A Review on Blue Roofs in New UK Constructions

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Abstract:

Flooding causes significant risk to the UK's infrastructure and the need for additional stormwater management systems is growing rapidly. The demand for housing, lack of land, cramped housing with no gardens, urban cooling, air pollution and aesthetics are all the issues that the Blue Roof System (BRS) can assist with. This paper reveals that there is a lack of knowledge, research and understanding of terminology for BRS in the UK construction and therefore more research and data collection is required to increase the utilisation of these systems. The government planning policies should be encouraging/enforcing flood risk management systems to be implemented as standard with financial incentives.

1. Introduction

The management of rainwater in new build developments are typically through the use of Sustainable Urban Drainage System (SuDS) ponds to control flooding. Rainwater harvesting systems can also be an option. However, the need for large storage tanks inside the building or underground cause space-related issues. BRS in the future may be a feasible option to help both gaining more space for development and help control flooding.

A BRS is a Sustainable Urban Drainage System (SuDS) used to manage storm water, promoting the prevention of flooding [1]. It is a system that is particularly used in urban developments on large flat roofed buildings. BRS are used globally with potential demand for future use in the UK. The objective of the BRS is to store some of the storm water from the roofs surface temporarily and allow it to slowly drain away in a controlled manner to rivers and sewers systems [1]**.** The more developed areas become, the less natural drainage there is - lack of plants and trees to soak up additional/general rainfall and more hard standing areas, paving and roads. The actual technology of the BRS depends entirely on the design / type of BRS and the requirements of the roof top [2].

BRS can be used on inverted, warm, or cold roof system [3]. An Inverted Roof System (IRS) is made up of various layers with the insulation directly on top on waterproof membrane whereas the warm roof has the insulation directly under the waterproofing and the cold roof has the insulation under the roof support [3]. Figure 1 shows some sections of BRS types although the actual details/configuration of the design relies heavily on the companies' patents and the materials they choose to use and trust.

Combining the different BRS together with an additional yellow roof (solar PV's on the rooftop) is also an option.

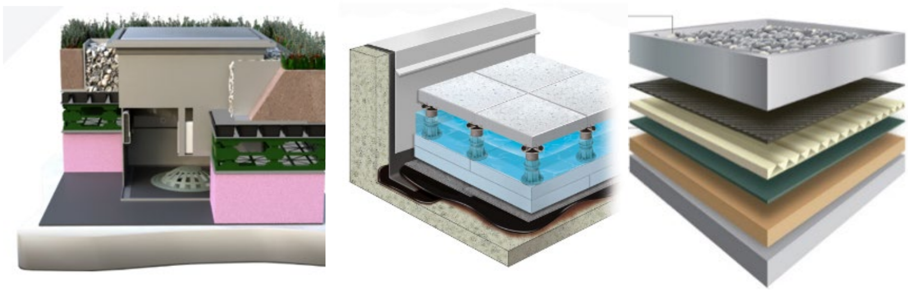

Figure 1 – From left to right, blue-green [4], Podium/paver deck [5], Modular Tray Blue Roof [6]

Some potential problems that may occur with a BRS could be inadequate installation - water may penetrate the roofs membrane causing water damage to the building, maintenance cost and extra load on the structure [3]. Furthermore, there is a lack of consistency in literature over the terminology of Blue Roofs (BR) / Blue-Green Roofs (BGR) and Green Roofs (GR). The table below compares these systems:

Table 1: Blue Roof, Blue-Green Roof, Green Roof similarities and differences

Similarities	Differences
-Used on flat/zero fall roofs (GR, BR, BGR) -Used for commercial & residential buildings (GR, BR, BGR) -all SUDS (GR, BR, BGR) -Retention of water/evaporation (GR, BGR) -retention of water (BR, BGR)	-Attenuation system with no green layer or vegetation on top (BR) -Has an attenuation system layer below green roof, layer or some form of vegetation on part of the roof (BGR) -Has no attenuation system under green roof layer (GR)

Case studies and reports have suggested that when a Blue-Green roof has been included in part of the design it has been referred to overall as 'Green Roof/Green Infrastructure', 'Green-Blue Roof' is also referred to as 'Green roof with retention layer'. This may cause a barrier to the blue roof market as figures showing the installation of them are not accurate and confusing different technologies hindering the BRS to become an independent and well known understood product [7].

2. Market sector and applications

BRSs are currently used in residential housing and non-residential buildings such as industrial, commercial, educational, and medical buildings as flood management systems to prevent flooding in properties and developments in the UK and globally. A study in Edinburgh, based on a new build residential development of 110 homes/HA with a requirement for a SUDS pond area of 0.37m/HA found that the space used for the suds ponds would be the equivalent space of 40 units (homes) [8]. With the demand for housing and lack of space, BRS could be used in developments to allow more housing on development plots.

The Ministry for Housing, Communities and Local government stated that in 2019, over 241,000 new builds were developed, with future plans to increase that to 300,000 new homes annually [9]**.** They have also suggested that the intention is to demolish certain commercial, industrial and residential flats and rebuild them with more sustainable designs, with bigger housing and taller high-rise blocks [9]**.** The demand for housing developments and drainage systems/ flood management will increase although figures regarding those systems to be implemented are not available currently. According to the UK Government, currently there are 161 schools in England included in the rebuilding programme, to be either demolished and rebuilt or extensive refurbishment [10]**.** BRS could be used as there will be large roof areas available. Combining podium decking, BRS and solar systems could be a major benefit to the schools as a landscaped rooftop garden/learning space. There was no mention of the rest of the UK although in it appears that the condition of 90% of Scottish schools are in satisfactory / good condition [11]. The Newcastle Declaration 2019 recognises the need for Blue-Green Infrastructure and plans to increase this in new developments [12]. It has also highlighted the preference for flood avoidance rather than repairing the damage caused [12].

The UK government has stated that the Environmental Agency has estimated that over 5 million businesses and homes in England are at flood risk over the next 2 decades due to climate change [13]. Since 2015, 242,000 homes were provided with more protection using over 700 new schemes for flood defence [13]. Due to climate change, the costs for maintaining and preparing flood defences is estimated to increase by 20-70% annually [13]. The Scottish government has estimated that over 280,000 properties are at flood risk [14]. In Scotland, overall flood risk is managed by Scottish Environment Protection Agency (SEPA), although the policy on flooding lies with the occupier to protect the actual property. Local Flood Risk Management Plans will benefit a portion of properties through the Formal Flood Scheme, but thousands will not [14]. Therefore it would be beneficial to implement BRS into new build developments to help manage current flood risk and prevent further increased flooding.

Based on the Green Roof figures in the UK there were about 700 green roofs in Central London in 2014 [15]. There appears to be no update from the government on this or figures for the rest of the UK. Although, data gathered for the Green Roof Market Report in 2017, claims that London has installed about 42% of UK green roofs with an annual growth rate of over 17%. It has also suggested that the main driver for the green roofs in London are due to planning policies [16].

Green roofs are used to tackle the flooding issues and urban cooling. The Urban Heat Island Effect is the temperature difference between cities and the countryside. This happens when the cities hard surfaces absorb sunlight, accumulating heat which is then released from the surfaces at night. This creates cities to become hotter creating a microclimate and causes increased air pollution. Urban Cooling reduces the heat of the air reducing the Urban Heat Island Effect. This is achieved by the evaporation of moisture in plants, soil cooling and improving air quality [17]. Table 2 compares performance criteria of the BRS and Table 3 shows different roofing requirements and possible types of BRS to suit them and where they could be used.

Table 2 BRS performance criteria

Thermal conductivity of roof – Heat	[18] reported 64.9% increased thermal transmittance for a limestone clay aggregate BR when wet in Spain	[19] reported an average of 40% higher roof temperature than in standard roof temperature in Italy.	[20] reported BR was highest for below membrane temperature at 24.6°C compared to BGR 22.7 –24.5°C & GR 21.8 - 23.4°C in Canada
Cooling – reduction of surface temperature	[20] reported a 2.92°C cooling effect for BGR & 2.2°C average for BR in Canada	[21] reported 5°C reduction on a BGR in South Korea	[19] reported 5%-7% reduction on a BGR in compared to standard roof surface temperature in Italy. [22] reported 40% higher surface temperature on a traditional roof compared to BGR in Amsterdam
Evapotranspiration Rate	[23] reported high allowance rate at 70% for BGR in Amsterdam. 40% more than standard green roof reducing heat stress	[24] reported 300mm – 600mm per year and upto approx. 80mm per month dependant on season for a BGR in Amsterdam	[22] reported 43 L/m2 evaporation for BGR compared to 18 L/m2 for GR in Amsterdam
Absorption – Retention Capturing rainfall	[23] reported 70%-97% on BGR in Amsterdam of extreme precipitation	[25] reported 85%-88% of absorption using BGR in Canada	[20] reported 49%-63% for BGR & 32% BR cumulative retention in Canada.
Outflow / Runoff	[26] reported 0.1l/s (litres per sec) compared to normal roof at 0.3l/s for a BGR in South Korea	[24] reported up to 80mm per month compared to normal roof of 75mm p/m depending on season, for BGR in Amsterdam	[27] reported BGR 38.6% increased runoff reduction compared to GR. With increased storage in BGR this increased to 78.6%

Moisture Resilient	[28] reported an average of approx. 25% of volumetric water content for BGR in Germany	
Hydraulic Capacity	[18] reported 4.8% increased hydraulic capacity for a limestone clay aggregate BR in Spain	

Table 3. BRS types and roof use

Blue Roof Type	Building Type / Roof Use
Podium Deck – walkable surface	-Residential properties with lack of garden & shared spaces / communal -Commercial – roof top bars & restaurants, shopping centres & airports -Educational & Health
Blue-green – green roof with additional drainage & storage layer	-Residential properties with lack of garden & shared spaces / communal -Educational & Health
Blue-green: biodiverse – no access, designed for wildlife, nature and aesthetics	-Residential – biodiversity for wildlife and nature -Possibly used in industrial and commercial settings, possibly to build up
Modular Tray – movable tray system	-Used on its own or alongside other blue roof systems
Combination: podium decking / blue-green / modular tray (and/or) yellow (solar). Used for a landscaped usable space	-Schools – learning space -Hospitals – garden for mental health and healing -Care homes – garden for elderly, mental health, mobility -Residential - Large multistorey flats / communal spaces

3. Regulations and Policy alignment

In the UK, there seem to be a lack of policy drivers for BRS. In England, the National Planning Policy Framework states that there will be an obligation for new developments to deliver biodiversity net gains to enable wildlife and nature to be preserved (29). Section 14 suggests that in new developments there is a requirement to improve in green infrastructure to reduce flooding impacts and use natural flood management systems. Section 15 expresses the importance of enhancing biodiversity in the natural environment [29]. The Mayor of London planning policy 5.11 also states green roofs should be used where feasible [17].

The City of Edinburgh Council City Plan for 2030, highlights the future requirement for green blue infrastructure in developments. They have suggested that contributions towards green-blue network offsite will be required if not integrated into development (30). The guidance for Blue Roofs is sparce and the Construction Industry Research and Information Association – CIRIA is working on developing more guidance for the Blue Roof industry [31]. The main Trade Associations for roofing are Single Ply Roofing Association (SPRA), Liquid Roofing and Waterproofing Association (LWRA) and National Federation of Roofing Contractors (NFRC) [17]. The Blue roof's success is reliant on the supplier being trained/experienced in installing correctly and inspected properly [32]. Table 4 shows the existing UK standards/guidance and their scope.

Table 4 UK standards for BRS.

Type	Standards / Guidance	Covers
British Standards for Flat Roofs [33]	BS 6229:2018	Flat Roofs (all aspects)
	BS 6229:2018 – 3.7.1 BS 6229:2018 – 4.2.2 BS 6229:2018 – 4.3 BS 6229:2018 – 4.5 BS 6229:2018 - 4.6.2.4 BS 6229:2018 - 4.7.2 BS 6229:2018 – 4.10 BS 6229:2018 – 7.2	Blue Roof Inverted Roof System Structure Rainwater Disposal Blue Inverted Roof Surface Condensation Surface Protection Inspections
National House Building Council [34]	Chapter 7.1.13	NHBC Standards – Blue Roofs
The Gro Green Roof Code [17]	Section 2.2.5 Section 5.2.5 Section 6	Relevant information on standards covering all areas of construction for Green and Blue Roofs
Local Authority Building Control [2]	Blue Roof Guidance Section 11	Warranty for Blue Roofs

The adoption of BRS in the UK is hindered by the lack of strong policy drivers. While there is some recognition of the potential benefits of them in reducing flood risk and improving water management, there is no clear strategy or guidance on how to implement and incentivize the use of them. In England, the National Planning Policy Framework (NPPF) acknowledges the benefits of SuDS which can include BRS, but does not provide specific guidance on how to encourage their use. In Scotland, there is even less policy guidance on BRS, and there has been little focus on incentivizing their implementation.

This lack of policy support may be due to a number of factors, including a lack of awareness of the potential benefits of BRS, concerns over the additional costs and maintenance requirements associated with these systems, and a focus on more traditional flood risk management strategies such as river engineering and hard flood defenses. However, with increasing concerns over climate change and its impacts on flooding, there is a growing recognition of the need for more sustainable and integrated approaches to flood risk management. As such, there may be opportunities to develop stronger policy drivers for BRS and other SuDS. Table 5 provide a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis of the BRS.

Table 5. SWOT Analysis of BRS:

Strengths	Flood risk management Added space on rooftop Urban cooling Space saver on housing developments / houses Multi-functional Roof membrane protected from radiation – longevity
Weaknesses	Structural & weight implications Additional costs compared to traditional roofs More maintenance required than traditional roofs Prevention of adding dormer windows Loss of attic space
Opportunities	Possible use as an allotment space Community gardens / learning spaces Improve air quality (BGR) Integrate nature / wildlife into urban areas (BGR) Use on most new build developments
Threats	Lack of research / knowledge Terminology / Confusion for different systems Resilience to use a new system / reluctancy for change Lack of investment in systems Not many incentives Lack of government guidance

4. Conclusion

There is a growing need for flood risk management systems to assist in future house building to prevent and improve the flooding issues. This has gained greater importance due to the frequency of extreme weather events as a results of changing climate. There is also an appeal for green roofs to be integrated into cities for aesthetics, air quality improvements, biodiversity, and urban cooling. This paper establishes that BRS is a viable solution in the UK across various types of construction projects, including residential, commercial, and industrial developments. BRS can effectively address multiple concerns, such as space utilization, stormwater management, aesthetics, urban cooling, and air quality.

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