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Comparison of Geotube and Stone Cemented Wall Stability as Coastal Protection System [Case Study and 2d Limit Equilibrium and FEM Modeling Analysis]

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Abstract: Geosynthetic structures for shore protection have demonstrably lower construction and lifetime costs than those of hard structures. This paper outlines the effect of scouring on banks protection structures stability in case of comparison between sand-stone wall and a geosynthetic structure that is commonly used for shore protection: geotextile wraparound revetments (GWRs). Different 2D Limit Equilibrium and FEM modeling analysis were carried out on a case study of sand-stone example. As a result, GWRs have been shown to adapt extremely well against differential settlement and scour erosion. Analyses show that many advantages of sand-stone structures remain, but that geosynthetic structures should not be regarded as an alternative shore construction method. Rather, they are a preferable solution for numerous coastal problems.

Key words: Stability; Geotube; Coastal protection; 2D Limit Equilibrium analysis; FEM.

INTRODUCTION

Today, about half of the world's population lives within 100km of a coastline. In recent years, new threats to coastal areas have emerged as a consequence of climate change and the rising sea level, which both result from global warming (Yasuhara and Molina 2007). Revetments are structures placed on banks or bluffs in such a way as to absorb the energy of incoming waves. They are usually built to preserve the existing uses of the shoreline and to protect the slope. Like seawalls, revetment armors and protect the land behind them. They may be either watertight, covering the slope completely, or porous, to allow water to filter through after the wave energy has been dissipated (Melville and Coleman, 2000). When a structure is placed in a riverside and marine environment, the presence of the structure will change the flow pattern in its immediate neighborhood, resulting in one or more of the following phenomena: the contraction of flow; the formation of a horseshoe vortex in front of the structure; the formation of lee-wake vortices (with or without vortex shedding) behind the structure; the generation of turbulence; the occurrence of reflection and diffraction of waves; the occurrence of wave breaking; and the pressure differentials in the soil that may produce ''quick'' condition/liquefaction allowing material to be carried off by currents. These changes usually cause an increase in the local sediment transport capacity and thus lead to scour waves, and combined waves and currents (Sumer, *et al*. 2001). Clearly, scour processes in the marine environment (with waves being the dominating flow effect) are more complex than in steady-current flows such as in rivers. In river hydraulics, a long tradition exists for studying scour around hydraulic structures. Scour at a bridge pier, for example, has been studied most extensively (Breusers and Raudkivi, 1991; Melville and Coleman, 2000), simply because it has been realized that this is an important cause of bridge failure. The scour problems in coastal and offshore engineering have not received the same kind of attention. Analysis of failures due to scour has proven that more basic knowledge on scouring needs to be accommodated in the design exercise. The scour is a threat to the stability of coastal structures such as piles, breakwaters, seawalls, etc. Commonly, such structures are exposed to currents, waves, and combined waves and currents. The purpose of the present paper is to provide a tentative engineering approach by comparison between geotube and stone cemented walls regarding their banks river protection ability.

Study Area:

Study area was riverside of Aghajari river which located in 35 km in North West of Shiraz city, in south of Iran. Figure 1 shows two of the critical points which mostly scouring happened in the study area.

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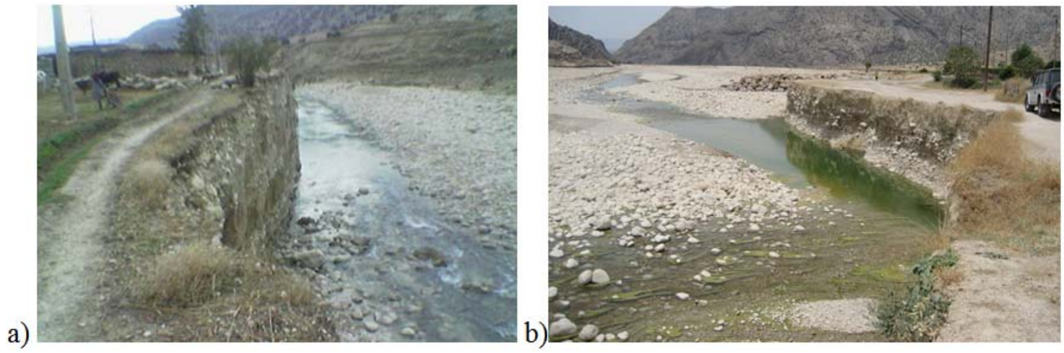

Fig. 1: study area and its high susceptibility to scouring

Remediation Countermeasure:

Stone cemented wall was used as a remediation countermeasure method enhanced controlling scour forces in the study area. Also, several field observations have done in order to monitor the structural behavior of stone cemented wall. Figure 2 (a and b), shows the mentioned wall during its operation and 3 months after collapsing. It is clear that the wall failure happened due to progressive scouring in the banks protection system toe. The man who stands in Figure 3.a can be used to show scaling and better understanding of significant amount of scouring forces.

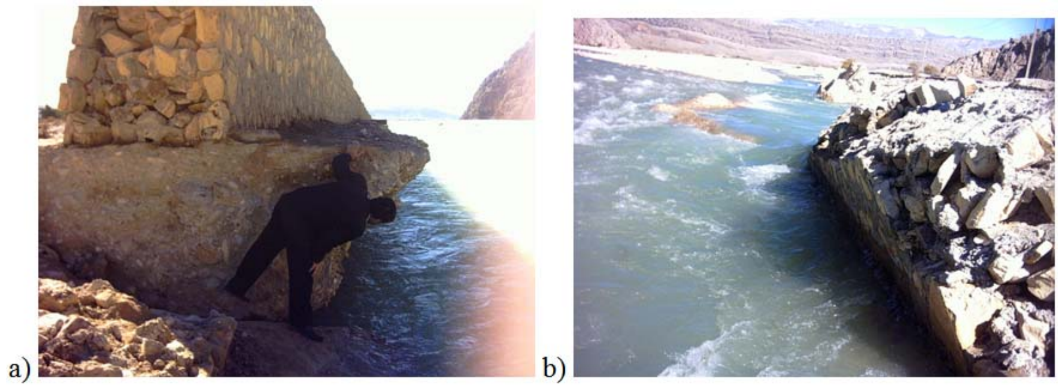

Fig. 2: field observation from stone cemented wall; a) 6 months before collapsing, b) 3 months after failure

The mechanism of scour in front of an emerged stone cemented wall may best be described in Figure 3. It should be mentioned that it has drawn based on field monitoring during 21 months of system operation.

2D Limit Equilibrium Modeling:

Figure 4.a shows an example of progressive scouring in banks protection structure. It should be mentioned that sliding appeared through the structure without seismic loading and only it has happened by cause of overweighting due to foundation scouring. Modeling of mentioned structure has analyzed by Slide 5.0 (Rockscience Software group). Slide is a 2D limit equilibrium slope stability program for evaluating the safety factor or probability of failure, of circular or non-circular failure surfaces in soil or rock slopes.

Figure 5 shows the factor of safety reduction during the structure lifetime. It should be mentioned that first cracking appeared after 18 months. Eventually, after 2 months such a progressive crack leads to structural collapsing.

Geotextile Wraparound Revetments (GWRs):

Geotextile applications were initiated in the area of coastal and hydraulic engineering. Other applications for geosynthetics in civil engineering grew from these beginnings. The first trials with sandbags made of synthetic textiles were initiated 50 years ago in the USA, the Netherlands and in Germany an etc. (Koerner and Koerner, 2006; Muthukumaran and Ilamparuthi, 2006; Saathoff, *et al*. 2007). In recent years, geotextile container technology has experienced an increasing growth leading to successful projects. Nowadays, geotextile sand containers find their application as construction elements for erosion control, bottom scour protection and scour fill, artificial reefs, groynes, dams, seawalls, revetments and dune reinforcement. Recently, geotextiles in the form of tubes and bags (or, geosynthetic containers) have been successfully used in various environmental protection facilities, such as underwater breakwater (Koerner, 1986; Pilarczyk, 1998), river dyke improvement (Fowler, 1997), streambank erosion control and erosion control of seashores (Koerner, 2000). Geotextile tubes made from high-strength fabrics are a growing technology to provide for both oceanfront and inland erosion control [Figs. 6 (a and b)]. Tubes of up to 3 m in diameter are available in either a woven (longitudinally seamed in the field), or a knitted (without seams) format (Leshchinsky and Leshchinsky 1996). There is no length limitation as far as the tube itself is concerned with the exceptions of handlability and filling. Filling is usually accomplished by hydraulically pumping a sand fill slurry, which flows from the point of entry. Entry locations are at relatively close, typically 10 m, centers due to the frictional drag of the slurry against the fabric's inner surface (Lawson, 1992). The main tubes often have a smaller diameter subsidiary tube attached to them (on their upstream side), which acts as an anchor in resisting lateral pressures. Also, it is generally necessary to cover tubes with a thin layer of soil to protect them from ultraviolet degradation and vandalism/ accidents. This is particularly troublesome from a maintenance standpoint when storms occur, or when the tubes are trafficked and the cover soil is displaced. As far as an emerging development of the technique is concerned, a rugged, high-strength fabric that can perform in an exposed condition for 206 years is actively being pursued. This could well be a composite fabric, which would also add to field ruggedness. This latter issue is necessary for certain fill materials such as coarse, angular gravel and limestone shells (Koerner, 2000).

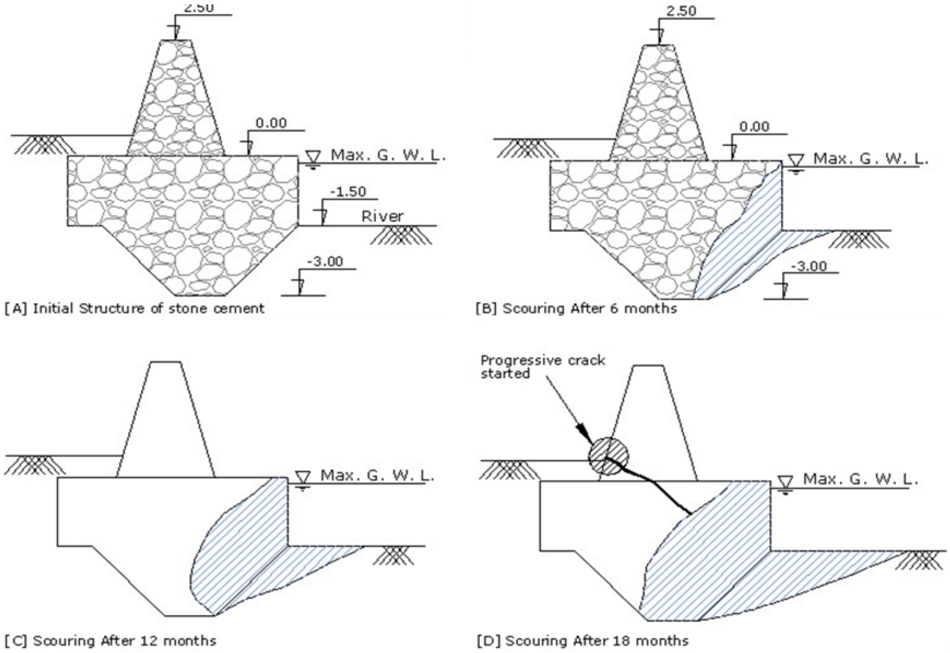

Fig. 3: Progressive scouring in stone cemented structure case; a) initial Structure of stone cement, b) Scouring in 6 months, b) Scouring in 12 months, b) Scouring in 18 months [before collapse]

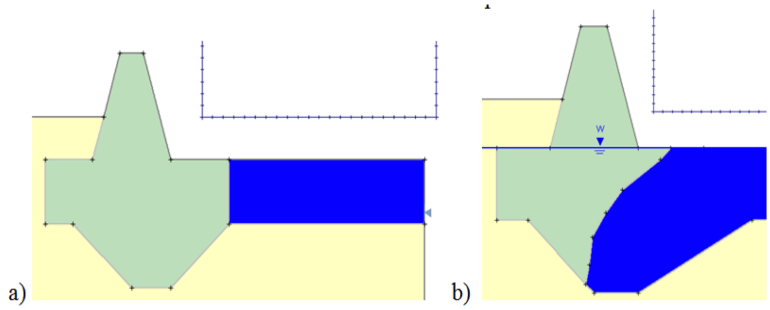

Fig. 4: 2D limit equilibrium analysis of stone cemented wall; a) first operating, b) after 18 months

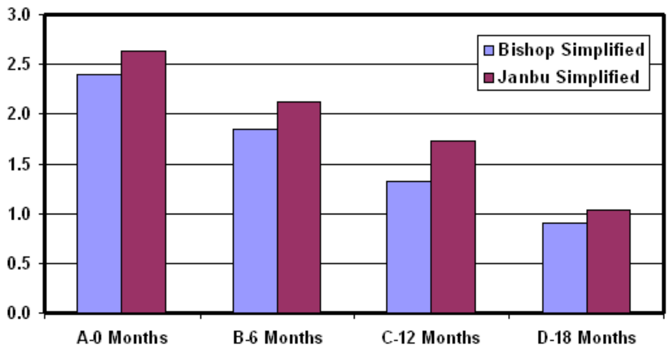

Fig. 5: Factor of safety against over turning during 18 months for stone cemented wall case

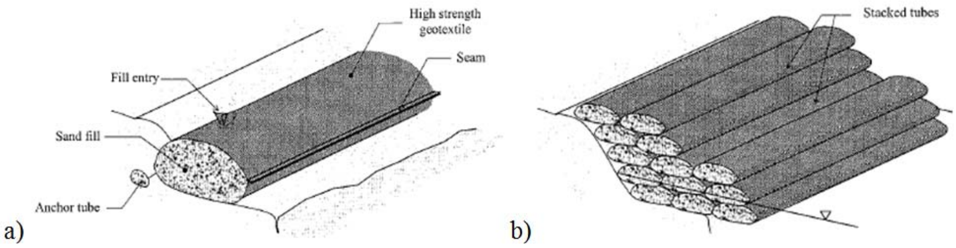

Fig. 6: Geotextile Use as Tubes for Erosion Control; a) Single tube arrangement, b) Multiple stacked, tube arrangement, (Koerner, 2000)

Finite Element Modeling, [FEM]:

As can be seen from the Figure 7 filled containers displayed typical dimensions of 1.5m long, by 1.2m wide, with a height of 0.30 m. The structure design includes an encapsulated self-healing toe. Finite element modeling was carried out with Phase 2 in order to calculate stress-strain relationships due to critical loading which may happen on geotube structure. Phase2 is a 2-dimensional elasto-plastic finite element program for calculating stresses and displacements around underground openings, and can be used to solve a wide range of mining, geotechnical and civil engineering problems.

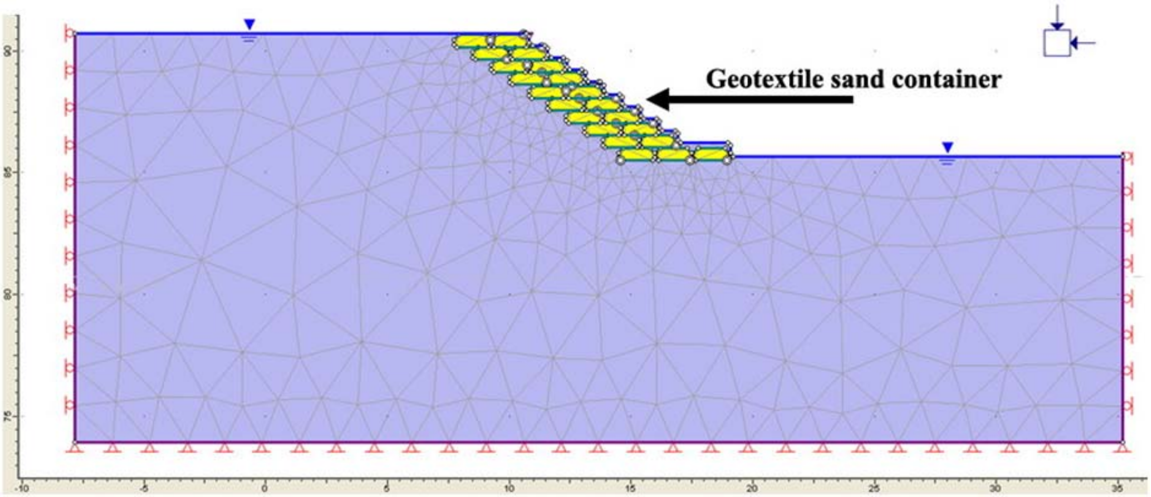

Fig. 7: Typical sand-filled geotextile container revetment.

In order to design an alternative option, a dual layer, stretcher bond with flexible toe design, placed on grade appropriate filtration geotextile was chosen. Figure 8 and 9 show total displacement and mean stress which described the insignificant deformation change in riverside and weight of banks protection system respectively.

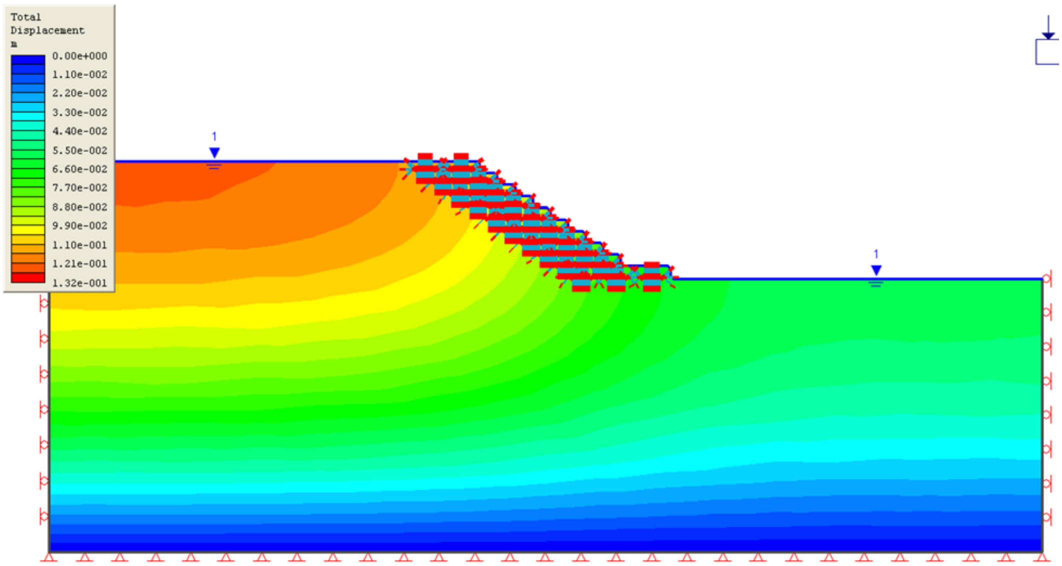

Fig. 8: Total displacement of geotube protection system

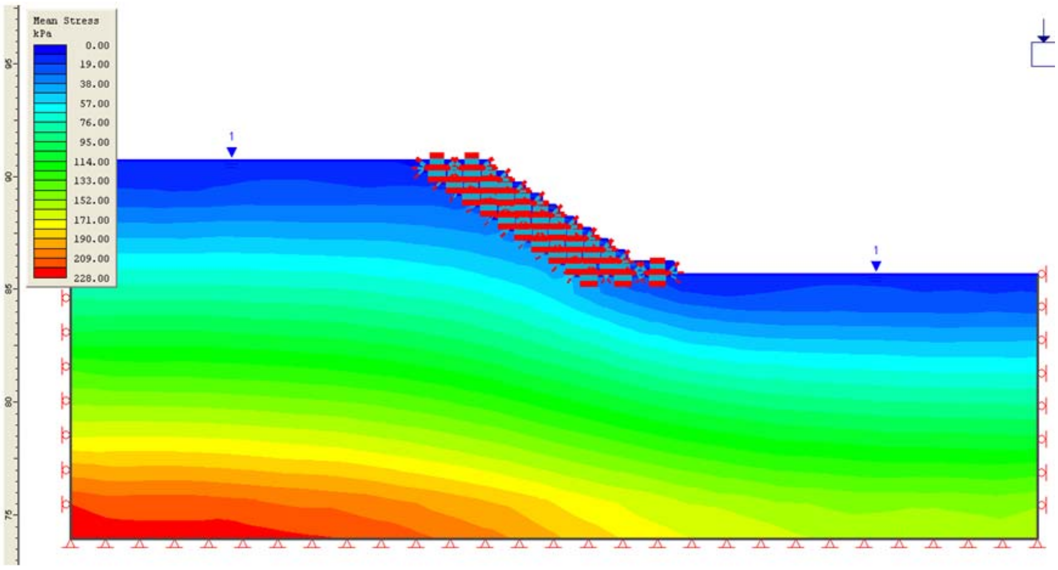

Fig. 9: mean stresses under the geotube as banks protection

It is well known that geotextiles sand container will design based on its tension absorption as well as its draining properties (Carrol, 1992). Figure 10 shows tension forces absorbed by Geotextiles. It is clear that by rising water level in river bed the absorbed axial forces in geotube which located in bottom of slope will be slightly reduced. So for considering critical situation in regard, water level was takwn place in the lowest position in river ground surface. Consiquently, the geotextile can be designed in different categorize based on its different tension stiffness in order to making project more cost effective. As an example, maximum axial forces which it is in the bottom layers show the tension absorption amount of 3.77 kN for current design.

Conclusion:

Geosynthetic structures such as GWRs have proven to resist storms. They present an optimal solution for many coastal problems. Nevertheless, reliable and standard design methods for these structures must be developed further. In presented research different 2D Limit Equilibrium and FEM modeling analysis on a case study of Aghajari riverside were carried out. Coastal protection structure which considered in study area was collapsed due to high amount of scouring forces. It actually happened in 18 months after construction and it was due to passing two heavy rainfall seasons in the mentioned area. On the one hand, GWRs have been shown to adapt extremely well against differential settlement and scour erosion by applying the same loading system and same condition. There is a lot of research to do, but the use of geotextile wrap-around structures will certainly increase in the coming years.

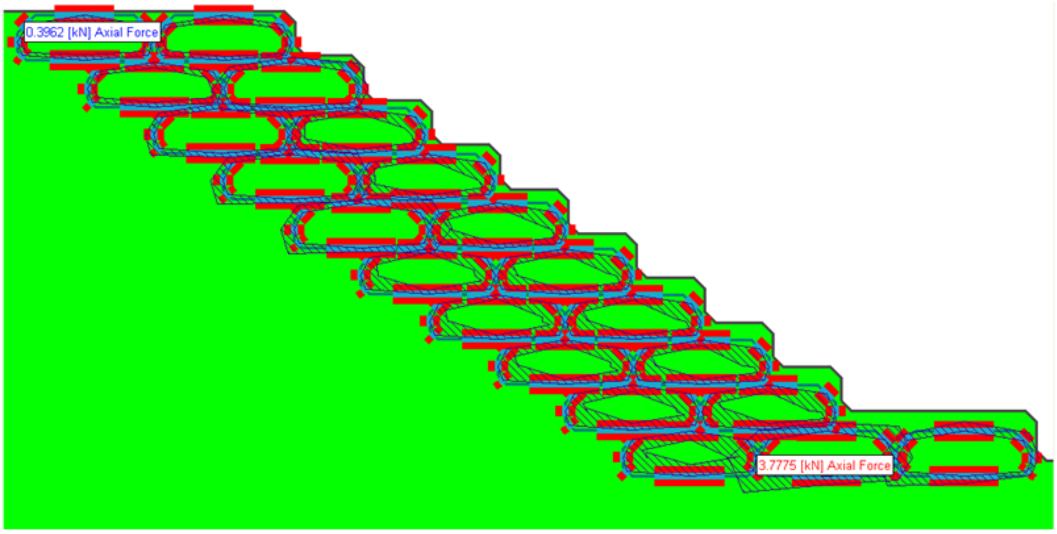

Fig. 10: Tension absorption in geotextiles

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