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A Feasibility Study on the Han River Area as the Construction Site for the Kyung Bu Canal

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Abstracts

To facilitate the carriage of goods and products, an improvement of the transportation system is greatly needed in Korea. The construction of the Kyung Bu canal that can traverse over the wide area of southern Korea is proposed to be one of the most favorable choices to resolve this need. To fulfill this plan, we investigated the possibility of connecting the Han River (in the midwest) with the Nak-tong River (in the southeast) via the Cho-ryeong tunnel (20.5 km long and 125 m high).

According to topographic and geological mapping analysis, we are capable of selecting the optimal locations for the tunnels and locking systems. The water requirement for high locking systems can be satisfied by constructing additional dams above the Choong-ju area or by introducing water saving lock systems. The results of our investigation support the idea such a canal system, if constructed, could lead to a revolution of the Korea's transportation system.

Key words : Kyung Bu canal, transportation, Han River, Nak-tong River, locking systems

I. Introduction

Traffic congestion is thought to be a significant problem in most urban areas of Korea. Causes of such problems are generally explored from the fact that the dominant portions of public activity occur exclusively along the major inland areas. At present, two thirds of the population and three quarters of economic activity center on several inland lines of Korea. The main line connects the three major cities in the following order : Seoul (the first largest city), Taegu (the third largest city) and Pusan (the second largest city). This is the so called, 'Kyung Bu line' where 'Kyung' and 'Bu' stand for Seoul and Pusan, respectively. To promote industrial activity in Korea, inland transportation system needs to be improved through a build-up of linkage between the large cities and major harbors such as between Seoul and Pusan. Problems associated with heavy traffic loads are common phenomena in Korea. Although the expansion of the rail road system is proposed as an alternative, other

possibilities also need to be examined.

The transportation by inland canal is far more economical than rail or highway (e.g. Coyle et al.[1], Fair and Williams[2], 1981; Kneafsey[3], 1975). In particular, the expense (cost per ton) for a canal system is estimated to be about one fifth of traditional on-land means (e.g. Petersen[4]). Because of the many advantages of a canal system, the efficiency of whole transportation systems has increased remarkably in many countries. For example, the increases of 20 % in transportation efficiency has been experienced in such countries as Germay, France and Belgium, whereas the Netherlands showed approximately 80 % increase (Aberle[5]). The canal system of the Netherlands covers the dominant portion of carriage transportation (ECMT[6]). The city of Rotterdam, the largest harbor of the Netherlands, as well as the whole of Europe is planning to extend canal transportation capacity by up to 40 %(Rotterdam Municipal Port Managemaent[7]).

In addition to economic advantages, canal systems are also favorable for environmental conservation compared to other transportation means. Their use is known to be capable of reducing NO_x emissions to 1/19 of those produced by truck, and to 1/5 of HC emissions produced by railroad cars (US Department of Transportation, Maritime Administration[8]). The pollution of water and soil systems, and the noise problems from land-based transportation can be lessened. The possibility of human casualties caused by traffic accidents can also be reduced (Schoppmann[9]).

In light of the rapid expansion of industrial activity across East Asian countries, Korea is anticipated to play a significant role in boosting the trade activities over and across the region. To comply with such demand, the construction of a canal system is proposed to be one of the most promising options. Over the past several years, a number of studies have been undertaken to investigate the various aspects concerning canal construction. Results of those studies point out that the construction of the Kyung Bu canal be a realistic option which can link the Han River (on midwest) with the Nak-tong River (on the southeast) (e.g., Choo et al.[10]).

Since those previous studies mainly focused on the economic and/or engineering aspects of the canal system, relatively little is known about the feasibility for the selected sites, especially with respect to geological characteristics. In the past, geological information was often neglected in the construction of canals. However, it is known that such negligence caused serious aftermaths (e.g., the Panama Canal: Montgomery[11], Keller[12]). In view of the complex geological conditions developed along our proposed Kyung Bu canal line, we need to put deliberate evaluation of areal characteristics to reduce unnecessary steps toward its construction. In this work, we present results of our preliminary studies investigating the geological and geographical characteristics of the sites selected for a canal passing through the Han River area above Cho-ryeong tunnel.

II. Considerations of Hydraulics and Hydrology

The Han River, the widest among all rivers within the Republic of Korea, drains over a watershed area of 26,018 km^2 ranging from 3 6° 30′ to 38° 55′N and 128° 24′ to 129° 02′E. Its main channel with a total length of 482 km binds numerous streams formed by precipitation as a result of the geomorphic cycle. The average runoff coefficient for the Han River is approximately 0.55 which is much higher than

those rivers in the United States or in the European countries (KOWACO[13]). Because of high runoff coefficient, a large scale runoff occurrs frequently due to local torrential rainfall in the Han River area. The occurrences of flooding center between June through September, amounting to two thirds of annual precipitation in Korea. The river beds upstream, thus, tend to be exposed during the dry season. Consequently, the ratio between the maximum and minimum discharges of the rivers in Korea is generally found out to be significantly high relative to other rivers in the world (Table 1) : 22 for the Yangz River, 14 for the Rhine River, and only 4 for the Congo River. However, this ratio has been reduced greatly by the construction of the Choong-ju dam and reservoirs upstream (Table 2). High discharges during the flood season can now be relieved by enhanced the storaging capacity of the reservoir. On the other hand, low discharges during dry season can be compensated by the supply from the reservoir. In light of these systematic differences in discharge patterns, the construction of a dam and a reservoir in the Han River basin would seem to be essential for the provision of favorable conditions for canal navigation.

The aim of the Kyung Bu canal is to provide an efficient waterway navigable by cargo motor ships of up to 2,400 ton deadweight, with a dimension of 105 m (long), 11.4 m (wide), and 3.2 m (draught). This may be considered the standard type of container vessel in Europe (Rotterdam municipal port management[14]). The dimensions of the canal cross-section requires at least 50 m (width) and 5 m (depth) (Kubec et al.[15], Moosbrugger[16]).

Ⅲ. Site Characteristics of the Dams and Locks for the Construction

Fig. 1. depicts the proposed route of the Kyung Bu canal with locations of both existing and newly proposed dams. For the central portion of the proposed waterway (between the dam of Shin-gok and Choong-ju Balancing Reservoir (CBR)), the Korea Water Resources Corporation (KOWACO) has already conducted an evaluation for the feasibility of constructing an inland waterway (KOWACO[17]). This study concluded that the Han River, if developed to accomodate three locks at upstreams of the

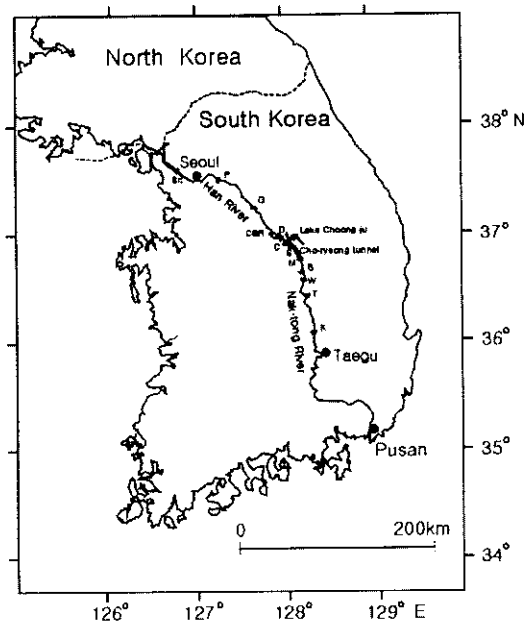

Fig. 1. A proposed route of the Kyung Bu canal with both pre-existing (solid rectangles) and newly proposed dams (white ones). Sh, Shin-gok dam ; P, Pal-dang dam; G, Gang-cheon dam ; CBR., Choong-ju Balancing Reservoir ; D, Dong-ryang dam ; C, Choong-ju dam ; S, Song-gye dam ; M, Mo-gok dam ; B, Bul-jung dam ; W, Woo-ji dam ; T, Twe-gang dam ; K, Ku-mi dam.

Pal-dang dam, would be advantageous in both transporting and supplying the materials for construction from its own riverbed. The first lock would be located 34.9 km from the Pal-dang dam and the height of lock would be maintained above 11 m. The second lock, 25.7 km apart from the first, would be 12m high. The third lock, 29.5 km apart from the second, should then be 16 m high.

However, since such a locking system would be expected to diminish the operational efficiency of a barge, it is reasonable to reduce the total number of locks (or dams) for a given canal. If one decides to maintain a limited number of locks in the whole canal system, it is essential to extend the heights of the locks. If locks are built with a chamber dimension of 118 m long and 14 m wide, they will facilitate the passage of the standard container vessel; one time lockage with a height of 25 m will consume a total water volume of 41,300 m³. The provision of side ponds adjacent to the lock can reduce the high water consumption rate caused by the build-up of a high lock system. Such attempts had been made previously in Bamberg on the RMD waterway (Chara[18]).

To secure the constant water supply during the dry season, many sections of the channel need to be excavated to a large extent. In case of the Panama canal, deep excavation failed because of the passage of the canal through geologically unstable layers (such as young volcanic rock, lava flows, and pyroclastic deposits, interbedding with shale and sandstone: Montgomery[11]). The Han River, however, mainly flows through the area of Precambrian rocks and granite that are geologically stable; thus, deep excavation is unlikely to be problematic for the area (Fig. 2).

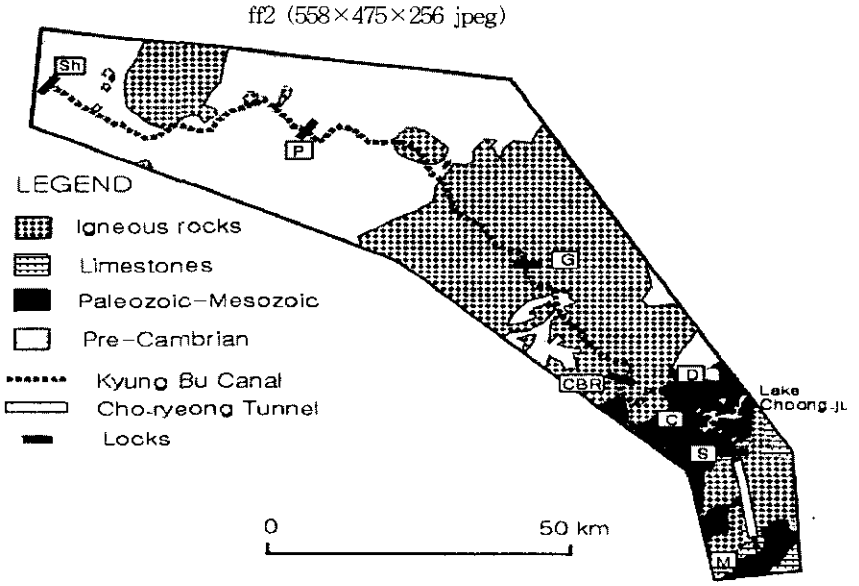

Fig. 2. A geological map of the Kyung Bu canal section between Shin-gok and Mo-gok dam. Shin-gok dam (Sh); Pal-dang dam (P); Gang- cheon dam (G); Choong-ju Balancing Reservoir (CBR); Dong-ryang dam (D); Choong-ju dam (C); Song-gye dam (S); Mo-gok dam (M).

The surface altitudes of the Pal-dang and Shin-gok dams(54 km long downstream) are 11 and 0.4 m, respectively. Because of this height difference, the operation of the barge is restricted during the dry season. To overcome this problem, the downstream portion of the Pal-dang dam has to be excavated to more than 9 m in depth. For a similar reason, the downstream portion of the Gang-cheon dam requires an excavation of almost 20 m in depth. This dam site was built in a valley 50 m in hight. The site consists of porphyritic granite known to be geologically suitable for dam construction. The width of the dam is 500 m, while the lifting height of the lock would have to be 23 m. The CBR dam is located 38.3 km apart from the Gang-cheon dam with the surface height of 48 m. The downstream portion of the CBR dam must be dredged so that the surface water is maintained at the height of 48 m.

A new dam, Dong-ryang, is scheduled to be built along the narrow valley, the wall of which should be higher than 150 m for both sides. This site is 16.7 km from the dam of the CBR. The dimension of the Dong-ryang dam are proposed to be 300 m wide and 50 m high.

The wall of the valley is made up of sedimentary rocks, including dolomitic limestone, which is very unfavorable for a dam site in a geological senses. To reduce water consumption, the Dong-ryang dam will accomodate two step locks, one for lifting from 65 to 90 m and the other from 90 to 115m.

A high lock system with a height of 26 m will be built with the Choong-ju dam to reach the altitude of 141 m ; this is the reservoir with the highest water level. A new dam, Song-gye must be built in the district of Song-gye, which is 15.5 km from the Choongju dam, across the lake. In order to maintain the variable water level between 125 and 141 m in Lake Choongju, the lock of the dam will be built to accomodate a vessel with a height of 125 m. About 1km south from the Song-gye dam, the Cho-ryeong tunnel begins and its characteristics are discussed below.

Ⅳ. The Cho-ryeong tunnel and a plan for water-supply to the Nak-tong River

The Cho-ryeong tunnel, with a length of 20.5 km horizontally connects Lake Choong-ju with the Cho-ryeong stream, which is a tributary to the Nak-tong River. The tunnel pierces Mt. Weo-lake (1,093 m), which divides the two major riverine systems in Korea, the Han and Nak-tong River. Another purpose of the tunnel is to act as a raceway from Lake Choong-ju to the Nak-tong River. Similarly to our tunnel construction plan, the United Kingdom has built a canal tunnel longer than 5 km (Tomlinson[19]), and Japan has a plan to construct canal tunnel 10 km in length (Choi[20]).

The surface geology above the Cho-ryeong tunnel consists of biotite granite (Cretaceous) with a minor portion consisting of Paleozoic sedimentary rocks, including limestone (Fig. 3). The limestone is part of the great limestone group deposited from the Cambrian through the Ordovician system. To prevent the drainage of water, the canal route of the limestone area can hence be treated with a sealing pavement. The south end of the tunnel is 800 m above the Bong-myeong bridge across the Cheo-ryeong stream. Below 1.8 km from the tunnel along the river, the construction of the Mo-gok dam has been proposed. The Mo-gok dam will be 200 m wide with a lock height of 25 m.

The essential source of water required to operate the locking system of the Mo-gok dam will come from the Lake Choong-ju. The

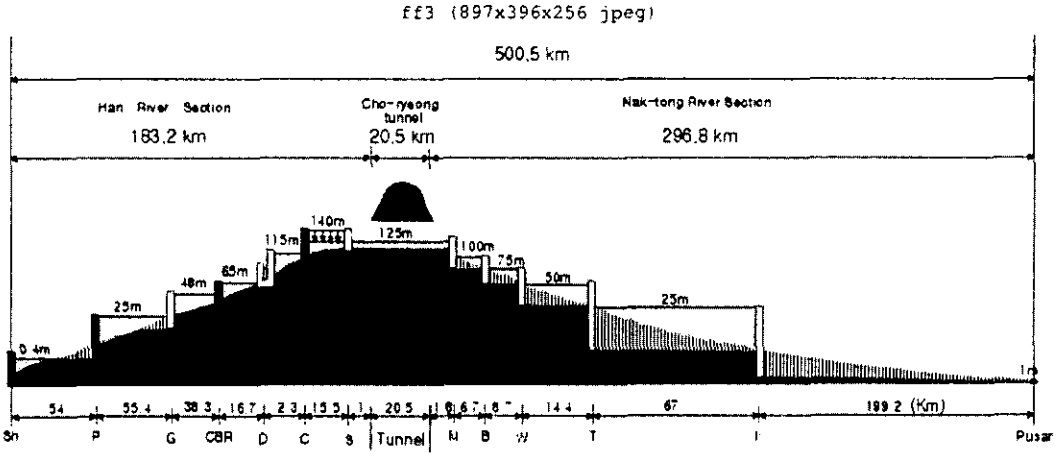

Fig. 3. Elevation plan for the Kyung Bu canal. The existing dams are denoted by a solid box and newly proposed dams by white ones, both of which are remarked by the same initials in Figs. 1 and 2. The dams (locks) in the Nak-tong River section are tentative ones. The lake above the Choong-ju dam has to have a controllable water level system from 141 m to 125 m. The hatched areas represent deep excavation.

watershed area of the Cho-ryeong stream above the Mo-gok dam is only 184 ㎢. If we consider annual rainfall amount of 1150 mm with a runoff coefficient of 0.55, less than 120 million ㎥ of water would be needed per year, on theoretical basis. Lake Choong-ju, on the other hand, has a basin width of 6,648 ㎢ and an outflow of 4,890 million ㎥. Above Lake Choong-ju, the construction of the Yeong-wol dam is designed to start. This dam, according to the estimates of the Korean government, will be capable of supplying a total of 490 million ㎥ of water to the Naktong River without interrupting the operation of the water power system at the Choong-ju dam (KOWACO[13]). A plan for additional dams has been made by the Korean government, and a list is provided in Table 3. These dams will operate not only as the major source of the water to the Nak-tong River but also as part of the Kyung Bu canal system.

V. Conclusion

We investigated the feasibility of building a canal in the Han River system of Korea. Although a previous study suggested the construction of three dams along the Han River section of the canal, we suggest that those three dams can be reduced to one (the Gang-cheon dam). Our alternative plan would not only save the passage time caused by locks, but would also reduce the submerged area by the dam reservoirs. However, the site selected above the CBR section is not feasible geologically because of the development of wide limstone area. In addition, the Nak-tong River section in Kyung Bu line is unfavorable as well, due to the development of thick, large alluvial sediment areas. The selection of dam sites was hence made to consider various aspects (Chung[21]).

The other main concern of our canal plan is

how to maintain the quality of water that could inevitably be affected by such factors as vessel navigation. For instance, the large reservoir of the Pal-dang dam is the main source of drinking water for the Seoul metropolitan and surrounding areas. Since the deterioration of water quality in the Pal-dang reservoir may produce undesirable effects, the Korean government is also considering to displace the main water source for the residents in and around Seoul from the Pal-dang reservoir to a upstream reservoir in another tributary, the North Han River (Choo, in press).

Acknowledgements

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