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Construction of modular green roof panel

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Abstract. This article is dedicated to make people familiar with process of creating new construction of modular green roof panel. Article also shows creative process of prefabricated panel and all versions of its construction from the first attempts to final ecological modular panel for green roof. Article also describes problems of every version of modular panel which was created, and solutions which were made for final versions of green roof modular panel. Article also shows a final modular panel with its construction and possibility of its use on the roofs. In the article you can also read about tests which will be done in the future for verification of right construction of green roof panels and its behaviour in the real outside conditions.

1. Introduction

Thanks to climate changes the awareness of people about ecological construction is rising. We already know about Heat Island effect which results to continual overheating of city centres. That is the reason why big cities and agglomerations are investing more money in construction of cooling zones made of greenery, especially green roofs and green facades as we can see for example in Wien (Austria) or in Milano (Italy). But these types of constructions are also bringing on the scene some challenging problems with which we have to deal. The main problem is probably long time which we need for transportation of material to the roof and for greening the roof. These constructions are about symbiotic living of organic (greenery) and inorganic materials. This leads to seasonal construction of these systems. For this problem we have an easy solution, making green roofs on the ground and after that transporting whole system on the roofs. We already have technology and possibility to make prefabricated panels for green roofs but in Czech Republic, Slovakia and Middle European countries, we are not using these possibilities and still using old fashioned types of constructions which was used with almost same processes as on the first green roofs built by the Vikings in the Scandinavian Peninsula. On the other hand, in the USA we can see usage of prefabricated panels. But there is a one big problem about it. These panels are built by HDPE plastic, which means these panels are not ecological and also not economical as it could be. This article main aim is about process of creating prefabricated green roof panel which will be ecological and economical as well. Article also describes all stages of research and unsuccessful types of construction panels. The reason of showing unsuccessful types of ecological panels is to show which materials has been already tested and which ways of research can be concluded as the dead end. At the end of the article is presented final successful panel with its characteristics and variations for extensive green roof and for semi-intensive green roof.

2. Design and realization of prefabricated ecological variants for green roofs

As a first step for the construction of prefabricated panel was realized brief review showing us the types of prefabrications which are used in Czech Republic, Europe and USA. Only prefabrication which is used in the Czech Republic as we could find is the prefabrication based on the using of grass or perennial carpets.

First types of panels were chosen with size 600×600 mm. This size was based on the USA model of prefabricated panels and was considered as the optimal thanks to possibility of better manipulation with panels and also the panels should have a lower weight. On the other hand, second type of the panels was decided to be bigger and heavier but with advantage of using current materials which is used on the roofs without necessity of cutting it or long modifications of it. Size of the second type of panel has been 1200×600 mm. This size was also considered as the biggest for possibility for manipulation on the roof and for savings of material which is used on the roof.

For both types of panels had been chosen similar layer composition for extensive green roofs. Extensive green roof was selected mainly because weight of individual panels for easy manipulation and survivability. In the composition had been used retention mats made by recycled polyester fibres interconnected with fusible fibres. This retention layer had 40 mm thickness. Function of the retention mats was protection of the waterproofing layer and retention layer for the green roof. Technical parameters of the retention mats are described in the table 1.

Table 1. Technical parameters of retention mats.

		Mat thickness 30 mm	Mat thickness 40 mm	
Basic weight	g/m^2	3 000	4 000	± 15 %
Weight of saturated mat	kg/m2	22	32	± 15 %
Thickness 0,5 kPa	Mm	30	40	± 15 %
Compressibility	Mm	20	20	
Dynamic stiffness	MPa/m	8.2	7.5	
Maximum water capacity - slope 0°	l/m^2	20	29	
Thermal conductivity – laboratory humidity	W/m*K	0.038	0.038	
Thermal conductivity – saturated state	W/m*K	0.142	0.142	

First were constructed panels with size 600×600 mm. These panels were designed and constructed in four variants. These types are marked as A, B, C and D.

As a first type A was constructed panel with supporting layer made of retention mat. On the mat was put a layer substrate for extensive green roof. Substrate was secured on the sides with polypropylene membrane. The main reason for this construction was its easy design and advantage of using retention mat for more purposes than just using it as retention mat. This construction thanks to its light weight had very good possibility of manipulation and properties for construction of the roof. As the first step for this panel had to be cut retention mats from its manufacturing sized 1200×600 mm to our size 600×600 mm. Around this load-bearing shape were constructed sides made of polypropylene membrane. These sides were tightened with steel profiles to our required shape. Sides were also tied up by metal wires. Reason for this was strengthening sides and bottom of the panel. These wires and polypropylene membrane were mentioned as removable after completion on the roof. This system would allow us to use same sides from polypropylene membrane again and don't waste it for only one usage. Into this load-bearing shape was poured in substrate for extensive green roof with height of 50 mm. Panel has been planted by sedums. For example, we can name Sedum Album, Sempervivum Arachnoideum or Sedum Reflexum. After that panel was observed for several months.

Second type of panel, type B has been constructed similar as type A. Supporting layer of the panel was made of retention mat as well as we can see at the type A. Size of the panel was 600×600 mm. Difference between these construction was that, sides has been moved by 50 mm from the edges to the panels centre. Reason for moving of the sides inside was reinforcing panels and avoidance to any possibility of losing substrate through the sides out of the panel. These 50 mm sides would be filled by substrate additionally during construction process on the roof. Or as the second option these sides could be removed before installation. Sides were from the same materials as at the first type of panel.

With panel type C it was decided to make panel with different supporting layer than just the retention matt. For creation more support of the substrate layer has been used thermal insulation from XPS with height 100 mm. The reason for usage of XPS was simple. It was decided to use material which will help with physical properties of the roof and at the same time won’t be heavier than previous version. This type of construction will help to buildings thermal insulation properties and impact insulation of the roof. If we would use higher type of XPS than we could use these panels also as the green roof with opposite construction of the roof. On this XPS panel was layer of retention matt with height of 30 mm. Sides of this panel were made of polypropylene membrane which was fastened to XPS panel with wires. Substrate layer on this type of panel had 50 mm height.

Panel type D was similar to panel type C. On this type of panel has been chosen to make more simple type on the sides. Material for sides was made of Mirelon. Mirelon has been tightened as tight as it was maximally possible around XPS panel (100 mm) and retention matt (30 mm). After that Mirelon has been tightened in more layers for ensuring of the stability. Mirelon has been also fastened to XPS panel by staples. Height of the vegetation layer was 50 mm.

Next two variants of green roof panel-were constructed in different way. With the experiences from making first four types was chosen construction of the panel with size 1200×600 mm. With this size was possible to avoid technical problems which appeared on the construction of first four panel types. Size of the panel 1200 x 600 mm hasn’t been chosen randomly but it is the actual size of the XPS panel and retention matt without adjustments. Also after consultation with the expert for perennial greenery prof. Pejchal from Mendel University in Brno, when he claimed that this size of panel will improve effectiveness of the panels by possibility of planting more plants for square meter than on the smaller types of the panel. These two different panels were signed as type E and F.

Figure 1. Extensive type E (photo author).

Panel type E was designed as a panel for extensive green roofs with planting perennial herbs, succulents or sedums. As the first thing which appeared to be necessary to do was construction of form in which will be panel constructed. Shape was constructed specifically for making construction of the panel easier and after construction of every panel could be transported to new panel and planted panels doesn’t use it anymore. Shape construction was made of OSB boards which were connected on the edges with screws. Boards were higher than future panel by 10 mm. Size of the shape has been bigger by 2 mm on every side than future panel for possibility to remove form after final realization of panels. As the first after construction of form has been putted XPS panel in this shape with height 150 mm and size 1200×600 mm. Sides of this panel has been created by jute net. Jute net has been dimensioned for packaging of retention matt and substrate layer together. This net was after this cut out and on it has been laid retention matt. This construction has been laid on the XPS panel with jute net freely extending beyond the edges of shape. Jute net has been designed to cover all sides of the future panel expect the XPS layer. Retention mat in this panel had height 40 mm. After that was net tightened together to make solid edges for substrate with staples. Only top side stayed free for pouring of substrate. Substrate layer has been 50 mm. After that was fastened to sides top side of jute net around the substrate. After this form was removed and sedums were planted with Sedum Album or Sedum Lydium.

Figure 2. Type F after construction (photo author).

Because type E was the most successful it was decided to make more ambitious version of this panel and make it with same construction but as a panel for semi-intensive vegetation roofs. This type was named type F. Construction of the panel was almost the same as the construction of the extensive type of panel. Substrate layer has been higher than substrate layer for previous types and its highness has been 150 mm. Chosen vegetation for this panel has been mix of meadow grasses. This type had also construction with size 1200×600 mm. Because this panel was higher it was necessary to make a new shape for construction of the panel. Process of the panel construction was the same as for the extensive version type E. After seeding of grasses started the experiment with long-term observation of panels viability.

3. Viability observation for all types of panels

All types of panels were tested in same conditions. All panels were located in research centre ADMAS in outdoor terms. All panels were on higher place for avoidance of contact with ground. The chosen place was chosen-because of presence of natural solar radiation during the day, but at the same time it is protected from the north side strong wind, which often occurs in the given area during summer months.

The surface was made of OSB boards. The individual panels were placed side by side to have as close growth conditions as possible. Individual panels were monitored in regular intervals of one week during three months from June to September. All panels were left without any maintenance to determine their viability. Only the semi-intensive type of panel, due to another type of greening, was regularly watered with clean water during first two weeks.

Type A looked very promising during first weeks but after sometime roots of sedums started to dying. At the same time, constructional deficiencies of the type A began to show up with increasing time. Due to the temperature change, the polypropylene membrane sides have been stretched and substrate gradually fell off the panel. Also the supporting layer from retention matt has proved to be not entirely suitable due to its gradual deflection during transfer.

Panel type B thanks to similar construction as a type A had also the similar problems with dying of plants and sides of the panels lost their tightness during the summer, which led to losing more substrate. Substrate fell of through the sides. In this case, the substrate fell of onto the support construction from retention matt. Onto the sides where it would be poured during implementation on the roof. However, this would be a major issue during the transportation of the panels on the roof.

Panel type C thanks to different construction than the previous two types didn't have problem with supporting layer and stayed compact during whole test and thanks to possibility of better fastened of sides to XPS panel was the amount of substrate falling of the panel lower than on any of the previous type. However, plants didn't survive through summer even on this type of panel.

Panel type D was the construction same as panel type C so its results about the survivability of plants were the same. Sides were made of Mirelon after only one month they started to bend in the middle thanks to pressure of substrate and water in it and that caused a lot of falling substrate out from the panel. In the end of the experiment we could also see some ruptures in the Mirelon material.

First of the bigger types, panel type E, was the most promising panel from the start of experiment. And during first of the three months it didn't have any major problems. Substrate was tightened in jute net and didn't have any possibility to fell off from panel. Sedums during these three months were growing as it was expected before the launch of experiment. Even after a long-time jute net didn't had any problem with its entirety. After three months this panel was also measured on the weights when it was fully saturated. Weight of the panel was 28 kg. So its weight is operable for one worker on the roof even if its fully saturated but we can assume at least two workers who will help with construction of vegetation roof to each other. This variant was considered as the best variant but with necessity of future upgrades.

Figure 3. Semi-intensive type F (photo author).

Semi-intensive type F was the most successful type. After almost the no-time started grow grasses through jute net. Roots of the grasses also tightened all substrate and jute net together so this variant was the most stable for transporting as well. Panel survived whole summer without any complications. Only problem of this type was its weight. Weight of this panel was 35 kg and when it was saturated it weight was around 75 kilograms. Which is too much for working on the construction just with one worker. This type was concluded as a success but inappropriate for more testing.

4. Conclusion

During this research were made six experimental types of panels for prefabricated vegetation roofs. All of these panels were constructed as economical and ecological variants appropriate for installation in ecological construction which green roof is. Panel types A and B were a failure because of its bad construction of supporting layer. Types C and D could be successful but because its small size of panels they didn't storage enough water and minerals for the plants which couldn't survived for the summer. Type F was the complete success, but it was experiment with possibility where we can go to make panel to comfortable transport and construction and from this side, we can say about this type it was also a failure. On the other hand, we found the best construction possibility in panel type E which we can consider as a complete success.

The best type, type E, has been chosen as a best variant from realised panels. This type had to be also modified during the next research and tested again on experimental roof but its first construction as you can see in this article was promising from the start. After making these adjustments the panel was patented as a utility model thanks to junior specific research FAST-J-19-5867.

As we can see in this article, we cannot expect every solution with which we are counting as a possible improvement and on the paper is looking as ideal solution is not every time a good solution. But thanks to experiments and further testing we can always find a way how to make an improvement to unsuccessful research and find the solution which will be successful.

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