SUSTAINABLE STORMWATER MANAGEMENT PRACTICES ON BUILDING CONSTRUCTION SITES: A REVIEW

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***Abstract*—** Sustainable stormwater management practices (SSWMP) is an integral component towards green building. The proponents of green building (GB) have continued to realize the future benefits of green SSWMP on the built environment and the ecosystem. Better and greener ways of stormwater management are gradually been put to practice and this shows great promise. This paper presents a comprehensive literature review of sustainable stormwater management practices (SSWMP) on building construction sites among construction stakeholders. The review is based on various literature that have been published in peer-reviewed journals. Through a systematic review of recent literatures, generic sustainable stormwater management practices where identified. A number of SSWMP were identified from reviewing 54 selected past studies. The paper presents three categories of the SSWMP. The three main categories of SSWMP identified are: structural management practices, non-structural management practices, and low impact development. This paper would enhance policy makers' and advocates' understanding of SSWMP for GB and help to further promote the GB concept. This paper lays a solid platform for researchers to conduct further studies into the topic and makes contributions to the knowledge base. It is recommended to have a holistic thought of sustainable stormwater management approaches, allowing the most effective and efficient opportunities for integration of techniques into the planning, design, and the actual construction processes.

Keywords: Green Building; Stormwater management; Management practices; Structural management practices; non-structural management practices; Low impact development

I. INTRODUCTION

The shift from conventional to green or sustainable construction is on the increase the world over, and it places so much prominence on the need for a reduction on the impact building construction activities have on the environment and a reduction in resource use [1]. Sustainability of construction sites is one of the main rating criteria for green buildings, and stormwater management is a key component [2]. Major green building rating systems such as Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), Green Building Index (GBI), Comprehensive Assessment System for Building Environmental Efficiency (CASBEE), Building Environmental Assessment Method (BEAM) and Green Building Labeling–Assessment Standard for Green Building (GBL-ASGB) etc. have stormwater management as a criteria. Poor management of stormwater could have an adverse impact to the sustainability of the natural environment [3]. There is an urgent need for efficient stormwater control on building construction sites. Due to an increase in impervious surfaces, the natural patterns of water flow has been altered [4]. As a result, construction managers are increasingly devicing more environmentally sustainable means of stormwater management.

Due to an increase in building construction projects, there is an increase of paving surfaces, due to pedestrian walkways, road construction, and roof surfaces. These areas reduce the natural grasslands and vegetation which creates hard scapes [5]. These results in to the increase of rainfall runoff volume that causes erosion and flooding, peak flow, discharge duration, and pollutants been washed off to other waterbodies, which distorts the natural flow of water , pollutes water bodies such as streams and rivers, and general urban hydrology [6]. Waste and pollution transported by stormwater constitutes quantity and quality problems, affecting public health and the quality of the environment [7]. Aside the preservation the natural hydrologic functions, many studies have identified the possibility of stormwater management to reduce the pollutant loads in stormwater, especially for total suspended solids and heavy metals. Hence the need for a review of stormwater management practices.

II. RESEARCH METHODOLOGY

This study is based on a systematic and comprehensive review of relevant literature from past studies on sustainable stormwater management practices on building construction sites. Many construction management researches have used literature review as a methodology for promoting/increasing knowledge on specific topics or areas of interest [8]. The review was based on the review of academic literatures obtained through internet searches using scopus search engine, web of science and google scholar. The searches where done using the following key words and phrases; “stormwater management”, “low impact development”, “structural method of stormwater management”, and “non-structural stormwater management methods”. It is worthy of note that other key words

or phrases could be used for this literature search but the ones chosen was for convenience purposes to have a number of papers that can be adequately managed. 102 papers where initially identified but after going through them, 54 where deemed as best suited for this research based on the following criteria:

- Papers reviewed must be papers that where based on qualitative and/or quantitative methods of research
- The papers must be from peer reviewed journals.

The search was conducted under the "article title, abstract, keywords" "section with document type "article or review" and date range was set at "published all years to present".

III. REVIEW OF SUSTAINABLE STORMWATER MANAGEMENT PRACTICES

Stormwater management practices refers to practices/actions taken with the intention of either reducing to the barest minimum or completely eliminating the impact of stormwater runoff on the natural environment. After an extensive literature search several classifications of stormwater management where identified. Some studies classified stormwater management practices as source and non-source management practices while others classified them into three namely low impact development practices, structural and non-structural methods of stormwater management. But for the purpose of this study, the later categorization is preferred. This research therefore studies low impact development practices, structural and non-structural stormwater management practices

A. Low Impact Development

Low Impact Development is used as an alternative method of managing stormwater to imitate the natural flow of water through passive designs to control stormwater runoff at the source rather than controlling it at a centralized location in the watershed [9]. Some examples of low impact development include but are not limited to practices such as green roofs, swales, rain gardens, constructed wetlands, permeable pavements through the use of commonly used surface materials (porous asphalt, porous concrete, cement brick, ceramic brick, sand base brick, and shale brick)[10] and rainwater harvesting [9, 11]. The above LID practices have metamorphosed from ecological experiments to a regular practice based on laid down rules and norms [12, 13]. The various practices of low impact development has the capacity of reducing and possibly preventing the following; urban flooding, sewer overflows, preventing pollutants from construction sites gaining access to receiving waters, restoring the hydrology cycle, enhances the replenishment of groundwater, reduces urban heat island effect by evaporative cooling and helps promote and sustain wildlife [14-16]. Table I shows some low impact development practices for stormwater management as identified in peer reviewed literature with the corresponding sources.

TABLE I. LOW IMPACT DEVELOPMENT PRACTICES

Practices	Source
Permeable pavement	[4, 10]
Green roofs	[17]
Swales	[18, 19]
Rain gardens	[20, 21]
Constructed wetlands	[22, 23]
bioretention	[24]

There is no denying the fact that the conventional method of stormwater management uses best management practices to control flooding, the aim of low impact development is to incorporate more natural methods instead of infrastructures-based designs to provide solutions. A typology of a low impact development site is shown in fig 1. below. It shows how the many low impact development practices can be incorporated on the same site.

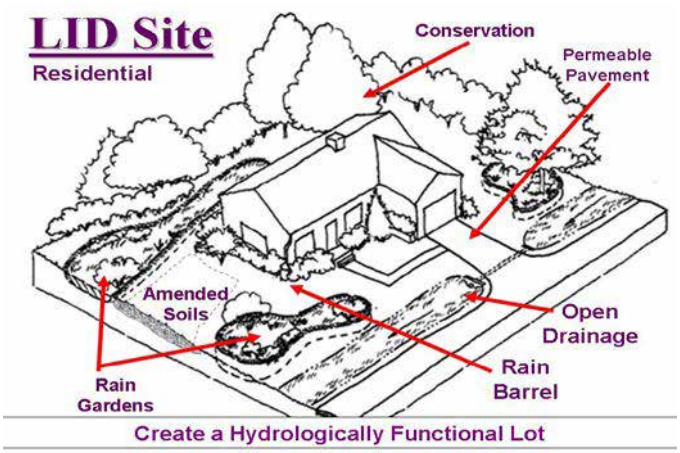

Fig. 1. Low impact development on site

B. Structural Stormwater Management Practices

Structural methods of stormwater management have been given different definitions by various authors. Moraes, Cancio [25], [26] defines structural stormwater management strategies as that which has its main area of interest in physical approaches and investments in engineered infrastructure for enhanced stormwater drainage. Structural methods of stormwater management involves treatment measures that are principally concerned with the collection, transportation or detention of stormwater with the aim of improving the quality of stormwater and also make provision for its reuse [27]. Structural stormwater management practices are classified into three types namely; source, pathway and receptor [28]. Some stormwater management practices using the structural approach are highlighted in table II below;

TABLE II. STRUCTURAL STORMWATER MANAGEMENT PRACTICES

Practices	Source
Diversion of runoff to garden beds	[29-31]
Rainwater tank/reuse scheme (ie. garden watering, toilet flushing)	[32, 33]
Infiltration and collection system (bio-filtration system)	[34, 35]

Native vegetation, mulching, drip irrigation systems	[36]
Dry detention basin	[37, 38]
Buffer strip	[39, 40]
Constructed wetland	[40, 41]
Pond and sediment trap	[40, 42]
Lake	[43]
Litter trap (gross pollutant trap)	[44]

C. Non-Structural Stormwater Management Practices

Pollution that results from stormwater flows can be mitigated by adopting non-structural approaches/strategies which is targeted at reducing the rate at which pollutants gain access to drainage systems from the building construction site [45]. This method is usually adopted in areas where flooding is inevitable and the resources to adequately manage the event of a flood is unavailable. They are generally cheap and flexible in nature. Non-structural stormwater management strategies for mitigation of flood impacts focus upon preventative action and rely predominantly on behavioural changes in order to be effective [45]. Non-structural practices can be in various forms such as a more comprehensive planning and resource management efforts [46], it could also be non-physical interventions such as regulation or education [47]. Table III. Presents some non-structural stormwater management practices.

TABLE III. NON-STRUCTURAL STORMWATER MANAGEMENT PRACTICES

Practices	Brief explanation	Source
Education and staff training(e.g. awareness raising and behaviour change campaigns)		[1, 48]
Solid waste management	Control of solids waste to avoid blockages and reduction in hydraulic capacity of the drainage system.	[49, 50]
Pollution mitigation (e.g. street sweeping)	Reduction in the discharge of pollutants that emanates from solvents and other building materials into the stormwater drainage system.	[51, 52]
Environmental considerations on construction sites		[53, 54]
Strategic planning and institutional controls		[1]

IV. DISCUSION OF FINDINGS

This study was set out to review the various stormwater management practices on green building construction sites. Several management practices where identified under the categories of low impact development, structural, and non-structural methods as presented in tables I, II and III respectively. These practices are discussed further in this section.

Low impact development practices as identified in table I are concerned about construction methods and processes that either assist in reducing the quantity of stormwater runoff onsite or reducing the speed of runoff mostly through natural methods. For instance green roofs reduces stormwater velocity and the use of permeable pavement aids in rainwater retention and reduction in the flow volume of stormwater. Typical examples of pervious/permeable pavement includes permeable asphalt or concrete, interlocking pavers, grassed paver surfaces, and many proprietary mixes for walking, driving, and parking surfaces etc. the infiltration rate of stormwater in permeable pavement varies from 2.4 to 4.0 mm/min [34] . The same can be said of other low impact development practices such as the use of swale, rain gardens, constructed wetlands and bioretention stormwater management practices.

The structural practices for stormwater management involves the construction of engineered structures to prevent flooding as highlighted in table II. This includes construction of drains to channel stormwater, use of stormwater storage tanks to collect rain water for use in the construction process and for other useful purposes on site. The structural methods of stormwater management as identified in table II are all aimed at preventing flooding through physical means or physical structures. From the literatures reviewed it is noted that when there is heavy downpour, the resulting stormwater can be diverted to garden beds which aids in reducing its speed through plant roots, and stems, thus preventing erosion of the soil. The collection of rainwater in rainwater tanks reduces the quantity of stormwater runoff and also reduces the likelihood of flooding. Other identified structural practices perform either one of the following purposes; prevention of flooding by creating channels for stormwater passage, preventing building materials or wastes generated on site from gaining access or entrance to water ways by providing barriers/traps, providing storages for stormwater collection and finally providing physical measures for reducing the flow velocity of stormwater.

For the non-structural stormwater management methods, behavioural change strategies including capacity building, social norms and commitment where advocated in the literatures reviewed as a means of reducing the inflow of pollutants into stormwater. Some of the identified practices been practiced globally include pollution prevention practices on site such as sweeping, strategic waste management plans before the commencement of the building project, management of solid wastes and preventing such waste from entering water drains, educating and training construction workers so as to create awareness on stormwater management practices with the sole aim of creating a change in behaviour. The application of non-structural methods aids in the reduction of litter in stormwater [54]. The behavioural changes brought about by the use of non-structural methods include; keeping stormwater drains clean and clear at all times, the storage and management of liquids or solvents used in construction works properly so as to prevent it finding its way into stormwater, securing loose materials and wastes, and finally avoiding the washing of construction tools and equipment into stormwater drains.

V. CONCLUSION AND RECOMMENDATIONS

There are several practices for stormwater management under the categories of low impact development, structural methods and non-structural methods. Each of these practices identified

from literature can be utilized depending on the peculiarities of the construction sites, the environmental and general climatic conditions of a given area. Also, the local construction laws, rules and regulations governing stormwater management practices in the geographical area where the construction is taking place is a major determinant factor in deciding which method of stormwater management to adopt. It is recommended that a combination of these practices should be blended for sustainable management of stormwater on building construction sites.

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