J. Eng. Technol. Manage. 28 (2011) 300–316

Contents lists available at ScienceDirect

Journal of Engineering and Technology Management

journal homepage: www.elsevier.com/locate/jengtecman

An assessment framework based on social perspectives and Analytic Hierarchy Process: A case study on sustainability in the Japanese concrete industry

Michael Henry *, Yoshitaka Kato

International Center for Urban Safety Engineering, Institute of Industrial Science, the University of Tokyo, 4-6-1 Komaba, Meguro-ku, Tokyo, Japan

ARTICLE INFO

JEL classification:
O31
O32

Keywords:
Sustainability
Concrete
Construction
Analytic Hierarchy Process
Sociology of technology

ABSTRACT

This research introduces a framework for assessing concrete sustainability which is based upon the concept that technology is defined by stakeholders' perspectives and which applied Analytic Hierarchy Process to translate these perspectives into quantifiable assessment values. A survey was conducted to identify important criteria, and several "design scenarios" were introduced which represent different value systems by varying criteria importance. Concrete materials with varying environmental impact were then assessed to observe the effect of different value systems and material properties, and it was found that the concrete with better properties was generally selected as most sustainable regardless of the design scenario.

Introduction

Sustainability and concrete

Sustainability, or sustainable development, was originally defined by the Brundtland Report "Our Common Future" to the United Nations (UN) in 1987, in which it was defined as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987). It is popularly visualized as the integration of the "three pillars" of sustainability: environment, economy, and society – a concept proposed by the UN Conference on Environment and Development in 1992 and formalized by the UN General Assembly in 2005 (United

* Corresponding author. Tel.: +81 03 5452 6472, fax: +81 03 5452 6476.
E-mail address: mwhenry@iis.u-tokyo.ac.jp (M. Henry).

0923-4748/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.jengtecman.2011.06.006

Nations, 2005). Visualization of sustainability in this fashion is intended to demonstrate the connection between the three pillars and the importance of integrating concepts which were viewed as mutually-exclusive in the past. Furthermore, this model shows that greater emphasis is being placed on economic factors at the expense of the environment, so it is necessary to restore balance between the pillars by increasing the importance of environmental factors.

Sustainable practice is a critical issue for the concrete industry, which has come under increasing pressure due to its environmental impact. Most notably, up to 10% of the world's CO_2 emissions can be attributed to concrete production and transportation (Sakai, 2009). Furthermore, concrete production was estimated to consume more than 11 billion tons of sand, gravel, and crushed rock per year in addition to over one trillion liters of water by Mehta (2001), and worldwide generation of concrete and masonry rubble from construction demolition was estimated to exceed one billion tons by Lauritzen (1998) – and these numbers have grown substantially over the subsequent decade due to increases in population and infrastructure development, particularly in Asia. These are in addition to other greenhouse gas and particulate matter emissions related to air pollution, health concerns from concrete dust, and more. As concrete is the world's second most-used resource after water (Sakai, 2009) – and a fundamental component for infrastructure construction necessary to improve quality of life – any reduction of these impacts could have widespread benefits for easing environmental burden and moving towards more sustainable construction systems.

A variety of strategies for sustainable practice in the concrete industry have been proposed. These include reducing resource consumption by utilization of industrial waste and recycled concrete; reducing CO_2 emissions through decreased usage of Portland cement, utilization of alternative cementitious materials, and optimized mix design by applying chemical admixtures; enhancing the durability of new concrete construction to reduce long-term resource consumption and emissions; implementation of maintenance management schemes to extend the service life of existing structures; selection of low-impact construction methods; and taking a holistic approach in both concrete technology and education (Malhotra, 1999; Mehta, 1999, 2001; Sakai, 2009). However, the competitiveness of concrete as a construction material must be maintained while implementing these strategies (ACI BACSD, 2005).

Means of evaluating sustainability are necessary in order to determine whether practices are more or less sustainable and to evaluate the state of a system; this is achieved through sustainability indicators (SI), which are typically used to evaluate different aspects of a system, with the total trend of all the indicators providing some idea of how sustainable a system is. There is a wide variety of green building evaluation systems available for assessing sustainability in the construction industry, but although the usage of concrete can help improve the final rating in these systems there is no specific consideration or evaluation of concrete. Concrete-specific standards include the International Organization for Standardization's (ISO) sub-committee on *Environmental management for concrete and concrete structures*, which is currently under development, and the Japan Society of Civil Engineer's (JSCE) "Recommendation of Environmental Performance Verification for Concrete Structures (Draft)," which provides general environmental principles across all phases of a concrete structure's life cycle (JSCE, 2006). As can be seen from the titles, however, these specifications focus primarily on environmental impact aspects only. Furthermore, these approaches to measuring sustainability – as well as any attempt at a generalized definition of sustainability itself – neglect a critical aspect of a greater issue: that sustainability is a human vision with human values, and it varies depending on who is applying it and under what conditions it is being applied (Bell and Morse, 2008). The concrete industry is composed of many stakeholders, each of which have their own perspectives and goals, and any attempt to implement sustainable practice, materials, and assessment of those practices and materials will require consideration of the stakeholders' input and negotiation between their differing goals and restrictions. Considering these varied perspectives, one means of establishing sustainability assessment criteria is through a bottom-up approach, whereby the stakeholders define sustainability and determine the assessment criteria, as they may be the best-placed to do so since they will be tasked with implementing sustainability (Bell and Morse, 2008). Tackling the issue of sustainability in this fashion will require the development of assessment systems which integrate the social perspectives on sustainability with the technical execution necessary to carry out those perspectives into practical application.