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Potential of geopolymer technology towards green buildings and sustainable cities

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Abstract

Sustainable cities of the future apart from having low energy consumption and greenhouse gas emissions should also adopt the "zero waste" principle. Geopolymers are cementitious materials with three dimensional structures that are formed by chemical activation of Al and Si containing solid materials at relatively low temperatures. Several wastes or by-products, including coal combustion ashes, metallurgical slags, construction and demolition wastes can be utilized for the production of geopolymer concrete and construction components.

The present paper outlines briefly the potential of geopolymer technology towards green buildings and future sustainable cities with a reduced carbon footprint.

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Keywords: geopolymer; sustainable building; carbon footprint; life cycle analysis

1. Introduction

Sustainable development is a concept that has several definitions [1]. The most common one declares that today's generation should not compromise the ability of future generations to meet their needs. The three pillars of sustainable development are economic and environmental protection as well as social development. It is known though that the Earth's capacity to support people is determined by natural constraints and human priorities [2].

Human population has more than quadrupled since 1860 while annual energy consumption has exceeded 130 TWh [3]. Cities consume today three-quarters of the world's energy and are also responsible for the same percentage of global pollution. Furthermore, United Nations predict that 60% of

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the world's population will live in cities by the year 2030 [4]. It is therefore necessary when we discuss the issue of future sustainability to consider the increasing domination of the city and determine its direct and side effects. The major cities are nodes that connect large networks of important infrastructure services. The resilience and robustness of city infrastructure is thus essential for their sustainability [5].

A critical question though is "which city is considered sustainable"? The concept of sustainability must recognise that the city needs to meet social, environmental, economic, physical, political and cultural objectives [6]. A sustainable city should provide high quality of life for its inhabitants without affecting human conditions in neighbouring regions [7]. Climate change, energy insecurity, low carbon economy through technological innovation and behavioural transition are some of the issues that should be seriously considered in future sustainable cities [8]. A sustainable city should have an accurately determined environmental footprint which is the measure of the equivalent area of land required to provide the necessary resources for its inhabitants. For example, a city with an environmental footprint of 20 means that it needs 20 times its current land use to cover needs for food, energy, etc. [9].

Buildings are energy consuming structures that have large impact on global climate change and other energy-related environmental issues. Buildings are responsible for almost 40 percent of the total primary energy consumption and 70 percent of electricity consumption. About 40 percent of CO_2, 50 percent of SO_2, and 20 percent of NO_x emissions are produced in the US as a result of building-related energy consumption [10]. Today there is a growing trend in most countries towards design and construction of green buildings. A green building should have certain unique features and during its entire life cycle should contribute to conservation of resources (energy, land, water and materials), reduction of pollution, improvement in indoor environment quality and protection of the environment [11-12].

The United States Green Building Council developed the Leadership in Energy and Environmental Design (LEED) Rating System in 2000 to provide the industry with consistent credible standards of what constitutes a "green building" in terms of design, construction and high-performance operation. The system has proved its effectiveness and has established itself as the benchmark of choice for federal agencies, as well as state and local governments across the United States [13]. "Energy" remains the most important type of cost to Canadian LEED accredited professionals. "Water" ranks second, whereas "Waste", "Productivity and Health", "Commissioning and Maintenance" and "Emissions" come in next with no significant difference [14]. It is therefore necessary that a validated tool including weighted indicators is developed to assist all involved stakeholders. Green building certificates incorporating various criteria are also required to improve sustainability in cities and living environment [15]. Modern green building design strategies should adopt eco-friendly design and construction techniques that are still facing economic and political barriers. So far, green energy efficiency research has been mainly directed toward the use of smart grids, development of more effective insulation materials, and minimization of greenhouse gas (GHG) emissions.

Green cities should gradually adopt the principle of "zero waste". This approach will definitely contribute to sustainable development and reduction of carbon footprint. This means that most wastes produced in the city or in the wider region should be recycled for the production of secondary materials that can be used in various applications including construction. Quality of these new materials and cost are issues that have to be considered. Quality is mainly a matter of engineering while cost, if higher, has to be fairly shared among relevant stakeholders.

The objective of this paper is to explore the potential of geopolymer technology in terms of industrial by-product and waste utilization, which is a global sustainability issue, for the production of concrete and new construction components that will subsequently reduce carbon footprint in sustainable cities of the future.