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THE POSSIBILITIES OF PORT INFRASTRUCTURE INVESTIGATIONS AND DEVELOPMENT*

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Abstract. Transport infrastructure development is based on cargo and passenger flows and the use of new technologies and technique can increase transport safety, optimize time of construction and decrease costs. Some of the new technologies of port infrastructure development and quality control technique and methods are presented in the paper.

Keywords: transport and port infrastructure, very high pressure method, trance construction method.

1. Introduction

Transport infrastructure and especially port infrastructure is the basis for the transport activity and includes roads, railways, ports, airports, pipelines and others. Transport infrastructure itself does not make any added value, but without transport infrastructure it is impossible to use transport means and provide transportation at all.

Transport infrastructure requires large investments and it is constructed for long terms [1–7] and for this reason transport infrastructure and especially port infrastructure mainly belongs to state or the municipality, what means that transport infrastructure is mainly public.

The development of transport infrastructure must be based on passenger or cargo flows because infrastructure is very expensive and it must be economically or socially effective.

Investigations of the transport infrastructure are very important that new technique and technologies, optimized costs, increased safety and other technical and economical parameters could be used [8–13].

Finally transport and especially port infrastructure development tendencies and possibilities are important from a research and practical point of view to optimize the investments for the development, to increase economical and technical parameters.

2. New Port Infrastructure Development Technologies

Transport and especially port infrastructure was constructed in antic time, when quay walls, roads, bridges and other infrastructure were constructed. Very actively transport infrastructure was started to construct after the construction of steam and other machines because at that time the size of the transport means, such as ships, trains has grown up very much.

Transport and especially port infrastructure today is the complex of new technologies and materials combination because transport infrastructure must keep transport means, which have capacity up to 0,5 million tons (ships), speed up to 300 km/h (cars and trains), weight up to 250 tons (airplanes) and so on [8, 9].

At the same time port infrastructure must use as less as possible investments, take as less as possible place. The optimization of port infrastructure in many countries is a very important task [1, 2, 11, 13, 14]. New materials and new technologies, such as geo textile, very high-pressure technology and other new materials and technologies, decrease the costs up to 2 – 3 times and increase the time of exploitation of the port infrastructure [6, 8, 10, 13, 15–18].

The quality of port infrastructure in case of using new materials and technologies is very important and quality control systems and equipment during construction and exploitation of the port infrastructure is one of the main tasks [8–10, 12, 17, 19].

The balance of transport infrastructure inside is very important, that all transport means on concrete direction or point would be equal. At the same time the philosophy of transport infrastructure construction for different transport means is different. Railways and road transport have a lot of limitations, such as width (railway gate is 1435 or 1510 mm), height (bridges above railways), and weight (axes weight on the roads). Maritime transport has no limitations and maritime transport infrastruc-

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* (Discussion of results of program "Transport: technologies, economics, environmental, health")

ture is based on the ship's size [1, 2, 16, 20].

Transport systems balance inside transport infrastructure direction is based on the technical possibilities what means that the following condition should be fulfilled:

$$Q_1 = Q_2 = Q_3 = ... \qquad (1)$$

here: Q_i – concrete transport system technical capacity in case when one of the transport system links with other transport system infrastructure, for example port and railway.

Port infrastructure technical capacity depends on the cargo and ships, but in many cases, there is a lot of influence from organizational and legal conditions. In fact every terminal must fulfill the condition:

$$\sum qi = \sum q', \qquad (2)$$

here: $\sum qi$ – terminal and its infrastructure technical – technological and market possibilities; $\sum q'$ total cargo flow, which goes in/out terminal.

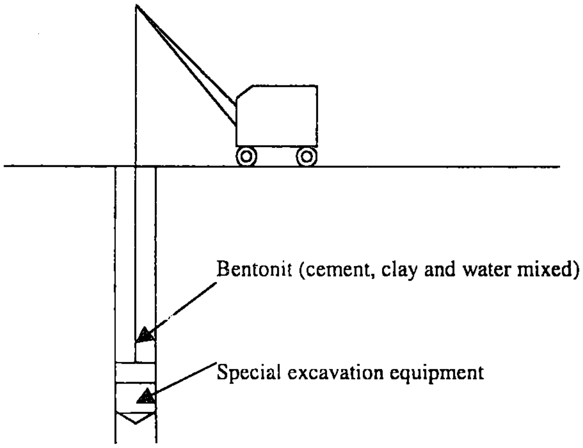

Fig 1. Trance preparation

Port infrastructure should be developed on the basis of new technologies, which can optimize investments and provide good quality service. More progressive transport infrastructure development technologies exist in maritime transport because maritime transport has fewer limitations than other transport systems. At the same time technologies which are used in maritime transport infrastructure development very often are not enough theoretically investigated and they make additional problems.

In some ports new methods of quay walls construction are used such as trance, very high pressure and other methods (Fig 1–5).

Trance quay walls construction method is used in progressive ports, such as Belgium ports.

In trance method balance should be solved on the basis of scheme in Fig 3.

In this case balance formula would be as:

$$q_0 h \cos\alpha \le q_1 h \cos\alpha_1 . \qquad (3)$$

Angle of internal friction of soil for the construction conditions can be taken as [9, 10, 21]:

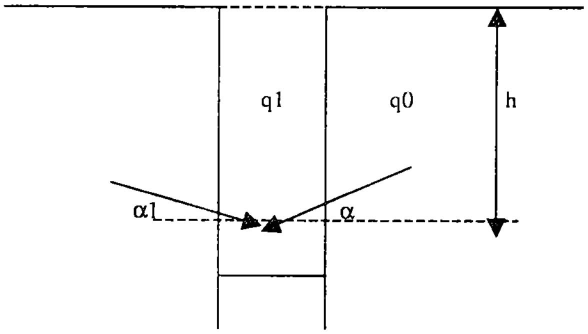

Fig 3. Trance quay wall calculation scheme: q_0 – soil density; h – calculation depth; α – angle of internal friction of soil; q_1 – bentonit density

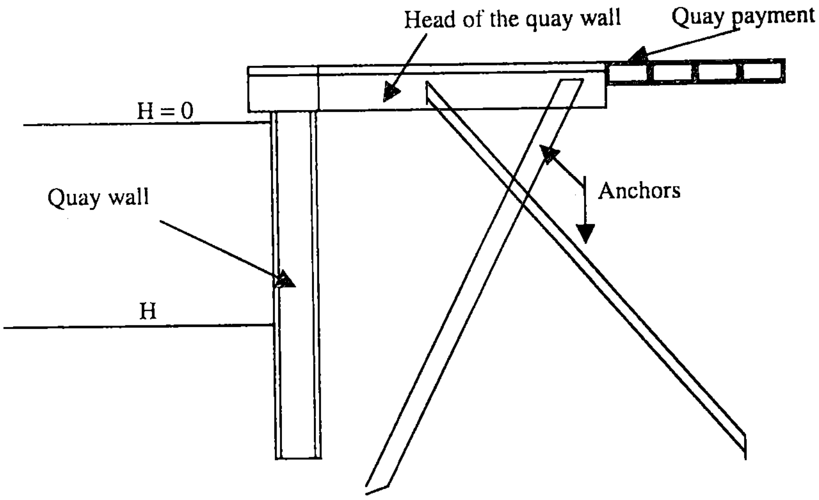

Fig 2. The fragment of quay wall construction

$$\alpha = 2/3\varphi', \tag{4}$$

here φ^1 – angle of internal friction new soil which for the new soil can be taken as $\alpha = \varphi^1$;

For the bentonit or other liquid material angle of internal friction practically is equal to zero, in this case formula (3) can be written as follows:

$$q_0 h \cos\alpha \le q_1 h \cos\alpha_1, \tag{5}$$

As an example for the soil with density about 1700 kg/m^3, angle of soil internal friction about 15 °, density of the bentonit should be not less then,

$$q_0 \cdot \cos\alpha = 1700 \cdot \cos 15^0 = 1700 \cdot 0,\ 97 = 1649 \mathrm{kg/m^3}.$$

For the quay walls construction railways or other basis preparation could use a "very high pressure" (VHP) method. This method mainly is linked with the diameter of VHP columns calculation depending on soil conditions, VHP equipment possibilities and materials, which are used [10, 14, 17].

The method is based on column washing in soil and filling these columns with the mix of water and cement (Fig 4).

After the formation of VHP columns by water-cement mixer, columns must be reinforced by steal profiles or other reinforced materials (Fig 5).

On the basis of geo technical information and VHP equipment possibilities, speed and pressure could be calculated that the requested diameter of VHP columns receive. In general the next condition must be fulfilled:

$$E_{gr} \le E_{pur}, \tag{6}$$

here E_{gr} – energy, which should be created, that destroys soil on the requested column; E_{pur} – energy, of a water and water-cement mixer when leaving boring head.

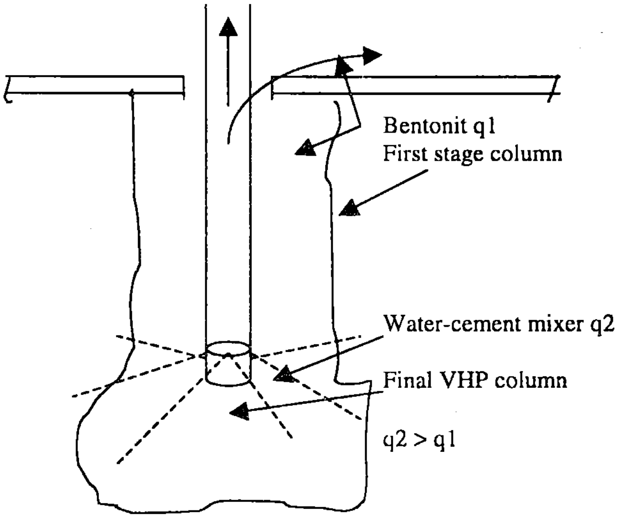

Fig 4. VHP column formation

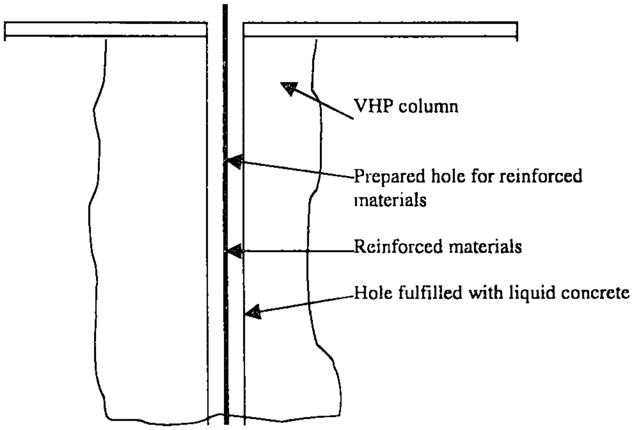

Fig 5. Reinforcement of VHP columns

On the basis of the mentioned parameters water or water-cement mixer velocity outside the boring head could be calculated as:

$$\vartheta_0 = p \cdot d \cdot Q, \tag{7}$$

here: p – pressure (N/m^2); d – diameter of the holes of the mixer; Q – productivity, kg/s.

In this case pressure can be calculated as:

$$p = \frac{\vartheta_0}{dQ}. \tag{8}$$

The pressure which is received by formula (8) can be used in VHP methodology to receive good quality of VHP columns and VHP wall at the end.

3. Investigations of the New Port Infrastructure Development Control Methods

A part of the port infrastructure is constructed on land and in this case it is possible to use typical construction control methods, but at the same time for the other part, which is constructed under land or in water, typical construction control methods are impossible to use and it is necessary to find new quality control methods during construction and maintenance.

Indirect construction quality control methods very often are necessary to be used for channels, quay walls and other port infrastructure constructions, which are constructed in water or under land.

Channels depth measuring is very important because in many cases it is impossible visually to evaluate bottom conditions. For the channels depth measuring mechanical and hydro acoustical equipment [5] is used. Mechanical lots are used in places where it is impossible to use any other equipment, but such equipment gives deterministical results and from these results it is impossible to receive a full bottom picture and to find stones and other small obstructers. As an additional measuring method divers inspection is used, which is very expensive and requests a lot of time.

For the depth measuring very often hard and soft trials are used which measure minimum depth of the channels (Fig 6).

The main disadvantage of the trail is that it is possible to measure just minimal depth (until tops of the bottom) and it is impossible (the same as with a lot) to receive a full bottom picture.

Hydro acoustic depth measuring equipment is divided into the top equipment which is constructed to ship constructions and zounds which are tugged by a ship or a helicopter. Hydro acoustic systems are single beam and multi beam [11, 17]. With these systems it is possible to measure a full bottom and to receive a real bottom picture (Fig 7).

Measuring zone width can be calculated as follows:

$$b_m = 2(H - T)tg(\theta / 2), \qquad (9)$$

here: H – depth; T – ship draft; θ - angle of signals spreading.

In case T= 2 m, H = 12 m, $\theta = 90^\circ$ measuring pass width bm will be about 20 m.

Now hydrographic ships use high accuracy positioning systems such as differential global position system (DGPS) with accuracy of 0,1 – 0,3 m. In this case measuring passes should be close each other not less than calculated by the following formula:

$$\Delta b = L \sin \Delta k + P' \delta y, \qquad (10)$$

here: L – ship length; Δk – ship rolling around its course angle, for the small ships this angle is up to 3°; P' – probability coefficient, in case of probability not less than 95 %, this coefficient not less than 2,5; δ_y – ship position observation accuracy, in case of using DGPS it could be 0,2 – 0,8 m.

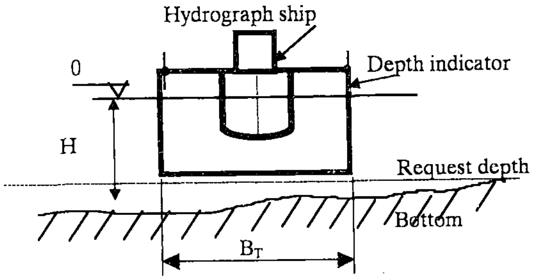

Fig 6. Hard trail: B_T – trailing pass

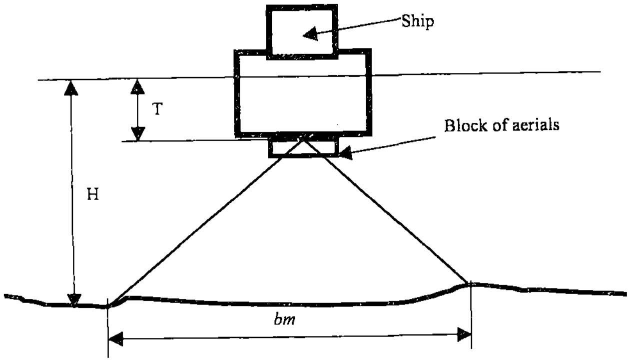

Fig 7. Hydro acoustic measuring system: T – distance between water level and bloc of aerials; H – depth

The minimum number of the ship sailing that could guarantee covering the measuring area by measuring passes can be calculated as follows:

$$n_{pl} = \frac{B_a}{bm - \Delta b}, \qquad (11)$$

here: Ba – width of the measuring area.

Measuring passes length can be calculated as follows:

$$l_{mat} = La + \Delta l, \qquad (12)$$

here: La – length of measuring area; Δl – additional sailing for the ship turning from one pass to the other pass.

Measuring ship position increasing accuracy minimizes the number of ship sailings. In Fig 8 and Fig 9 measuring areas with different measuring ship position accuracy are shown.

New port infrastructure construction control methods are very complicated, because a lot of work is done under water or underground and it cannot be visually checked. The next new port infrastructure construction methods are complicated:

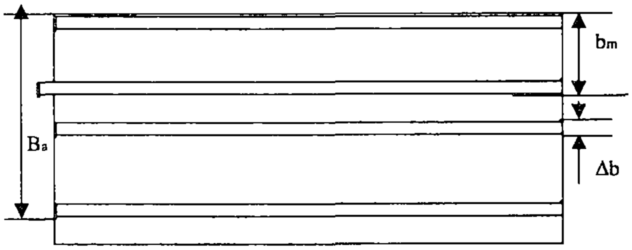

Fig 8. Covering of the measuring passes in case of high measuring ship position accuracy

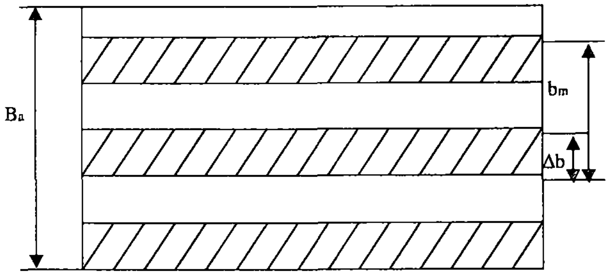

Fig 9. Covering of the measuring passes in case of low measuring ship position accuracy

- concrete quay walls construction on the land in the hole;

- VHP construction methods.

Concrete quay walls can be checked by acoustic or magneto metric methods. In case of a magneto metric method, exact information of the reinforcement steal position must be and in advance very accuracy calibration of the measuring equipment must be made. Acoustic methods are easier, but measuring equipment itself is more complicated. In Fig 10 construction (a) and results on registration pass (b) in case of different materials in construction are shown.

VHP method requests to make measuring diameter of the VHP columns and VHP columns wall quality. Diameter of the VHP columns can be measured by umbrella equipment, which is shown in Fig 11.

For more exact checking of the columns wall, on the "umbrella" ends pjezo elements could be implemented which react on more resistance (Fig 12).

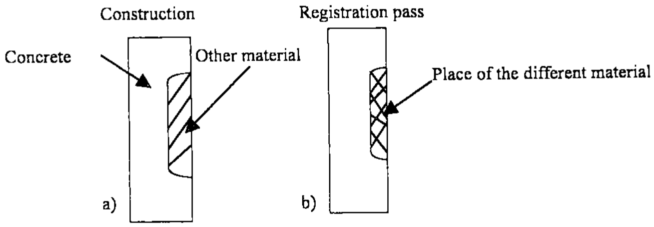

Fig 10. Different materials in construction and on registration pass

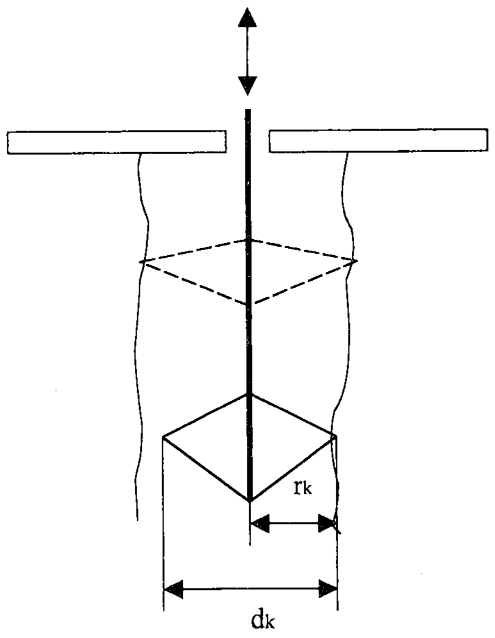

Fig 11. VHP columns diameter measuring by "umbrella" equipment: rk – radius of the column; dk – diameter of the column

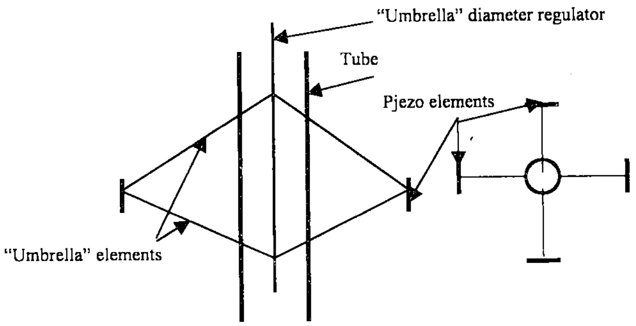

Fig 12. Pjezo elements in "umbrella" equipment

In VHP method VHP columns diameter (cement spread in soil area) is very important and VHP columns screen between water and shore. To check VHP columns diameter and screen vertical and horizontal borings on different depths and soil conditions investigations could be used.

Vertical borings are necessary to check how good columns are close to each other and if there are no empty places (soil) between columns. Such vertical borings should be made at each 50 – 100 m (Fig 13).

Horizontal borings can assist to check screen quality and see if there are any direct relations between water and soil behind the quay wall (Fig 14).

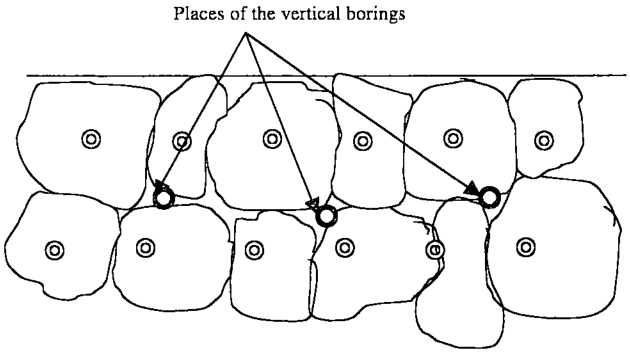

Fig 13. Vertical boring places

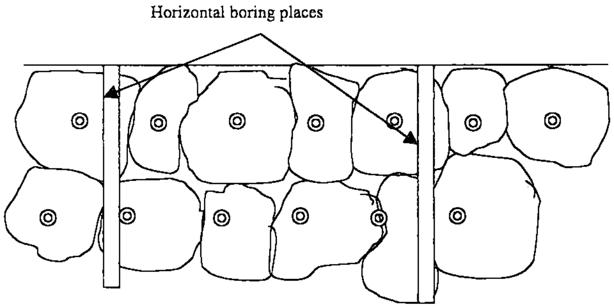

Fig. 14. Horizontal boring places

VHP "weak" place is VHP column deviation what means that column direction changes depend on the soil characteristics and column deviation conditions and deviation influence on screen quality could be controlled by horizontal borings and direct contacts between water and soil behind quay wall (shore)cannot occur (Fig 15).

Finally, it is very important that ground cement screen would be at least 30% of the planned VHP column diameter.

The movements of the construction during exploitation are very important and it is necessary periodically to provide measuring of all possible geometrical parameters of the quay walls. Quay wall geometrical parameters measuring could be made by the topographic methods and by inclinometers. Topographical marks must be prepared on the charactering quay walls places every 200 – 400 m (Fig 16).

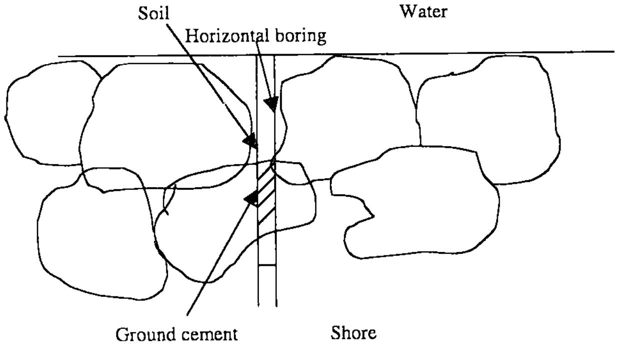

Fig 15. Parts of the soil between VHP columns, ground cement and screen quality

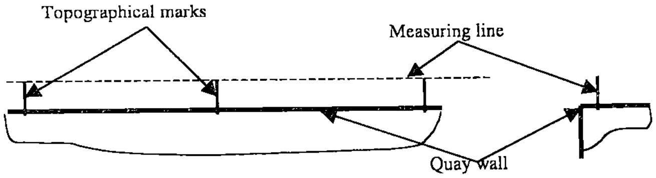

Fig 16. Topographical marks location

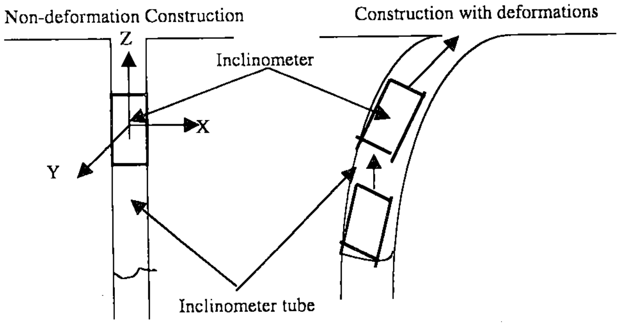

Fig 17. Inclinometer system for the construction movement measuring

Inclinometer systems can be used for the construction, such as quay walls, breakwaters and so on, movement measuring inside construction (Fig 17).

Measuring of the port infrastructure is on the basis of the following conditions [9–11, 13, 14]:

$$S_x \leq [S_x]; \tag{13}$$

$$S_y \leq [S_y], \tag{14}$$

here: S_x and S_y – real movement of the construction; $[S_x]$, $[S_y]$ - theoretically possible movements of the construction.

Finally, port infrastructure the same as any transport infrastructure, quality must be controlled in pre-visibility, visibility, design, construction and exploitation stages.

4. Practical Possibilities and Problems of Using New Technologies in Lithuania

New transport infrastructure technologies could accelerate construction work and decrease the cost of construction. At the same time there is very big resistance from existing local construction companies because local construction companies delay the implementation of new technologies, materials and equipment, and are afraid to lose the local market.

First implementations of the new technologies in the Klaipeda port infrastructure, such as the VHP method showed that the time of the construction work decreased more than 30 percent, the cost of the construction decreased about 25 percent, there was much less environmental impact, especially noise, in comparison with traditional technologies.

At the same time on the competition basis very big resistance from local construction companies was arranged, some of Lithuanian scientists, press, politicians were included and it was stated that it is impossible to use the VHP method in Lithuania because there are different conditions than in the rest world.

5. Conclusions

1. Transport infrastructure is rather expensive and its development must be on the basis of cargo and passengers flows.
2. The development of transport infrastructure technologies is orientated to optimize infrastructure itself and costs, and every new steps are progressive, so it is necessary to investigate all advantages and disadvantages of new technologies.
3. During the preparation of new technologies first of all it is necessary to investigate the basic principles and later to go into details.

4. Very often new transport infrastructure development technologies are based on experience, but they have not enough theoretical background.

5. New transport infrastructure technologies in Lithuania must find place and implementation because delays make a lot of additional costs.

6. Quality control systems, equipment and methods are very important for the new port infrastructure development because much work is done in ground or under water.

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