

# **STUDY OF GREEN ROOFS: GREEN ROOF GUIDELINES, WATER QUALITY AND PEAK RUNOFFS**

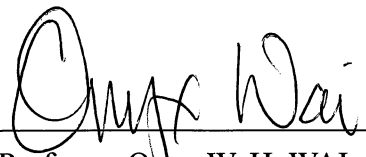
## **Executive Summary**

**Report for:** Sewerage Projects Division, Drainage Services Department, HKSAR

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## Executive Summary

“Study of Green Roofs: Green Roof Guidelines, Water Quality and Peak Runoff” is a comprehensive study not only focused on the stormwater runoff behaviors of green roofs, but also the major concerns in green roof design, installation and maintenance. For this purpose, multiple approaches were included in this study. Firstly, full scale extensive green roofs were designed and constructed in Sha Tin Sewage Treatment Works (STSTW) to study the quantity and quality of green roof runoffs, as well as other key issues in green roof design and construction, including loading, wind safety and waterproofing. Secondly, laboratory experiments were designed to find the significance of the factors affecting green roof runoff mitigation, such as the vegetation, soil substrate, rainfall intensity, roof slope, and soil moisture contents. The Hydrus-1D numerical model was also constructed to simulate water movement in green roof systems, and the results were compared with the physical experiments in the laboratory. Furthermore, numerical wind field simulations were conducted in three regions in Hong Kong, namely the STSTW green roof site, the Northern side of Hong Kong Island, and the urban region of Tsim Sha Tsui and Hung Hom, in order to investigate the wind safety of extensive green roofs on tall buildings and near coastline. Finally, a green roof survey was conducted to gather information and experience about green roof construction in Hong Kong.

The performances of runoff mitigation of extensive green roofs were found to be closely related to the aforementioned factors. In rainfall events under 30mm/hr intensity (i.e. amber rainstorm warning signal), the tested extensive green roofs systems have an average retention rate improvement of 31.9-53.5%, and an average peak runoff delay time improvement of 21-35 minutes, as compared to traditional flat roof surface. Rainfall intensity, substrate thickness, antecedent moisture content, vegetation coverage and roof slope are the more significant factors determining runoff mitigation, while plant species, soil types and the age of the green roof are relatively less influential. Design recommendations for extensive green roofs in Hong Kong are listed in the guideline section in the end of report.

In terms of runoff quality, green roof runoffs contain more suspended solid and nutrients such as reactive phosphorus and nitrogen (in forms of nitrite, nitrate and ammonium) than the runoff from the normal roof. However, the heavy metal contents including copper, lead and zinc are lower, and the pH values are less acidic in green roof runoffs, suggesting the ability of extensive green roofs as a buffer for heavy metals and acidic rains.

The results from the wind field numerical modelling, which included three case studies, indicate that wind risks on extensive green roofs exist on tall buildings and in locations where shielding effect is insufficient. Also in some rare cases, strong uplifting wind may even appear on low-rise building roofs due to the strong vertex formation caused by the spatial arrangement of the nearby tall buildings. To reduce damages due to wind loading, inspections before and after greening are recommended. A parapet wall surrounding the green roof is a good option, since it plays a significant role in wind protection as found in the STSTW case study.

From the green roof survey in Hong Kong, it is found that the most common challenge in practicing roof greening is waterproofing failures and seepage problems. To study this phenomenon, a literature review on green roof waterproofing techniques and recommendation in overseas guidelines and publications was conducted. Although so far there is no universal standard specifically written for green roof waterproofing, it is widely believed that inspections and tests before green roof installation are essential, and that renewing the waterproofing layer before greening is usually worthwhile in long term prospective.