GEOTEXTILE TUBE APPLICATION FOR CONSTRUCTION OF DALSUNG WEIR ACROSS NAKDONG RIVER IN KOREA

J.C. Choi[1], T.W. Yee[2] and S.P. Hwang[3]
[1]President, JC Enterprise, Seoul, Korea; Tel: +82-2 3461 8178; Fax: +82-2 578 6073;
Email: chjongch@yahoo.com
[2]Technical Manager, TenCate Geosynthetics Asia, Shah Alam, Malaysia; Tel: +60-3 5191 2609; Fax: +60-3 5191 4761; Email: tw.yee@tencate.com
[3]President, Woojin ENC, Seoul, Korea; Tel: +82-2 488 6640; Fax: +82-2 488 6654;
Email: woojinenc@empal.com

ABSTRACT

The Dalsung Weir Project involves the construction of a composite concrete weir and bridge structure across the Nakdong River, southwest of the city of Daegu in Korea. This structure is part of the grand Four Rivers Restoration Plan of Korea. To construct the weir structure dry work platforms have to be created to allow construction works to be carried out. The weir structure was constructed in three stages. The first stage involved the middle section. The second stage involved the section connecting the middle section to the southwestern bank of the river while the third stage involved the section connecting the middle section to the northeastern bank of the river. For each section, temporary cofferdams were constructed to create a dry work platform on the riverbed, while the river was allowed to flow adjacent to the area surrounded by the temporary cofferdams. Geotextile tubes were used as part of the design for the first and second stage temporary cofferdams. The primary function of the geotextile tubes is erosion protection of the temporary earth cofferdams. The geotextile tubes also served as retaining structures, Thus allowing steeper overall side slopes to be built safely for the temporary earth cofferdams.

Keywords: River restoration, weir, dry work platform, cofferdam, geotextile tube

INTRODUCTION

The Four Major Rivers Restoration Plan of South Korea involves Han River, Nakdong River, Geum River and Yeongsan River (see Fig. 1). This river restoration plan is designed to provide water security, flood control and ecosystem vitality. This plan was first announced as part of the "Green New Deal" policy launched in January 2009 but later included in the South Korean five-year national plan released by the government in July 2009 with a budget of Won 22.2 trillion (or approximately USD 17.3 billion). The five key objectives of the project are as follows:

- securing abundant water resources to mitigate water scarcity;
- implementing comprehensive flood control measures;
- improving water quality and restoring the ecosystem;
- creation of multipurpose spaces for local residents; and
- regional development centered on rivers.

Apart from plans to revitalise the four major rivers, works will also involve their 14 tributaries as well as other smaller sized associated streams.

Fig. 1 Map of South Korea showing the rivers that form the Four Major Rivers Restoration Plan

Nakdong River

The Nakdong River with a length of 521 km is the longest river in Korea. It flows from the Taebak

Mountains in Gangwon Province, passing through the major cities of Daegu in Gyeongsangbuk Province and Busan in Gyeongsangnam Province before draining into the Korean Strait. The Nakdong River suffers from drought upstream and flooding downstream. The Nakdong River Restoration accounts for about 60% of the total budget for the Four Major Rivers Restoration Plan.

Dalsung Weir Project

The proposed Dalsung Weir project site is located along the middle third of the Nakdong River, southwest of the city of Daegu (see Fig. 2). Figure 3 shows the artist impression of the proposed Dalsung Weir, a composite weir and bridge structure, across the Nakdong River.

Fig. 2 Map showing the location of the proposed Dalsung Weir across Nakdong River

The weir is 544 m in length and cuts across the Nakdong River from southwest to northeast. The northeastern end of the weir truncates at a planned wetland to be created adjacent to the river bank. The generally fixed height weir include three sections, each 45 m in length, with adjustable heights; one fish-way; and one 2,800 kW mini-hydro power plant adjacent to the southwestern bank. A concrete bridge designed at elevations above the long term flood levels runs from the southwestern bank, above the concrete weir and over the wetland, to the northeastern bank of the river.

Geotextile tube cofferdams have been used in past projects for the creation of construction working platforms in Korea (Yee et al, 2007), (Yee and Choi, 2008), (Yee et al, 2008). For the Dalsung Weir Project geotextile tube cofferdams were used for the same purpose. However, the Dalsung Weir Project represents the first time where geotextile tube cofferdams were used to create dry construction working platforms on a river bed in Korea.

COUNTRY BACKGROUND

The Korean Peninsula with an area of 222,196 km^2, extends southwards for about 1,100 km from the continental Asian mainland into the Pacific Ocean and is surrounded by East Sea on the east, Korea Strait to the south and Yellow Sea to the west. The country of South Korea is situated on the southern half of the Korean Peninsula. Mountains cover 70 percent of the Korean Peninsula, mainly to the North and East.

Along the southern and western coasts the mountains descend gradually towards broad coastal plains. Arable plains are generally small and far in between the successive mountain ranges. The eastern coast of the peninsula runs directly along the skirt of the steep mountain slope range, while the western and southern coasts have curved shapes and wide alluvial plains.

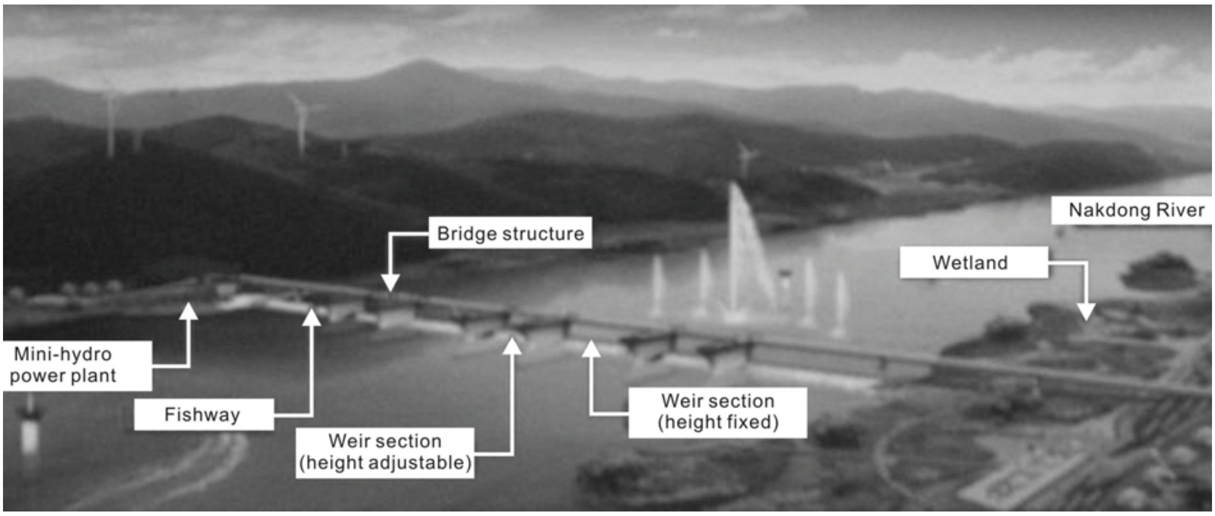


Fig. 3 Artist impression of the proposed Dalsung Weir across Nakdong River

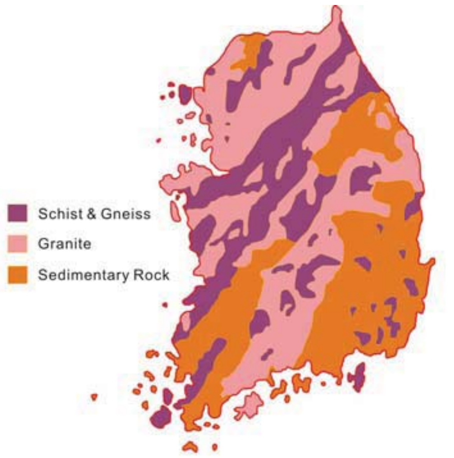
It is presumed that this asymmetrical topography was caused by tilting movements; subsidence in the western coast and upheaval in the eastern coast, and thus, the ridge line of the watershed runs on the eastern side of the peninsula.

Geological Characteristics

The land consists of various geologic strata of Archean to Cenozoic era (Park and Kim, 1999). Gneiss and schist complex of Archean to Middle Proterozoic eons compose the base rock formation. Later granite intruded the basement rock during Mesozoic era throughout the peninsula. The southeastern part of the peninsula is covered with Mesozoic sedimentary rocks and Tertiary sediments. The bedrocks are mainly granite, granite gneiss and granitic gneiss, which cover almost two thirds of the area. Figure 4a shows the simplified geology of the southern half of the Korean peninsula. The river bed consists of deposits of sand overlying sedimentary rock formation.

Hydrological Characteristics

The climate of Korea is subject to the influence of the Asian monsoon. The period from October to April is generally classified as the dry season while May to September is the wet season. Figure 4b shows the distribution of annual precipitation of Korea from 1959 to 1988 (KOWARCO, 1996). Heavy rainfall is concentrated in July and typhoons usually land to the peninsula from late August to September. Figure 5 shows the average river discharge monitored at three different stations along the Nakdong River (SAGE) and provides an idea of the flow characteristics of Nakdong River in an average year. Waegwan Station is located upstream of the project site while Jindong Station and Samnang Station are located downstream.



(a)

(b)

Fig. 4 Geology and annual precipitation of South Korea (a) geology (b) annual precipitation

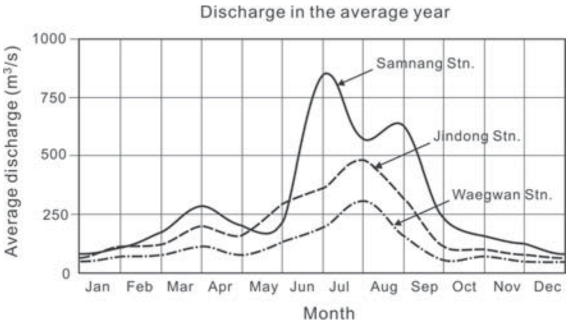


Fig. 5 Average river discharge monitored at three different stations along the Nakdong River (SAGE)

GEOTEXTILE TUBE

Geotextile tube is defined as "a large tube [greater than 7.5 feet (2.3 m) in circumference] fabricated from high strength, woven geotextile, in lengths greater than 20 linear feet (6.1 m)", according to GRI Test Method GT11: Standard Practice for "Installation of Geotextile Tubes used as Coastal and Riverine Structures".

Geotextile tubes used in coastal and riverine applications are most often filled hydraulically with slurry of sand and water. Geotextile tubes can also be filled using a mechanical/hydraulic combination filling method.

A geotextile tube is typically supplied with closure seams at both ends of the tube. Also associated are "fill ports" which are geotextile sleeves sewn into the top of the geotextile tube into which the pump discharge pipe is inserted (see Fig. 6).

After filling, the geotextile tube the port sleeves are closed and secured in a manner that prevents movement of the sleeve by wave action. Geotextile tubes may be used to replace rock as conventional building blocks in marine and hydraulic engineering dyke structures. The geotextile tube option is often more economical when compared with the use of rock and its application can also reduce construction time.

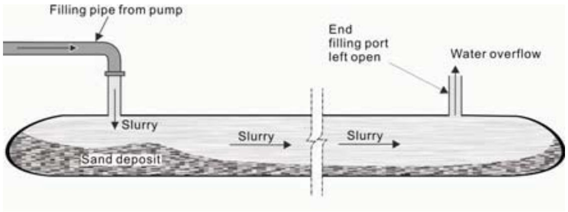
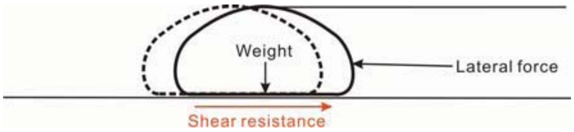


Fig. 6 Filling of geotextile tube (Yee et al. 2007)

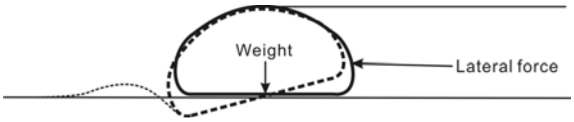
Design Methodology

From a technical standpoint the geotextile tube needs to fulfill the following (Yee, 2002):

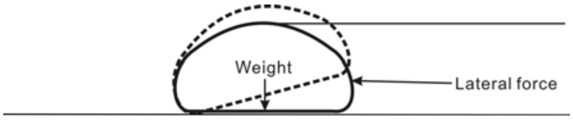
- Internal stability
    - The geotextile used to fabricate the tube, including seams and closure, need to withstand the stresses that may be encountered during placement and filling process
    - The geotextile tube should prevent excessive loss of fines but be sufficiently permeable to prevent excessive build up of pressures during installation
- External stability
    - The geotextile tube should be hydraulically stable against waves and currents
    - The geotextile tube should be geotechnically stable against sliding, bearing, overturning and global slip failures (see Fig. 7)
- Durability
    - The geotextile should endure and perform the engineering functions over the lifespan of the design



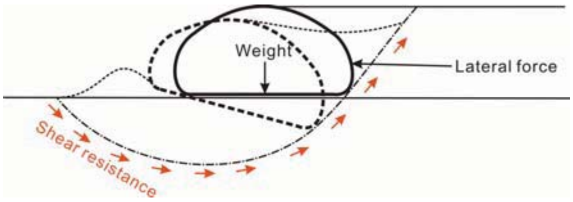
(a)



(b)



(c)



(d)

Fig. 7 Geotechnical stability checks (a) sliding (b) bearing capacity (c) overturning (d) global

The critical stressing period for a geotextile tube is during the pumping of slurry into the geotextile tube. The hydraulic pressure will put the geotextile tube in circumferential as well as longitudinal tension. Design software (GeoCoPS, SOFFTWIN) that will determine tensions and geometry of geotextile tube are available. Numerical analysis is based on the equilibrium of an encapsulating flexible shell filled with pressurized slurry.

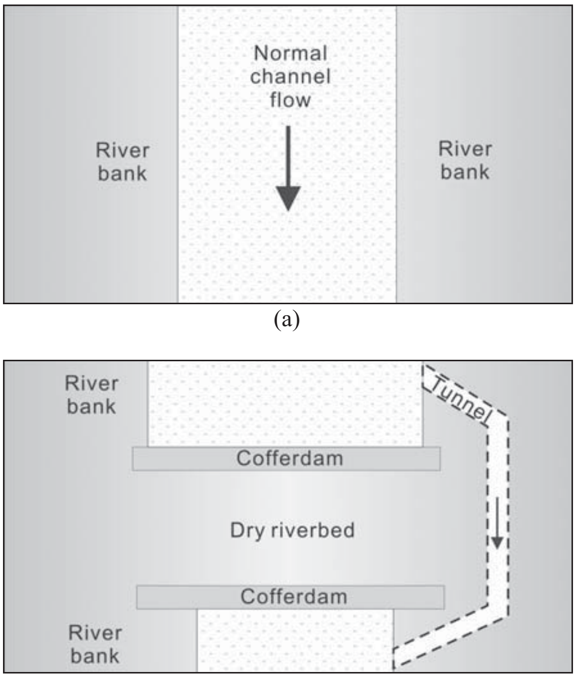
Conditions that influence the properties of the geotextile over time should be considered. The polymers used for the manufacturing of geotextiles today are generally durable in biological and chemical environment of commonly found soils. Ultra-violet light exposure can degenerate polymeric materials including geotextiles. This can be significant in Asia where a large part of the continent receives high radiation intensities throughout the year. The geotextile used to fabricate the geotextile tube should be stabilized through the addition of inhibitors during manufacture to enhance durability against ultra-violet degradation. Submerged portions of the geotextile tube attract relatively reduced radiation intensities and biological growths or other depositions on the tube surface will offer additional shielding from exposure. It is necessary to apply factor for creep, construction damage, environmental damage, seam efficiency, etc. to arrive at the required ultimate tensile strength of geotextile to be used for fabrication. Typically, a global factor of 4 to 5 is not unusual.

There are two fundamental geotextile properties that govern how it behaves hydraulically, namely AOS (apparent opening size) and permeability. The AOS of a geotextile is a measurement of its effective pore channel diameter. Since it is not possible to manufacture geotextiles with a uniform pore channel diameter the AOS is normally expressed as some percentage of the distribution of pore sizes. The permeability of a geotextile is a measurement of its capability to allow water to pass through and is expressed either as a Darcy's 'permeability' coefficient, by a 'permittivity' value or by a volume 'flow rate'. These two geotextile hydraulic requirements are determined by applying geotextile filtration design rules.

There are many filtration design rules available. Generally all the available design rules are conceptually similar; an effective filter needs to prevent the uncontrolled loss of fines over time while at the same time allow sufficient water to flow to prevent build up of excess pore water pressures. The two may be competing in the selection of an ideal geotextile filter as smaller AOS is more effective in preventing fines from passing through but larger AOS directionally means a more permeable geotextile that would be beneficial for preventing build up of excess pore water pressures. The design and selection of the geotextile filter is often a case of compromise, depending on which of the two properties may be more critical to a structure.

RIVER FLOW DIVERSION OPTIONS

The proposed concrete weir structure has to be constructed on a dewatered river bed. Figure 8a represents the normal flow of the river channel at the location of Dalsung Weir while Fig. 8b, 8c and 8d show the three proposed options of river channel flow diversion to create dry river bed condition for construction of the weir structure (KOWARCO and Hyundai, 2009).



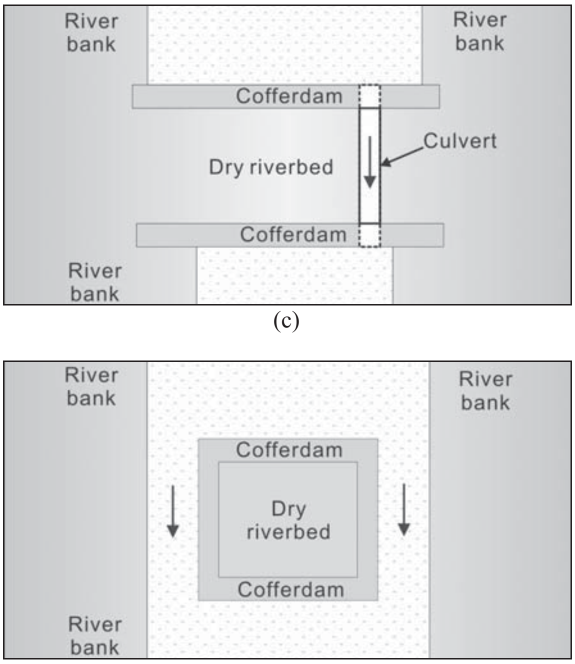


Fig. 8 Options for river flow diversion during construction of proposed Dalsung Weir (a) normal channel flow (b) tunnel flow diversion (c) culvert flow diversion, (d) constricted flow diversion

Option 1: River-Wide Cofferdams Upstream and Downstream with Temporary Tunnel Bypass Diversion

Option 1 involved the construction of temporary cofferdams across the entire width of the river upstream and downstream of the proposed weir and an associated temporary tunnel constructed for bypassing the river flow (see Fig. 8b). The big advantage of this option is that the entire width of river bed can be dewatered in one operation for unrestricted construction works. The disadvantage is the high cost of constructing the tunnel. Besides, as the bypass flow will be severely constricted the flow rate through the temporary tunnel will be fast and scour downstream of the outlet of the temporary tunnel will need to be addressed.

Option 2: River-Wide Cofferdams Upstream and Downstream With Temporary Culvert Diversion

Option 2 involved the construction of temporary cofferdams across the entire width of the river upstream and downstream of the proposed weir and an associated temporary culvert constructed for channeling the river flow within the dewatered river bed (see Fig. 8c). Although the cost of using a temporary culvert as bypass will be lower when compared to using a temporary tunnel, construction will need to be in phases with realignment of the temporary culvert.

Option 3: Phased Containment and Dewatering using Geotextile Tube Cofferdams

Option 3 involved the creation of dewatered river bed in phases while river flow is constricted (see Fig. 8d). This is done by constructing temporary cofferdams and dewatering within the confines of the cofferdams in phases. This option allows the widest flow channel possible thereby allowing the largest flow rate possible among the three options. Option 3 was also the most economical option among the three options.

GEOTEXTILE TUBE COFFERDAMS

The option of phased containment and dewatering using geotextile tube cofferdams was chosen for the construction of the proposed Dalsung Weir Project. The geotextile tube cofferdam solution was adopted because it was the most economical solution and it was easy to remove the temporary cofferdams when they have served the design functions. The geotextile tube specification is shown in Table 1.

Table 1 Geotextile tube specification for Dalsung Weir Project

Property	Test method	Unit	Value
Tensile strength (md)	ISO 10319	kN/m	≥200
Tensile strength (cd)	ISO 10319	kN/m	≥200
Elongation (md)	ISO 10319	%	≤15
Elongation (cd)	ISO 10319	%	≤15
Seam strength (cd)	ISO 10321	kN/m	≥160
CBR puncture	ISO 12236	kN	≥16
Drop cone	ISO 13433	mm	≤6
UV resistance	ASTM D4355	%	≥90
Pore size	ISO 12956	mm	≤0.45
Water permeability	ISO 11058	l/m^2/s	≥15

Construction Phases

Dry working platforms were created in three phases (KOWARCO and Hyundai, 2009); the first phase involved the middle section (see Fig. 9), the second phase involved the southwestern section (see Fig. 10) while the third phase involved the northeastern section (see Fig. 11).

During the first phase, construction of the middle section of the concrete weir included two height adjustable sections of the weir. During the second phase, flow can be guided through the two height adjustable weir sections that were completed during the first phase construction. Within the second phase the southwestern section would include construction of the mini-hydro power plant, a fish way to allow fish migration upstream or downstream across the weir structure, as well as the third height adjustable weir section. During the third phase, flow can be guided through the three completed weir sections of the first and second phases. During the third phase construction a wetland will be crafted adjacent to the northeastern bank of the river.

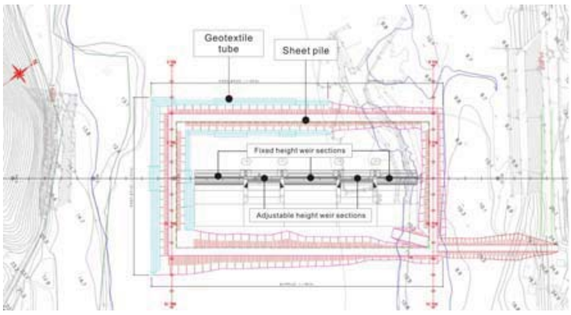


Fig. 9 Cofferdam for construction of middle portion of proposed Dalsung Weir

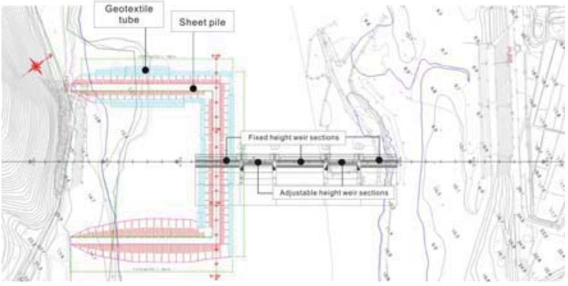


Fig. 10 Cofferdam for construction of southwestern portion of proposed Dalsung Weir

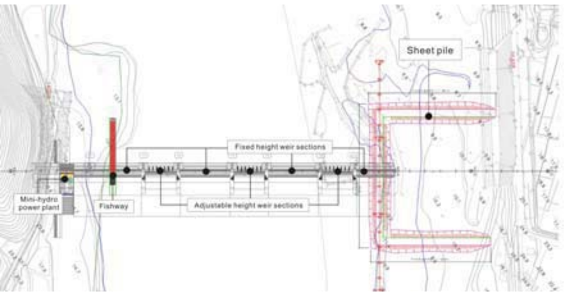


Fig. 11 Cofferdam for construction of northeastern portion of proposed Dalsung Weir

Design Flow Conditions

The planned cofferdams during the different phases will result in different temporary diversion flow conditions. For economical reasons, for each of the construction phases the geotextile tube is provided only up to the mean high flow level while the finished level of the cofferdam needs to be above the extreme high flow level expected. Analysis was done based on flows recorded at surveying stations upstream and downstream of the weir site. In the analysis, the design flow rates of 4,500 m^3/s for extreme high flow condition and 209 m^3/s for mean high flow condition were used (KOWARCO and Hyundai, 2009). The extreme high flow levels for cofferdam crest design for first, second and third phases were EL. 15.40 m, EL. 15.70 m and EL. 15.95 m respectively (KOWARCO and Hyundai, 2009). The design finish level for geotextile tube protection was above the mean high flow level at EL. 8.00 m for all three phases (KOWARCO and Hyundai, 2009). The maximum flow velocity for all scenarios was 0.84 m/s (KOWARCO and Hyundai, 2009).

Geotextile Tube Cofferdam Details

The layout of the geotextile tubes for the various phases of the cofferdam construction are shown in Fig. 9, Fig. 10 and Fig. 11. Geotextile tube protection is only provided for the upstream and along-stream sections of the cofferdams up to EL. 8.00 m. The downstream sections of the cofferdams are not in direct exposure to current flows as long as these sections are built last in sequence. The typical cross section of the geotextile tube cofferdam which included the use of a steel sheet pile driven through the cofferdam for effective seepage cut-off is shown in Fig. 12.

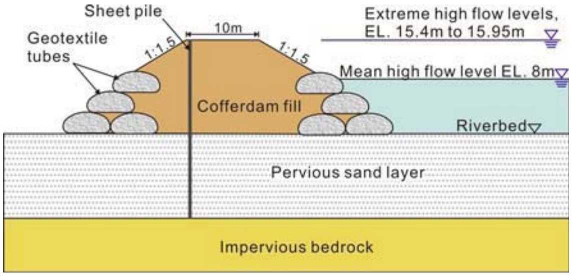


Fig. 12 Cofferdam for construction of northeast portion of proposed Dalsung Weir

Installation

The first geotextile tube was installed in December 2009. The geotextile tube was supplied fully factory fabricated and rolled on a steel pipe. Figure 13 shows the laying out of a geotextile tube at site. Figure 14 shows the geotextile tube being filled with a slurry mixture of sand and water.

Filling ports were spaced along the top of the geotextile tube at maximum spacing of 15 m. Filling began through the filling port of one end of the geotextile tube. The filling port of the other end of the geotextile tube was left open while the intermediate filling ports were closed.

This allowed the pressurised sand slurry to flow from one end of the geotextile tube to the other end. The solid particles gradually settled at the bottom inside the geotextile tube as the slurry pressure dropped. Some water was forced out of the geotextile tube through the fabric while the rest flowed within the tube from one end of the tube to the other to discharge out of the filling port that was left open.

This was continued until the geotextile tube was filled with sand to the desired height. To achieve a more even top elevation of filled geotextile tube, the filling point was moved to different filling ports during the final filling process. Once the desired height was achieved, the filling ports were all closed. The process was then repeated for the adjacent geotextile tube. The connection between adjacent geotextile tubes was by simple overlap of the ends that were partially filled.

Fig. 13 Laying of geotextile tube

Fig. 14 Pumping of geotextile tube

A total of 130 geotextile tubes with a circumference of 12.5 m and of lengths ranging from 30 to 75 m were supplied to the project. This amounted to a total of 6,570 m of geotextile tubes. The rate of filling of geotextile tube ranged between 10 to 15 m/hr. Figure 15 shows the overall view of the first phase geotextile tube cofferdam with a dewatered platform to allow construction of the composite weir and bridge structure. The geotextile tube cofferdams were completed by end 2010.

Fig. 15 Completed first phase geotextile tube cofferdam

CONCLUSIONS

The use of geotextile tube cofferdam to create dry working platform on the Nakdong River riverbed to facilitate the construction of the proposed Dalsung Weir, a composite weir and bridge structure, represents a pioneering application in Korea. The geotextile tube option was chosen over other cofferdam options and provided significant cost savings to the project.

REFERENCES

GRI Test Method GT11: Standard Practice for "Installation of Geotextile Tubes used as Coastal and Riverine Structures"

KOWARCO (1996). Appendix of long term plan for water resource (1997-2001), Report Korea Water Resource Co. (in Korean).

KOWARCO and Hyundai Construction Company (2009). Nakdong River Restoration Project 22nd Section, Temporary Dyke Evaluation Report (in Korean).

Park, Y.W. and Kim, S.K. (1999). The status and characteristics of landslides in Korea, Commemoration Publication Eleventh Asian Regional Conference on Soil Mechanics and Geotechnical Engineering, Seoul, Special Publication on Geotechnical Engineering Case Histories in Korea: 117-125.

SAGE. River Discharge Database, Website Center for Sustainability and the Global Environment, Gaylord Nelson Institute for Environmental Studies, University of Wisconsin-Madison.

Yee, T.W. (2002). Construction of underwater dykes using geotextile containment systems, Proceedings of the Seventh International Conference on Geosynthetics, Nice, France:3: 1161-1164.

Yee, T.W., Zengerink, E., and Choi, J.C. (2007). Geotextile tube application for Incheon Bridge Project, Proceedings of the CEDA Dredging Days 2007 Conference, Rotterdam, The Netherlands, CD Vol.

Yee, T.W. and Choi, J.C. (2008). Geotextile tube application for Ilsan Grand Bridge Project, Korea, Proc. of the First Pan American Geosynthetics Conference and Exhibition, Cancun, Mexico: 712-719.

Yee, T.W., Choi, J.C., and Zengerink, E. (2008). Revisiting the geotextile tubes at Incheon Bridge Project, Korea, Proc. of the Ninth International Conference on Geosynthetics, Guaruja,Brazil:3:1217-1.