

Development and Performance of the Unit type Green Roof System

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ABSTRACT

We are facing a number of ecological problems in a city due to reckless urban development and damage of green areas. A roof garden has been brought to the fore as an effective and practical solution to such problems. However, a roof garden is considered to degrade durability of a building and additional load imposed on a building makes it difficult to introduce the system. Despite such problems, local self-governments as well as Seoul City are promoting roof gardens as a method of conserving green areas in a city. Moreover, the market of roof gardens is growing with such governmental support. Therefore, a new technology should be developed for roof gardens of easy installation and light materials so as to widely distribute the system. In order to meet such demand, therefore, we have developed a new technology for a green roof system.

The new construction method for a green roof uses green units in a form of a box to prevent roots and to drain water. Green areas are formed by being connected with the units. This construction method makes possible fast and easy installation of a green roof. And it reduces an urban heat island by providing places for drainage, increasing the amount of evapotranspiration.

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1. Purpose and Backgrounds

The purpose of this study is to develop a technology for a roof of apartment houses. A roof takes up a relatively smaller amount of building surface and its utilization is low, but it has greater potential for creating various types of space and applying ecological greening technology.

The major achievement of this study is the development of unit-type green roof system, a new ecological technology for greening artificial ground, and providing backgrounds for turning this technology to practical use.

This study aims to extend the application of greening technology, based on development of key technologies and related materials for localization of green roof system technology, by developing an extensive GRS prototype with the function of an underflow for increased evapotranspiration as well as a removable GRS prototype applied to a gentle slope ($\leq 30^\circ$) or

steep slope ($\geq 30^\circ$) roof.

2. Scope of the Research

This study involves development of the total green system and its application, including development of key technologies as well as evaluation of their performance. The key technologies of providing suitable conditions for plant growth shall be verified before a conclusion is drawn from long-term monitoring of experiments so that any experimental error can be minimized.

Further research shall be conducted in order to solve any problem arising from applying the system to vegetation and to increase the quality of the greening technology.

3. Key Technology of Unit Type Green Roof System – The Unit

First, this research aimed at developing a prototype making possible mass-production system through design and production of a metal pattern.

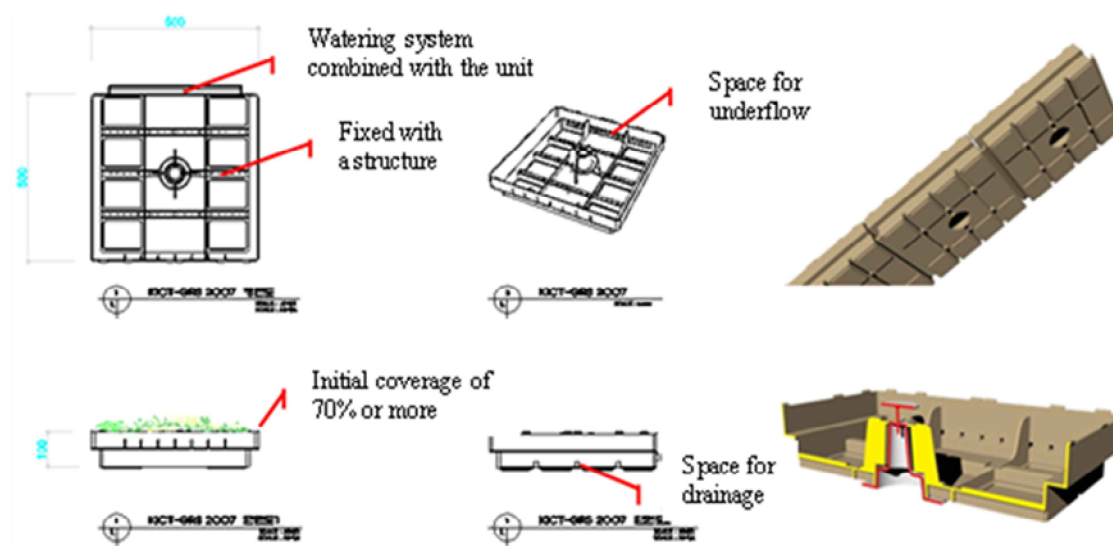
3.1 Problems to be Solved

This research has collected various opinions and experience to understand the problems of green roof application and figured out that the following is necessary to provide a proper system.

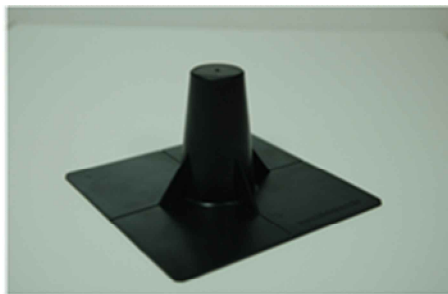
1. The green roof should have a fine outward appearance
2. High coverage and green area formation should be possible right after the installation
3. Soil loss, one of the biggest problems of previous green systems, should be prevented.
4. The system should be applied to both gentle and steep slope roofs.
5. Preventive measure should be provided for wind pressure on high-rise apartment buildings.
6. The system should be equipped with functions of increased evapotranspiration to improve urban climates and proper underflows for growth of vegetation.

As a result, a unit type green roof system was developed, meeting the above-mentioned requirements, and the following is the design of the unit, a key technology of this system.

3.2 Design of Green Units



Basically, the latticed bottom of the unit was designed to have underflows, providing soil with moisture, which often lacks when installed on steep slope roofs. This is intended to supply plenty of moisture for vegetation and increases evapotranspiration to improve urban climates. The design also contributes to frequency of watering, minimizing the maintenance work. The bottom of the system designed to create underflows naturally provides space for drainage, and the ventilation passage at the center of the unit, which also helps to fix the system, increases air permeability for plant growth. And preventive measures for wind pressure on high-rise apartment buildings can be provided by using a cone fixed to a building and the unit. The cone is fixed at the center, which also plays a role as a passage for maintenance.



Cone – fixes and supports the bottom using adhesive strength and stepping space



Bottom – provides space for drainage and ventilation

PE materials were used to make easier unit production and manufacturing, and standards required for a waterproof layer are not excessively high compared to those of previous systems due to the use of waterproof and rootproof materials. And this could reduce costs of system installation significantly.

One of the strong points of this system is that no additional rootproof layer is required, for the system itself has such a function through the design and installation methods.

A watering system is an option often selected for facilitating plant growth and, in that case, the system should be combined with the green unit so as to guarantee sustainable durability.

In this project a watering system was installed at the side of the unit, creating an integral design, making easier the installation, and preventing irrigation pipes from being seen which may ruin the fine view of installed systems.

Moreover, a surplus of water can flow from an upper part to a lower part of the unit along the slope of a roof, which enables an intermittent watering system



Connected units – provides space for underflow when installed on a sloped roof

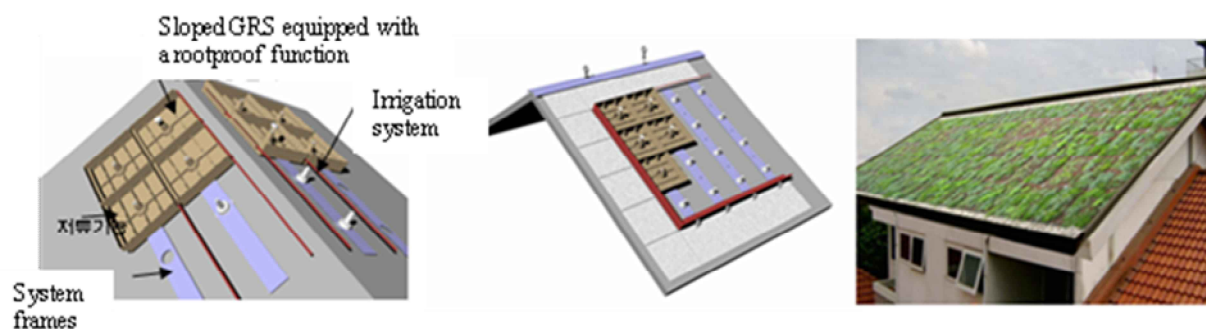


Watering/drainage passages – provides space for stepping also when connected

Due to the use of a unit, creation of green areas can be done only by delivering the units from a farm or a greenhouse and installing them. And initial coverage can be achieved up to 70% or more, providing a fine view right after the installation.

3.3 Suggestion for Green Systems and Prototypes

The prototype of the green system using the developed units solve problems of previous systems and can be applied to both gentle (common apartment houses) and steep slope roofs (high-rise buildings), further expanding its actual application.



The green system consists of green units, a cone fixing the unit with the building, and a watering system combined with the green unit. Additionally, there are a passage for installation or maintenance, a safety ring the edge of a roof for workers, and finishing parts of units contacting eaves.

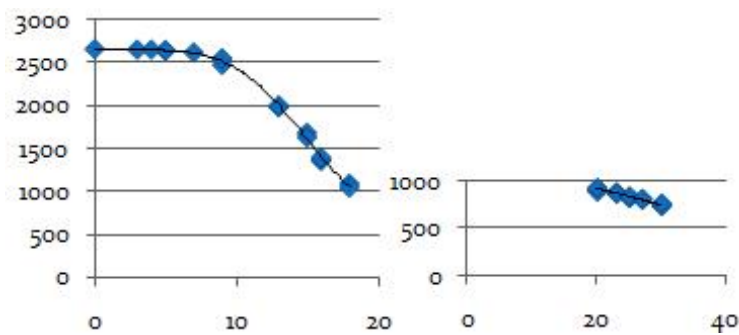
4. Performance Evaluation of the Unit Type Green Roof

4.1 Simulation for Drainage Performance

In order to predict the amount of drained water according to the slope of a roof, water supply through the irrigation system of the unit was simulated under the same conditions as an installed system.

At the slope of about 20° sudden change in the amount of underflows was observed due to the space for ventilation in the unit, and a formula was developed to calculate underflows of each unit according to a slope of a roof through repeated experiments.





: Amount of underflows at the slope of $\geq 0^\circ \sim < 20^\circ$ (ml)

$$y = 0.004x^5 - 0.160x^4 + 1.198x^3 - 3.128x^2 + 0.153x + 2645$$

: Amount of underflows at the slope of $\geq 20^\circ$ (ml)

$$y = 0.038x^3 - 3.152x^2 + 68.27x + 503.9$$

It was concluded that at least an amount of 2L or more can flow at the bottom of the unit at the slope of $\geq 20^\circ$ through the simulation.

4.2 Simulation for Wind Load

The system is expected to be first applied to a roof of apartment houses, high-rise buildings with more than 10 stories. And a green roof system has not been widely introduced so far due to strong wind pressure.

And a design wind load was calculated as follows, which is applied to a common apartment house according to Building Design Standards.¹

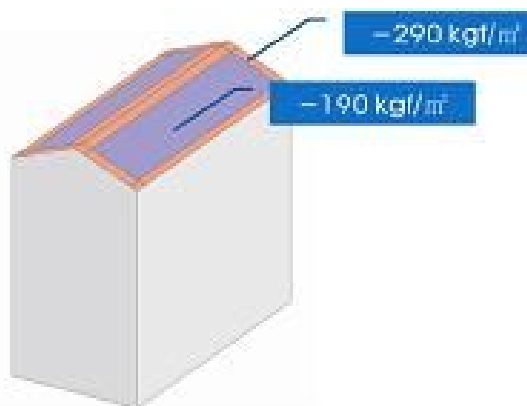
: Size of a model - 30M $\times$ 60M $\times$ 50M /slopes - 20% (11.3°)

: Design wind loads · Edge of a roof [-290kgf/m²: negative pressure]

· Center of a roof [-190kgf/m²: negative pressure]

Some of factors influencing design wind loads are the shape of a building (aspect ratio), height, usage, slope of a roof, and location.

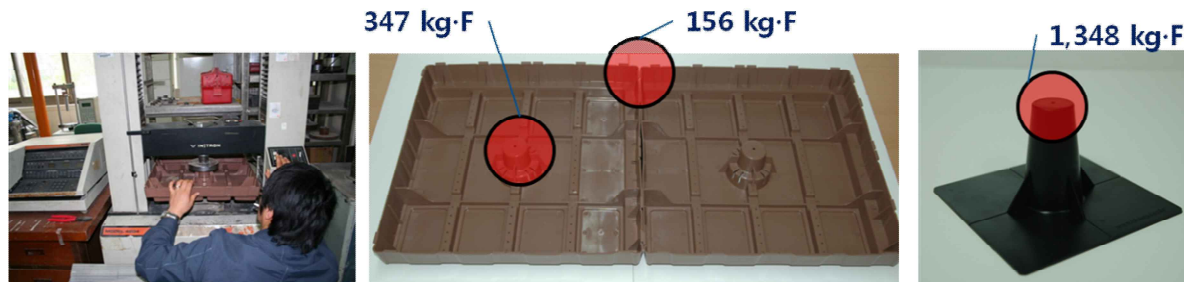
The size of a unit is 0.25m²/ea, and a cone fixes the unit to a building with butyl tape. According to an experiment, the adhesive force of a cone (its attached area is 0.15M $\times$ 0.15M) for a concrete structure was 125kgf or greater per a cone. Given that 4 unites are installed per m² and about 72.5kgf strength is required, at least 1.7 times greater force can be guaranteed.



Calculated Wind Loads of a Model and Experiment of Adhesive Strength on a Cone

4.3 Compressive Strength of the System

A passage in the created green areas is essential for maintenance after installation. According to an experiment of compressive strength on a cone, fixing of a cone and structure, and unit connection, the unit was designed to have sufficient durability to bear loads.



5. Conclusion

Application of the unit type green roof is expected to produce the following effects.

- Green areas can be created in an apartment complex utilizing the unused space of a roof, and a ratio of green coverage increased to make a city more environmentally-friendly.
- Thermal or cooling loads of the top story of an apartment building can be reduced as insulation of a roof is improved.
- Public health is enhanced by improving a indoor visual environment by adjusting lights.

The technology can minimize the value loss of a top story of an apartment building as residents avoid a top floor, and a building using the technology can serve as a landmark of low energy consumption and environmentally friendly building.

Likewise, the GRS green units solve the problems pointed out by previous technologies and improve coverage by growing vegetation in advance and installing it later. And the system is not limited by slopes of a roof, expected to distribute more stable and effective technology for greening.

6. Reference

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