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Building Integrated Vegetation Systems into the New Sainsbury's Building Based on BIM

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ABSTRACT: Today, there is a growing need of environment-friendly buildings, so-called 'green', facilities, and energy saving buildings to decrease environmental pollutants released into cities by construction activities. Green-Building Information Modeling (Green-BIM) is a purpose-built solution which supports to forecast energy consumption of 3-D model of a building by augmenting its primary 3-D measurements (width, height and depth) with many more dimensions (e.g. time, costs, social impacts and environmental consequences) throughout a series of sequential phases in the lifecycle of a building. The current study was carried out in order to integrate vegetation systems (particularly green roof and green wall systems) and investigate thermal performance of the new Sainsbury's building which will be built on Melton road, Leicester, United Kingdom. Within this scope, a 3-D building model of the news Sainsbury's building was first developed in Autodesk® Revit® and this model was then simulated in Autodesk® Ecotect®once weather data of the construction site was obtained from Autodesk® Green Building Studio®. This study primarily analyzed data from (1) solar radiation, (2) heat gains and losses, and (3) heating and cooling loads simulation to evaluate thermal performance of the building integrated with vegetation system or conventionally available envelops. The results showed that building integrated vegetation system can potentially reduce internal solar gains on the building rooftops by creating a 'bioshade'. Heat gains and losses through roofs and walls were markedly diminished by offering greater insulation on the building. Annual energy loads for heating and cooling were significantly reduced by vegetation more significantly through the green roof system in comparison to green wall system.

KEYWORDS: BIV (Building Integrated Vegetation), BIM (Building Information Modeling), BGD (Blue Green Dream) Project

1. INTRODUCTION

1.1 Objective

The environmental impact of construction activity coupled with the rising cost of energy has become an unavoidable issue for many construction companies, government and the public to face urgently. Hence, professional parties, including architects and designers, who share important virtual in–formation model of a building using building information modeling (BIM), bear undisputable responsibilities towards the built environment by adhering to climatic identities and therefore able to achieve a significant energy reduction without compromising quality of life. Forecasting building energy performance can be used as a decision support system during design phase before changes become too costly during post–designing phases.

Amongst a wide range of passive and low energy building systems available to the public, massive integration of vegetation in architecture which is also known as building–integrated vegetation (BIV) system is witnessing a rapid growth in both research and market development[(1).] Although their adaptation still remains relatively limited and slow in the UK, there is an urgent need to refurbish the existing non–domestic building typology in order to satisfy the UK government policies contributing to greenhouse gas reduction target[(2)].

The overall objective of this project is to analyze interaction of BIM and use it as a test case in evaluating energy performance of the new Sainsbury's building which will be located on Melton road, Leicester, UK by applying this building integrated vegetation system

1.2 Extents and methods

Three main steps were conducted in order to carry out this study. Firstly, a 3–D model of Sainsbury's building was drawn using Autodesk® Revit® 2013 software. Secondly, weather information in the area of the new construction site was

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obtained from Autodesk® Green Building Studio® and Autodesk® Revit® 3-D building model exported into Autodesk® Ecotect® analysis software. Lastly, the energy performance in regards to the solar and heat influences on the building was measured by Autodesk® Ecotect® Analysis software

2. BIV & BGD Project

2.1 BIV (Building Integrated Vegetation)

Urbanisation has changed the appearance of green infrastructure in the urban residence by degenerating open green space with materials in the rooftops of buildings such as bricks and concretes. For instance in Greater London alone, buildings (and therefore the rooftops) spread through a remarkable 24,000 hectares or 16% of the overall area (Greater London Authority, 2002). It is a striking to learn that every year; 0.4 hectares per one acre of vegetation in a city park can take up an amount equivalent to CO_2released from driving an average for 41,000 km (26,000 miles) [7]. Hence, one of the undisputed ways to restore green surfaces is by integrating gardening system or vegetation (grass, small crops, pergolas, or even trees) on the building elements not used as functional space, including defunct roofs and walls. These vegetated surfaces can significantly change the microclimate around them, and if this is applied on an urban scale, the thermal effect could be noticeable for the whole city. More specifically, there would be a direct effect on energy savings from air conditioning buildings, on outdoors thermal comfort, in addition to the air quality improvements [8], psychological benefits for urban dwellers [9] and, if designed properly, aesthetics.

BIV system consists of green roofs and green walls in which the term 'green' can embrace broader meanings including 'living', 'breathing', and 'vegetation'. The BIV system in architecture offers numerous visual, social, economic and environmental benefits to the urban area at a private to public scales. In particular, green roof system are well recognized by effectively alleviating the urban heat island (UHI) effect, enhancing building energy performance, reducing storm water run-offs and improving water and air quality. Along with these many advantages provided from green roof systems, research into green wall system has also became a center of current interest focus since the exterior wall accounts much more than the rooftops of a building[10].

2.1.1 Green Roof

The term "Green roof" is largely subdivided as a roof garden of usually ornamented planting or a fertile area which has been specially designed to colonise and develop naturally [11]. The categories of green roofs which have been identified by the German Landscape Development Research Society are three according to their use, construction method and maintenance requirements of the roof; the intensive, the extensive and the simple intensive roof [8].

Intensive green roofs are the equivalent of parks and gardens at a roof level. Their soil layer is generally at least 15 cm deep and vegetation on them might vary from grasses to shrubs and trees. They are usually constructed on flat roofs, reinforced to bear the weight of vegetation and normally they are accessible. They are usually more expensive to construct and maintain than extensive roofs. Extensive green roofs are vegetated with grass and, in general, ground covering plants. Their soil layer depth is between 2 and 15 cm. Normally, they are not intended for regular human usage. Their static loads are not so large (approximately 0.50 kN/m^2)[12] and can be placed on either plane or tilted roofs. Generally, they are less expensive to build and maintain. The final classification, is the simple intensive green roof, which is in-between the intensive and the extensive roof. Usually it is covered with grasses and for reasons of completeness, the term "green-sky" is introduced here; with this term, the formation of a pergola is described, which creates a shaded space on the roof or at the building's yard (Figure 2-3C). The soil layer is not on the roof itself, but inside containers, or even on the ground for low level constructions. From a construction point of view, these elements could not be described as green roofs. However, from a micro climatic point of view, they act as a horizontal layer of green above the roof, creating an outdoors shaded space in between.

2.1.2 Green Wall

Green walls, or green façades, describe a system where vegetation is applied to the vertical elements of a building. The planting medium is usually not adjacent to the building element, but to another surface, either the ground or a container. For reasons of classification, four types of green walls have been distinctive; the green wall, where creepers and ivies climb directly on the wall, covering the wall layer. The green wall adjacent to the building, where creepers, ivies and plants generally climb over a construction adjusted to the wall, leaving an air gap between the wall and the construction. Third type is the green curtain, to describe the case where greenery is not climbing on the wall or an adjacent construction, but plants hang loose in front of the building, without any structural support. The last type is the living wall system, which can be attached to improve interior air quality by air filtration.

2.2 BGD (Blue Green Dream) Project

As previously described, there has been a desperate need to initiate a genuine paradigm shift for the fight against uncontrollable climate changes which are heavily due to the consequences of excessive investment in urbanisation. Most desirable planning and management of new buildings and urban developments are required to embrace environmental factors to minimise manmade environmental impacts yet maintaining the socio-economic benefits from these developments. Particularly, a newer sustainable development programme is urgently required to synergise blue assets (e.g. water systems) and green assets (e.g. urban vegetated areas) from the ecosystem as one entity as they are often approached as two separate elements

In pursuit of dedication to ensuring preservation of the environment, world-class experts from Climate-KIC and numerous consultancy firms from 4 countries (Germany, United Kingdom, France, and Netherland) have launched the Blue-Green Dream project. Climate-KIC is Europe's largest public-private innovation partnership focused on mitigating and adapting to climate change. Currently, leading public-private European networks are working together to couple a new paradigm in bridging blue and greet assets at various scales across urban areas obtain a wide range of multiple benefits as illustrated in the next page;

3. Methodology

3.1 Background

The future development plans for the new Sainsbury's

Figure 3-1 Area plan and orientations of proposed new Sainsbury's building

building include the construction of new Supermarket of 11,757 m^2 (126,552 ft^2) Gross Internal Area, with 11,894 m^2 (128,027 ft^2) gross external area at ground floor level for ancillary car parking and associated service facilities such as petrol filling station, car wash and jet wash. Area plan and orientations of proposed new Sainsbury's building is illustrated in Figure 3-1.

More specifically, proposed store provides a conforming sales area, allowing Sainsbury's to provide a more spacious environment, improving customer circulation and clarity of retail offer. The customer cafe, located at ground floor, is in a highly visible position providing activity to the western, shop front elevation and to the southern elevation to Troon Way.

3.2 Methodology

Within this scope, a 3-D building model of the news Sainsbury's building was first developed in Autodesk® Revit® and this model was then simulated in Autodesk® Ecotect® once weather data of the construction site was obtained from Autodesk® Green Building Studio®. Layers of green wall and green roof were created also using Autodesk® Ecotect®. Similar with the simulation model of a climber covering wall created by Holm et al [26] in 1989, green wall consisting of three different elements; including leaves, stems and air gaps, were used in this study. Figure

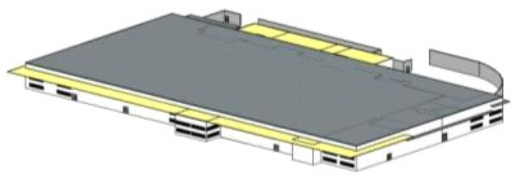

Figure 3–2 Simplified building design using Autodesk® Revit® (3–D view)

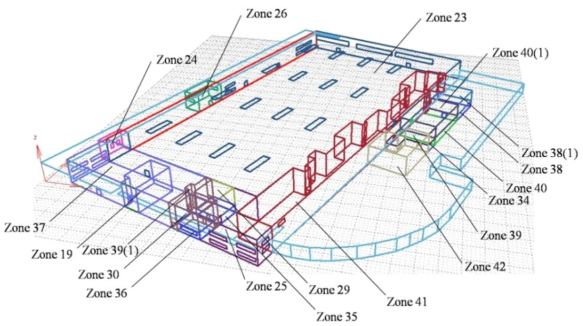

Figure 3–3 Autodesk® Ecotect® showing 3–D building model with a detailed layout of all zones on both Level 1 and 2 after importing gbXML file generated from Autodesk® Revit®

3–4 shows the horizontal cross–section of the green wall system used for simulation. Softwood (stem) with a thickness of 15 mm was chosen to illustrate stems of Ivy and its density of 550 Kg/m^3 was decreased by 80% to make it equivalent

Table 3–1 Zone setting properties

Zone	Types of system	Common properties of the Sainsbury's building
19	Full Air Conditioning	Lower Band: 19 °C Upper Band: 24 °C Sensible Gains: 5 W/m^2 Latent Gains: 2 W/m^2 Air Change Rate: 0.5 Air changes/hr Wind Sensitivity: 0.25 Air changes/hr Hours of Operation Weekdays: on–7:00 am to off–24:00pm Weekends: on–8:00 am to off–19:00pm
23	Heating Only	
24	None	
25	Full Air Conditioning	
26	None	
29	Full Air Conditioning	
30	Full Air Conditioning	
34	Heating Only	
35	None	
36	None	
37	Full Air Conditioning	
38	Cooling Only	
40	Cooling Only	
38(1)	Cooling Only	
39	Heating Only	
40(1)	Cooling Only	
41	None	
42	Heating Only	
39(1)	Full Air Conditioning	

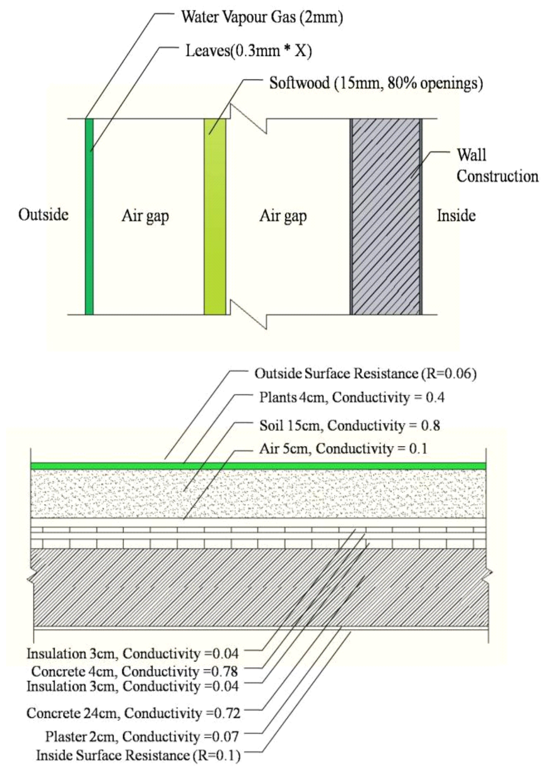

Figure 3–4 Green wall setting and green roof setting (Autodesk® Ecotect®)

to 20% stem mass within the green wall layer. A layer named 'water vapour' was added with a consideration that a sub–stantial amount of water can be evaporated from green leaves. To note, the thermal performance was determined on the new Sainsbury's building models with two different green wall system one supplemented with reinforced concrete (labelled as 'heavy') and the other supplemented with timber frames (labelled as 'light'). The properties of each component of a heavyweight and lightweight layer were manually added into Autodesk® Ecotect®. Once the green wall setting was completed, external wall of Autodesk® Ecotect® were selected, in order to compare the thermal performance of the building these green wall systems or other conventional wall systems (Brick plaster, Concrete block plaster, Framed plasterboard). Also, as shown Figure 3–4, green roof systems were set from green roof layers of other literatures. This study primarily analyzed data from (1) solar radiation, (2) heat gains and losses, and (3) heating and cooling loads simulation to evaluate thermal performance of the building integrated with vegetation system or conventionally available envelops.

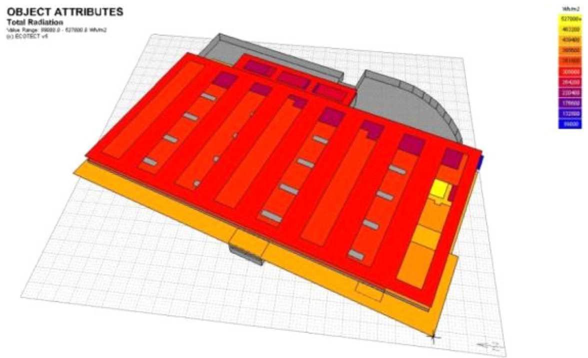

Figure 4-1 The annual solar radiation for the green roof surface (Autodesk® Ecotect®)

4. Results

4.1 Green Roof – Solar Gain Analysis

Figure 4-1 and below tables (Table 4-1 and Table 4-2) illustrate summary of the summer, winter and whole year values of internal solar gains of the new Sainsbury's building incorporated with either conventional roof or green roof. It is clearly illustrated in this figure that almost a half of whole year internal solar gain is obtained in the summer with the conventional roof. The solar gain in the winter has almost a negligible contribution to the whole internal solar gain in a year. The data from green roof or 'shading device' simulation study clearly demonstrates that the level of internal solar gain drops significantly during both summer and winter, and this effect corresponds to the overall reduction of internal solar gain of the whole year.

To illustrate further, green roof which was designed to cover roughly 50% of the rooftop of the new Sainsbury's building can effectively provide 42% of internal solar gain reduction throughout the year. This proves that green roof can act as an effective cooling device by naturally reducing the building heat-gain. In long terms, green roof can potently provide thermal comfort within the building without a significant need of energy required for cooling and air conditioning.

Together, green roof can be certainly used to improve the energy efficiency of the new Sainsbury's building by maintaining the internal temperature as demanded and not influenced by the external solar gains in Leicester.

Table 4-1 The results of the annual internal solar gain using conventional roof

	Summer	Winter	Whole year
Annual internal solar gain	1,247,788.149 Wh/ m^2	182,488.995 Wh/ m^2	2,725,516.862 Wh/ m^2

Table 4-2 The results of the annual internal solar gain using green roof

	Summer	Winter	Whole year
Annual internal solar gain	725,503.263 Wh/ m^2	108,596.043 Wh/ m^2	1,590,975.872 Wh/ m^2

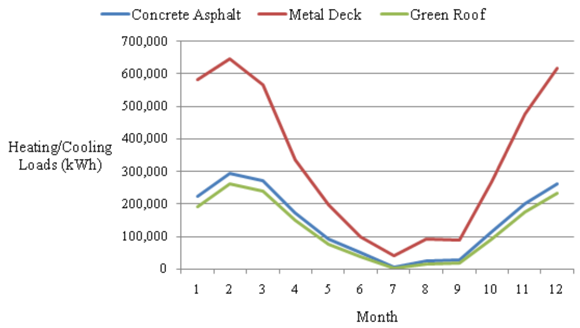

Figure 4-3 Annual heating and cooling loads three different materials of roof

4.2 Green Roof – Thermal Analysis

Green roof system has also shown to reduce annual heating and cooling loads in comparison to concrete asphalt system by 15% overall throughout the year.

4.3 Green Wall – Thermal Analysis

These results have shown that green wall system placed on the new Sainsbury's building does not have a prominent impact for the system to effectively lower the heating and cooling loads (Fig. 4-4).

Instead, green wall system provides location-dependent benefit to the building thermal performance. Further studies

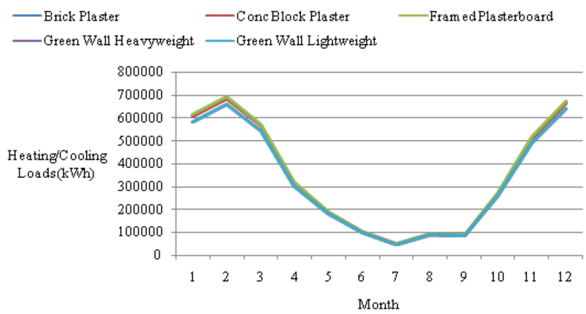

Figure 4-4 Annual heating and cooling loads three different materials of wall

Table 4-3 Positive and negative effects of using green wall in zones

	Zone
Positive Effects of Heating/Cooling Loads	19, 23, 25, 34, 37, 39
Positive Effects of Annual Passive Heat Gains	24, 26, 36, 38, 40
Negative Effects of Heating/Cooling Loads	38, 38(1), 40(1)

were required to view dissected vision of individual zone and investigate the level of benefits offered by green walls in each zone.

5. Conclusion and Discussion

Combining these two wall systems of these two wall systems allows energy saving up to 1,707.1 kWh required for heating and cooling loads rather than using single wall system using a green wall heavyweight system only.

Also, when this recommended system is assumed to be installed in practice, the new Sainsbury's building is expected to reduce up to the amount summarised in Table 5-1.

In terms of the energy consumption aspects of this project, future work is be required to fully assess a cost-benefit analysis and compare these data with the initial cost of investment to measure the payback time and calculate the future cost and benefit of using BIV system. This study will certainly help to guide decision-making processes involved throughout the life cycle of a building.

In terms of the physical properties of green walls and green roofs, a deeper understanding of the actual properties of vegetation is required in order to decide on the best choice of plants. For instance, the viability of insects growing within the greenery should be thoroughly investigated so that the chosen BIV system does not compensate its thermal benefit from increasing the risks of having insects residing near or inside the supermarket.

Table 5-1 Recommended wall system on each zone (as highlighted as red) to deliver most effective energy saving to the new Sainsbury's building

Zone	Brick (Wh)	Conc (Wh)	Framed (Wh)	GreenH (Wh)	GreenL (Wh)
19	38949476	38186996	40181816	35997252	36182532
23	3510566912	3478607616	3535118848	3401606912	3402210816
25	130912112	127807584	135561344	118461488	119438896
29	21751682	21767958	21818394	21791124	21804240
30	21021422	20190180	22144994	17851792	18054014
34	9636702	9242339	9778358	8202716	8202847
37	256250736	249210304	266523024	229916224	232003856
38(1)	6104927	6198320	7724857	6948732	7576457
39	42955120	42955120	43378928	41131840	41143872
39(1)	25446470	25104372	25702920	24232292	24240322
40(1)	9902438	10267895	11116100	10718747	11092074
42	95644032	91575424	99352352	80302344	80538000

Table 5-2 The amount of energy saved from heating and cooling loads from recommended wall system when compared to three conventional wall systems

	Brick plaster	Concrete Block plaster	Framed plasterboard
Recommended model	4.2%	3.1%	5.3%
	173,539 kWh	124,962 kWh	222,826 kWh

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