Sustainable Urbanism with Green Roofs – Natural Stormwater Management

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1 ABSTRACT

In the district Zazenhausen, the City of Stuttgart (Germany) is developing the new building site, 'Hohlgrabenäcker'. In total, the final construction on an area of 16.7 ha shall comprise approx. 265 private homes and 9 apartment buildings in relatively dense development. Through the combination of cisterns, infiltration pavement and green roofs, significant costs could be diverted from rainwater management. Concurrently, the green roofs provide the important contribution of reducing the impact of the building measures on ecosystem functions.

2 INTRODUCTION

In recent years flood disasters have become 'an inconvenient truth' for many people. On a local scale this problem is very often man-made due to the paving over of open land. As a result, the natural water cycle is defective and most of the precipitation during a rainstorm is immediately routed into overloaded storm-sewer pipes. Moreover, the impacts of global warming and the attendant stronger storms with more rainfall have intensified the situation. This means that at present, public water authorities are at a crossroads. They can try to solve the problem conventionally by costly end-of-pipe interventions, e.g. the extension of stormwater collection, storage and treatment facilities. However, these efforts fail to address the source of the problem – impervious surfaces. Therefore, modern stormwater management policies go upstream and manage the problem in a sustainable way by using green roofs for temporary water storage.

Within the array of preventive stormwater management techniques green roofs play an outstanding part. This is not only due to the fact that 40-50 % of sealed surfaces in urban agglomerations represent roofs. Moreover, green roofs are real all-rounders in both an economical and ecological sense. Depending on the green roof system build-up and substrate, the immediate water runoff from vegetated roofs can be reduced by 50-90% (ROTH-KLEYER 2009). A large part of the water returns into the natural water cycle by transpiration of the plants and evaporation from the substrate. The accompanying cooling effect of this process contributes to a better microclimate and a decrease of the 'urban heat island effect'.

The remaining excess rainwater drains from green roofs with a substantial lag time so the peak flow rates are reduced. Due to the natural drainage pattern of green roofs less or smaller dimensioned sewerage systems can be installed on new development areas or large projects. Innovative stormwater master-plans include the combination of green roofs with cisterns, so the roof water not absorbed by the green roof build-up will be captured and provide grey water for other uses (e.g. irrigation, flushing toilets). As stormwater volume reduction benefits the budgets of the municipalities, many water authorities promote the opening of scaled surfaces with financial incentives. In Germany, for example, property owners receive a special discount on the annual stormwater taxes for areas which are covered by green roofs (ANSEL 2009).

3 CASE STUDY STUTTGART-ZAZENHAUSEN

The first indication of integrating green roofs into the development of the building site "Hohlgrabenäcker" in Stuttgart-Zazenhausen already appears in the land development plan of the City of Stuttgart. Effective since 2000, the land development plan 2010 is the pivotal controlling tool that directs urban planning and development of Baden-Württemberg's capital city on a sustainable course. In order to minimize encroachment and provide internal compensation measures in the building site 'Hohlgrabenäcker', ecological stipulations were proposed in the land development plan for the comprehensive building site, notably green roofs and stormwater retention and -infiltration.

Given that the development of the housing area assumes significantly detrimental impacts on the environment, an Environmental Impact Assessment (EIA) was conducted before the development plan was assembled. In doing so, the Environmental Impact Assessment considers the effects of a construction project on the protection of humans, animals, plants, soil, water, air, climate, landscape, as well as culture and other real assets. The measures that were recommended on the basis of the assessment - for prevention, minimization and compensation - are then found again as regulations in the development plan. While the regulation of green roofs as minimization measure for the protection of species, biotopes, water, climate and natural scenery has become standard in the interim, the active integration of green roofs with drainage planning is still rather something of a special case.

To this end, layer depth of the green roof substrate plays a decisive role for green roof function as primary stormwater storage and for delayed runoff occurring from long-lasting rain events. For the regulation of extensive green roofs in the development plan, therefore, from the framework of an integrated approach, a higher value for substrate depth was deliberately selected (12 cm), such that the runoff coefficient from the roof surfaces would achieve the desired value of 0.3.

The regulations for extensive green roofs in the development plan are as follows:

“Free-standing garages and carports must be greened. Here the green roof must have a substrate depth of at least 12 cm. The substrate layer is to be planted with grasses and wild herbs and shall be preserved as such (extensive green roof).”

„For retention of stormwater, areas with flat and single-pitch roofs are to be covered with green roofs. … Here the green roof must have a substrate depth of at least 12 cm. The substrate layer is to be planted with grasses and wild herbs and shall be preserved as such.”

The total green roof area of the building site ‘Hohlgrabenäcker’ adds up to a total of 18,300 m². Regulating green roofs into the development plan was therewith an important step for achieving the ambitiously low degree of 20 % imperviousness within the building site.

4 SPECIFICATIONS AND BASIC CONDITIONS FOR THE DRAINAGE DESIGN

4.1 Legal basis

According to the Water Act for Baden-Württemberg (WG) § 45 b Abs. 3, when technically possible and without incurring damage, stormwater from new development sites should infiltrate or be conveyed away separately. It is important to note here that selective runoff infiltration in Baden-Württemberg may only be accomplished in troughs with over-grown topsoil layers.

4.2 Municipal specifications

Because of limited capacity of existing sewers, the planned new development site ‘Hohlgrabenäcker’ is required by statement of Stuttgart City Council to comply with a maximum runoff co-efficient of 0.3 (impervious degree of 30 %).

4.3 Hydro-geological conditions

The soil analyses that were conducted indicate predominantly homogenous, cohesive soils in the upper layer, which is the layer that is relevant for precipitation abatement. These soil types have limited suitability for stormwater infiltration. Prospecting did not reveal noteworthy levels of groundwater. Furthermore, the steep hillside situation (in parts over 10 %) strongly restricts the possibilities for surficial stormwater infiltration.

5 THE DRAINAGE CONCEPT IN PRACTICE

Due to the specifications and basic conditions described above, drainage by separate sewer system is obligatory. Residential wastewater is collected via drainage system and passed into an existing combined wastewater sewer. The basic conditions encountered at the building site did not permit comprehensive and selective stormwater infiltration, so a combination from various basic elements of stormwater management came into use.

5.1 Drainage from private areas:

Facilities for rainwater storage and -use on all built surfaces upon which single- or semi-detached housing (loose development) are planned and for which no obligation for green roof construction exist. Rainwater storage results from cistern facilities on private properties which empty partially by force. The part of the cistern volume that is not partially emptying can be used by the property owners for rainwater use. In accordance with DIN 1989, rainwater can be used in house and garden for toilet flushing, washing clothes and irrigation. In addition to the residential water management benefits of retaining and damping runoff peaks, the cistern solution offers additional ecological benefits:

- a) Conserve drinking water
- b) Cost reduction for sewers and wastewater treatment.
- c) Reduction of the pollution load discharge to the discharge system.

The drain outlet from the cistern throttle can be connected to the new stormwater sewers in the development roads.

Figure 1: Cistern installation

In the more densely built area, green roofs are specified for runoff minimisation. Other paved areas must be furnished with permeable coverings. Drains from these properties must also be connected to the stormwater sewers in the development roads.

Fig. 2: Single-pitch roofs with vegetation layer

5.2 Drainage of public/ open areas:

In terms of transportation, public streets and development areas are restricted to a minimum to reduce the impervious degree as much as possible. Streets and path surfaces are connected to the new stormwater sewers. The stormwater sewer discharges directly into the receiving water course (Feuerbach).

Through the consistent use of pervious-friendly material for all of the paths, storage- and living spaces, as well as the use of green roofs and cistern facilities, an impervious degree of just ca. 20% could be achieved in the residential area.

Parameters for the development:

- Catchment area stormwater sewers: 15.3 ha
- Paved area: 3.2 ha
- Pervious paving of streets and paths: 16,000 m²
- Total green roof surfaces: 18,300 m²
- Cistern facilties for single-family homes: 47
- Cistern facilties for multi-family homes: 09

Fig. 3: Infiltration pavement - buildup

6 ECONOMIC COMPARISON

By economic comparison, the stormwater design described above can hold out against conventional stormwater management as well. By conventional construction, the imperviousness of the new development area would swell to over 40%, and centralized stormwater retention would necessarily require 1,400 m³ useable volume. In open cut construction, an area of at least 1,200 m² would be required. The acquisition of the land area alone, which comprises around 4 lots, can finance the construction of the decentralized cistern facilities, as well as the additional costs from the pervious paving and green roofs.

Furthermore, the operational costs of centralized stormwater retention, as well as dropped stormwater fees for the split wasterwater levy, speak clearly to the conceptual design of the stormwater management selected for the new development area.

Comparison investment costs:

Conventional stormwater conveyance with separate sewer system

Land acquistion for centralized stormwater retention:	1,200 m² x 600 €	720,000 €
Investment costs for stormwater retention:	1,400 m³ x 120 €	168,000 €
Additional costs estimated for cross-section enlargement of conduits:		50,000 €
Total costs conventional stormwater discharge:		**938,000 €**

Decentralized stormwater management in new development area

Cistern facilities in single-family homes:	47 x 1,200 €	56,400 €
Cistern facilities in multi-family homes:	9 x 5,000 €	45,000 €
Additional costs for pervious paving instead of asphalt:	17,000 m² x 20 €	340,000 €
Additional costs for green roof: (Substrate depth 12 cm instead of 8 cm)	18,300 m² x 05 €	91,500 €
Total costs decentralized stormwater management:		**532,900 €**

Cost savings investment costs:

Decentralized stormwater management vs Conventional stormwater conveyance: 405,100 €

Even when the complete installation costs for the extensive green roofs of ca. 20 Euro / m² are included in the cost comparison, decentralized stormwater management is still over 100,000 Euro more economical than conventional discharge. And this says nothing of the annual ecological yield from conserved stormwater fees which were introduced to Stuttgart in 2007. The basis for this stormwater fee is the built and impervious land area from which stormwater is discharged into the public sewer system. Measures which serve for natural stormwater management and which reduce discharge into the sewers are rewarded with significant annual fee reductions.

Decentralized stormwater management: Annual savings in stormwater fee

Cistern facilities	8,240 €
Pervious paving	8,400 €
Green roof:	9,040 €
Total savings from decentralized stormwater management:	**25,680 €**

Savings in stormwater fee over 30 years: 770,400 €

Already in 1998, a cost study by the Ministry of Building and Housing in the German state of North Rhine-Westfalia came to the conclusion that green roofs are always more cost effective than gravel roofs, when reduced rates for water retention by green roofs are recognized within the framework of a municipal bylaw.

7 CONCLUSION

With its approach, the building site ‘Hohlgrabenäcker’ could assume a pioneering task in the matter of ecological stormwater management for new building sites in Stuttgart. In doing so, the full effectiveness of green roofs arises through integrated planning. Minor modifications to substrate depth can suffice for cost savings on the order of five-figures (Euro). That green roofs also provide cost savings on heating and air conditioning through their insluative and shading effects, that they improve the urban climate, and that they provide new habitats for plants and animals are further important aspects which, in this case, are bonus.

8 IGRA – THE INTERNATIONAL GREEN ROOF ASSOCIATION

The International Green Roof Association (IGRA) is a global network for the promotion and dissemination of information on green roof topics and green roof technology. IGRA´s services include networking, workshops, conferences and all kinds of public relation work. Please find more information at www.igra-world.com.

9 REFERENCES

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