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Mechanization of reloading works at the landfills of large volumes

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The paper presents one solution for mechanization of municipal waste handling at the large landfills. Means of transportation are functionally integrated into transportation chain. This solution excludes the usage of trucks for waste disposal at the landfill area, which significantly reduces the costs of waste disposal and excludes the possibility of trucks to get stuck in the landfill.

The entrance storage bunker, the transporter for charging the bucket and the steel rope system for the transportation of loaded and empty bucket to the discharge point are components of the flexible solution for the mechanization of municipal waste handling, which is especially convenient for the large landfills.

Keywords: Mechanization, waste handling, landfill, transport mechanization, steel ropes, example.

0. INTRODUCTORY REMARKS

Disposal of municipal waste is often done at unregulated and unprepared grounds, which has a negative effect on the population as well as on water, land and air pollution. It should be noted that collection, transportation and disposal of waste are done by municipal companies which, as a rule, use old mechanization and generally do not make selective classification of waste (there is no waste recycling) (Fig.1).

Fig. 1 Transportation and disposal of waste

To eliminate above stated negative effects it is necessary to perform the following activities:

- classification (sorting) of waste must be done before waste disposal,
- several municipalities should be involved in the project of sanitary landfills (formation of large landfills), with the application of good solutions and experience of Western European countries,
- protection of water springs, river flows, soil and air,
- by-products (landfill gas) should be converted into electrical energy,
- population should be regularly educated on the importance and role of landfills.

Regional sanitary landfills, as a justifiable solution, are becoming prominent in comparison to urban landfills, because they solve the problem of waste disposal over the long term. It is clear that the project of regional landfill is a complex infrastructural facility which requires many influential parameters to be solved:

- location of the landfill,
- type and amount of waste materials,
- properties of waste materials,
- availability of the area meant for landfill planning,
- geotechnical and urban preconditions which are needed to make the landfill profile (characteristics and properties of the land beneath the landfill, isolation of permeability of waste into the land beneath the landfill, use of landfill gas, landfill closure),
- later use of the area where the landfill is built,
- legal regulations and accompanying rules.

The landfill location should provide total sanitary and epidemiological safety of the local population and workers, as well as the protection against land, water and air pollution. Thus, the following locations are usually used to make landfills:

- coves sheltered by steep sides of cliffs,
- natural deep valleys,
- deep valleys made by extraction of ore or building materials, where the newly formed area should fit into the surrounding terrain after landfill is made (Fig.2).

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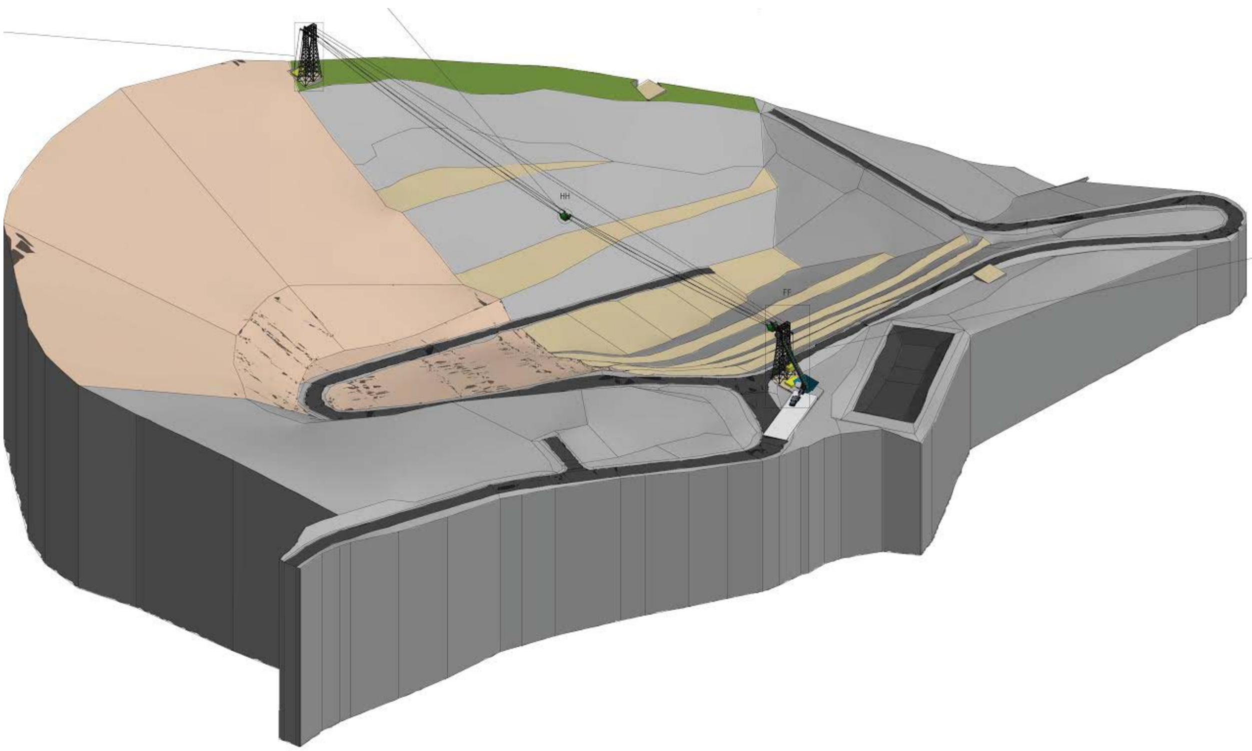

Fig. 2 The newly formed regional sanitary landfill

1. LOADING - UNLOADING WORKS ON LARGE LANDFILLS BY MEANS OF TRANSPORT MECHANIZATION

As stated above, transportation of waste materials to urban landfills is mostly done by special trucks for waste transport. Waste is unloaded from the truck, and then spread by bulldozers having loading shovel and compressed by compactors. Finally, it is covered by a layer of inert materials.

When it comes to large (regional) landfills (Fig.3) this method of waste disposal is inapplicable primarily due to the shipment of large quantities of waste material. It is hard and sometimes almost impossible to unload waste materials from trucks at the very area of the landfill, because the terrain itself does not provide conditions for adequate mobility, which directly influences the decrease of transportation capacity and increase of costs.

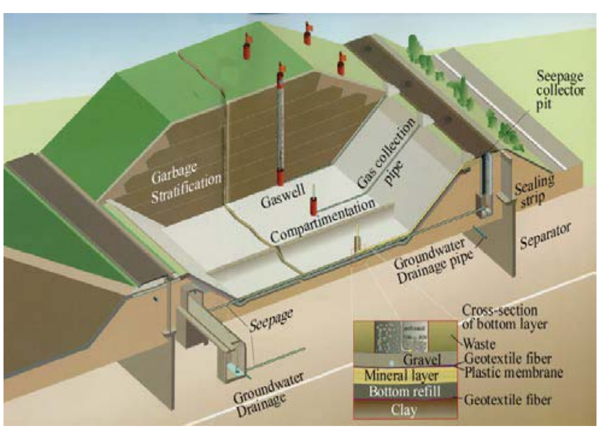

Fig. 3 Regional sanitary landfill

The concept of loading and unloading work by means of transport mechanization is a solution which can meet the requirements of efficient and economical disposal of large quantities of waste.

Functional connection between the means of transport mechanization is presented in Fig..4.

Scheme of transport mechanization for unloading, transport and waste disposal, is shown on Fig.5.

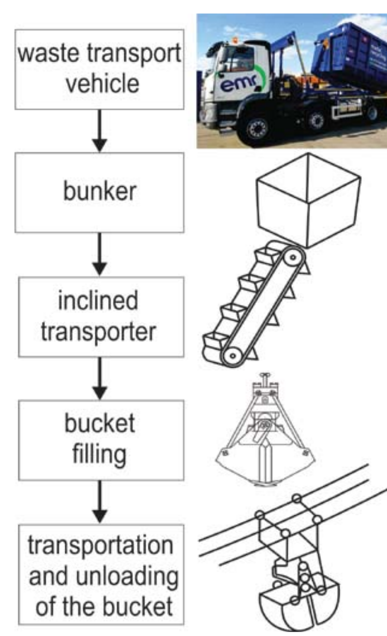

Fig. 4 Functional connection between the means of transport mechanization

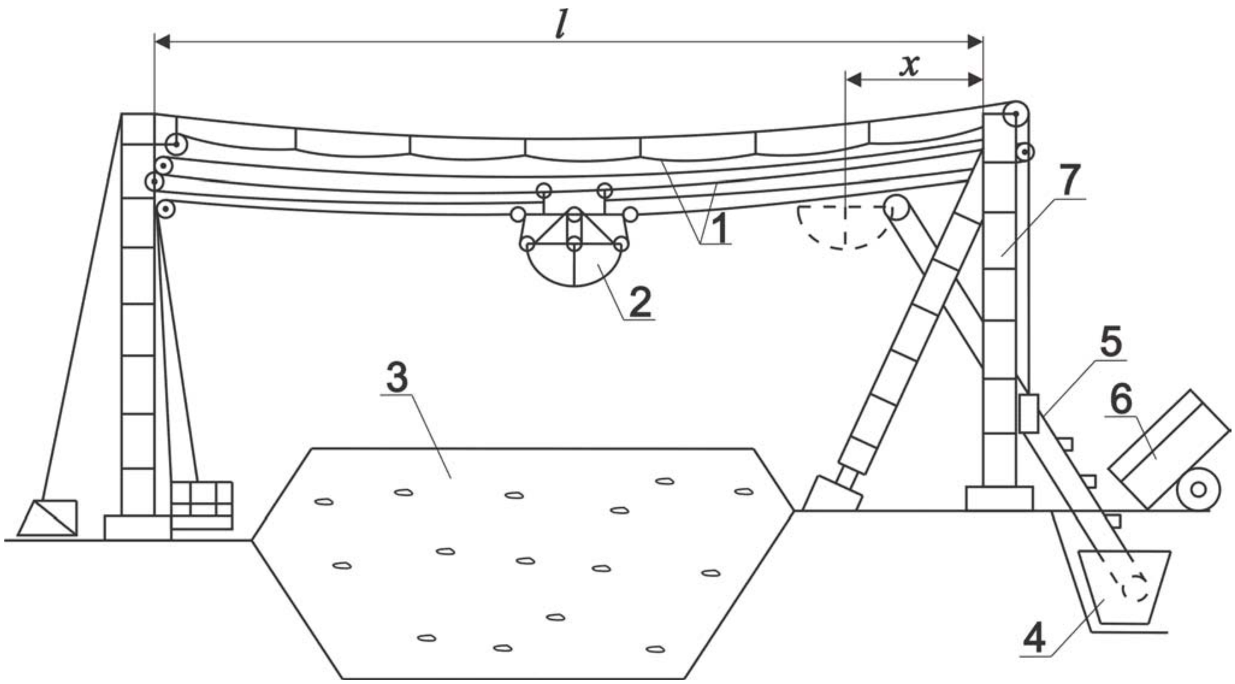

Fig. 5 Scheme of transport mechanization for unloading, transport and waste disposal

Positions shown on Fig.5 are:

1) Steel ropes,
2) Bucket,
3) Landfill,
4) Bunker,
5) Inclined transporter,
6) Transport vehicle,
7) Column.

From storage bunker (4) containing waste being unloaded from trucks (6), worm transporters or some other types of transporters (5) (such as scraper transporter) fill the bucket (2) on distance "x" from column (7) which is moved along the steel ropes to the loading position.

Basic parameters of the presented concept are:

- length of transporting path of the bucket: $50 \div 500(m)$
- bucket capacity: $1,0 \div 15(t)$
- column height: $5,0 \div 50(m)$
- speed of bucket lifting: $1,0 \div 6,3(m/s)$
- speed of bucket movement: $0,1 \div 0,3(m/s)$
- average time of bucket transportation cycle (depending on landfill width): $120 \div 180(s)$
- average time of bucket loading (depending on column height): $90 \div 120(\mathrm{s})$

2. ESSENTIALS OF CALCULATING THE PARAMETERS OF ROPE SYSTEM – CALCULATING EXAMPLE

To calculate the parameters of the rope system at the cable crane with the bucket (Fig. 5) the essentials of calculation theory can be used [1, 4] with the following parameters defined by the project:

$l = 200\,m$ - distance between supporting columns,

$\beta = 0,035(rad)$ - angle defining the difference between column tops,

$m_t = 5(t)$ - mass of load transported to and lowered at unloading place ($P_t = 49,05\,kN$),

$m_k = 0,7(t)$ - mass of bucket's self weight ($P_k = 6,86\,kN$),

$Q = 49,05 + 6,86 \approx 56kN$ - total moving load,

$m_d = 0,05(t)$ - mass of rope holders (three holders) ($P' = 0,49\,kN$),

$E_u = 1,6 \cdot 10^8\,(kPa)$ - elastic modulus of steel ropes,

$A_u = 0,003232(m^2)$ - area of metallic section of the rope,

$\sigma_v = 1372\,MPa$ - tensile strength of rope wires.

Determination of deflection at the middle of distance ($x = \frac{l}{2}$) (Fig. 6).

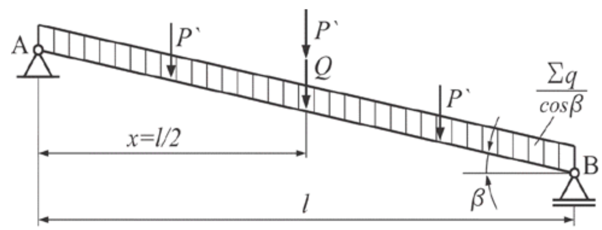

Fig. 6 Determination of deflection

Deflection of ropes when the bucket is loaded at the distance "x" is defined by the formula:

$$f_x = \left(Q + n \cdot P' + 0,5 \cdot l \cdot \Sigma q / \cos\beta\right) \cdot (l - x) \cdot x / l \cdot \Sigma H_x \quad (1.1)$$

The biggest defection occurs when the loaded bucket is at $x=\frac{l}{2}$:

$$f_{(l/2)}=\left(Q+n\cdot P'+0,5\cdot l\cdot \Sigma q/\cos\beta\right)\cdot l/4\cdot \Sigma H_{l/2} \qquad (1.1,a)$$

To determine deflection at the middle, the empirical formula can be used

$$f_{(l/2)}=\left(40+0,05\right)\cdot l/\sigma_v=\left(40+0,05\right)\cdot 200/1372=7,3\,m$$

or it can be determined through the diagram (Fig.7) with allowed deflection at the middle.

$$f^d_{(l/2)}=\left(0,03\div 0,08\right)\cdot l=\left(0,03\div 0,08\right)\cdot 200=\left(6\div 16\right)m$$

Uniformly distributed load Σq is defined through the dependence

$$\Sigma q=\left(Q+n\cdot P'\right)\cdot C_q/\left[528+\left(0,66-0,5\cdot C_q\right)\cdot l\right] \qquad (1.2)$$

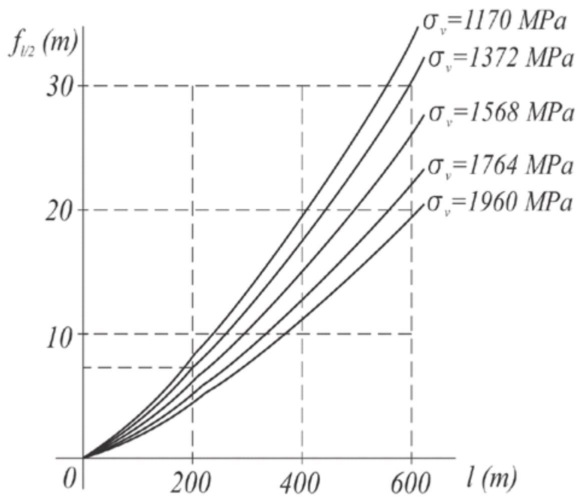

Fig. 6 Total tensile forces at supports A and B

where $C_q=1{,}13$ - is the coefficient of cable crane with grabber.

After replacing the value in (1.2) we obtain the following:

$$\Sigma q=\left(56+3\cdot 0,49\right)\cdot 1,13/\left[528+\left(0,66-0,5\cdot 1,13\right)\cdot 200\right]$$

$$\Sigma q=0,12\frac{kN}{m}$$

Rope weight G is obtained from the expression:

$$G=l\cdot \Sigma q/\cos\beta=200\cdot 0,12/0,9994=24\,kN$$

At the position where the loaded bucket is at the middle, horizontal tensile force in the system of ropes is:

$$\Sigma H_{(l/2)}=\left(Q+n\cdot P'+0,5\cdot l\cdot \Sigma q/\cos\beta\right)\cdot l/4\cdot f_{(l/2)} \qquad (1.3)$$

After substitution

$$\Sigma H_{(l/2)}=\left(56+3\cdot 0,49+0,5\cdot 200\cdot 0,12/0,9994\right)\cdot 200/4\cdot 7,3$$

$$\Sigma H_{(l/2)}=476\,kN$$

Vertical tensile force at support A and B is determined from the formulas (1.4) and (1.5)

$$\Sigma V_{Ax}=Q\cdot\frac{l-x}{l}+n\cdot P'\left(1,5-\frac{x}{l}\right)+\left(\frac{l}{2\cos\beta}\right)\Sigma q\pm \pm\Sigma H_x tg\beta \qquad (1.4)$$

$$\Sigma V_{Bx}=Q\cdot\frac{x}{l}+n\cdot P'\left(0,5-\frac{x}{l}\right)+\left(\frac{l}{2\cos\beta}\right)\Sigma q\mp \mp\Sigma H_x tg\beta \qquad (1.5)$$

For $x=\frac{l}{2}$, it follows:

$$\Sigma V_{Ax}=56\cdot\frac{200-100}{200}+3\cdot 0,49\left(1,5-\frac{100}{200}\right)+ +\frac{200}{2\cdot 0,9994}\cdot 0,12+476\cdot 0,035=58\,kN$$

$$\Sigma V_{Bx}=56\cdot\frac{100}{200}+3\cdot 0,49\left(0,5-\frac{100}{200}\right)+\frac{200}{2\cdot 0,9994}\cdot 0,12- -476\cdot 0,035=25\,kN$$

Total tensile forces at supports A and B (Fig. 6) are:

- support A:

$$\Sigma T_{A(l/2)}=\sqrt{\left(\Sigma H_{(l/2)}\right)^2+\left(\Sigma V_{A(l/2)}\right)^2}= =\sqrt{476^2+58^2}=479\,kN \qquad (1.6)$$

- support B:

$$\Sigma T_{B(l/2)}=\sqrt{\left(\Sigma H_{(l/2)}\right)^2+\left(\Sigma V_{B(l/2)}\right)^2}= =\sqrt{476^2+25^2}=477\,kN \qquad (1.7)$$

The angles of rope deflection at supports A and B are defined from the following expressions:

$$\left.\begin{aligned}\alpha_{A(l/2)}&=arctg\frac{\Sigma V_{A(l/2)}}{\Sigma H_{(l/2)}}=\frac{58}{476}=0,12\,rad\\ \alpha_{B(l/2)}&=arctg\frac{\Sigma V_{B(l/2)}}{\Sigma H_{(l/2)}}=\frac{25}{476}=0,05\,rad\end{aligned}\right\} \qquad (1.8)$$

Loading of the bucket is done at the distance $x=20\,m$.

Horizontal components of ropes are determined from the equation (1.9)

$$\left(\Sigma H_x\right)^3+\left(\Sigma H_x\right)^2\left\{E_uA_u\left[\frac{\cos^5\beta}{2l\left(\Sigma H_{(l/2)}\right)^2}\int_0^l\left(\Sigma Q_{b(l/2)}\right)^2dx\pm \pm\varepsilon\Delta t\cos\beta\right]-\Sigma H_{(l/2)}-E_uA_u\frac{\cos^5\beta}{2l}\int_0^l\left(\Sigma Q_{b(l/2)}\right)^2dx=0\right. \qquad (1.9)$$

It can be assumed that $\Delta t=0$.

Having in mind that

$$\int_0^l\left(\Sigma Q_b\right)^2dx=\left[Q\left(Q+2nP'+G\right)+nP'\left(nP'+2\frac{G}{3}\right)\right]\cdot \cdot\left(l-x\right)\cdot\frac{x}{l}+\left(nP'+G\right)^2\cdot\frac{l}{12} \qquad (1.10)$$

After replacement it follows:

$$\int_0^l \left(\Sigma Q_{bx}\right)^2 dx =$$

$$=\left[56\left(56+2\cdot 3\cdot 0,49+24\right)+3\cdot 0,49\left(3\cdot 0,49+2\frac{24}{3}\right)\right]\cdot$$

$$\cdot\left(200-20\right)\cdot\frac{20}{200}+\left(3\cdot 0,49+24\right)^2\cdot\frac{200}{12}=83130\,kN^2m$$

The expression (1.11)

$$\int_0^l \left(\Sigma Q_{b(l/2)}\right)^2 dx = \left[Q\left(Q+2nP'+G\right)/4+\left(2nP'+G\right)^2/12\right]\cdot l \quad (1.11)$$

also implies that

$$\int_0^l \left(\Sigma Q_{b(l/2)}\right)^2 dx = \left[0,25\cdot\left(0,25+2\cdot 3\cdot 0,49+24\right)/4+\right.$$

$$\left.+\left(2\cdot 3\cdot 0,49+24\right)^2/12\right]\cdot 200=244500\,kN^2m$$

After replacing (1.10) and (1.11) into (1.9) the following equation is obtained:

$$\left(\Sigma H_x\right)^3+\left(\Sigma H_x\right)^2\left(1,6\cdot 10^8\cdot\frac{0,003232}{2\cdot 200\cdot 476^2}-244500\cdot 0,9994^5-\right.$$

$$\left.-476\right)-\frac{1,6\cdot 10^8\cdot 0,003232\cdot 0,9994}{2\cdot 200}\cdot 83130=0$$

After calculations, we get the final form of equation (1.10):

$$\left(\Sigma H_x\right)^3+915\left(\Sigma H_x\right)^2-107470464=0\,,$$

whose solution is:

$$\Sigma H_x=298\,kN$$

The vertical component of tensile forces of ropes at support A, when $x=20\,m$, is:

$$\Sigma V_{A(20)}=56\cdot\left(200-20\right)/200+3\cdot 0,49\cdot\left(1,5-20/200\right)+$$

$$+\left(0,5\cdot 200\cdot 0,12\right)/0,9994+298\cdot 0,035=75\,kN$$

The vertical component of tensile forces of ropes at support B, when $x=180\,m$, is:

$$\Sigma V_{B(180)}=56\cdot 180/200+3\cdot 0,49\cdot\left(0,5+180/200\right)+$$

$$+\left(0,5\cdot 200\cdot 0,12\right)/0,9994-298\cdot 0,035=54\,kN$$

Total tensile forces at supports A and B are:

$$\Sigma T_{A(20)}=\sqrt{298^2+75^2}=307\,kN$$

$$\Sigma T_{B(180)}=\sqrt{298^2+54^2}=303\,kN$$

Deflections of ropes are:

$$\alpha_{A(20)}=arctg\frac{75}{298}=0,25\,rad$$

$$\alpha_{B(180)}=arctg\frac{54}{298}=0,18\,rad$$

One of the columns and bucket on the loading position are shown on Fig.7 and Fig.8.

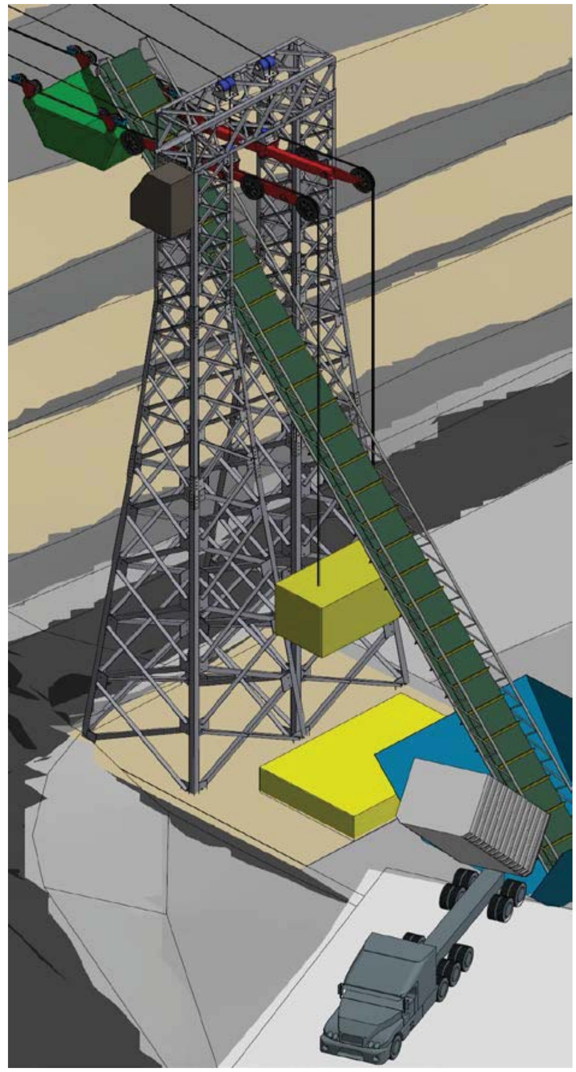

Fig.7 Columns and bucket on the loading position

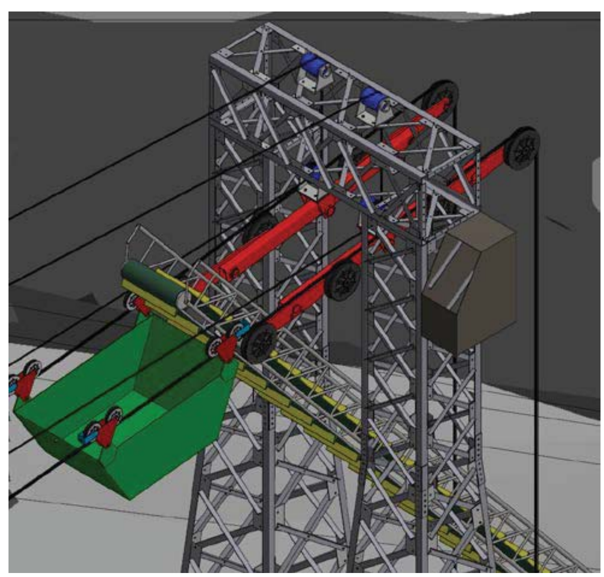

Fig. 8 Bucket on the loading position

3. CONCLUSION

Application of means of transport mechanization is an optimal concept of unloading and loading work at large landfills because:

- costs of transportation within the very area of the landfill are diminished,
- transportation trucks cannot be stuck in the area of the landfill,
- a large capacity of waste disposal can be achieved,
- dimensions of the landfill are not limiting parameters (length x width) for unloading and loading activities,
- after the landfill is closed, the means of transportation mechanization can be moved to a new location.

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