Project Cavendish, Sheffield City Centre

SuDS used

- *Blue roof storm water attenuation system with paved, ballasted and extensive green roof surface finishes*

Benefits

- *Attenuation of storm water to help meet a challenging allowable overall site discharge rate of 110 l/s over a total catchment area of 6,782m^2. Blue roofs helped as part of the SuDS strategy on 4,220m^2 of the roof areas onsite.*
- *The blue roof areas restricted the flow rate to 24 l/s, covering 62% of the catchment area but only contributing 22% to the permitted site discharge.*
- *Both living roof and blue roof systems are rated some of the most sustainable 'at source' techniques within the SuDS hierarchy. The roof areas incorporating a green roof surface finish provide biodiversity and a valuable ecosystem for local wildlife.*
- *Terrace areas provide valuable amenity space for the building's tenants in the centre of the city.*
- *Filtration and separation geotextiles within each 'blue roof' restrictor chamber and around the attenuation voids, in addition to the natural green roof surfaces, help to improve water quality, removing pollutants from run-off before it is drained via the rainwater outlets into the sewer system and ultimately the local river network.*

1. Location

Grosvenor House, 1 Wellington St, Sheffield City Centre, Sheffield, S1 4HP

2. Description

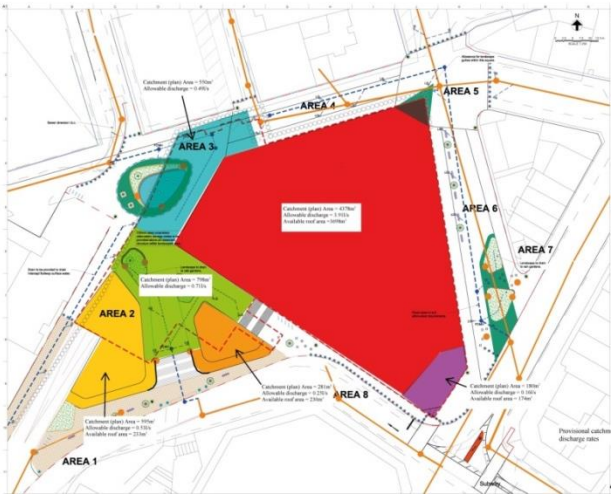
Project Cavendish is the development name for a new 6 storey commercial building and adjoining food and beverage pod constructed in Sheffield City Centre. The finished building has been renamed Grosvenor House and is designed to a detailed client brief from HSBC, who moved into the offices in June 2019. The main block (D) occupies the site of the former Grosvenor Hotel and the Charter Square roundabout / subway, providing circa 15,000m^2 of office floor space over four levels; including a central atrium, two levels of retail accommodation, a screened roof-top plant area,

basement car park, service area, and associated works. Significantly, the building is the first finished element of 'Heart of the City II', a £500m council-backed project to redevelop the city's shopping district. The sustainability credentials of the building were assessed according to BREEAM for the retail elements of the scheme ('Very Good') and LEED for the office element of the scheme ('LEED Silver').

3. Main SuDS components used

In accordance with the National Planning Policy Framework (NPPF), local planning authorities should prevent both new and existing developments from contributing to, or adding to the risk of flooding and water pollution. The Sheffield Development Framework 'CS67 Flood Risk Management Policy' listed a number of requirements for the new development to reduce the extent and impact of flooding, by significantly limiting surface water run-off and requiring the use of Sustainable Drainage Systems on all sites. A site 'Flood Risk Assessment and Drainage Strategy' prepared by Arup was implemented to address these requirements; including a combination of green, brown, and blue roofs and lined permeable paving. Early consultation with Yorkshire Water and Sheffield City Council defined the constraints on discharge of surface water from the development area. The allowable rate of run-off / discharge to public sewers was to be a reduction of 30% on the existing rate of run-off from a 1-in-1 year rainfall event. This was estimated as 110 l/s, encompassing the total 6,782m^2 catchment area. The surface water had to be controlled on site for up to 1-in-100 year return period events, plus a climate change allowance of 30%.

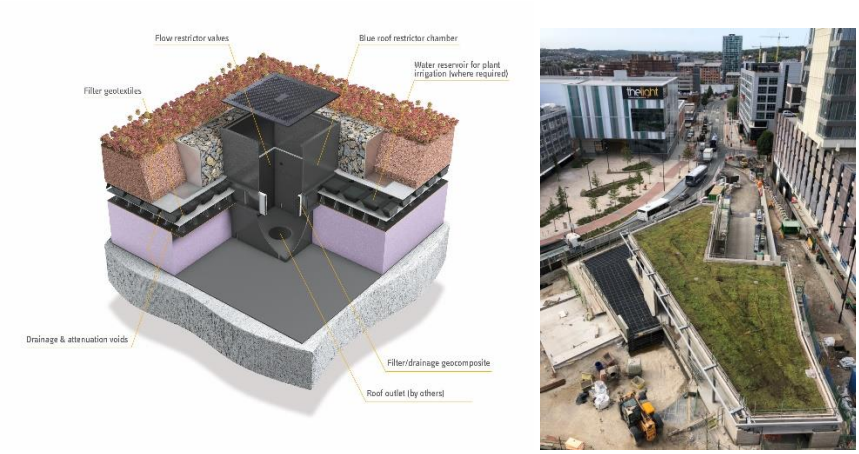
The SuDS attenuation for the buildings is provided at roof level by the blue roof system. Roof areas covering 3,500m^2 were utilised for the main Level 60 attenuation system (the red shaded area, in plan below) with a paved and ballasted surface finish. This enabled building services plant and maintenance access to be securely supported, whilst also providing the required attenuation capacity across the whole roof area, including four 'blue roof' restrictor chambers. 270m^2 of blue roof system with 2 restrictor chambers were used for the Level 50 terrace (the purple shaded area) and 450m^2 of blue roof with an extensive green roof finish and 4 restrictor chambers for the adjoining food and beverage pod known as 'The Kiosk' (the yellow and orange shaded areas).



4. How it works

The blue roof system comprises an attenuation and drainage void within the roof build-up that is designed to temporarily store storm water, before gradually releasing it over a calculated number of hours, via the blue roof restrictor chambers to reduce the risk of flooding downstream. During a design storm event, the system fills to the maximum height, requiring a complex calculation taking into account the roof parapet height, the finished floor levels of access points, and the catchment and attenuation areas of the site. The attenuation voids and restrictor chambers include a filter geotextile to remove debris and pollutants before the water drains into the rainwater outlets, and ultimately the local sewer network. SuDS and blue roof designs are calculated on probability of storm events with provision made for exceedence. The blue roof restrictor chamber is unique in that the exceedence overflow is contained within the same chamber as the outlet for the attenuated water to save on the number of roof penetrations required. The restrictor chamber utilises vertical orifices that are protected from clogging by a replaceable filter, and so are not susceptible to debris like simple horizontal plates.

In the case of the green roof areas used for the food and beverage pod, an additional water reservoir is included above the attenuation and drainage void (see below). This is filled as rainwater first percolates down through the soil layer to fill the reservoir cuspates, and over time evapotranspirates back into the growing media above. When the reservoir cuspates become full, water flows into the attenuation void layers below, and then into the roof outlets at a controlled rate via the 'blue roof' restrictor chambers. During the key design storm events, the system fills to the maximum depth which is calculated with the design engineer. The system manages water at stages 2 and 3 of the SuDS train (source and site control). The blue roof on green roof areas includes a 20mm deep reservoir board which is a high density polyethylene (HDPE) geocomposite with a bonded filter / separation geotextile. This geotextile prevents particulates and fines down to 100 microns (µm) from clogging the reservoir and also the attenuation control orifices. An 80mm depth of extensive growing media' is installed directly on to the reservoir board and for the planting a pre-grown sedum mat (including 16 individual sedum species) was used.



5. Specific project details

As part of the design process, the behaviour of the blue roof during the key storm events is modelled, with rainfall depths and storm duration data for the location taken from the Flood Estimation Handbook (FEH). Flood Studies Report (FSR) data can also be used. The attenuation void capacity is calculated to meet the requirements for a 1-in-100 year design storm event plus an additional 30% allowance for the effects of climate change and to meet the maximum allowable discharge rate.

Project Cavendish - 3500m2, Sheffield

Prepared for:	ARUP		
Issue status:	PRELIMINARY	Calc. Version	1.1
ABG Project ID:	9085	Revision:	1
Designed by:	MH	Design Date:	03/02/2017
Checked by:	RH	Check Date:	03/02/2017

Brief

Maximum allowable discharge rate of ~14l/s for a 1 in 100 year storm event + 30% allowance for climate change. Limited to four restrictor box locations.
There is one storage area, ~3500m2. The total catchment area is ~4520m2. (Taken from supplied drawing SRQ-ARUP-ZZ-ZZ-SK-D-1300 Rev A)
The design rainfall information was generated using the FEH for point (435213,386985).

Storage and catchment areas to be confirmed, values used in this calculation are estimates.

Input Parameters - Rainfall Information		
Return Period	100 years	*As supplied by Client*
Allowance for Climate Change	30 %	*As supplied by Client*

Input Parameters - Roof Information		
Catchment area	4520 m^2	*As supplied by Client*
Storage area	3500 m^2	*As supplied by Client*
Maximum restricted outflow	14.0 l/s	*As supplied by Client*

Output - Rainfall Calculation

Duration	Rainfall (l/s/m^2)	Storage Required (l/m^2)	Time to Empty	Restricted Outflow (l/s)
5 mins	0.0577	21	2 hours and 10 minutes	5.9
10 mins	0.0438	32	3 hours and 30 minutes	8.1
15 mins	0.0356	40	4 hours and 10 minutes	9.2
30 mins	0.0238	53	5 hours and 20 minutes	10.8
1 hour	0.0153	65	6 hours and 20 minutes	12.2
2 hours	0.0091	70	6 hours and 40 minutes	12.8
4 hours	**0.0055**	**71**	**6 hours and 40 minutes**	**12.8**
6 hours	0.0041	66	6 hours and 20 minutes	12.3
10 hours	0.0028	54	5 hours and 30 minutes	11.0
24 hours	0.0015	26	2 hours and 40 minutes	6.9
48 hours	0.0009	14	1 hour and 0 minutes	4.1

Notes:
1. This document contains a design proposal which has been prepared by ABG Ltd and is preliminary only and not a detailed design
2. Further details on the design theories used in this illustrative design are available upon request from the ABG designer. The values given are indicative and correspond to nominal results obtained in our laboratories and testing institutes. In line with our policy of continuous improvement the right is reserved to make changes without notice at any time.
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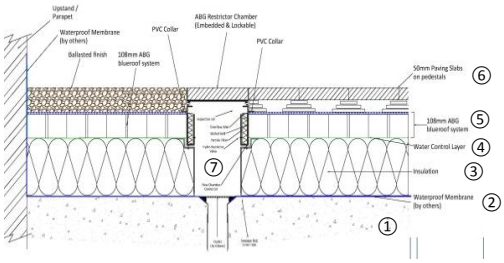
Design Calculations

Attenuation calculation for roof level 60

The main 3,500m^2 blue roof on Level 60 of the project also houses the building's HVAC and building services plant. The building services layout only allowed for 4 restrictor chamber locations, which are specified in accordance with NBS section Q37 for inverted roof systems (whereby the waterproofing membrane is installed below the insulation layer to protect the membrane).

The Level 50 & 60 flat roof build-up includes:

1) concrete roof deck structure
2) waterproofing membrane
3) insulation boards
4) water flow reducing layer (to insulation)
5) blue roof attenuation void formers/crates
   (108mm deep system to provide 100 l/m^2 capacity)



Level 60 blueroof extent showing the 4 restrictor chamber positions

6) paved and ballasted surface finish
(for maintenance access only)

7) restrictor chambers & RWO

Sustainability assessment methods

As part of the pre-planning process, an application was made to evaluate the office areas under the American LEED scheme rather than BREEAM UK due to HSBC's requirement for a 'LEED Silver' rated building. The LEED assessment method is broadly similar to BREEAM, working towards a number of tradable credits to achieve the rating level. LEED covers all aspects of the building's design; and specifically from a SuDS perspective a Rainwater Management credit (3 points) applies to the reduction of site runoff volumes, and also to the improvement of water quality by replicating the natural hydrology and balance of the site. For a new construction, run-off should be restricted to the 95th percentile of regional or local rainfall events. Credits are also available for 'heat island reduction in urban developments' (2 points), including requirements to meet minimum solar reflectance index values. This determined the use of high reflectance roof materials on the project. These included paving materials with a three-year aged solar reflectance (SR) value of at least 0.28, and light coloured pebbles as ballast, with an initial SR of at least 0.33 at installation. Areas of vegetated roofs and large planters on paved areas are also creditable, and used to absorb CO_2 and provide shade.

The retail area of the building is covered by a 'Very Good' BREEAM assessment. The blue roof system directly attributes key credits to the scheme under sections POL5 (10 credits), reduction of noise pollution (3 credits), and sections LE4 (2 credits), LE5 (3 credits) & LE6 (2 credits) for enhancing site ecology and having a positive long-term impact on biodiversity.

'Blue roofs' are also identified as one of the most effective SuDS treatment methods on tight urban sites for reducing flood risk and pollutants and avoiding the need to excavate expensive ground or basement attenuation storage tanks, with the associated carbon output incurred from large heavy goods vehicle movements.

Installation of the blue roof attenuation system and insulation boards on main roof Level 60

6. Maintenance & operation

For the first 4- 6 weeks after installation, watering of the sedum mat was carried out by the waterproofing contractor under the guidance of the green roof contractor. An ongoing maintenance agreement is in place with the contractor over a 3 year period, with 2 visits per annum scheduled for the green roof surface finishes and the blue roof systems. A dedicated mains water supply (min 2 bar pressure) is always recommended at each green roof level for post installation watering. Sedums are typically very drought resistant, but during long dry spells they will require additional watering.

7. Monitoring and evaluation

Regular / ongoing maintenance checks is key for all SuDS processes, and as such all the blue roof areas are checked twice per year. This includes all the restrictor chamber control orifices and integral overflow positions. A 3 year maintenance programme is agreed on all new 'blue roof' installations, so that key maintenance is carried out for the first part of the system's lifetime and not missed at client handover.

8. Benefits and achievements

- Blue roofs total discharge flow restricted to 24 l/s/m^2 over 8 outlets, covering 62% of the catchment area but only contributing 22% to the permitted site discharge.
- Blue roofs with paved, ballasted, and extensive sedum mat green roof finishes installed, on-time and to budget over a total of 105 days.
- **Level 60** - 3,500 m^2 of 'blue roof' system, roofing insulation, water flow reducing layer and geocomposite drainage / reservoir boards and 4 stainless steel restrictor chambers. 830 m^2 paved area, 2,628m^2 of 20-40mm pebble ballast to 85mm deep, 414 lm of aluminium upstanding between paving and ballast installed.
- **Level 50** - 270 m^2 of blue roof system and paving surface finishes installed, with 2 stainless steel blue roof restrictor chambers.

- **The Kiosk** - 450m^2 blue roof system with extensive growing media and sedum mat planting onto a combined resevoir and drainage/attenuation with 4 polypropylene restrictor chambers (suitable for non / lightly trafficked areas).
- 'LEED Silver' rated building
- 'Very Good' BREEAM assessment with the adoption of the blue roof system directly adding 10 credits to the scheme
- Achieved a 30% reduction in discharge compared to the original site before redevelopment.

9. Lessons learnt

Modifying the blue roof system to fit around multiple penetration details. Installing insulation, pavers, attenuation voids and the adjustable blue roof restrictor chambers to work around the roof plant & services framework, mechanical system risers, concrete upstands for site screens, roof parapet and threshold details. Designing and installing different 'blue roof' system & surface finish build-ups over the 3 different roof levels. There were many logistical challenges to overcome, including delivery of materials to a city centre location and the corresponding co-ordination of crane schedules / slots, working around other contractors and stormy weather conditions.

10. Interaction with local authority

Frequent meetings with Leonard Design Architects and Arup's design team to determine the appropriate blue roof capacity and system configuration to meet the site-wide maximum discharge rate targets given by Sheffield County Council.

11. Project details

Construction completed: Completed May 2019, with the 'blue roof' green roof system and surface finish installations completed September 2018

Cost: £90m overall and the 'blue roof' SuDS areas £350k

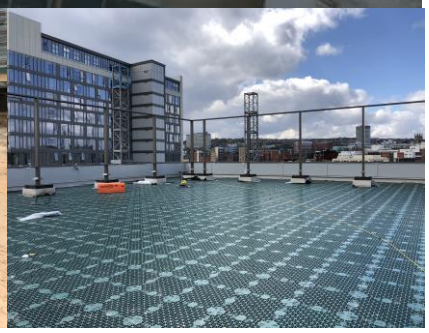
Extent: 6,100m^2 of roof areas onsite – with 4,220m^2 of blue roof attenuation

12. Project team

Funders	• Sheffield County Council • Queensbury Real Estate	
Clients	• HSBC	
Designers	• Leonard Design Architects • Arup (Flood Risk & Drainage Strategy) • ABG Geosynthetics	
Contractors	• BAM (Main Contractor) • ABG's installation team Geogreen (blue roof systems, paving / ballast, green roof surface finishes and insulation) • Roofdec (structural waterproofing & roofing membranes)	

Insulation boards installation Level 60

Restrictor chamber Level 60



Section of attenuation voids on Level 60

Restrictor Chamber & RWO Level 60

Paving slab maintenance walkway on Level 60

Level 50 terrace area with paved finish

Installing water flow reducing layer to Level 50

Level 50 chamber lid recessed into paving

Green roof installation on 'The Kiosk' building