# CONSTRUCTION OF ANTI-FLOOD BARRIERS SOLVED BY RECYCLING OF WASTE PLASTICS

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The structure of the development anti-flood barriers from recycled plastics is composed from metal and plastic sources. When designing the geometry and constructing the barrier, the first stage was to design a structure based on the shape of unified blocks made from PP and PE. The last generation of metal construction was constructionally optimized by renowned producer KONSTRUKTA-Industry, a.s.. Unified plastic blocks were designed in Slovakia at Chemosvit Environchem, a.s. in cooperation with Chemosvit; the focus was to produce blocks made from recycled materials and their subsequent application for beneficial use. The structure underwent numerous optimization processes including load field trials, finite element analysis (FEA) and internal/external stability analysis. Production documentation, prototypes, and field tests were also performed. The latest changes to the design are being performed in order to prepare it for mass production. Our development is the subject of protection [Soos 2011], [Soos 2013], [Soos 2014b], [Soos 2014c], [Soos 2014d]. The latest generation of the strategy is in fig. 1

**KEYWORDS**

recycled plastic, flooding, watergates, flood barrier, self-stabilization, flood wall, flood protection

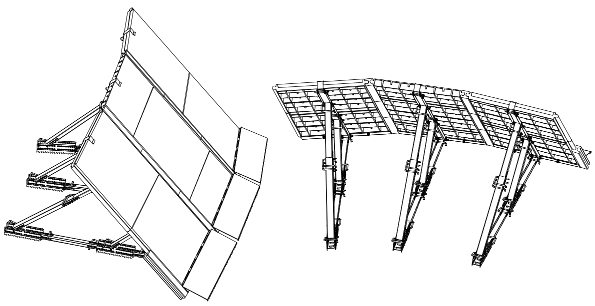

**Figure 1.** Modular flood barrier structure

## 1 INTRODUCTION

The designed modular flood barrier structure consists of an angled and horizontal part (Fig. 1). In this design, the water acts on the barrier from the outside, where the connecting braces are loaded in compression. The hydrostatic pressure of the water on the sloped surface ensures adequate anchorage to prevent its movement.

If the barriers are installed on firm ground, then a rubber seal is placed below the horizontal parts of both water barriers. In the case that the barriers are located on uneven or soft ground, then anchoring pikes are used on the horizontal parts. Connecting of the vertical parts is done by using attachment bars. To obtain greater stability, the vertical parts are mounted to each other in a pattern (long to short to long etc… Fig. 4) and are connected with bars. The structure, to a certain extent, allows for a curved barrier. For a convex shape (Fig. 2) it is not necessary to connect the horizontal parts. Horizontal connection of the panels increases the overall resistance of the wall. The difference in stress with and without horizontal connection is shown in Figure 4. For concave shapes (Fig. 2) it is only necessary to connect every second horizontal part. The modular structure of the flood barrier also allows for deployment in uneven terrain (Fig. 3). In this configuration, the horizontal bars are not necessary.

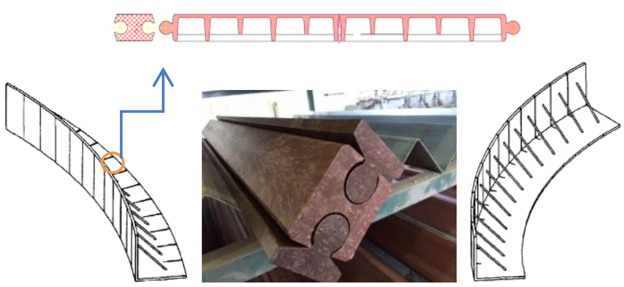

**Figure 2.** Convex and concave engineering solution

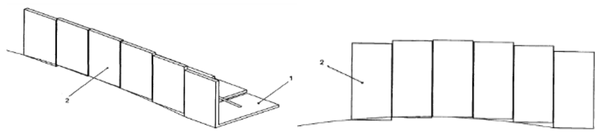

**Figure 3.** Following uneven terrain

The angle configuration of the sloped part is adjustable by the length of the braces and the position of their attachment point. The modular structure allows for a change in the length of the sloped parts. The technical advantages of the modular structure are evident in the effects induced externally.

## 2 DEVELOPMENT AND OPTIMIZATION

An important part of the development process was the continuous assessment of the structure by experts in the area of FEA and statics (Fig. 4). The initial, relatively simple, simulation indicated that the system can become unstable and therefore it was necessary to perform a more complex analysis of the assembly which included all important interactions so that the simulated state best represented real conditions.

In the next phase, the construction was optimized, mainly with respect to satisfying the manufacturing processes for the test model. A parametric simulation model was constructed with variable geometry in order to obtain the most suitable shape of the structure. The simulation consists of a load F1=17720N, pressure acting on the walls at a water level of 1.6m, water pressure on the flap $p_1$= 0,016MPa, and the assumption of terrain between the base and the surface $f_6$=0.55, $f_7$=0.55, $f_8$=0.55. All of this resulted in the stress spectrum and deformation of a system which best represents the real conditions, states, and reactions in important nodes of the device (Fig. 5, 6, table 1). This simulation is only an outtake from a series of simulations in which the assumed critical states were verified at various burdening conditions and terrain contingencies. The results of the simulations were later compared with actual measurements in the terrain (Fig. 7, 8, 9.)

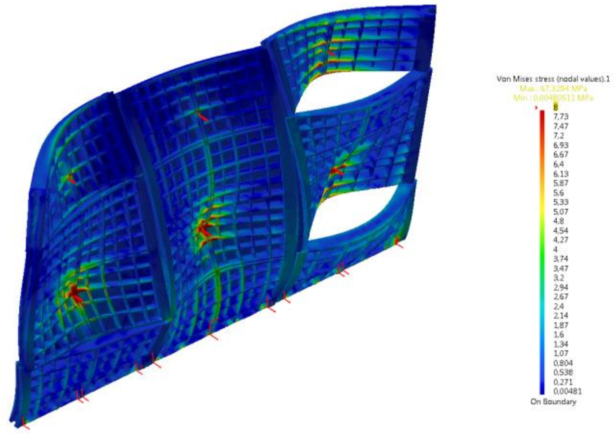

**Figure 4.** Finite element method FEM analysis of the arrangement of plastic block loading [MPa]

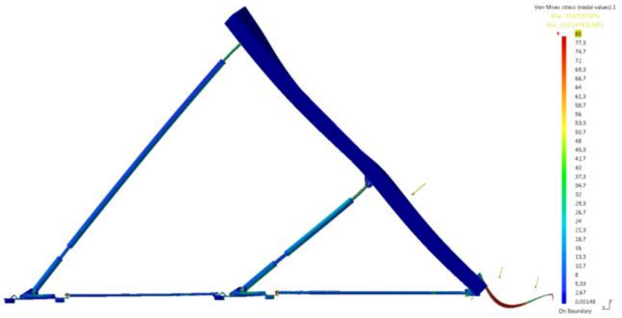

**Figure 5.** Finite element method FEM analysis of back construction loading [MPa] (def. M 20:1)

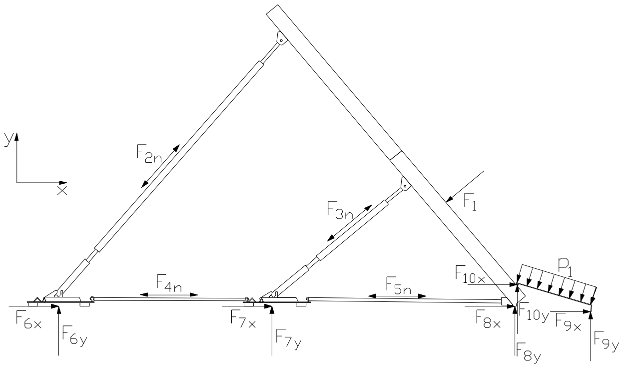


**Figure 6.** Graphic interpretation of the complex FEA simulation reaction of our solution design.

| Force | [N] | Force | [N] | Force | [N] |
|---|---|---|---|---|---|
| $F_1$ | 17720 | $F_{6x}$ | 2490 | $F_{8y}$ | 4506 |
| $F_{2n}$ | 3360 | $F_{6y}$ | 946 | $F_{9x}$ | 1915 |
| $F_{3n}$ | 5560 | $F_{7x}$ | 3655 | $F_{9y}$ | 7236 |
| $F_{4n}$ | 1231 | $F_{7y}$ | 2613 | $F_{10x}$ | -4194 |
| $F_{5n}$ | 2829 | $F_{8x}$ | 9439 | $F_{10x}$ | -5426 |
| | | | | | |
| Other specified options: | | | | | |
| friction: $f_6 = 0{,}55$; $f_7 = 1$; $f_8 = 0{,}55$ | | | | | |

**Table 1.** FEA simulation for a specific condition state of friction, reaction values.

## 3 FIELD TESTS OF FLOOD BARRIERS

A series of flood tests were performed to test the capacities of the system to resist water pressure and the stability of the individual modules.

In the first test at the Vistuk dam close to Pezinok, a 3.6 m high wall was built in the channel with a stone foundation and relatively steep sides. It was implemented on 07.06.2012.

The second test, from 08.06.2012 comprised the building of a basin with square dimensions of 3 x 3 meters. For this test corner elements were made to fill in the corners of the basin. Water from a water tank was pumped into the basin until the maximum height of 160 cm. was reached. The base level was formed of soaked grassy vegetation by which the suitability of using these barriers even in difficult terrains was tested.

The third, dry, test was carried out on the occasion of the conference, “Techniques of environmental protection” - TOP2012 26.-28.6.2012 with the goal of publicizing and proving the functionality, degree of modularity and flexibility of the system. In a similar manner the system was also presented at a Mechanical Engineering trade fair in 2013 in Nitra.

Another test at Gabcíkovo 14.-25.11.2013 was the largest in terms of the amount of construction elements and also of the time and means for the implementation (Fig. 6). A 5x10m basin was built, part of which were 3 conceptions for working out the barriers (Fig. 6). Innovations of new types of connectors and local solutions of construction were applied. In addition to this, a wall (dry) 13m long was implemented to test applicability and flexibility of the system for varying use conditions. On the wall were presented various height wall ranges, applied flexible units for greater workability and flexibility and a method for burdening the sealing elements with bags of sand and sealing weepers from foil.

**Figure 7.** Test in Gabcikova, Basin 5x10m and demonstration wall, 12m

## 4 VERIFICATION OF THE PROPERTIES OF SOLUTIONS

All of the performed tests brought a good deal of knowledge and other ideas on how to improve the system. The construction was stable and withstood the pressure from the water in even the most difficult conditions. The final test at Gabcikovo was accompanied by extensive measuring of the movement of the construction and simulations of the potential failure of the selected elements in order to guarantee the theoretical assumptions of stability. Also at Gabcikovo there were carried out tensometric measurement of proportional extensions and the determined stress in the support construction of the individual variants of thee solution. We compared the results with the results of the simulations and so confirmed the accuracy of our theoretic assumptions.

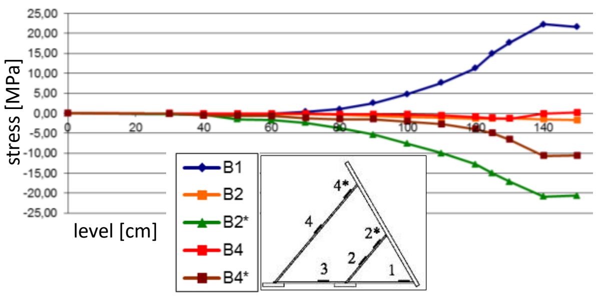


Figure 8. Illustration of the results of the tensometric measurement of stress, in dependence on the watter level [Soos 2014a]

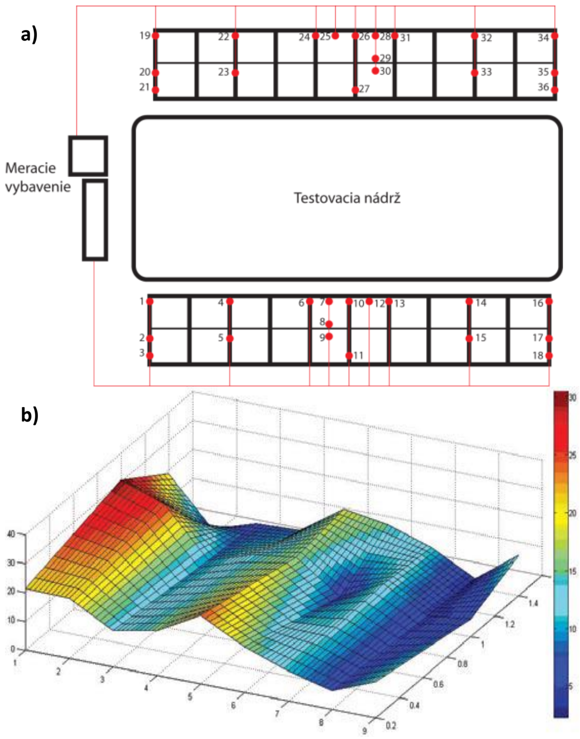


Figure 9 a) Measurement scheme. b) Experiment of the failure one steel support part - demonstration of the measurement results of collapsing wall deformation measuring [cm] [Kopunec 2015].

The newest generation of the flood barriers system was subject to burdening tests on 7 – 9.6. 2016 at the TOP 2016 conference ("Engineering for Environment Protection – TOP") in the grounds of the Casta – Papiernicka purposed facility near the town of Píla, which was stricken by a destructive flood in 2011. In the interests of protecting key innovations, the implementation collective has submitted a number of utility models and patents [Soos 2011], [Soos 2013], [Soos 2014b], [Soos 2014c], [Soos 2014d].

Figure. 10 Modular flood barrier structure – test basin at TOP 2016

The newest solution of the barrier system is modular and compact. The compactness of the solution is guaranteed by a unique execution of the construction joints so that the whole system can be broken down into thrifty handling and storing segments .(Fig. 11) The blocks forming the wall filling are monolithic (Fig. 12) as opposed to the former implementations are equipped with advanced vertical connectors and horizontal locking.

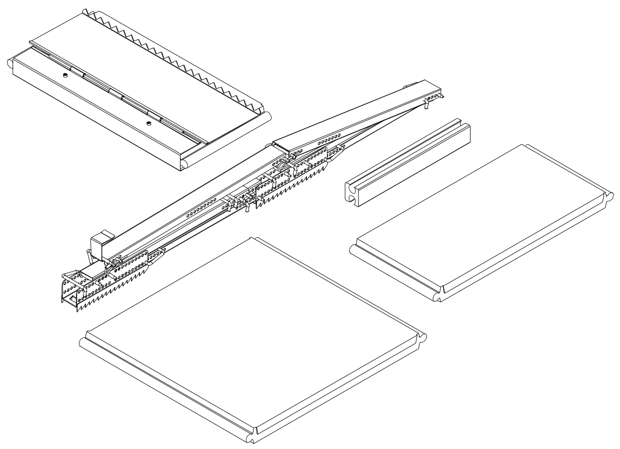

Figure 11. Basic parts of the modular structure of walls in disassembled state before assembly

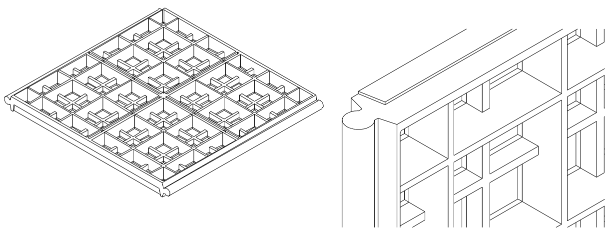

Figure 12. Newest shape of the monolith blocks with vertical and horizontal locks.

## 5 CONCLUSION

Our solution completely fulfills the requirements for putting into practice from the standpoint of resistance and the conditions of assembly in the terrain. Its effective placing on the market prevents problems in the area of certification of products of this type. At present there is no unified methodic for assessment of mobile systems of flood protection. The individual producers using only for a voluntary certification for declaring the construction limits of the selected parameters of the products. Another problem is the financial demands for the manufacture of the production of monolithic plastic blocks and connection modules by the technology of 'infinite' stamping. Despite all the problems our solution is prepared to face these competitive market conditions due to its unique parameters and properties, and also the calculated sales price.

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