Connecting People and Ideas . Proceedings of EURO ELECS 2015 . Guimarães . Portugal . ISBN 978-989-96543-8-9

The recovery sustainable urban water systems management and Green Roofs. Widespread conversion of impervious surfaces existing greened surfaces in urban areas

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ABSTRACT: The conversion of impervious surfaces in greened surfaces can reduce adjustment of sewer systems problem, reducing the overload produced by events of downpour, improving urban water systems management [01]. The feasibility in existing building depends on the extent of the new applied loads. In order to check the endurance of green roofs in Mediterranean climate (Rieti -inner central Italy), in real conditions, with only 80 mm of substrate, an experimental roof has been set up . A reference roof and two kinds of green roofs has been built up on a laboratory roof. Measures are conducted in natural weather. A first set of measures is showed, providing the performance of accumulation and drainage layers. Moreover a qualitative analysis of planted vegetation growth is provided.

Keywords: Green Roofs, Rainfall retention, Building renewal, Green Infrastructure

1 INTRODUCTION

The relationship between building and tree, built surfaces and green areas, artificial and natural has always been a central theme in the architecture design research , so that, since its first rise on the banks of the Euphrates, it proposed a wonderful syncretic solution in the legendary green-Gardens of Babylon.

This comparison has gone through since the history of architecture and has produced continuous relations capable of giving life to wondrous hybridizations and wonderful mutations of specific components of the two different systems. From the window to the bowers; from atria shady orchards; by winter gardens, greenhouses odorous; gardens, green architecture and botany began a complex and rich history of continuous mutual references.

In our contemporary world featured by, both, inescapable and ambiguous searches for solutions able to decline a sustainable choices and the increasingly evident issues of development , the relationship with the green could not take on new issues and hybrids; therefore the renewed attention given by ancient architectural design roof gardens and, at the same time, the increasing importance that has taken in the context of technological and scientific research about green roofing.

Our goal is not to analyze the architectural and linguistic aspects of this element of ancient tradition, although unrecognized and, especially, misunderstood in its specific potential, but rather to assess the environmental and construction in relation to the contribution that its spread in the Mediterranean cities can make to the improvement of the microclimate and the greater efficiency of retention of rainwater.

The purpose of the research is focused on the design of interventions to reuse the roofs of the existing buildings, in order to improve living conditions of inhabitants of cities, the environmental comfort of the enclosed spaces in addition to open ones and the sustainable management of water resources in the urban environment.

2 THE TRANSFORMATION OF WATERPROOF COVERS IN EXISTING BUILDINGS: STRUCTURAL ISSUES.

It seems evident that the integration of green roofs in existing buildings, by converting the waterproof surfaces, produces a significant change in the loads on coverage; it is therefore necessary to undertake a careful evaluation of the new conditions in terms of static, and seismic aspects, if required. In favour of safety, in the mandatory preparatory verification stage, it is appropriate to consider that the elements, constituting the new stratigraphy, can be in conditions of maximum water saturation. Densities under saturation conditions of each element are, therefore, the input data of the main project in order to perform the subsequent structural verification. In these interventions on existing buildings it is the permanent loads (G) that varies , namely, those actions that act during the nominal life of the construction that are the weight of all structural elements of the ground and the forces induced by the ground itself (excluding the effects of variable loads applied to the ground) and the forces resulting from the pressure of water (where there's a permanent load of this kind). The verification of safety in a static environment and the eventual design of subsequent interventions of consolidation are therefore a key element. In this context it should be, in fact, take into account aspects of the assessment and in-depth knowledge of the state of the work, for this purpose it is suggested that the method of the "cognitive stage"[14]. The safety assessment and intervention planning is performed with reference only to the ultimate limit states SLU, compared to the condition of preservation of human life SLV or, alternatively, to the condition of collapse SLC. The case in which the intervention includes the installation ex novo of green roofs on existing constructions entails, on one hand, a change of destination of use of a part or the whole of the roof surface concerned and, on the other, the change of load combinations acting on the structure. In order to limit the possible interventions of consolidation may, after prior verification, change the intended use of the object to be covered in a practicable not feasible. In addition, recent results produced by a research conducted at the School Laimburg, in Bolzano (Alpine climate), confirmed that the minimum thickness to be provided for the growing medium is equal to 80 mm, as indicated by the UNI 11235 [04], suitable to maintain the conditions necessary the life of Sedum ground cover vegetation[13]. This experimental result, if confirmed in conditions of prolonged drought, would be particularly interesting in applications on existing buildings, as legitimizing the use of only 80 mm layer of culture and it would minimize the total loads applied and to limit potential interventions consolidation on the existing structure.

3 THE POSITIVE CONTRIBUTIONS OF GREEN ROOFS

The value of the integration of Green roofs in building could be found in the dialogue with the city in the urban scale. In this case we measure the relevant effects of this system, which are the basis of incentive policies and diffusion throughout the world.

The main positive effects, readable on an urban scale that, when properly contextualized, justify its use and recommend the diffusion are: the improvement of the microclimate in urban neighbourhood scale and the improvement of urban water systems management through a reduction of precipitations of overloads the sewer system [01].

Other positive contributions are the reduction of air pollution[06], thanks to the elimination of fine particles in the air, protection against noise and contributing to the transformation of carbon dioxide[05]. The interventions of reduction of waterproofed surfaces in urban areas through the implementation of widespread Green roofs, unlike what traditionally stated, do not appear to have a direct and supporting intervention at the level of adjustment of the internal microclimate of the building on which insists that, despite the expected improvement in energy efficiency, does not seem to be justified by the significant investment costs and management-maintenance in comparison with other specific types of intervention [08] [10]. This system can, however, lead to an improvement of urban water systems management of precipitation, by reducing the overload on the sewer system, offering itself as a viable solution to the problem of the adaptation of the network[07]. This problem of adaptation is denounced by the inability of existing sewer systems to meet the changing needs in terms of the capacity of wastewater and disposal of products from overload events of downpour and is confirmed by recent events. If climate events of downpour, more and more phenomena represented by high intensity focused in a short time, will intensify more and more, as expected, the importance of interventions in the water cycle will increase. At present, in Italy, it is estimated that the sewer system would require a "replacement rate" of 38% for a modernization of the system. In the country, municipal sewer system are mostly of mixed type, or unitary, that gather in the same duct is the waste water from settlements of civil and / or production, also called "water in dry weather," both rainwater. Therefore it is clear that the implementation of Green Roofs takes on a particular importance for urban water systems management of precipitations in urban areas.

The volume of water that flows in networks is further increased by both the constant per capita consumption of water, estimated equal to 6 times in the last 50 years, both from the increase in impervious surfaces, which lack the ability to drain, releasing instantaneously collected water in the disposal system. [12]

Considering the substantial irreversibility of the processes related to urbanization growth , shown in the attached graph, with a continuous increase . Drainage can be partially restored through a widespread introduction of absorbing surfaces in built-up areas, just like Green Roofs.

4 APPLICATIONS OF THE ROOF- GARDENS IN THE WORLD AND IN ITALY

A monitoring of current diffusion of Roof- Garden worldwide has been conducted, to identify the presence of application protocols, in terms of incentives, regulations or any object with these systems. The use of the technique of construction of the Roof- Gardens meets a significant political and legislative confirmation in Europe and America, as showed by the map where places with a specific regulation are signposted.

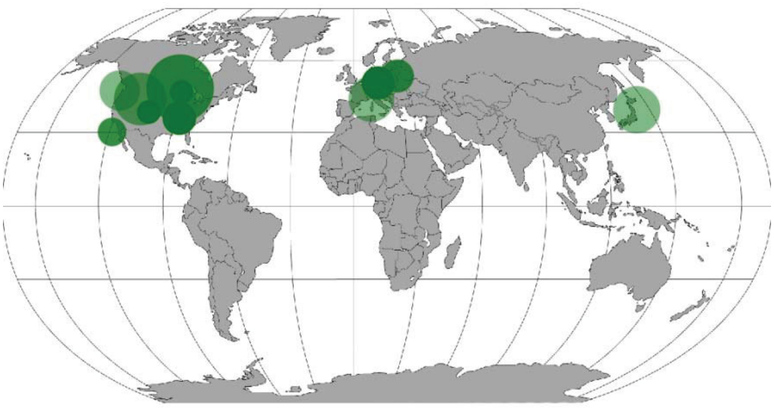

Figure 1: Qualitative representation of the diffusion of the Roof Gardens, edited by author

The local administration of Chicago in 2006 initiated a protocol: the Nation Centre for Environmental Design has promoted construction of nearly 300,000 square meters of rooftop garden and now candidates the city to the primacy of the greenest city in America.

Figure 2: City Hall Chicago- The commitment of the Administration to promote the dissemination of this construction method is declared in 2011 with the creation of a roof garden right on the cover of City Hall.

In Europe, especially in Germany, Switzerland and the Netherlands, the new techniques of green roofs are well established with thousands of square meters of built area.

Although most of collected results refer to countries in the northern temperate zone, some applications has been found in California, that is generally temperate-warm subtropical with a thermal condition and rainfall very similar to its Mediterranean climate, or even harder.

In Japan, in Tokyo City, in the urban plan of 2000, it has been established that at least 20% of the surface of the buildings with covers superior to 1000 square meters should be built with roof gardens.

In Italy there is no national legislation that recognizes the application of the roof gardens and available incentives and regulatory references are related solely to local authorities. However, there are many local administrative realities that mention this construction system. The most significant example is represented by the commitment of the administration of Trieste that has been promoting a policy of re-development of the historic buildings that characterize the historic centre, promoting interventions of roof greening, already originally flat, with the creation of roof gardens[11]. The actions already implemented have produced a remarkable diversification of the times of stormwater runoff in the green treated areas compared to traditional coverage areas. This commitment of the Trieste administration wishes to be the answer to the problem of adaptation of the drainage system, particularly evident in city on seaside.

5 EXPERIMENTAL VALIDATION STARTUP

At present, although advanced simulation tools are available, we still want to experiment the actions coming from the study of the real prototype. Indeed, on one hand there are several mathematical simulation models capable to reproduce each aspect of green roof. On the other hand there is not any mathematical formula able to explain all phenomena and their interactions. The validation of the system through the use of simulations with mathematical models is therefore not sufficient [09].There are, for example, algorithms for calculation of thermal action and thermo hygrometric fields through the layers that aren't able to consider temperature mitigation due to evapotranspiration phenomena associated to the presence of the layer of vegetation. There are, also, fluid models that reproduce the water action and its vapor inside the cultivation substrate, but it is a complex integration with the phenomena that occur in the layers of drainage and water accumulation. Although we can simulate one specific meteorological event by appropriate equipments and conditions, it is more complicated to simulate more meteorological event together. This makes more complicate to study the performances of a specific climate. The effect of the meteorological component, on the available experimental data, is experimented in the Mediterranean climate by mean the prototypes. The equations applied represent the reality as long as there are the same climate conditions.

In the experimentation we have three sample sections: the reference one (non greened roof) and two tanks containing the roof prototype. The difference between the two green roof systems is limited to the retention of the drainage layer: one with 16 l/m² storage capacity, the other one, simply draining, without storage. Both systems are of extensive type with 80 mm cultivation layer planted with a selected variety of Seduum. The prototype of the roof of reference has the only waterproofing layer, constituting the sample with which to compare the performance of green roofs. The samples of the flat roof have been registered with 2,5 % in slope, as expected for minimum slope for the planar flat roofs from the norm UNI EN 12506-3[02].

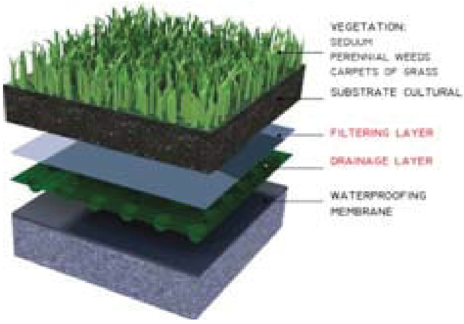

Figure 3: Stratigraphy of the experimental section

The extension of the coverage portion is relevant for drainage performance. To size the prototypes, minimum dimension representative of the drainage path taken by the water in a real case has been identified.The drainage flow depends on the resistance coming from the layer percolation, which is in turn a function of water route through the stratigraphy. The dimension corresponds to a water spout of a flat roof building in line with 10 m in depth. The longest drainage path for rainfall water is equal to half of the side of the roof, where descendants are generally present on both sides of the cover, figure 2. Thus, the size of every tank is 2,0 m x 5, 0 m, held on six stands, each connected to a load cell. In this way water retention of the prototype can be measured, through the continuous monitoring of changes in weight of the tank.

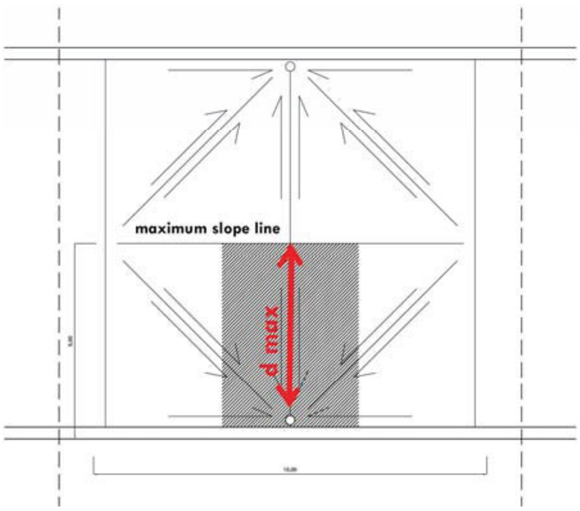

Figure 4: scheme: plant a cover type dimensions 10m x 10m

The amount of the drained water is measured through the waste water, conveyed in a proper tanks and connected to a load cell which measures the weight change. Therefore, flow rate can be obtained by numerical derivatives. Next to measurement site, on top of the same building , at the SOS_UrbanLab, located in Rieti, there is a weather station which provides climatic data. Measured values are temperature, wind direction and speed, humidity, solar radiation and amount of the rainfall.

Figure 5: Photo of SOS_UrbanLab: The Test Center. In the foreground the tank containing the prototype of a Green Roof without water storage, the second floor in the bath sample, third floor, the tank containing the prototype of a green cover with water storage

6 RESULTS AND DISCUSSION

The prototypes have been monitored for 132 days, from April 22nd to September 1st. The period corresponds to spring and summer in Mediterranean climate, relevant to the validation of the endurance of the system.

The prototypes are in natural conditions exposed under the sun, not watered, except for the initial 30 days in order to help the engraftment of the vegetation layer. Measurement data are available from July 13rd to September 1st, registering 16 rainfall days (with more than 2mm of cumulative precipitation). The maximum sampled precipitation in a single day has been of 52.0 mm, while the single event with higher intensity is 14.4 mm in 1 hour on the last day of the set. The sampled rainfalls might be classified in 11 of minor events (>2mm) in 7 of mid intensity (2-10mm) and 8 of high intensity (>10mm). The daily minimum temperature measured during the study changes from 11,2 °C to 17.,7 °C. the daily maximum temperature from 20.5 °C to 31.1 °C. The maximum dry period has lasted 22 days .

By observing continuously the load change of the tanks, it has been possible to measure the metabolic activity and evapotranspiration that describes how the system works in daytime and at the night. In Figure 6, showing measurements of water load in the tank with the storage layer, it is clearly shown that there is a change in water evaporation in different periods of the day. This seams to be linked to metabolic phenomena of the layer of vegetation and evapotranspiration activity, associated with environmental conditions. There is an almost constant evaporation during daytime (section AB). Weight loss stops next to sunset (segment BC). The contribution of the relative humidity is significant in the analysis of this trend , as in the early hours of the day, from 3.00 am to 7.00 am, it reaches values ranging from 96 to 100% with condensation, resulting in a slight increase of the load of the tank (segment CD).

The layer cultivation has not shown suffering for the lack of rain for 22 days in summer weather regardless of the presence of water storage in the drainage layer.

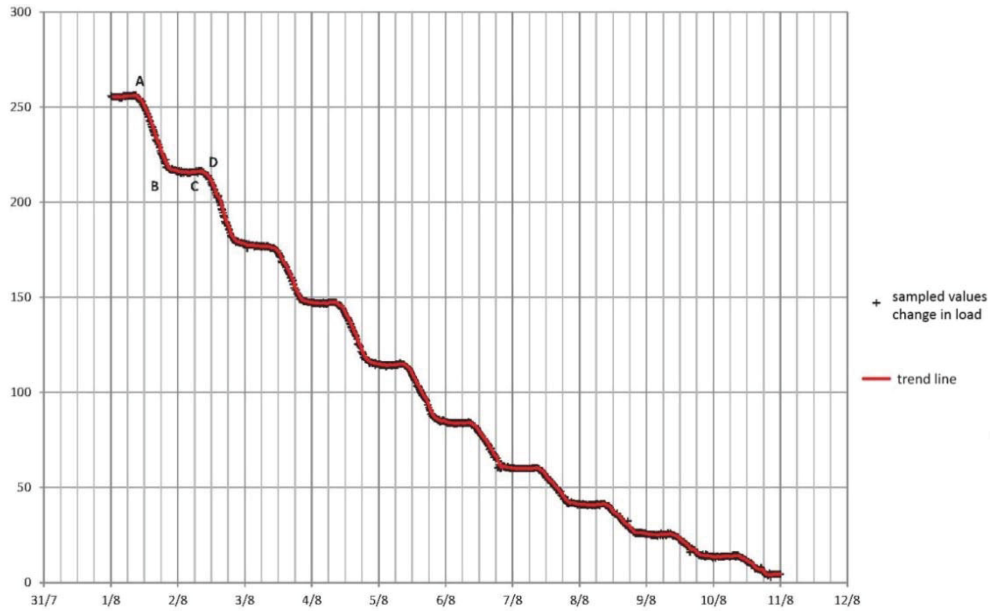

Figure 6: Variation of loading of the prototype with a layer of water accumulation by day during the time interval of drought detected

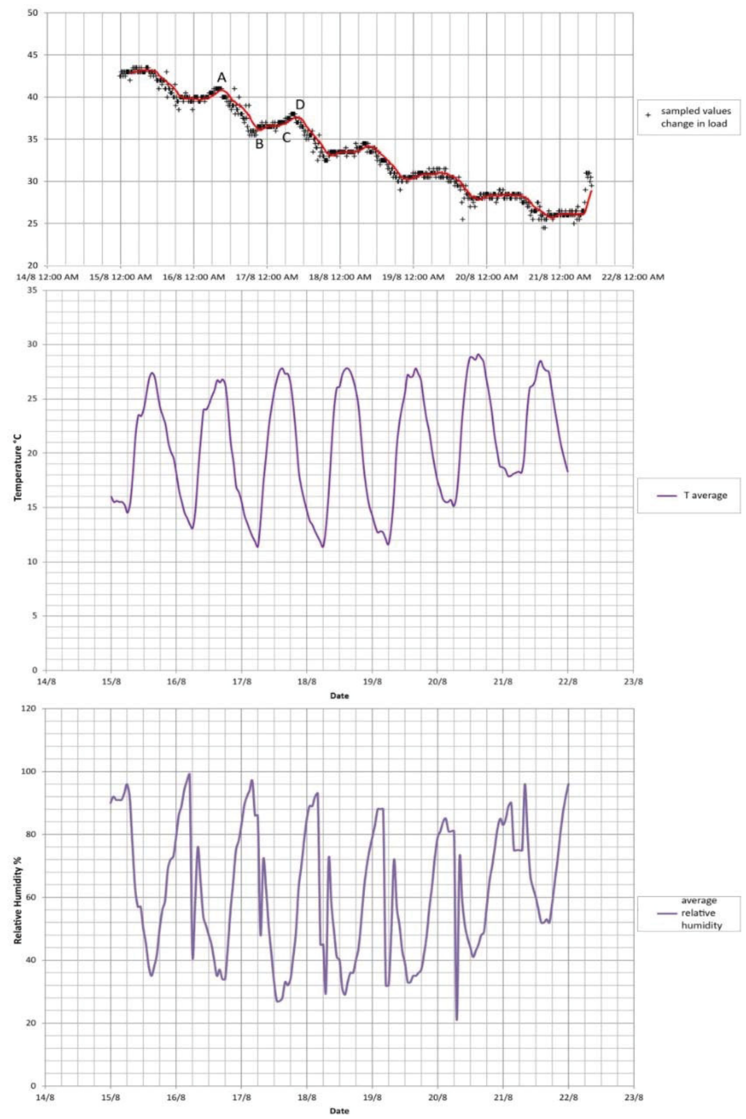

Figure 7: Variation of load the prototype layer accumulation water- Performance of maximum and minimum temperature trends Moisture detected will mean relative

The observation of growth and engraftment of planted vegetation showed almost no difference between the prototypes. One month after planting, at the end of the irrigation period, the development of vegetation in the tanks with and without storage layer were similar. At the end of the second month, in the complete absence of irrigation, engraftment of vegetation in the prototype without water accumulation resulted to be better than that achieved by the other, whether for the extension of the covered green surface and the dimensions of the plants. This has been confirmed at the end of the third and fourth month monitored.

Figure 8: Comparison of the state of growth and fouling growth at monthly interval

Actually, the absence of a storage layer has not affected the growth of Seduum. It should be noted that, at the slope of 2.5%, the layer of accumulation is actually able to perform its function for only 1/3 of the total length of the tank, draining the water of the remaining 2/3 as the storage areas are higher than the free surface of the fluid, set by the overflow of the panel itself.

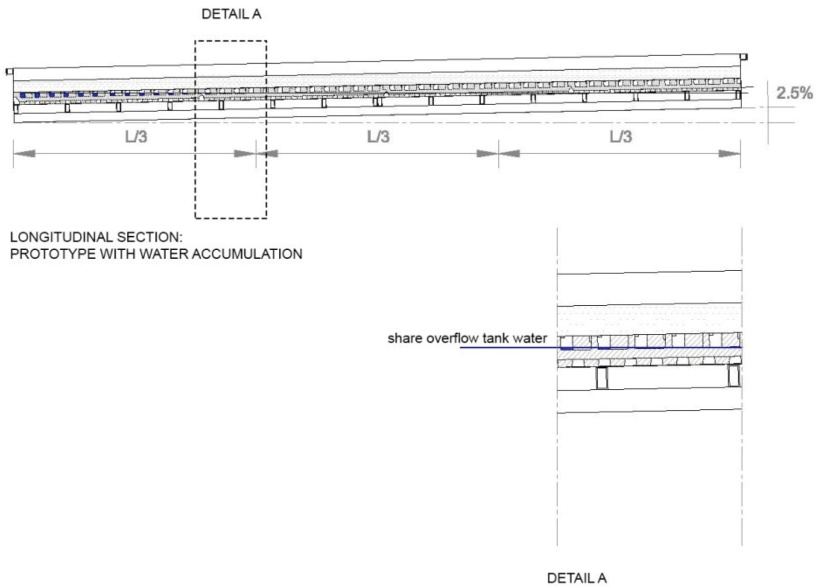

Figure 9. no caption provided

This seems rather obvious by the observation of the early stages of cultivation of green roof illustrated in fig. 6.

Figure 10: Photo Angle of Prototype with water storage where the state of growth of vegetation clearly highlights the portion of the length is achieved where the accumulation of water, compared to that with inclination greater where, in fact, there is no accumulation of water.

7 CONCLUSIONS

The data collected during the present phase of the experiment, conducted at the SOS_UrbanLab, are a first validation of light green roofs stratigraphy in Mediterranean climate. They prove the ability to self feed in the summer season, in periods up to 22 days with no rainfall in summer, without any intervention of artificial irrigation. This is actually a mandatory requirement for passive roofing systems that can really give a positive contribution to water management.

During the period of observation, the prototype with the stratigraphy without a storage layer has shown a growth and engraftment of vegetation equal to that observed in the traditional stratigraphy . Thus , a specific water storage layer does not seem to be necessary. The growing substrate is sufficient to keep the meteoric water and is able to absorb dew in early hours of the day as so to ensure the hydration of the growth layer, also in condition of prolonged absence of precipitation. This will make possible the use of such systems in the renewal of existing roofs.

However, it will be necessary to carry on the experiment for a longer period in order to have a complete validation of the results described.

As the conversion of impervious surfaces in greened surfaces in existing buildings, implies the change of loads on the structure, the identification of a stratigraphy able to optimize the applied loads, widens the applicability of the system. The preliminary result obtained, justifies the adoption, in the Mediterranean climate, of a stratigraphy composed of only 80 mm of growing substrate without any layer of accumulation, making it suitable for intervention of transformation on existing buildings; reducing the need to strengthen the structure or avoiding it at all.

Finally, according to presented results, some considerations emerge on the conformation of the structural system adopted for intensive green roofs. The study conducted, shows that nominal performances for water storage layers are higher than actual performances due to the slope of the covering where they are backed on. Thus, these systems should be revised in order to preserve their efficacy in applications that need it.

ACKNOWLEDGEMENTS

The experimental setup was done with the valuable contribution of Daku Italia, a leading company in green roof systems.

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