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Using of geocomposite with superabsorbent synthetic polymers as water retention element in vegetative layers

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A b s t r a c t. Many earth structures are protected against erosion with grass cover. 'Green' protection is often applied in difficult conditions of water deficit - on slopes, over high permeable layers, over drainage. Geocomposite with superabsorbent (SAP) placed in the root zone could improve the situation, because of SAP ability to retain water which can be later used by plants during draught periods. Preliminary tests made in different scales (in small containers and in natural conditions) have shown that the presence of SAP geocomposite in the vegetative layer causes more intensive growth and better development of grass root system. Positive results of research on the new material usage in biotechnical slope protection was an impulse to begin investigation on its applications in agriculture, horticulture, forestry. At this stage only qualitative evaluation tests, based on observations, have been made. The investigation will be continued with a more comprehensive program and quantitative analysis of results.

K e y w o r d s: geocomposite, superabsorbent, anti-erosion protection, water retention

INTRODUCTION

Plants are often used as a part of earth structures to stabilize them and as protection against rainfalls, winds and mechanical damage. To grow and to fulfill the functions mentioned above, they need not only fertile subsoil, but appropriate amount of water, too. If there is not enough water during the vegetative season, irrigation can be an effective - but expensive - solution of the problem. Use of superabsorbent synthetic polymers (SAP) could be a simpler and cheaper method. SAP is able to store water which, if necessary, is accessible for plants. The simplest direct application method - by mixing with soil – could be disadvantageous for stability of vegetation layer if it is used *eg* in biotechnical protection of slopes. That is why a new product, eliminating these problems – geocomposite containing SAP – was developed. The first aim of research was to study SAP influence on the formation of a surface layer reinforced with root system in biotechnical slope protection *eg* in flood banks. Then it was found that the scope of possible usage of this composite could be much wider. So the same basic program was extended onto some horticulture, agriculture and forestry applications.

The experience of companies using SAP has proved many advantages of its application in agriculture. The most important of them are the following:

- lower costs of plant production;
- important improvement of water management and increase of water accessibility for plants (amount of water normally used for irrigation could be reduced by more than 50%);
- increased amount of soil aggregates, better permeability and soil aeration;
- easier evacuation of carbon dioxide from the root zone;
- improvement of microflora and bacteria contained in soil;
- increased osmotic moisture and possibility of nutrients absorption.

Taking into account the advantages of SAP properties, it is used in arid regions (Frenchel *et al*., 2001), in land melioration, on forest plantations, in founding new vineyards, in reclamation of lands deteriorated by industry, in park and landscape formation.

SAPs are very useful in biotechnical protection systems, too. In earth structures there are zones where only capillary water suspended in humus layer is present. In such places there is not enough water during the summer season, which causes plants to wither and, as a result, to lose their protective functions. Such problems can be encountered in *eg* upper parts of slopes, in soil cover of dams and embankments

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drainage systems, in protection structures made of gabions and stabilized with vegetation. Apart from increase of water reserves for plants, another advantage of SAP usage is reduction of run-off during heavy rains.

There are different techniques of SAP application: from the simplest one – spreading and mixing with soil – to more sophisticated, like injection into the ground or placing in irrigation tubes (Frenchel *et al*., 2001).

The aim of this paper was to present the results of preliminary studies of the new composite containing SAP in agriculture and environment protection.

MATERIALS

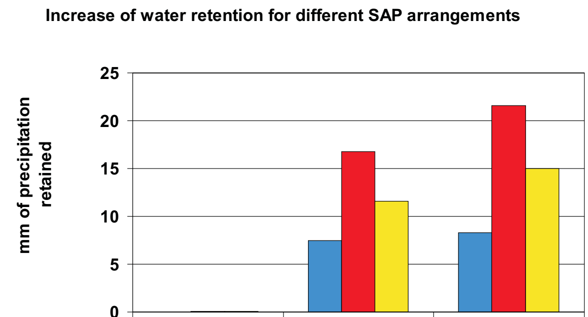
SAP - superabsorbent synthetic polymers - general description

According to IUPAC Recommendations (2004), superabsorbent polymer is a polymer that can absorb and retain extremely large amounts of a liquid relative to its own mass. The liquid absorbed can be water or an organic liquid. Mass production of SAP hydrogels has started at the end of the last century. At the beginning superabsorbents were made from chemically modified starch and cellulose, and from other polymers like PVA (polivynyl alcohol) or PEO (polyethylene oxide). Nowadays they are made from partially neutralized, lightly cross-linked polyacrylic acid. SAP are water swelling, but not water soluble (Elliot, 2004). They are characterized by an ability to absorb big amounts of water. Depending on the quality and chemical composition, SAP can retain up to 1000 times more pure water than its dry mass (Glados and Maciejewski, 1998). Much smaller is the absorption of water containing *eg* urine or metal ions, sometimes water absorption capacity is reduced even ten times. SAP is widely used in production of many hygienic articles like *eg* baby napkins and panty liners. Yet the list of possible usages is much longer *eg* mine waste treatment, sludge dehydration, as concrete admixture, *etc*. (Deyu Gao, 2003; Jensen and Hansen, 2001). SAP proper- ties are interesting for agriculture, too. There are many examples of superabsorbent uses in plant production. The main advantage of placing SAP in subsoil is additional water retention, water which can be regained by root system. Positive changes of soil and substrate properties are observed (Martyn and Szot, 2001). Fertilizers and pesticides can be absorbed together with water and gradually returned to be used by plants. Service life of SAP is estimated at 6–9 years. Decomposition products are water, carbon dioxide and nitrogen.

New composite containing SAP and possibilities of its application

Laboratory tests have started with investigation of the influence of SAP particles arrangement on effectiveness of water retention. The tests were carried out in a 300 mm diameter column with 250 mm thick layer of pure medium sand inside without organic matter. The amount of SAP, with 250:1 swelling ratio, was calculated so that theoretically it could retain maximum 30 mm of precipitation. Then heavy rain with 48 mm of water falling during 10 min was simulated and repeated 3 times. The amount of water retained by the soil was determined after every stage. The tests showed that in pore space of medium sand without SAP all rainfall water was caught after the first stage, after second precipitation maximum soil water capacity was reached and stabilized on the level of *ca*. 68 mm. From this moment only sand containing SAP could absorb additional amounts of water. Additionally to the increase of water reserves for plants, another advantage of SAP usage was proved – reduction of run-off during heavy rains.

The biggest additional water retention, as it is shown on the diagram (Fig. 1), was achieved when SAP was placed in 10 layers with 60 mm spacing of application points in both perpendicular directions, and points in lower level were shifted in relation to the points of higher level. It was more



Series	1	2	3
60x60 mm	0,03	7,5	8,3
60x60 mm transposed	0,08	16,8	21,6
SAP mixed with sand	0,08	11,6	15

Fig. 1. Additional retention of water from precipitation in sand with SAP for different SAP arrangement in a column test. Theoretical sorption possibilities of SAP amount used in tests – 30 mm of rainfall.

then 2/3 of the theoretical retention possibilities. When all the points were situated in 10 layers, but one beneath another, the amount of retained water was smaller – better results were obtained even when SAP was mixed with the soil. These simple tests indicated how important for water absorption SAP particles position is. By traditional, simple application there is no control of its arrangement – hydrogel is randomly distributed, usually not the most optimal way. In some engineering applications *eg* on slopes, uncontrolled concentration of SAP in one place could lead to local landslides, because of forming potential slip surface by gel which has much lower strength parameters than soil.

To avoid such problems, the authors, together with the manufacturer of geosynthetics, applied for and were granted a patent for a geocomposite consisting of 2 layers of non-woven geotextile and SAP closed inside (Fig. 2). The geotextile is needle-punched along both edges. Its dimension and structure is chosen so that there is enough space for SAP swelling. It can eventually expand a little bit under swelling pressure. The enclosure of hydrogel is particularly important in application on inclined surfaces. It protects upper layer from slides which could occur if SAP would be used directly, without control of its spatial distribution and possibility of local concentration, dangerous for stability.

Fig. 2. Gecomposite made of non-vowen geotextile with superabsorbent (SAP). On the right – small strip of the geocomposite swelled after water has been absorbed.

Usage of geocomposite allows to know more precisely where SAP is placed, what is its amount, and at what depth it was applied. SAP can be on the site soaked with water, so water retaining possibilities can be better utilized. Water amount necessary to mobilize full sorption potential can be reduced, too. If necessary, SAP can be removed later from the subsoil, even after several years.

RESULTS OF PRELIMINARY APPLICATION TESTS

Preliminary tests were started with hand made geocomposite at the beginning, and continued later with a small quantity of test production of geocomposite with SAP. The influence of its application in the subsoil on grass root system was investigated. This stage of tests was limited to qualitative evaluation of results obtained under different conditions. The arrangement of the test is presented in Fig. 3.

At the beginning, 3 containers with grass were situated, during the hot and dry summer of 2003, on the roof of the Institute building. There were two containers with geocomposite containing SAP, and one without it. Grass was seeded on a thin humus layer – underneath there was sandy permeable subsoil. The only water for the plants came from precipitation. The difference between root systems developed in soil with and without geocomposite after 6 months including the hot summer season can be seen in Fig. 4.

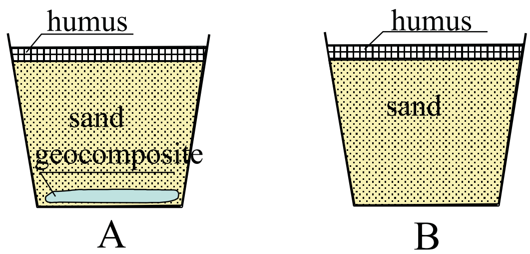


Fig. 3. Arrangement of humus, sand layers and SAP geocomposite position for preliminary application tests: A – container with a strip of geocomposite containing SAP; B – control container without superabsorbent; layers thickness: humus – 20 mm, sand –300 mm, geocomposite – *ca*. 50 mm.

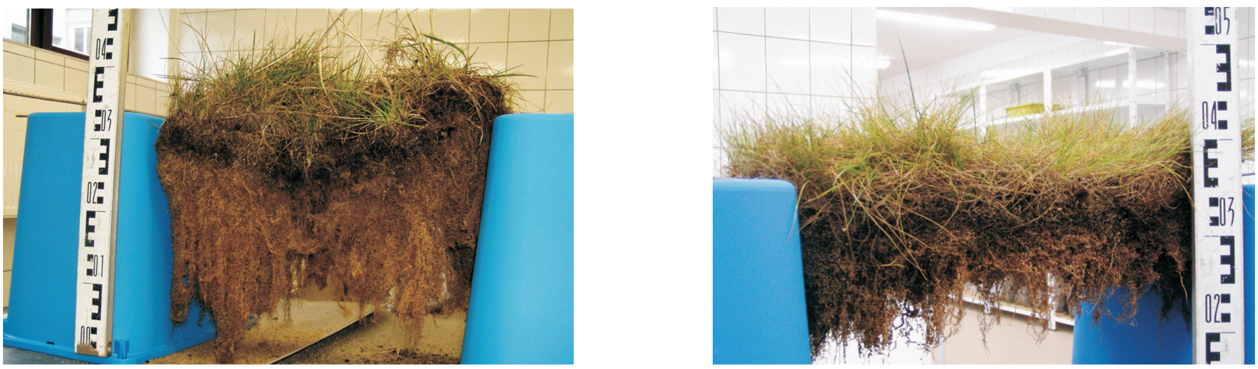


Fig. 4. Grass root system developed on a subsoil with (left) or without (right) SAP geocomposite.

One can easily notice that the short section of geocomposite placed in the bottom zone of the container caused an intensive development of root system which reached 0.3 m in depth. Without the SAP geocomposite the depth of the root zone was about 0.1 m.

Investigation carried out in natural conditions was the next step. Geocomposite with SAP was installed on an existing flood bank slope to serve as a water reservoir for grass protecting the surface against erosion. Results of this test are presented in Fig. 5. The geocomposite was placed only in the zone marked as zone 2. Grass in zone 1 was left without any intervention which could improve plants vegetation conditions. Zone 3 was watered regularly during the test. Results obtained after one vegetation season showed that the application of the geocomposite created the most suitable environment for grass growth. After the completion of tests currently in progress, the root system of grass from every zone will be compared. It will be checked if, as expected from tests in containers, it is the most developed in the zone where the superabsorbent was present in the subsoil.

Fig. 5. Test application of geocomposite with SAP on a flood embankment slope.

Some simple tests on utilization of new geocomposite as a water retention and regulation element were made outside geotechnical engineering, by placing it in a subsoil of vegetable and flowers cultures. The geocomposite with SAP was used in celery, cucumbers and chrysanthemum (in pots) cultivation. Observation was made without precise quantitative analysis of tests results. The results are promising, the growth of the plants was more intensive. Now it is planned to continue the investigation by studying all the aspects of this form of SAP application in agriculture or horticulture. Example of the effects obtained through the application of the geocomposite with SAP to intensify the growth of celery is presented in Fig. 6.

Fig. 6. Celery cultivated on subsoil with (left) and without (right) SAP geocomposite.

In agriculture or horticulture the geocomposite with SAP would be usually placed along axis of a row of planted vegetables. It can be used in the form of a short strip, closed at both ends, put in the bottom zone of a pot. At present the depth of installation is chosen arbitrarily, but it needs further studies to determine optimised location for different kinds of subsoil and plants.

PROPOSED ARRANGEMENTS OF GEOCOMPOSITE WITH SAP IN BIOTECHNICAL SLOPE PROTECTION

SAP geocomposite can be applied pointwise, as a linear element – *eg* in agro- and horticulture, or as a grid with horizontal and vertical components, when it is necessary to cover with plants a defined area. This is the case of biotechnical slope protection. Usually it is a grass cover strongly bound with subsoil forming an earth structure element resistant against water or eolian erosion. Running water can take away soil material, starting the process of destruction, if plants are not dense enough. There are of cause many methods to form ‘green’ protection *eg* turfing, as one very commonly used, or rolled grass carpets. Independently of the applied method there is always the same problem – supply of water necessary for the vegetation. Deficit of water can spoil protection effects of the grass at every stage of a structure life. If there is not enough precipitation and soil retention is very small *eg* grass cover laid on gabions or eco-mattresses filled with coarse soil material, regular watering is the only solution, but not applicable everywhere because of expenses or difficult accessibility of the site. In such circumstances usage of new geocomposite can solve or reduce the problem by retaining additional amount of water from precipitation, which could be released during periods of draughts improving vegetation conditions and, as observed during the tests, improving root system development. Long sections of geocomposite strips laid parallel to a slope toe form the simplest arrangement. They can be also arranged in a grid pattern (Orzeszyna *et al*., 2004). Suggested patterns of placing geocomposite on a slope are shown in Fig. 7. Usage of new geocomposite does not exclude the application of other means of slope erosion protection which are used in geotechnical engineering. Those are different synthetic materials, like anti-erosion mats placed near the surface. Mats stabilize the position of plants which are growing through openings of mesh or textiles, but have no or very little influence on water retention in the subsoil. They strengthen the surface in a mechanical way.

Further investigation should answer the question of optimal spacing between sections. During preliminary tests the distance between neighbouring geocopmposite strips was about 0.33 m, with quite good results achieved. If cuttings are to be planted, short geocomposite strips with SAP should be used. Strips are applied pointwise, behind the cuttings, as presented in Figs 8 and 9.

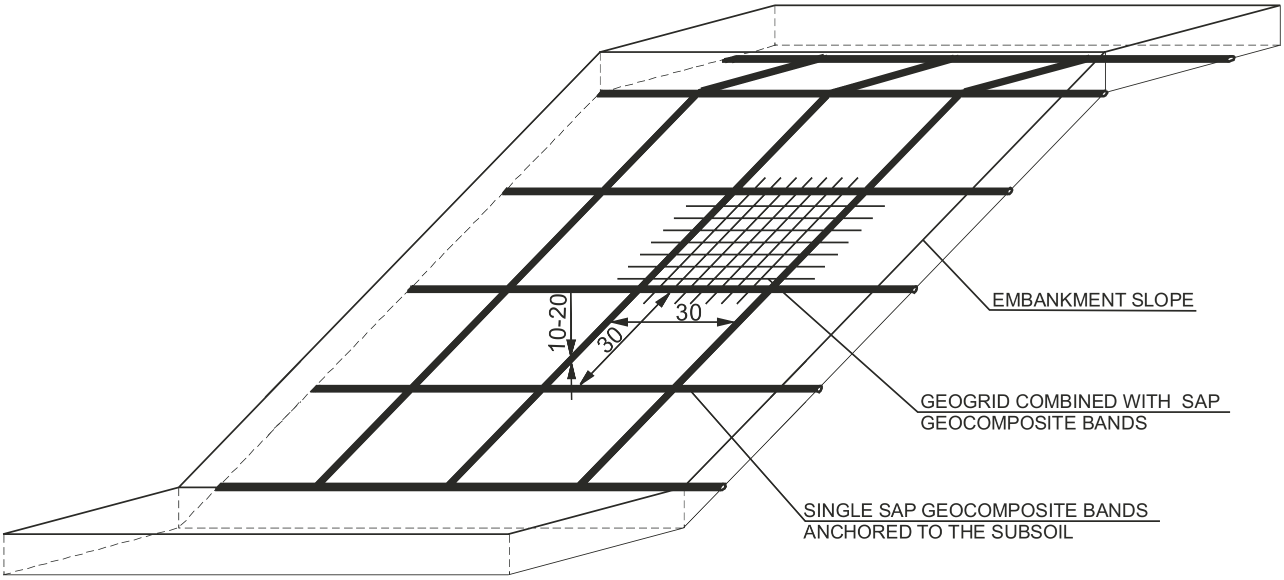


Fig. 7. Possible arrangements of geocomposite with SAP applied on slopes.

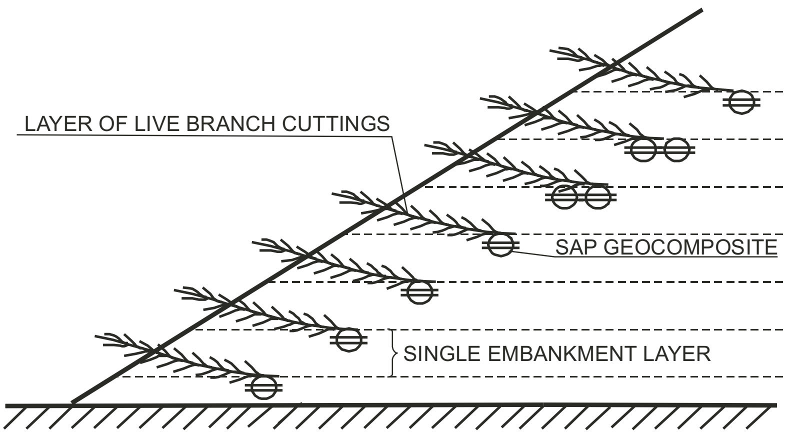


Fig. 8. Application of geocomposite with SAP on a slope with live branch cuttings.

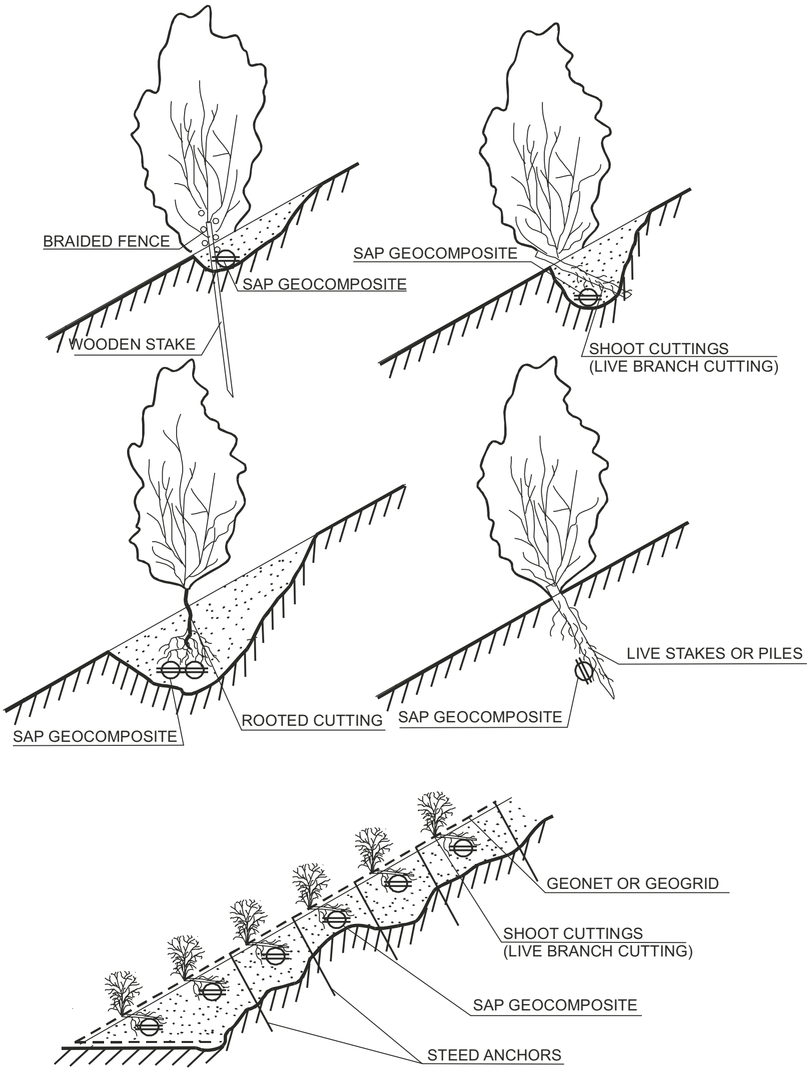


Fig. 9. Application of SAP geocomposite in terrace protection.

CONCLUSIONS

1. Geocomposite with SAP can be successfully used in agriculture and environment protection.

2. Preliminary tests, carried out so far, have shown that its application is relatively simple and has a positive effect on the growth of plants and root systems, securing better water supply during draught periods or in difficult moisture conditions.

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