not only protect the land, make the dredging of silt be fully utilized, but also save some cost

of the brick raw material. It has good social and economic benefits, and is an important aspect of utilization of sludge. In Nantong City, Jiangsu Province, China, it has been about 20 years to begin to use the silt to produce fired brick from the early 80s of last century. The silt fired perforated brick has significant insulating effect; it is a good new energy-saving wall materials.

1. UTILIZATION STATUS OF SILT IN DOMESTIC AND INTERNATIONAL

Internationally, for the effective use of sludge treatment, many countries have used commercial method of silt in rivers and lakes for the comprehensive development. Currently, more than 80 countries and 170 cities around the world have specialized development and utilization agencies or collection and treatment plants, to collect the silt more than 95 million ton each year. with annual income over 6.0 billion dollars. As economic and social benefits are very good, many countries have developed the business of the future use of sludge as an important economic and social development of the environmental policy[6].

Currently, the comprehensive development and resource utilization of rivers and lakes silt in domestic and international are mainly in land use, fill materials and construction materials.

1.1 Land Use

Land use is to make full use of rivers and lakes silt to rehabilitation and reconstruction of farmland, woodland, grassland, green and severe disturbance of municipal land. To re-enter the natural silt dredged material, energy and recycling, and reduce of negative effects. Silt contains some harmful ingredients inevitably, such as organic pollutants, heavy metals and a variety of pathogenic bacteria. So, before the land use, non-toxic treatment to be approved (usually high-temperature composting). If excessive heavy metals in the dredged mud, it also need to take certain measures to avoid secondary pollution on the environment.

Dredging silt contains organic matter and plant required for nitrogen, phosphorus, potassium and other nutrients, and a more balanced fertilizer containing more humus composition and colloid formation of soil aggregate structure that can maintain the role of nutrients. It is valuable biological resource[7]. ZHU Guangwei et al studied and compared the feasibility of the landscape and its ecological effects on the silt from the Beijing-Hangzhou Grand Canal (Hangzhou section) for agricultural and virescence use. And found that a large number of soil mixed with dredged sludge on seed germination rate have some influence[8]. T Neville Burt[9], who pointed out that the dredged material, can be used as habitat for plants and animals, this sludge utilization method on the rehabilitation and construction of ecological environment has important significance.

All that remains after mining mines, abandoned borrow pit construction, forest harvesting fields, landfills and other serious damage to the surface is a serious disturbance of the land area required reclamation. These lands generally have lost the original good characteristics of the soil. Planting trees and grass can not be directly, fill in the dredged sludge can increase soil nutrients, soil properties, plant growth promoting surface. This method can dispose of a large number of dredging silt and restore the ecological environment. In New York and West Harbor of New Jersey, dredged mud was mixed with ash and limestone, backfilled to Pennsylvania's open pit ore to remove the original Sulfur in acid leaching solution, settle the two environmental problems of dredged mud and water pollution at the same time[10].

1.2 Fill Materials

Using dredged mud as fill material, must improve its high water content, the nature of low intensity to suit the engineering requirements, and then backfilling construction use. Pretreatment methods often include physical methods such as drying, dehydration, chemical methods (curing process) and heat treatment method (scorification processing). Chemical curing is the most flexible method with wide scope in engineering applications. The silt after chemical curing can be used instead of sand and soil material without consolidation settlement, but higher strength, water permeability etc, for backfilling, embankment reinforcement, and road works.

There are lot of typical projects, such as backfilling reclamation, pier new construction, coastal zone development and the coastal cities of municipal engineering. Implementation site of the project and the dredging silt place are closer, which is the best for filling. The artificial island, Board island in Nagoya, Japan, used part of the curing treatment silt as fill materials. Sun Island in Rudong, China, is the first artificial island off seashore. The reclamation area is 1.44 km^2. Firstly, enclosed the island built range with steel sheet pile and riprap at the landfill around, then blowing sand into the island. In United States, dredging silt is used as a basis for tidal floodplain and building various berths, grain silos, coal, agricultural and forestry products and other goods in the storage area. In Europe, the dredged silt is used as construction material for land filling and the old terminal reconstruction and construction of commercial parking field.

Cured with high intensity, small water permeability characteristics of the sludge can be a good embankment material. For sea dike construction made lakes. It can also be heightened, widened embankment treatment, to meet the slope stability, seepage and anti-erosion requirements. The same applies to road works in the roadbed, embankment.

In short, the dredged sludge treated as a renewable

resource use, can produce environmental protection, technical and economic, security, comprehensive benefits and reasonable.

1.3 Construction Materials

Currently, fired brick, concrete, etc. is still the largest amount in the wall material. Brick, cement and other industries have a lot of demand on the clay. Digging clay resources, has seriously affected the quantity and quality of rural land. At the national policy of prohibiting the use of solid bricks, using silt to make sintered bricks instead of clay materials would greatly reduce competition in manufacturing and agricultural. It is the main way of silt resources utilization. Sludge can also be used to manufacture lightweight aggregate concrete and silicate gel materials.

Japan is the most active country to resource recycling of sludge. Sludge was used to produce advanced materials, began to export since 1994 with very expensive price. Silt bricks with light weight, breathable, easy to color processing, suitable for a variety of building decoration. In University of Maryland, a "bio-bricks" was produced use sludge as raw material, and was promoted as advanced technology for sludge resources recycling[11].

LI Kejun et al[12] used the Yellow River silt to make brick and test since 1991, and adjusted the operation of brick molding, drying, kiln code, fire brick workers and firing temperature and other production processes. J. H. Dijkink[13] from Holland used a certain process to stabilize the river mud for building materials after the test. And pre-granulation, briquetting to fixed shape. T Neville Burt[14] proposed the feasibility of mud brick in 1994, and pointed that requires the amount of silt in the sand is less than 30%, and said the technical level at that time could not produce good quality bricks. Wu Jiabao town of Jinan used Yellow River silt, mixed with slag, coal gangue, coal ash, etc., brick, made pottery, decorative ceramic tile manufacturing high art, to achieve the economic growth mode from extensive to scale and intensive changes. The annual output was more than 100 million brick block, saving clay 80,000 m^3 [14]. XUE Shihao et al[15] use Nanfei River sediment in Anhui province for silt brick tests. The measured dry bulk density is 1364kg/m^3, which is 20% less than normal brick. Thermal conductivity is 1.44kJ/kg, which is 53% lower than the Clay Bricks and has a thermal insulation effect. LIU Guiyun[16] used the silt from Shanghai Longhua harbor to conduct brick tests, which contains a large number of organic matter loss on ignition in the roasting process produces porous, that can reduce product bulk density, also confirmed that the sludge fired brick has good insulation. And other physical properties of the basic technical also answered the requirements for Clay Bricks.

T Neville Burt[13] pointed that using sludge is a viable preparation of ceramic clay and silt pollution treatment methods. But because of raw material to be dredged, it can not guarantee a steady supply of raw materials, and bring some difficulties of industrialization. WANG Zhongping[15] used sludge samples from Suzhou River (Zhejiang Road Bridge section) as the main raw material, adding fly ash and iron fired ceramic aggregate used in construction, ceramic clay product performance to fully meet the national standards. Since 1998, Japan began produce eco-cement sludge, the cost is only 3/4 of Portland cement, and with faster solidification speed[6].

2. SILT FIRED PERFORATED BRICK PRODUCTION AND ECONOMIC ANALYSIS

In the many ways of silt utilization, the technology of simple treatment for raw materials to produce perforated bricks directly is currently more mature, and has the most significant economic benefit of practice.

In recent years, some developed countries like the United States, Germany, France, Italy, all developed the fired brick with 4.6% pace and put it as high-grade wall materials, green building materials included in the scope of a standard brick. And can be sold for 2.5 yuan RMB per piece. In Japan, a silt fired brick, can be sold for one dollar[11].

Nantong City, Jiangsu Province, China, began to use mud brick from 80's last century. After years of effort, make full use of the Yangtze River silt admixture of silt and other power plant fly ash, sludge production and sintered bricks. Only account for the new building materials companies along the Yangtze River in Nantong, can make 250 million silt sintered bricks annually worked out a more reasonable production process. Correlation analysis and explanation are presented taking Nantong, for example.

2.1 The Main Production Processes and Technology

Nantong has staggered water network, with rich silt resources. Only the inner river silt reserves amount is about 27,500 m3. Silt reserves in shown in Table 1. The majority of the Yangtze River and inner river silt has the characteristics suitable for production of fired brick. Brick production with silt from Yangtze River has been practiced and explored for many years, and technology is maturity. At present, the technique involves harvesting mud, dehydration, raw materials preparation, brick molding and drying, baking and other links. General process is like digging silt with mud slurry → impurity into the pool (or transfer ashore artificial impurity)→ fragmentation of natural or artificial drying → Roll out the vacuum machine → added admixture (fly ash, cinder, etc.)→ mixing aging → crushing mixing → automatically extrude → cut billet → artificial code → drying → baking→ products out kiln.

Table 1
Data Tables of Nantong Rivers and Ditches[18],[19]

Channel level	Number of rivers	Channel length(km)	Silt reserves (million m^3)
First level river	12	730	30.47
Second level river	111	1901.04	29.85
Third level river	1277	5746	36.52
Fourth level river	11535	13000	57.99
Min ditch	165304		120.00
Total			274.82

2.2 Economic Analysis

(1) Investment cost

Take a construction materials plant in Nantong for example, it took nearly 10 years of gradually put in development, the annual output of was about 30 million pieces of pure silt fired perforated brick. Make full use of existing plant equipment, transportation equipment, brick field, developing the pure silt fired perforated, the new equipment added into was about 1.84 million RMB.

(2) Raw materials cost and benefit calculation

Using river silt to instead of buying mountain clay, the production cost of its raw materials of fired brick is shown in Table 2. In calculation, the cost of raw materials of silt considered mineral resources, transfer fees, sludge dredging costs, miscellaneous fees, transportation fees and other expenses. Clay brick farm borrow mineral resources of raw materials costs, including transfer fees, farmers compensation, road maintenance, pressure green fees, transportation fees.

Calculate the cost of sludge materials fee is 7.33 yuan per ton, compared with the raw material costs of original brick-making clay materials fee 12.85 yuan per ton; it saves 5.52 yuan per ton. To produce 30 million bricks, the consumption of 75,000 t of soil need to calculate, the cost of raw materials can reduce costs 424 thousand yuan. The period of discounted payback as a new equipment is about 4.5 years. If take average annual consumption of 7.82 million t of sludge for example in Nantong sintered products, the saving of raw materials cost can be 43.16 million yuan.

These are just a narrow economic analysis, it is limited to brick and tile benefits, does not include dredging companies benefit analysis does not include dredging the silt water sector had to pay money, as well as the environment and resource protection projects and new wall material use, and government financial subsidies and tax support.

Table 2
Cost Table of Raw Materials of Silt Fired Perforated Brick

Serial number	cost item	cost (yuan / t)
1	Depreciation of fixed assets	1.20
2	wages	2.00

To be continued

Continued

Serial number	cost item	cost (yuan / t)
3	Electricity	0.12
4	fuel surcharge	1.41
5	repairs	0.40
6	transfer fee Mineral Resources	2.20
total	cost of raw materials costs	7.33

3. ANALYSIS OF SOCIAL AND ECOLOGICAL BENEFITS

3.1 Using Silt for Brick Protect Farmland

Using silt to make brick protect arable land is conducive to resolving the conflict with the brick production. The implementations of silt brick production can solve the outlet of the sludge from dredging for river renovate. It is a smooth development of an effective way. Brick and tile industry is no longer dig fields, the turn towards to the dredging sludge. Nantong city's production amount of silt fired perforated brick in 2010 (equivalent standard brick) is 3.72 billion; the total amount of river silt is 7.82 million tons. Equivalent to occupy as farmland 326 hm2 (take 2 meter for average dig depth).

3.2 Solving the River Dredging Problems

Rivers usually need to be dredged every 5-8 years. Originally, fiscal should put a large number of funds into dredging works for human power and material. And also need to solve the problem of sludge pile. Now, silt becomes the brick-making raw materials, dredging companies funded initiative to reduce the pressure on government funds. Dredging by a professional construction team, under the supervision of the government can guarantee the quality and progress on dredging, channel dredging to achieve market-oriented operation. If take Nantong city's annual average usage of sludge 7.82 million tons for account. It is equivalent to saving water sector dredging cost 20 million yuan, and reducing a single water pressure on land dredged sludge waste.

3.3 Finding a Way out for the Brick Companies

Excavation of land is not fertile, in the absence of resources mud, brick kilns can not survive, fired brick products industry is very restricted. Development of river silt brick production, to solve problems and achieve sustainable development of mud brick-making enterprise. Under the guidance of relevant policies in the country, shutting down high energy consumption, low productivity, polluting small kilns. Making specialization in the silt brick-making industry to reposition the chain, such as the establishment of dredging companies, professional transport companies, and provide for the brick and tile enterprise a whole new idea.

3.4 Conducive to Building Energy Efficiency

By means of thermal performance comparison test in silt fired perforated brick walls with clay fired bricks wall. The results show that the heat consumption of silt brick wall is 8.94% lower than that of clay brick wall. If take 75% of annual energy consumption of residential buildings by the external structure of the consumption of heat transfer calculation, in Nantong for example. An annual increase of multi-storey residential building area is 500 million m2, coal indicators is 6.60t/m^2, calculated with the heating period 98 days, the total saved standard coal (refer to the cold northern region) in Nantong city is about 320 thousand tons.

3.5 Protecting Environment and Ecology

Encourage the use of sludge in producing sintered porous brick, the village Min ditches and rivers also get dredging, water become clear, and prevent the eutrophication of water, rural water environment improved significantly, to achieve a healthy ecological system. Silt material itself, content high water, dehydration drying to a certain extent when mixed with coal ash is no longer consume a large amount of water in the production process, it reduce the water consumption and can save 3.6 tons water for per million ton silt. And save the city's annual water consumption 2815 ton.

When fix the raw material of fired perforated brick mixed with fly ash, cinder and other waste materials, with a roasting effect, as well as saving coal about 1/3. The quantity of production of fired perforated brick in Nantong 2010, is 3.72 billions, the whole city's fired brick-making industries can save standard coal 55.8 thousands ton, and to reduce carbon emissions, reducing environmental pollution.

CONCLUSIONS AND RECOMMENDATIONS

From the water, shipping, water conservation, environmental protection point of view, it need to solved the problem of way out of the sludge generated from periodic dredging of rivers and lakes. The silt resource utilization can be used for land use, filling materials and construction materials. However, the optimal use of resources remains to be government-related administrative functions and coordination with the management, considering the advantage and disadvantage of dredging waste. Pay attention to economic, social, and ecological and many other benefits in order to truly maximize the use of surface features. In line with local conditions, utilizing waste river sludge to produce silt fired perforated brick which is energy saving, environmental protecting, and gathering experience in Nantong. By calculation and analysis, the economic benefit is significant as well as good social and environmental benefits. It has broad prospects and the promotion of higher value. But the domestic status of the industry such as product quality, process equipment, production management, business organizations show a gap compared with developed countries, which restricts the industry's rapid development.

At the national energy and land saving policy, the road of wash out small brick enterprise that occupation land, waste resources, inefficient, with outdated equipment and technology behind. And union industry together to the professional division of labor is imperative.

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