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Investigating the potential of applying vertical green walls to high-rise residential buildings for energy-saving in sub-tropical region

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ABSTRACT

In metropolitan cities like Hong Kong, residential buildings are mostly high-rise developments. These buildings do not have external insulation. In sub-tropical regions with mild winter heat loss from buildings in winter is insignificant and hence heat transfer from the interior of the building is low. Heating systems are rarely installed. However, heat transfer through the external façade into the interior is high in summer necessitating air-conditioning for thermal comfort and consuming large amounts of electrical energy. Vertical greenery, installed to the external walls of buildings, has been proved to be a good insulation system. This research studied the feasibility of applying a double-skin green façade, to high-rise residential buildings in Hong Kong in order to reduce energy consumption for cooling in hot and humid summer. The study concluded that substantial energy saving is possible. Further research on the application of vertical green wall systems to high-rise residential buildings is recommended.

Contents

1. Introduction

The metabolism of the city is responsible for the greatest consumption of materials, energy and water [1]. The construction of city buildings and infrastructure has been accused of causing environmental problems from excessive consumption of global resources in terms of construction and building operation, which pollutes the surrounding environment [2]. Energy is consumed to regulate the indoor microclimate. Greenhouse gases like carbon

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dioxide are released from mechanical cooling/heating systems. In sub-tropical regions, temperature rarely falls below 10 °C and central heating is not common in high-rise residential buildings. The external walls of these buildings are commonly constructed of 125–250 mm thick concrete without thermal insulation [3]. However, the temperature in summer can rise to over 30°C and heat gain through external walls is significant. Air-conditioning, which is operated by electrical energy, is the major cooling mechanism used in high-rise residential buildings. An important goal for the building sector is to produce buildings with minimum environmental impact [4]. This means that the building envelope in sub-tropical regions should be designed to reduce cooling load.

A green roof can provide a cooler interior environment [5] [6] [7]. In high-rise buildings the effectiveness of roof garden is limited as a large area of the roof is occupied by building services. However, the high wall to roof ratio can offer larger areas for planting [8]. The use of vertical green walls (VGW) as passive energy saving systems should therefore be explored [9].

Hong Kong has a sub-tropical climate and is characterized by high-rise developments [10]. The majority of the residential buildings are developed into high-rise blocks over 20 storeys [10] [11] offering large façade surface for installing VGW. This paper investigates the potential of applying VGW to high-rise residential buildings in Hong Kong to reduce cooling load and examines the feasibility of the implementing VGW solutions.

2. Green facades

The original concept of vertical vegetation can be traced back to the hanging gardens of Babylon [12], which were used to shade external façades from the hot sun. A VGW is facade system in which evergreen or deciduous climbing plants directly grow on walls or are potted in hanging containers in special supporting structures in a controlled fashion with regularly maintenance to cover the facades [9] [13] [14]. The design of VGW can offer multiple benefits depending on many factors, such as local climate, building orientation, plant species and system components [14]. A green façade can improve building energy efficiency and indoor air quality, reduce noise penetration, sequestrate carbon dioxide and protect building envelope [14] [15] [16]. It can also provide biodiversity and create natural animal habitat [14]. The aesthetic appearance can stimulate psychological positive effect as well as increase property value [14] [15]. Careful selection of plants suitable to the peculiar conditions of the particular types of vertical greenery system is vital to successful performance [17]. In this regard, local plant species, which have already adapted to the local climate and environment, are usually selected. Plants have the ability to dissipate the absorbed solar radiation into sensible and latent heat [15]. Foliage can improve thermal [18] and sound insulation [19] filtering dust and chemicals from air [14], produce oxygen and reduce carbon dioxide by photosynthesis. VGW can be considered as an external cladding [20] and insulation layer.

Green facades can be classified into 3 main categories (Fig. 1) according to the supporting structures as listed below [20]:

(A) Traditional Green Facades of which climber plants use the façade materials as a support
(B) Double-skin Green Facade (DSGF) of climbing plants, which are supported by a double-skin framework separated from the wall by an air space
(C) Perimeter Flower Pots where shrubs are grown and planted around the building

Type (B) DSGF is suitable for high-rise buildings as the double-skin framework can be constructed in modular panels which can easily integrate into the façade design (Fig. 2). The created air space between the vegetation skin wall and the façade acts as an insulation layer [13]. This study focused on exploring the potential of applying DSGF to reduce cooling load in high-rise residential buildings in Hong Kong.

VGW saves energy by four fundamental mechanisms: (a) the interception of solar radiation, (b) thermal insulation provided by vegetation and substrate, (c) evaporative cooling by evapotranspiration, and (d) acting as wind screen [9].

2.1. Shadowing effect

Vegetation can play an important role in regulating microclimate of buildings. By shading with plants a reduction in temperature between the external wall and the interior is created [21]. Many species of climbing plants raise their leaves in response to the high-angled sun creating a ventilation blind effect; in which the warm air is vented out at top and replaced by cool air from outside [22]. Solar transmittance of single and five layers of creeping plants, such as Virginia Creeper (a native plant in UK and North America), range from 0.43 to 0.14 [23] and can reduce solar radiation by about 40%–80% [17] [23] [24]. 5–30% of the remaining solar radiation passes through the leaves and affects the internal climate of the building [13].

Virginia Creeper is a deciduous climber which belongs to the grapevine family. The dense foliage blocks the high-angled sun in summer reducing glare. Leaves are shed in winter allowing the low angle solar radiation to enter the building [23]. Foliage protects the external finishes, such as the cladding, painting or tiles, from

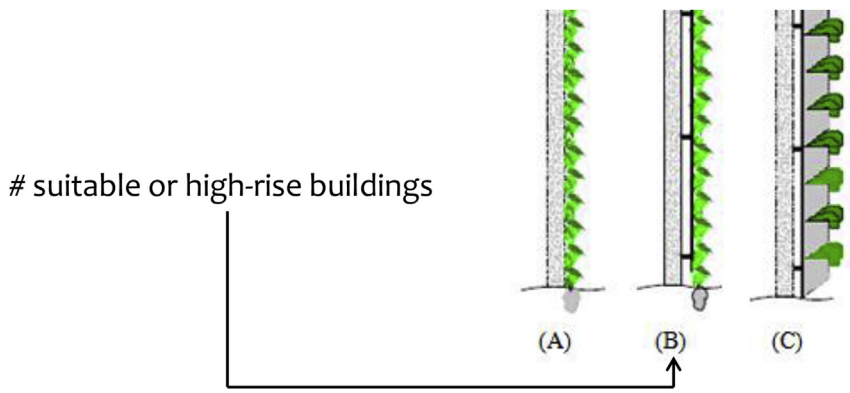

Fig. 1. Three main types of green façade [13].(For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)