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UNDERGROUND STORAGE TANKS AND CONTAINERS FROM PLASTIC MATERIAL

1. Introduction

The use of plastic materials for construction of underground storage tanks and containers is standard nowadays. The following is a list of its advantages.

— High resistance against aggressive impacts. External impacts are given by the character of the environment. Inner impacts are given by the type of mixtures temporarily or permanently placed inside of the containers.

— Simple production, fast and easy assembly.

— Favorable purchase price.

The disadvantage of these materials is the inconsistency of their physical and deformational parameters dependent on time, temperature, and achieved deformation. High values of physical and deformational parameters of the produced tubular or wall elements from plastic materials are significantly decreasing after some time. Such a decrease can happen multiple times. Some other negative properties of these materials are that along with a decrease of physical and deformational parameters, their deformational characteristics change as well. Tough material changes into brittle material.

The above stated facts can be documented by an occurrence of extraordinary cases where walls of storage tanks and containers got significantly deformed after a certain period from their manufacturing.

2. Calculation parameters of materials

The basis for calculation of plastic constructions regarding underground storage tanks and containers is determination of their physical and deformational parameters:

$\sigma_{al.}$ — calculation strain under operating conditions,

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$E_{c(al.),\,St}$ — calculation module of flowing under operating conditions for the calculation of stability,

$E_{c(al.),\,D}$ — calculation module of flowing under operating conditions for the calculation of deformation.

The above stated parameters have to be derived from values stated by the manufactures; such values are consequently adjusted regarding time, temperature, and some other circumstances such as:

— correction factor highlighting impacts of specific strain A_1,
— correction factor highlighting impacts of surrounding media A_{2K},
— correction factor highlighting impacts of surrounding media on change of flexibility module A_{2E},
— short-term welding factor,
— long-term welding factor f_1,
— safety coefficient S.

The following examples, implemented in accordance to the ČSN EN 1778 standard document the potential extent of change regarding physical and deformational parameters.

The calculation of strain allowed under operating conditions (al, for a durability life of 25 years and a temperature of 10°C results from a value of long-term resistance K. Values of the parameters regarding correction factors used for the calculation ($f_1 = 0.6$; $A_1 = 1.1$; $A_{2K} = 1$; $S = 2$) are taken from the ČSN EN 1778 standard. Plastic material resistance (polypropylene, PP-B type) stated by manufacturer, company PLOMA a.s., is 33 N/mm². After an inclusion of time and temperature impacts, the long-term resistance is K = 11 N/mm².

$$\sigma_{al.} = \frac{(K \cdot f_1)}{(A_1 \cdot A_{2K} \cdot S)} = \frac{(11 \cdot 0.6)}{(1.1 \cdot 1 \cdot 2)} = 3 \ \text{N/mm}^2.$$

The calculation of flow modules under the operating conditions for the calculation of stability $E_{c(al.),\,St}$ and for the calculation of deformations $E_{c(al.),\,D}$. Module of flowing E_c for expected conditions, temperature during straining, time for polypropylene is $E_c = 215$ N/mm². The values of parameters regarding correction factors used for the calculation of flowing ($A_{2E} = 1$; $S = 2$) are taken from the ČSN EN 1778 standard:

$$E_{c(al.),\,St} = \frac{E_c}{(A_{2E} \cdot S)} = \frac{215}{(1 \cdot 2)} = 107.5 \ \text{N/mm}^2,$$

$$E_{c(al.),\,D} = \frac{E_c}{A_{2E}} = \frac{215}{1} = 215.0 \ \text{N/mm}^2.$$

These low values significantly reduce the possibility to document the proposal regarding plastic underground storage tanks and containers by a positive calculation. They also

explain the frequent cases of absolutely obvious deformation of the vertical walls of the plastic constructions regarding the underground storage tanks and containers.

3.   Types of plastic containers

The plastic containers are manufactured as two basic types.

The first one is a circular cylindrical container (see the Fig. 1a). The vertical walls are made from corrugated plastic boards with a thickness up to 8 mm. The boards that have a maximum thickness of 8 mm can be easily corrugated into required semi-diameters and welded in joints. To an external surface of the vertical wall, flat vertical segments (usually 6) are welded along the perimeter of cylindrical containers. The segments are from the same material and of the same thickness as the wall. The purpose of the segments is to reinforce the construction of the cylindrical container.
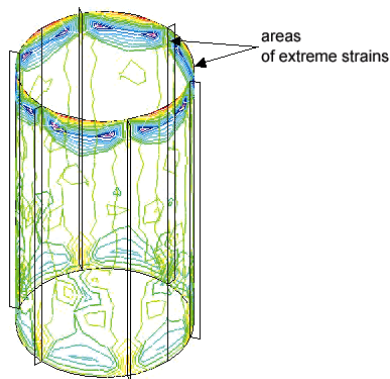
a)

b)

Fig. 1. Cylindrical plastic tank sewer: a) view on cylindrical plastic tank sewer;
b) the strain in the wall of cylindrical tank sewer

The second type of containers is a right-angled — rectangular section plan (see the Fig. 2a). The dimension of the shorter side is constant and usually is 2 m. Only the length of the longer side is changed. The vertical walls are made of plastic wall ribbed elements (VBL 100 021). The wall ribbed element is approx. 80 mm thick. The individual wall elements are screwed together. The contact gap is sealed. The vertical walls of both types of plastic containers are usually provided with a concrete lining on an external perimeter. The height of both types of plastic containers is between 1,5 to 3 m.
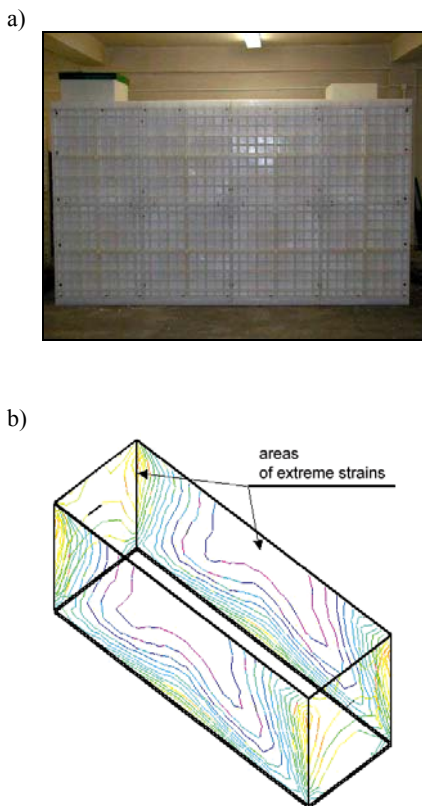
a)

b)

Fig. 2. Boxy plastic tank sewer: a) view on boxy plastic tank sewer;
b) the strain state in the wall of boxy tank sewer

4. Solution and evaluation method regarding container walls made from a composite material

The static solution of the container construction was implemented by a deformation method, linear calculation, with the program system FEAT 2000. The wall of the container

forms a composite from plastic material (polypropylene, PP-B type), concrete, and steel (angular containers). The cylindrical container's composite is formed by two homogenous layers. The inner 8 mm layer from plastic material and external 100 mm layer from concrete. The overall thickness of the composite is 108 mm. The angular container's composite with plastic wall ribbed elements (VBL 100 021) is formed by a plastic material, concrete, and steel KARI mesh. The composite is formed by 5 layers; three homogenous and two heterogeneous layers. The inner composite layer is from a plastic material. There is a heterogeneous layer connected to the layer from the plastic material formed by plastic ribs and a concrete filling between the ribs. The third layer is homogenous and it is formed by concrete. The fourth layer is heterogeneous and it is formed by steel members of the KARI mesh and concrete. The last, external layer of the composite is homogenous, it is from concrete and it serves as a surface layer for steel members of the KARI mesh. The thickness of the composite is in this case 170 mm or 300 mm regarding the length of the wall of the container (Fig. 3). The thickness of 300 mm was proposed for lengths exceeding 4 m.
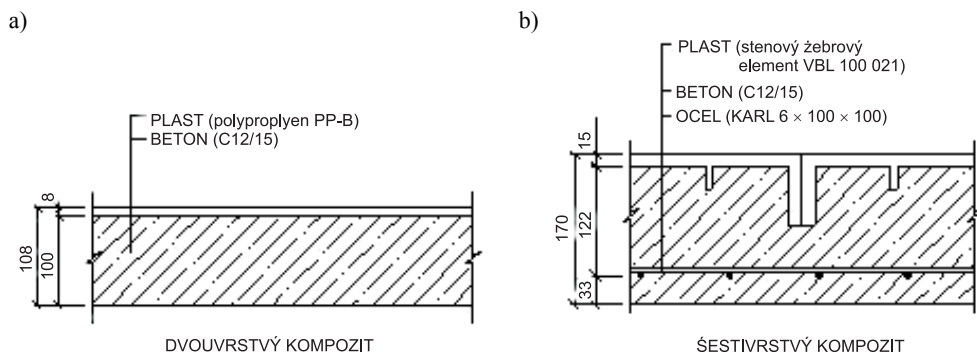

Fig. 3. Schema of the container construction: a) 2-layers composite; b) 6-layers composite

5. The method of determination of deformational parameters regarding the container walls made from a composite material

Deformational parameters — flexibility module and Poisson's number — of the composite material are derived from homogenization advancing of heterogeneous layered material (VSB-TU Ostrava, 1997).

The homogenization method results in and maintains continuance regarding transfers of dislocations between individual materials (layers).

The value of the flexibility module of alternative homogenized material, which is used for static calculation, is calculated based on deformational parameters of the composite com-

ponents — the flexibility module and Poisson's number, a plastic material and a concrete and their geometric parameters — the thicknesses and also from the semi-diameter of wall bending.

Straining coefficients a1 calculated for each material of the composite are also determined by means of the homogenization method. Such a coefficient serves for the transformation of results — the values of strain in the profile, gained by means of calculation implemented with the flexibility module of alternative homogenized material. The values of actual strains in materials of the composite profile (Tab. 1) are determined by multiplication of values of strain in the homogenized material profile and the straining coefficients.

TABLE 1

Table with values of straining coefficients of the composite — the angular container wall (wall thickness 170 mm)

Course of each composite layer	Thickness of the layer [mm]	Type of the layer	Material	$a1_{in}$	$a1_{out}$
1	15	homogenous	plastic	0.01	0.01
2	25	heterogeneous	plastic	0.01	0.01
			concrete	1.02	1.02
3	40	heterogeneous	plastic	− 0.08	− 0.08
			concrete	1.02	1.02
4	54	homogenous	concrete	1.02	1.02
5	6	heterogeneous	steel	10.08	10.08
			concrete	1.05	1.05
6	30	homogenous	concrete	1.36	1.36

Note:
$a1_{in}$ — value of straining coefficient inside of each layer of the composite
$a1_{out}$ — value of straining coefficient outside of each layer of the composite

Composite components parameters:

— polypropylene PP-B — flexibility module value of plastic material E_{plast} = 100 MPa, Poisson's number $\upsilon_{pl.}$ = 0,3;

— concrete C12/15 — flexibility module value of plastic material E_{bet} = 23 000 MPa, Poisson's number υ_{b} = 0,2;

— steel — flexibility module value of plastic material E_{steel} = 210 000 MPa, Poisson's number υ_{b} = 0,2.

Homogenized material parameters:

— flexibility module of homogenized profile E_h = 17 800 MPa,
— Poisson's number of homogenized profile ν_h = 0.3.

6. Container construction straining

Static calculation is implemented for straining given by summation of the following straining conditions:

— the actual weight of the construction;
— ground pressure (effective);
— hydrostatic pressure of water affecting only the external surface of the container walls; the internal container walls are not strained, that means that the container is empty; this straining condition is required by a standard, it presents the boundary situation;
— additional straining of the container ceiling by overlying terrain and straining by people; overlapping by soil is expected to be 0.3 m.

7. Conclusion

From the viewpoint of wall deformation and distribution of internal forces inside the composite, the circular containers are favorable. The course of wall deformation is influenced by radial segments.

The maximum strain values occur in areas where radial segments are welded to the wall (see the Fig. 1b). The concrete lining does not require any reinforcement by steel mesh.

The results from angular containers are less favorable. The longitude of angles influences the extent of wall deformation and the values of internal forces inside the composite. There are two areas, regarding the construction of angular containers, where maximums are located. The first area is located on the top end in the middle of longer wall. The other area is on the vertical edge on place where the two neighboring walls are attached. (see the Fig. 2b). Regarding the angular containers, it is necessary to reinforce the concrete lining by steel mesh. The thickness of the composite is related to the length of the wall.