Influence of urban planning over the effective utilization of retaining structures

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ABSTRACT: The report discuses a structural project for construction of retaining walls in difficult geological conditions and unfavorable urban planning. According to the design prescriptions numerous different retaining structures had to be built: gravity concrete retaining walls, reinforced retaining walls with shallow foundations and combined with drilled piles, thin diaphragm walls.

1 INTRODUCTION

In 2005 was developed a project for closed settlement located at the foot of Vitosha Mountain in Simeonovo. The village is situated in 30 000 m2 area and consists eight four-storey buildings, arranged in a circle on the higher part of the area, 16 single family houses located in the lower part of the area, club house with shops, swimming pool, wastewater treatment plant and security building at the entrance of the village. According to designed General plan of the settlement the access from a near street in Simeonovo was located at a higher elevation of the natural terrain. In order to meet the administrative requirements inner- settlement roads had to be designed with a slope no greater than 12% in village's area (Godinyachky et al, 2005). As a result obtained high cuttings and embankments had to be reinforced with retaining walls. To reduce their height the retaining walls were mostly situated on the side regulation lines.

2 SITE CONDITIONS AND CHARACTERISTICS OF DESIGN DECISION

The design of retaining walls was consistent with report from geological site investigations. The foundation base of the walls was composed mostly from Quaternary deposits made from brown to black clays with firm to soft consistency. Clay layer's thickness varied from 2,20 to 1,80 m. High levels of the soil water, often near to the natural terrain, caused swamping of some of the lowlands. Shallow landslides were occurred at two locations on the village area.

After seismic response investigation "in – situ" the evaluated value of seismic coefficient k_s was 0,35. Above - mentioned shows a very weak soil base, which was virtually combined with other unfavorable circumstances. They can be summarized as follows:

- Location of retaining walls on the parcel boundaries. This circumstance obliged us in any case not to affect properties of the neighbours. If according to the design technology, an excavation or an anchoring shall be made, the investor should seek permission from owners of adjacent properties.

- Significant height of retained terrains- in some areas to 5,00 - 5,50 m.
- Weak soils below wall's foundations. At a depth of 0 - 2,0 m soil has very low frictional coefficient μ = 0,25, which reduces sliding resistance and requires additional measures to ensure the structures against failure by sliding at the base.
- High soil water table. High water table reduces strength and increases deformability of soil base. This leads to complications not only in design of retaining walls but also during their construction process.
- High seismic coefficient k_s = 0.35. This leads to a substantial increasing of the cross – section sizes of those wall types, which are subjected to design for load combinations with seismic actions (Ordinance № 3/2004, BGS – 1990). These were all wall sections with height between the crown and plinth gap more than 4,0 m.

To meet all requirements and taking into account all unfavorable circumstances, following retaining walls had to be designed:

- Gravity retaining walls from concrete (Fig. 1). As such type were designed those walls which had small height and a relatively low active earth pressure load. Gravity retaining walls resist to the action of active earth pressure mainly with their weight (BS EN 1997-1:2004). The absence of reinforcement usually leads to simplification of building technology and shortening of construction terms.

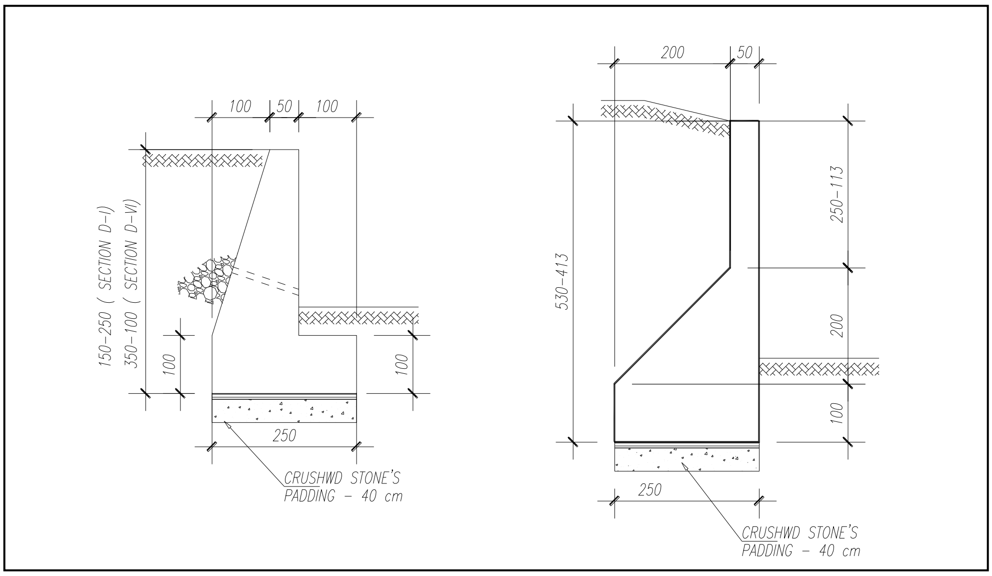

Figure 1. Cross-section through gravity retaining wall type.

- Reinforced concrete retaining walls (Fig. 2), where the weight of backfill soil material and surcharge load also play stabilization role (BS EN 1997-1:2004). As the length of the hill of the cantilever wall is not enough to satisfy the sliding verification, for very high retaining walls, it is possible to replace the weak soil layers in the base with crushed stone or gravel. Crushed stone has a higher coefficient of friction - μ = 0,6, which leads to improvement of the ratio between frictional force and shearing force.
- Reinforced retaining walls on drilling pile foundations (Fig. 3,4). As such types were designed the highest sections built on unfavorable soil base and without the possibility of anchoring. The possible entering into neighboring properties had to be overcome. A short piles were used with a diameter of 0,4 m and a length of 4,0 m. The joint between the wall shallow foundation and the pile shafts were designed stiff - with no allowable displacements.

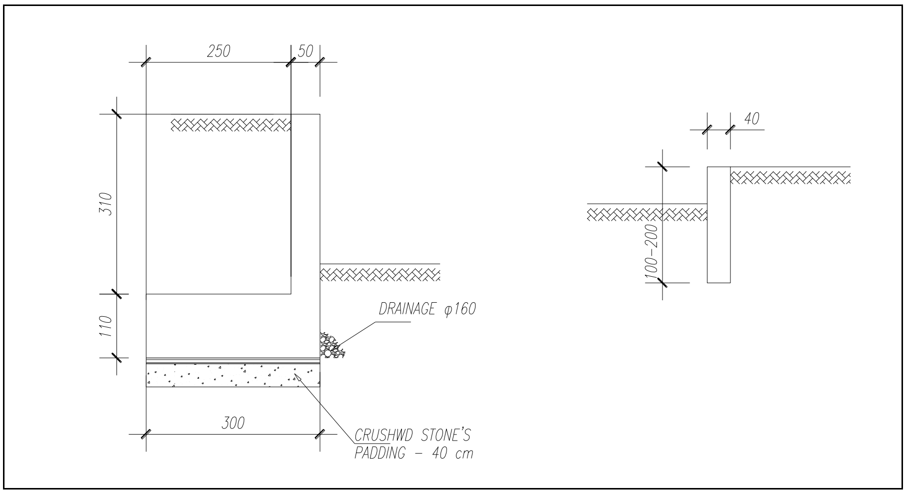

Figure 2. Cross – section through reinforced concrete retaining wall type and thin retaining wall type.

Pile foundations of the walls enable to transfer loads from upper structure to a stiffer and stronger soil layer and provides additional resistance to a transverse loading without significant increasing of the weight of the retaining walls (Hamova et al, 2009). Thus leads to elimination of the most difficult requirement in ultimate limit state design of gravity walls – failure against sliding in the base.

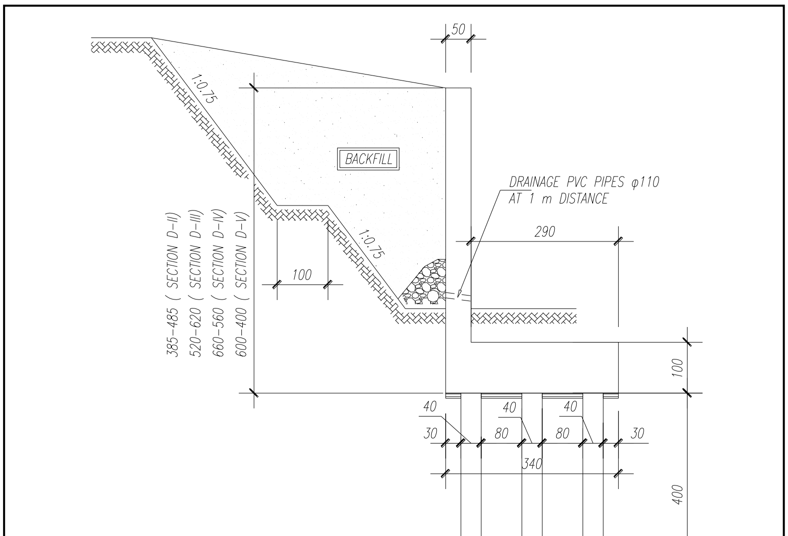

Figure 3. Cross–section through reinforced retaining walls on pile foundation.

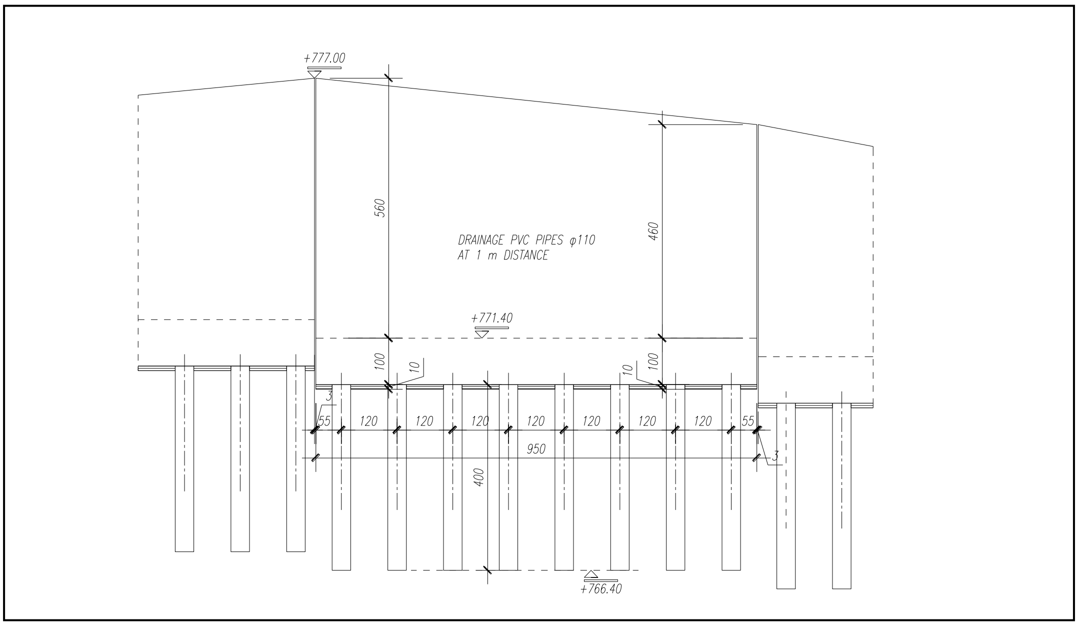

Figure 4. View of the section.

- Thin retaining walls without foundations (Fig. 2). As such type are designed the lowest retaining walls. Their construction technology is similar to the excavation method of reinforced embedded walls under the protection of bentonite suspension when the water table is high.

Different retaining wall sections were separated by gaps of 3 cm, with average section's length between 12 m and 15 m, according to the plan configuration of the walls and the requirements of government standards.

For draining of the backfill soil material a local drainage system was designed, allowing the infiltrated and surface water from the gutters to be led to the nearest ravine.

Drainage pipes ø110 mm from PVC were integrated in the body of the walls aligned into two rows at a distance of 1 m, depending on the walls height. The integrated PVC pipes were combined with underground drainage system consisted from corrugated pipes HDPE ø160 mm and formed from graded material "crushed stones to sand" filter, also known as "reverse filter".

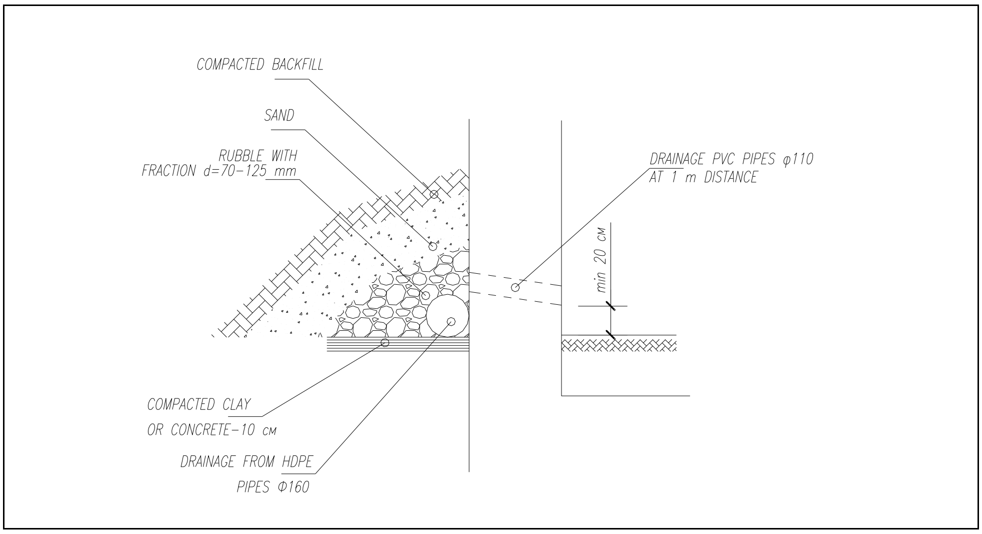

Figure 5. "Reverse filter" around drainage facilities

Underground parts of the reinforced concrete and gravity walls were coated with waterproofing compound.

For carrying out of drilling procedure, pile wells had to be simultaneously drilled and filled with bentonite slurry with density ρ = 1,05 - 1,03 g/cm3.

Concrete had to be done with vertically rising pipe by the "Contractor" technology, without interruptions. Every new portion of concrete should be laid in previous one to avoid formation of horizontal gap. This required the concrete to be in plastic consistence with bigger amount of cement in the mixture (20% more than usual).

Such construction technology had to be applied to the smallest retaining walls where the previously assembled reinforced skeleton is dropped into the pit and concreted to the plinth gap. The reinforcement and concrete should be done under the protection of clay suspension if the water table is high or when any possibility of failure of pit's sides exists. In that case the vertical gap between wall's sections had to be made at 4 m to 5 m distance.

7 SUMMARY AND CONCLUSION

Retaining walls in the village "Simeonovo" were with a total length of about 350 m. Based on the urban design they varied both in plan and height. Depending on the height and loading of different sections, diverse construction technologies, section materials and static schemes were applied.

Building the walls will undoubtedly consume many financial resources, labour and materials. After completion of construction high embankments, excavations and retaining walls are going to dominate over the buildings in the village and to some extent to spoil the mountain view. A better urban planning (Kolev, 2006) related to a different approach to construction area is going to decrease the amount of infrastructures served the inner village road network and halve the cost of construction. Such different approach could be achieved from the lower part of the natural terrain.

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