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Innovative reservoir sediments reuse and design for sustainability of the hydroelectric power plants

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ABSTRACT

In the process of producing hydroelectricity, plants all over the world are faced with the problem of reservoir sediment. If this sediment is removed but not properly disposed of, it can become a secondary pollutant. This study proposes a way to resolve this problem through reuse and recycling.

In this study, the process is based on Design for Six Sigma (DFSS) where reservoir sediment and the masonry waste from the construction industry are combined with cement and a curing agent. The resulting mixture transforms into a high strength, non-sintered cured brick after 28 days of natural curing. This product is a new walling material that is friendly to environment, fulfill the goal of energy conservation, waste recycle, protect ecosystems, and promote sustainable development. Large scale recycling of reservoir sediment solves the problems that reservoir sediment poses, as well as increasing the capacity of reservoirs and the effectiveness of hydroelectric power plants. The green milestone reached by the technology is of great industrial, economic and social significance.

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1. Introduction

The increasing fossil fuels consumption since the industrial revolution has resulted in massive greenhouse gases in the atmosphere. It results in global warming which has received greater international attention. After the adoption of the Kyoto Protocol and the convening of the Copenhagen Summit, the international response to energy crisis, environmental protection awareness, and the development of new energy sources have become critical issues in the twenty-first century. The development and utilization of renewable energy are important tools to solving the problem of global warming. The term "renewable energy" refers to natural resources that can be replenished continually, such as solar energy, wind energy, geothermal energy, hydro energy, or bioenergy. Finding ways to reduce greenhouse gas emissions and increase the production of renewable energy sources are prerequisites to sustainable development. The long-term use of renewable energy is essential to a nation's competency and sustainability. From an environmental standpoint, renewable energy reduces the risks of climate change associated with the greenhouse gas emissions caused by burning fossil fuels [1]. However, the development of renewable energy in many countries is in its infant stage, and is still in need of much investment in technical, financial, and political resources [2]. At present, costs of renewable energy are higher than those of fossil fuels [3]. Although market penetration of renewable energy has increased, it is still limited, because of the higher production expenses [4] and a lack of public support. Renewable energy needs both an influx of technology and financial subsidies [5]; therefore, governments should employ research and development (R&D) funds and cost subsidies to support the development of renewable energy.

The development of renewable resources requires large amounts of capital because they are much more expensive compared to fossil fuels. Many technologies for renewable energy are immature and the development of renewable resources faces many bottlenecks. Hydro energy and its application on hydroelectricity is the only form of renewable energy that has been in use for over 100 years. Both the technology and the experience of this renewable energy are mature and the cost is relatively low. Table 1 lists ten countries with the most reservoirs. Using China's Three Gorges project as an example, hydroelectric power plants supply power to over half of China and reduces the use of coal and the carbon dioxide emissions by 50 million tons and 30 million tons, respectively.

In the hydroelectric power plants, reservoir sediment is a waste product and has become an environmental concern for all reservoirs worldwide. If sediment is removed but not disposed of properly, it causes secondary pollution to the environment and ecology. If the sediment is properly disposed of by converting it to a reusable resource, it would not only reduce the amount of waste, but also prevent the sediment from becoming a secondary pollutant. This would also serve to conserve energy, which has major contribution in energy consumption. Recycling waste would truly conform to the intent of using renewable resources. Therefore, corporations should consider the green concepts [6].

Recycling waste materials to increase the energy supply should be within the scope of utilizing new energy resources. Internationally, energy conservation is considered as the fifth major source of energy (the other four are coal, oil, renewable energy, and nuclear energy) and is a new method for increasing the supply of energy. Therefore, renewable energy, green energy, and conserving energy all belong to the new energy. Corporations that emphasize innovative green design technology reduce waste and harmful substances as well as highlight their environmental friendliness [7]. Efficient innovative energy production increases the corporation's market value, while enhancing its reputation and environmental performance [8]. Corporations can also improve the competitiveness of their products and their environmental sustainability and development. Wee et al. [9] surveyed the renewable energy supply chains, performance, application barriers and strategies for further development.

Currently, recycling is highly valued. Operational problems arise from trying to integrate recyclable materials from different sources into sustainable processes and remanufacture them into new products [10]. Therefore, to reduce the negative effects of pollution to the environment, corporations should maximize green consumption, recycling processes, waste reduction, and energy conservation.

A novel method to combine reservoir sediment with masonry waste from construction industry into a high value product is described in this study. A new manufacturing process that produces a strong non-sintered cured brick and fulfills the objectives of environmental protection, energy conservation, and waste recycling is discussed.

2. Optimization methods applied to reservoir sediments

In recent years, due to energy crisis and worsening environmental issues, environmental protection and the concept of greening have become very important. Industries have paid more attention to environmental concerns [11]. Various environmental problems have been experienced by reservoirs worldwide due to natural and

Table 1
Ten countries with the most reservoirs.
Source: Water Resources Agency, Ministry of Economic Affairs, R.O.C., 2005.

Country	Number of reservoirs
China	22,000
United States	6,575
India	4,291
Japan	2,675
Spain	1,196
Canada	793
South Korea	765
Turkey	625
Brazil	594
France	569