LIMIT DEFORMATIONS OF RETAINING WALLS IN LITHUANIAN HYDROSCHEMES

Raimondas Sadzevicius*, Tatjana Sankauskiene, Feliksas Mikuckis*****
Aleksandras Stulginskis University, Institute of Hydraulic Construction Engineering
E-mail: *raimondas.sadzevicius@asu.lt, **tatjana.sankauskiene@asu.lt, ***feliksas.mikuckis@asu.lt

ABSTRACT

In accordance with Standard STR 2.05.04:2003 all deformations of hydraulic structures are divided in two groups: 1) main – deformations of whole structure and 2) local – deformations of joints, supports, etc. Retaining walls of the used hydraulic structures are under the influence of climatic conditions, water, soil pressure and other types of loads. Deformations appear because of the aggressive environment and the load influence. The aim of the work is to evaluate the limit deformation of retaining walls on hydroschemes.

The state of 14 reinforced concrete retaining walls of hydroschemes was evaluated during the scientific expedition in the period 2007–2012. Retaining walls of hydraulic structures in Kaunas, Marijampolė, Kėdainiai, Panevėžys, Šilutė districts were examined and main deformations were determined.

Key words: retaining walls, limit deformation, hydroschemes.

INTRODUCTION

After the analysis of the state of 155 dams' hydraulic structures constructed in Lithuania was made (Patašius, 2009), it was found out that the most common deformations are these: cracked, leant, displaced, crumbled retaining walls (RW) of reinforced concrete. RW are considered as the main constructions of hydraulic structures (main constructions are those, which hold the pressure of soil and water). The questions of the evaluation of the state and reliability of these constructions are important because, if the evaluation of deformations of RW is carried out and the repair or reconstruction works are made in time, not only the collapse of RW but also the breakdown of the whole hydroscheme is prevented. Field observations and analytical methods were used for the evaluation of limit deformations of hydraulic structures' (HS) retaining walls. In accordance with Standard STR 2.05.04:2003 all deformations of hydraulic structures are divided in two groups: 1) main – deformations and displacements of the whole structure and 2) local – deformations of joints, supports, etc. This Standard does not specify which limit values define the deformations of RW. Limit cases of RW construction deterioration are given in Standard STR 2.05.14:2005, nevertheless it is not specified in this document, what limit values of vertical and horizontal deformations (fig. 1) are applied in the evaluation of the state of RW.

Vertical and horizontal deformations of building constructions and their limit values are defined in Standard STR 1.12.01:2004 app. 1, however the document does not say anything about RW deformations' limit values. In science literature, they were described by Lithuanian (Gurskis, 2006; Patašius, 2009; Jokūbaitis, 2007) and foreign (Witzany, 2007; US Army Corps of Engineers, 2002) scientists. In accordance with the analysis of reviewed literature, it was found out that the characteristics of materials' physical and mechanical properties are correctly evaluated not in all cases, there is a lack of data about the values of RW deformations, calculation methods are complicated and do not give accurate results, consequently additional research of the evaluation of RW deformations' limit values have to be carried out.

Object of research – Retaining walls of hydroschemes, which are located in Kaunas, Marijampolė, Kėdainiai, Panevėžys, Šilutė districts.

Aim of research – to evaluate limit values of deformations of retaining walls in hydraulic constructions.

Tasks to reach the aim:

- To evaluate retaining walls' geometrical characteristics and to measure deformations in Kaunas, Marijampolė, Kėdainiai, Panevėžys, Šilutė districts;
- To evaluate the compressive strength of concrete of retaining walls;
- To determine the inclination of retaining walls dependence on wall's height.

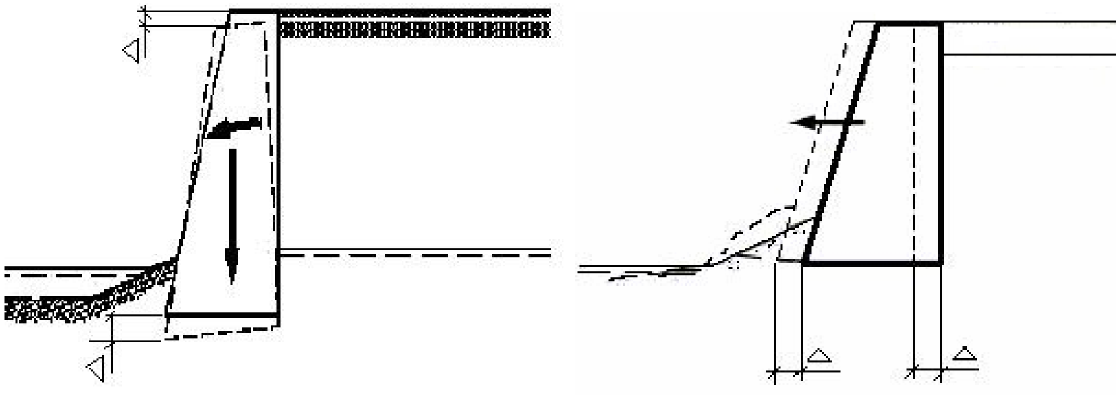

Figure. 1 The illustration of retaining wall horizontal and vertical deformations

METHODS OF RESEARCH

According to the researches carried out earlier (in 1998 – 2007) by the researchers of the Department of Building Constructions in Aleksandras Stulginskis university, hydroschemes with noticed considerable deformations of retaining walls were chosen. In Kaunas, Marijampolė, Kėdainiai, Panevėžys, Šilutė districts, RW inclinations were noticed in retaining walls of 14 hydroschemes. Analyzing in detail, how limit deformations depend on RW geometry, RW deformations' dependencies on wall's geometrical properties were determined.

Analyzing the state of retaining walls, the following diagnostics methods were used: visual examination, deformations photofixation, nondestructive methods for the estimation of RW strength, field observations.

Visual examination is the examination of an object at the same time making the simplieste necessary measurements and using simple tools such as a tape-measure, a ruler, a sliding caliper, a camera and a plumb line.

RW lengths, widths, heights, inclinations and deflections were measured during field observations (fig. 2).

Photofixation method – everything was sequentially photographed.

Figure. 2 Illustration of retaining walls deformations' measurements

Using the nondestructive method with a rebound hammer of concrete Cat.58−CO181/N (Schmidt's system), an actual compressive strength of concrete was measured.

Testing concrete with the rebound hammer in specially prepared construction's places, 10-12 hits were made in accordance with the usage instructions of the instrument. Research results were statistically evaluated – an average compressive strength of concrete f_c, variation coefficient v and root-mean-square deviation σ were calculated using „Microsoft Excel“ macros.

RESULTS AND THEIR REVIEW

Table 1 represents construction sites' names, minimal values of RW compressive strength of concrete f_c, variation coefficient v, root-mean-square deviation σ, RW inclination and RW height which were investigated in 14 hydroschemes.

Table 1

Results of the research of retaining walls' compressive strength of concrete and deformations in hydroschemes

No.	Name of hydroscheme	Minimal values of compressive strength of concrete, f_c, MPa	Variation coefficient *v*, %	Root-mean-square deviation σ	RW inclination, cm	RW height, cm
Kaunas district						
1.	Gailiušiai	7.6	40.74	3.08	12	320
2.	Panevežiukas	5.6	21.74	1.22	7	237
Marijampolė district						
3.	Pilviškiai	16.8	32.12	5.9	R 7.2 L 5.3	R 165 L 170
4.	Totorvietės	14.1	20.22	3.0	–	–
5.	Marijampolės marios	22.1	24.73	5.8	R 15 L 6.5	–
Panevėžys district						
6.	Jotainiai	19.0	24.77	5.0	R 4.5 L 12	880 – 440
7.	Pažibai	11.2	32.97	3.9	R 8.5 L 13	280
8.	Žibartonys II	25.4	39.82	10.7	R 6 L 5	235
9.	Paviešiečiai	4.4	42.54	2.0	–	–
10.	Žibartonys I	14.5	35.77	5.5	R 6	300
Kėdainiai district						
11.	Kėdainiai town	11.9	24.46	3.1	11.5 and 5	780 – 260
12.	Dotnuva	4.7	46.76	2.3	4	250
13.	Kruostas	31.2	30.42	10.8	R 2	910
Šilutė district						
14.	Žemaičių Naumiestis	25.3	15.77	4.9	L 3 R 17	480

Notice: R– right RW, L– left RW, "–" Measurements not carried out.

According to the research results presented in table 1, it was established that, out of 14 hydroschemes, the smallest compressive strength of concrete was in Paviešiečiai dam's RW (4,4 MPa), the biggest one – in Žibartonys II dam's RW. In accordance with earlier (during the course of design) valid requirements of regulations, the class of compressive strength of concrete in these constructions should have been no lower than B15, these days it would correspond to the C12/15 class. The concrete of retaining walls of Marijampolės marios, Jotainiai, Žibartonys II, Žemaičių Naumiestis hydroschemes meets the requirements of these standards. In accordance with currently valid Standard STR 2.05.05:2005 constructions, used in the conditions of XC4 and XF3 exposure classes, must designed from the concrete whose the least strength class is C30/37. The RW concrete of none researched hydroscheme meets this requirement.

The smallest RW inclination was found in Dotnuva hydroscheme (4.0 cm), the largest – in Žemaičių Naumiestis dam (17.0 cm). According to the indices of emergency state described in Standard STR 1.12.01:2004 app. 1, it is considered that vertical or horizontal deformations, which are larger than 1/50 of wall's height, are one of the indices of the emergency state of RW. Taking into consideration that Žemaičių Naumiestis RW height is 4.8 m, its limit deformation is 9.6 cm. Since the measured wall deformation is 17 cm, it can be stated that such deformation exceeds the limit value almost twice (deformations are larger than 1/50 of wall's height). Retaining wall is in emergency state.

Analyzing the reasons of RW deformations appearance in hydraulic structures, it was established that various deformations can appear due to an increased load (i.e. due to the weight of motor vehicle on the slope), an increased pressure of soil or groundwater (Panevėžiukas and Dotnuva hydroschemes), an undermining of the base under the foundation (Pilviškiai hydropower station's RW inclinations could appear due to this reason), seepage effects etc.

During the researches in 2007 – 2012, RW inclination was the most frequently recorded deformation. The main possible reason of inclination is the increased soil pressure. RW "blowouts" are also frequently noticed when the wall is canted as a result of not functioning drainage, especially when water gathers after a heavy rain beside the RW construction. Pressure notably increases in winter, when the gathered water freezes, its volume expands (up to 9 %) and it pushes the wall (Kėdainiai and Pažibai hydroschemes).

On the basis of the research results presented in table 1, RW inclination was plotted as a function of wall's height (fig. 3).

As the results of RW deformations' research shows (fig. 3), the inclinations of almost every examined construction exceed the limit value of 1/50 of wall's height (this value is marked with the above straight line).

The deformed retaining walls of reinforced concrete in hydroschemes can be strengthened using the following principles described in literature (Venckevičius, 2000; Hidrotechninė statyba, 2000):

- Cross-section enlargement (using concrete encasement in the compression zone; using reinforced concrete encasement in the compression zone; using reinforced concrete encasement in a tension zone (at the same time the baseplate of a wall is strengthened); using reinforced concrete core in a tension zone; using double-sided reinforced concrete encasement).
- Reinforcement extension (using internal, external or external prestressed reinforcement).
- Changing the design model (with additional supports, cantilever beams, reinforcing steel strings with prestresed muff.
- Changing the tension state (by reducing the load, with a prestressed reinforcement or relieving plates.

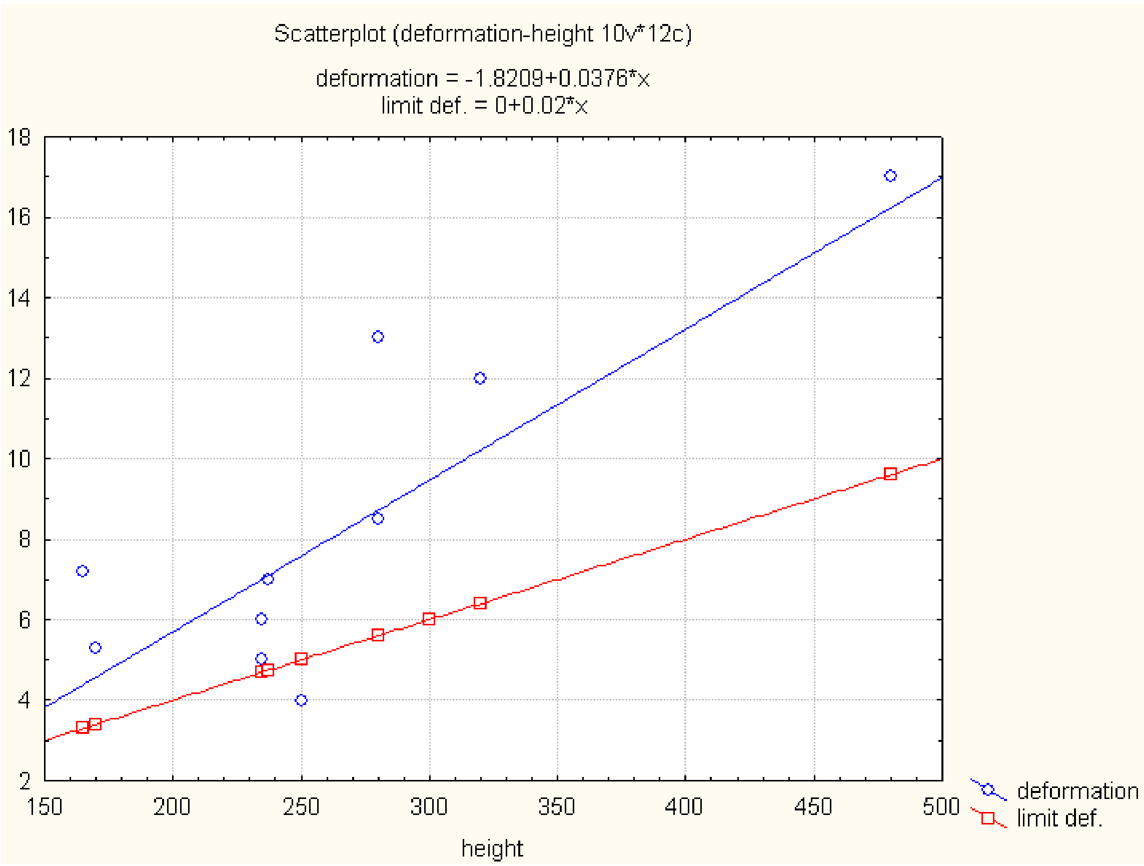

Figure. 3 Retaining walls' deformations-height dependence

CONCLUSIONS

1. According to the results of the field observation of 14 hydroschemes, it was established that the smallest retaining walls inclination was in Dotnuva hydroscheme (4.0 cm), the largest – in Gailiušiai (12.0 cm), Pažibos (13.0 cm) and Žemaičių Naumiestis (17.0 cm) dams.

2. Taking into consideration that the limit deformation is equal to 1/50 of wall's height value, it was established that the inclination in Pažibai hydroscheme (13.0 cm) exceeds the limit value (4 cm) more than three times and the inclination in Žemaičių Naumiestis hydroscheme (17.0 cm) exceeds the limit value (9.6 cm) almost twice.

3. After the retaining walls inclination analysis was made, it was established that the retaining walls of 150 – 300 cm height are most commonly prohibitively inclined, their inclination reaches from 4 to 13 cm.

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