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DRAFT FOR TWO BRIDGES IN THE PEOPLE'S REPUBLIC OF KOREA

by Graduate Engineer Rolf Naeser

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DRAFT FOR TWO BRIDGES IN THE PEOPLE'S REPUBLIC OF KOREA

[Following is a translation of an article by Graduate Engineer Rolf Naeser, Hamhung, Korea, in the German-language periodical Bauplanung-Bautechnik (Construction Planning -- Construction Technology), Leipzig, Vol. X, No. 7, July 1956, pages 280-286.]

Early in 1955, the Council of Ministers of the German Democratic Republic decided to assist in the reconstruction of the provincial capital of Hamhung (Province of Ham-Gen-Nam-Do) by dispatching German engineers and skilled workers and by delivering machinery and construction materials.

The author of this article is a member of a delegation of German specialists who are playing a key role in the rebuilding of the city of Hamhung in the Korean People's Republic. The economic situation and the geographic location of Korea indicate certain designs and structures which are also of interest to our construction engineers in Germany. It was part of the job of this group of German specialists to prepare the drafts for two major bridges. These projects constitute the subject matter of this article.

Geographic Peculiarities

The Korean People's Republic extends from the 38th to the 43rd parallel. It thus lies in the transition zone from subtropical to moderate climate. The land is mostly mountainous; its elevation in the north, for instance, exceeds the 1,000-m line quite often. On the basis of these two above-mentioned factors, we have considerable deviations in temperature and precipitation, compared to those of Central Europe; these temperature and precipitation deviations are of great importance in construction work.

This fact is also expressed strongly in Hamhung. This city lies in the eastern part of the country, in the region of the North Korean coastline of the Sea of Japan. This strip is on the average 40 km wide and is separated from the interior of the country by mountain ranges. Most of the region, including the city of Hamhung, is traversed by consequent rivers. The rivers have valleys whose lower courses have been greatly widened through lateral erosion and have thus created alluvial deposits. Huge quantities of rubble are carried along from the upper courses, which consist of narrow V-valleys.

It is characteristic that the rivers consist only of upper and lower courses. There is no middle course as such. The rivers are relatively short and are not navigable.

The Sea of Japan coastline is that part of Korea which is most effectively closed off against the west and the northwest by high mountains. The climate accordingly differs from that of the rest of Korea. In Hamhung, we have the following temperatures, for instance.

	Elevation in m = 13	Mean Values	1955
January	Mean temperature	-6.0°	-5.0°
	Mean minimum temperature	-12.5°	--
	Absolute minimum temperature	-28.7°	-15.6°
August	Mean temperature	23.8°	23.8°
	Mean maximum temperature	28.0°	--
	Absolute maximum temperature	38.2°	42.0°

Precipitation is concentrated during the months of July and August, at which time a third of the entire annual precipitation falls during the rainy season (Figure 1). The rivers at that time rise extraordinarily within a few hours. Since the rainy season falls precisely during the main construction season of the summer months. we have a considerable loss of working time in bridge building here, especially when there is no work being done on the foundations. There is almost no precipitation during the winter. The water level is extremely low. There is no ice flow here.

As we said before, the city of Hamhung stands on very thick alluvial deposits. This is also why the building ground is poor throughout the city area. Even three-story buildings must be built on piles. In the area of the two bridges, we made thorough soil studies to which we shall come back later.

Economic Conditions

Every construction engineer who does not want to work exclusively with imported building materials must familiarize himself with the economic situation of the particular country. It was one of the special tasks of the German team to explore and use domestic construction materials as much as possible. The design therefore had to be adapted to the available construction materials. Sometimes it was even necessary to make compromises which are not customary in Europe.

Like German industry, after 1945, North Korean industry is today unable to supply sufficient quantities of cement, which is the principal construction material. But considerable quantities can be made available for engineering construction through the use of other binding agents, such as lime. It is natural that the cement is used as sparingly as possible. Reinforced concrete is made by the Korean

People's Republic itself. The delivery capacity is still limited at this time, but will increase constantly through the increase in production and the reconstruction of the industry. The quality corresponds to that of our Grade I reinforced concrete. Steel suitable for prestressed concrete is not yet available. This was one of the reasons why no prestressed concrete was used for the two drafts, though there was a great temptation to do so. This task will have to be solved by Korean engineers several years hence. Then the required skilled labor will also be available.

Until now, Korean construction hardly ever used natural stone. Some of the very good rock types were used merely as broken material.

Korea still has considerably more building lumber than we in the German Democratic Republic, for instance. But the forests have suffered greatly during the war and the ruthless tree cutting of the Japanese. It therefore had to be one of our most important tasks to show the Korean engineers how to develop good constructions with little lumber. Only in this way can a lumber shortage be avoided in the near future.

Particular bottlenecks are bitumen and tar paper. These two items are available only in very small, imported quantities. We therefore could not insulate the bridges, as we are accustomed to doing in the German Democratic Republic.

Traffic

The country's road traffic mirrors its development. The means of transportation in Korea are the age-old oxcart and the modern truck and bus (Figure 2). The percentage of animal-drawn traffic (mostly teams of oxen) is still quite high at this moment -- about 50% -- but it is being slowly displaced by the constantly increasing number of motor vehicles. The average speed of the motorized vehicles is at this time slower than in Germany due to the damaged roads.

In addition to the vehicles, the number of pedestrians is still very high. These people must run across the bridges in the traffic lanes of the vehicles, since the Japanese, in their construction projects, did not allow for any sidewalks on bridges. Though the existing bridges are very narrow (7.5 m at a length of 500 m), and though they can hardly handle all the traffic during market periods, traffic accidents are very rare. This is due primarily to the great care and consideration of the drivers.

Construction Materials

We referred to the supply of construction materials in our discussion of the economic situation above.

Let us look at the use of these construction materials hitherto in this light. The former vast forests supplied enough lumber. Old wooden bridges however are no longer standing. Lumber was not replaced with steel concrete until after 1900. Many wooden bridges were ripped away each year by the sudden floods during the rainy season. The currently permissible bending stress is 100 kg/sq cm, as in Germany. Reductions in this ratio for fresh lumber and lumber used in structural parts exposed to humidity and or moisture are made only in part.

It is still very difficult to produce good concrete. Since the Japanese for almost 50 years used only their own skilled labor from Japan in a deliberate attempt to deprive the Koreans of specialized knowledge and skills, we have especially a shortage of skilled workers now.

The process of making up aggregate for concrete according to the screen line method was not known. The solidity of the concrete was to be attained through a very high cement admixture. That is why the Koreans were now all the more enthusiastic about in learning from us. In addition to skilled laborers, there was above all a shortage of good mixers. The cement available for bridge construction comes very close to our Z 225 cement, qualitywise. Aggregate is available in good quality and sufficient quantity near the city of Hamhung in the form of river gravel and broken material. The screen line of the river gravel however must in most cases be further improved, since there are no middle grain size groups as a result of the structure of the rivers. The permissible stress -- taken over from the Japanese -- is very modest. This stress takes into consideration the great uncertainty and unreliability in the production of concrete. In the case of road bridges, we have σ_b = 50 kg/sq cm for plates and beams; for railroad bridges we have σ_b = 45 kg/sq cm.

The German standards were used for the drafts at hand. We figured on the basis of the permissible stresses in these standards. The required concrete grades B 225, respectively, B 300 can be attained.

The use of steel in construction so far differed only in the somewhat lower permissible stress of σ_e = 1,200 kg/sq cm.

1. Hamhung Bridge across the Ho-rion-tson

Existing Situation

The road from the provincial capital of Hamhung to the coast and on to the north of the country crosses the Ho-rion-tson right behind the city. Though this river is very short (40 km), it is 300 m wide between the dams in the area of the city. The river profile is filled for the entire width only during the rainy season. The middle channel is only 35 m wide and shifts every year.

The old bridge crossed the river at a right angle. Since the highway axis approaches the Ho-rion-tson at an acute angle, the bridge was tied in with two small bends. This solution, which used to be customary in Germany in the past, was used by the Japanese in all cases. The author did not find one highway bridge in North Korea which cuts across the river diagonally.

The structure consisted of a steel concrete plate on I-beams with 10-m spans. The piers were made in the form of steel concrete frames. The inside roadway width between the massive railings was 7 m. There were no sidewalks or catwalks. This system can be found in many steel concrete bridges; it was apparently a sort of standard solution. In the overall appearance, it is especially the pier frames which made a bad impression. They create a sort of unruly picture.

All steel concrete bridges were executed without insulation - a fact which seems rather unusual for European bridge builders (Figure 3). The average thickness of the plate is 25 cm. The lateral gradient on either side was achieved through a special concrete slab topping. The bridges were built between 1920 and 1935. The concrete is entirely compact, though traffic has been moving on these plates for 20-35 years. In no case were we able to find wet spots or blisters on the undersides of the plates, not even after the rainy season. We examined a total of 4,000 sq m of plates for density. On the basis of these long years of experience, one must conclude that the roadway plates remain compact and dense even in case of dynamic load or stress when good concrete is used. We in the German Democratic Republic should also pay more attention to the use production of directly-travelled roadway plates in case of sectional bridges.

Figure 4 shows, on the right, the dynamited Hamhung Bridge and, on the left, the piers of the railroad bridge. The Americans blew up the old structure. To maintain traffic, an auxiliary bridge was built. It is about one meter lower than the destroyed structure and is connected to the existing roads by means of short, steep ramps. This is a bad traffic bottleneck.

Location of the New Bridge

The new bridge was so chosen as to meet the traffic requirements for a neat, direct line. Accordingly, the bridge crosses the river at an angle of 75°45'. The basic speed used as construction criterion was 60 km/hr.

City planning calls for the road from Hamhung to the Ho-rion-tso to run along its current line. The bridge thus had to be started on the cityward bank, approximately on the old abutment. This solution also had the advantage that the current ramp could be used during the first construction phase. For the final structure, a new ramp with a radius of 250 m is planned.

Figure 5 shows the situation plan of the Hamhung bridge across the Ho-rion-tson River.

It was intentionally avoided to have the bridge cross the river at an even more oblique angle, since in that case the new piers would partly have had to be based on the foundations of the destroyed railroad bridge. This line would have been theoretically possible, since the railroad bridge was likewise blasted and is not to be rebuilt in this same spot. The partial use of the railroad embankment is likewise not advisable. The necessary widening of this embankment would easily cause unevenness in the road surface. The new ramp connects the landward abutment, having a radius of 237.5 m, with the existing road.

The height of the structure's bottom edge was given by the requirement for a safety interval of 30 cm along the abutments above maximum high-water level. But it was very difficult to get even halfway safe values for the maximum high-water level. The Japanese, who took water level readings from time to time until 1945, destroyed all data prior to their withdrawal. Since then, the water level at Hamhung has not been recorded. It was not until 1 January 1955 that the Meteorological Bureau of the city of Hamhung began regular water level measurements. The questioning of the larger number of older inhabitants at first led to no useful results, but in the course of time we did pin down a mean maximum value. Numerical data were available for the catastrophic flood of 1954. This value was 11.30 m above normal level; this was still a little higher than the other values and was therefore used as basis. The structure's bottom edge at the abutments therefore is 11.60 m.

The two ramps have a gradient of 2%. In between, we have the bridge with 7,650 m [sic] arch rounding. As a result, the bottom edge in the middle of the bridge is 13.13 m, i.e., 1.83 m above maximum high-water level. This dimension offers adequate safety for drifting objects which are often swept along during floods.

Traffic Widths

The bridge is located on a main highway which is heavily travelled even now. It must be expected that this traffic will increase much more, since the bridge will have to take, first of all, the traffic from the new industrial areas and the freight yards south of the Ho-rion-tson to the city, and, second, since it connects the port and industrial city of Hungnam with the provincial capital. We therefore made plans for four driving and one standing lane with a roadway width of 14.5 m. On both sides, we then have bicycle paths of 1.5 m width, each, and sidewalks of 2.1 m width, each. A trolley bus line is to run across the bridge later.

Static System and Cross Sections

To examine the subsoil for the selection of the static system and the foundations, we made 10 drill holes along the new bridge axis. The average drilling depth was 14 m below the surface. Both the choice of the drilling sites and the evaluation of the drilling samples were made by subsoil specialists. Here are their findings.

The subsoil consists mostly of fine and medium sands, layered in medium density. They contain silty-organic admixtures. In between, we have several thick silt layers; they are 0.1 to 1.8 m thick. The silt has a soft, plastic consistency and is therefore highly compressible. The silt layers are 3 m, respectively, 7-8 m below the surface. Further silt layers, which are thin, were found at greater depth.

In the middle channel bed, the upper layers, up to the height of the river bottom, consist of fine and medium sands; on the left foreland, however, an organically impure layer of brown silt was found with a thickness of 4-5 m.

In view of these findings, it was recommended that a statically determined system be used; a beam on two support pillars was best suited as the simplest structural form. Then we roughly calculated a series of bridge cross sections. In doing this, we also investigated a sectional and a prefabricated bridge, since the requirement for lumber had to be kept as small as possible.

The table below will show us the approximate material quantities required for each system (including piers and foundations).

	Plate bridge	Plate and beam bridge	Sectional bridge	Prefabricated bridge
Steel	0.170 t/sq m	0.140 t/sq m	0.240 t/sq m	0.160 t/sq m
Cement	0.590 t/sq m	0.410 t/sq m	0.274 t/sq m	0.600 t/sq m
Wood	0.515 cu m/sq m	0.535 cu m/sq m	0.053 cu m/sq m	0.110 cu m/sq m

We selected the cross section with the steel concrete prefabricated parts for this bridge.

1. The river cross section must be kept clear during the rainy season. If a falsework were to be used, there would always be danger of having it torn away by an extraordinarily strong current.

2. Considerable lumber quantities could be saved if we did not use a falsework [skeleton scaffold].

3. Construction is speeded up considerably, since the prefabricated beams can be inserted immediately after completion of the pillars.

4. Construction work can be continued in the winter, if a heatable shed (possibly steam heating) is erected for the production of the prefabricated parts.

5. Until now, the Korean engineers were not familiar with the method of using prefabricated parts; they could thus learn from this example for future projects.

The table above shows that the prefabricated bridge offers considerable advantages but that the most economical cross section in this case is found in the sectional bridge. For spans of 20-40 m (in case of 37 spans), this system is superior. But we could not use the idea of a sectional bridge for the Hamhung bridge, since the steel quantities required for profile steel and sheet steel could not be supplied.

The Superstructure

The bridge consists of 18 fields with 17 m pier interval, each; it thus has a total length of 306 m.

The superstructure is formed of prefabricated steel concrete parts, laid next to each other. They have a wide lower flange (which replaces the concrete form /sheathing/) and are combined into one full plate by means of spot [locally prepared] concrete. They are 1 m high and weigh 12 t. The prefabricated parts are positioned parallel to the bridge axis and have a span of 16.40 m. While the middle prefabricated parts have the cross section of an I-beam, special L-forms were used for the edge in order to create a pleasing appearance. The greater part of the steel reinforcements lies in the lower flange. Of these irons, however only the middle two, which lie in the area of the footpath could be bent upward. The other upward bends are covered by irons which are laid in the spot concrete between the prefabricated parts. The entire main reinforcement is 128 sq cm/m.

Figure 6 shows the cross section of the bridge.

The lateral steel reinforcement is inserted through openings in the girders after the emplacement of the prefabricated parts. This is done from both sides, each time up to the middle, before the edge [spandrel] beams are emplaced. The numerous recesses in the girders also increase the bond between the beams and the spot concrete.

Figure 7 explains the cross section of the prefabricated parts.

The footpath [sidewalk] protrudes 1.5 m and is made of spot concrete. The concrete form here is supported by three boards.

Traffic moves directly on the concrete roadway. The latter does not have any special insulation. As we said before, this manner of executing the driveway sprang from the shortage of insulation material and from the long experience with structures having thin roadway plates. An upper mat reinforcement is emplaced according to DIN/Germand Industrial Norm/ 1075.

The concrete surface of the bicycle paths is rippled and the sidewalks have a plate cover. For the telephone and high-voltage lines, we have three-strand cable form stones under the two bicycle paths. No pipes are used here.

At an interval of 34 dm, i.e., above every other pier, we have the poles for the trolley bus line and the street lighting, placed in prepared openings. The electric line for the illumination can be laid in a special cable pipe which runs along the poles.

The railing consists of rod steel. It does not have a knee or foot bar and the rods are spaced closely. This type of railing is not yet customary in Korea at this time. All solid bridges still have open steel concrete railings. These are very heavy and quickly reveal damage.

Hollow spaces to reduce the weight of the part were not placed in the plates in order to make the construction work as simple as possible, since few skilled laborers were available in the beginning. These skilled laborers can be used to advantage in the production and emplacement of the prefabricated parts. This high-quality work is concentrated in a small area and makes supervision easy; at the same time it also constitutes a quick way to train the Korean workers.

Foundation of Piers and Abutments

On the basis of the subsoil study, we considered two foundation types for the statically determined system.

1. Flat foundation with wide pedestals and 6-m long sheet pilings for erosion protection. The settling here will probably be about 2-4 cm.

2. Pile foundations with an average of 7-m long piles. Sheet pilings are required only in the middle channel to enclose the pits.

We selected the pile foundation. If we had used the flat foundation, the sheet pilings would have had to be made of steel concrete, which would have required additional quantities of cement and steel. In addition, it would have been necessary to drive through a silt layer in the area of the foreland. This would have required foundation depths of 5-6 m under the terrain surface. The decisive factor in favor of the choice of the pile foundation was however its economy.

Drainage of the Bridge

The surface water is drained from the bridge through down-pipes. The latter are emplaced along the curbstone into the driveway and conduct the water directly to the river bed. We did not want to insert special sand traps because these become easily clogged in case of poor maintenance. Sand traps and their maintenance are unknown in bridge construction in Korea. This also applies to steel bridges. The interval between the down-pipes is 8.5 m and their diameter is 7 cm. The sidewalk and bicycle path dip toward the driveway and are drained by the same down-pipes. The pipes are pushed through recesses in the lower flange of the prefabricated parts.

Architectural Design

The old bridge was a completely utilitarian structure, without any architectural features. This point can be observed not only in bridges, but in all Japanese-built stuctures, especially in buildings, where architectural features are certainly even more important. It was therefore important to emphasize the beauty of a clean design in this construction. The plate bridge offered a good opportunity for this. The railing is deliberately light and thin. In line with Korean mentality, the rigid rod railing was loosened up with ornaments. Rhythm is attained in the many openings by emphasizing every third light pole.

2. Manse Bridge across the Song-tson-gang

Existing Situation

The extension of the main thoroughfare of the municipality of Hamhung crosses the Song-tson-gang at the edge of the center of the city. At this point, the river is 500 m wide. The bridge runs along the line of the main highway Hamhung -- Pyongyang and thus is of considerable importance in long-distance transportation. In addition, it connects the sections of the city east of the river with the center. A large part of the agricultural drainage area is connected with the city via the Manse Bridge. The nearest bridge across the Song-tson-gang is 10 km downstream, shortly before the river flows into the Sea of Japan.

The old bridge likewise consists of a steel concrete plate on I-beams. The piers are frame constructions. The spans are 12.50 m wide. This solution makes an even worse effect in the middle of the city than in the case of the Hamhung bridge. This bridge likewise does not have any special insulation of the roadway plates. The bridge crosses the river at a right angle.

The structure was destroyed by artillery fire and three to four fields were destroyed each time. Altogether 60% of the bridge were destroyed. The gaps were filled with wooden structures, so that traffic can at this time again move across the bridge. The current bridge cross section is 7.5 m, which is by far too narrow, since the numerous pedestrians do not have any sidewalks.

Figure 8 shows the current condition of the Manse Bridge across the Song-tson-gang.

There is great danger during the rainy seasons, since the Song-tson-gang carries considerably more high water than the Ho-rion-tson. Only last year, during the heavy downpours, the improvised temporary bridges were torn away and driven against the temporary railroad bridge 500 m downstream. This bridge likewise had to give under the water pressure and was destroyed. Figure 9 shows the current old pile-frame structure of the old Manse Bridge.

The New Location of the Bridge

As we said before, the highway axis crosses the river at a right angle. The line thus need not be improved. The only thing is that our Korean friends at first thought that they ought to build a new bridge for vehicular traffic, right next to the existing structure, and that they ought then to repair the old bridge and use it as pedestrian bridge.

We had to reject that solution, since it was both architecturally and trafficwise impractical. Let us merely then consider the fact that if the Korean solution had been adopted, the pedestrians on the sidewalks on either side of the connecting roads would always have had to cross the roadway before they could get to the pedestrian bridge. The selection of the system for the new bridge was greatly influenced by the existing structure. Especially the span could not have been selected in an economic fashion. It was thus decided to build a new bridge for all traffic, next to the old one. In view of the connecting roads, only the downstream side came into consideration. The new bridge axis is 27 m away from the old bridge axis and runs parallel to it. The inside distance between the ledges is 12.50 m. This insures that traffic on the old bridge will not be disturbed during construction even when prefabricated parts are inserted.

The maximum high-water level of the Song-tson-gang is 13.20 m, i.e., an average of 1.10 m below the dike crest. Accordingly, the bottom edge of the structure along the abutment was placed at 13.40 m, so that, at a structural height of 90 cm, the upper edge of the road would be on the level of the dike crest, hence at 14.30 m. Like the Ho-rion-tson, the Song-tson-gang is not navigable. At mean water level, the water depth is only about 0.5 m. In the selection of the span width and height, we therefore did not haveto take into consideration any river traffic.

The ramp gradient on both sides was kept small in view of the location of the bridge in the city. It is 1.41%. The rounding radius of curvature is 17,650 m and covers the entire bridge. At the two center piers, the height of the bottom edge of the structure is thus 1.05 m above maximum average high-water level.

Special attention was devoted to the crossing of the narrow-gauge railroad line right behind the cityward abutment. At this time, the narrow-gauge railroad is about 1 m lower than the gradient at the bridge, so that the ramp climbs steeply. The distance from the abutment to the narrow-gauge railroad is 30 m. At first we thought of making an underpass under the narrow-gauge railroad in order to avoid a grade crossing. But this would have been very expensive, since the upper edge of the rails would have had to be placed under the high-water level of the river. Besides, the narrow-gauge line is to be moved out of the city in a few years. We therefore kept the grade crossing, but the gradient of the railroad had to be raised 50 cm up to the new highway ramp.

Traffic widths

According to the new city plan of Hamhung, the Manse Bridge in the future is to be used mainly for downtown and local traffic. For long-distance traffic, the long-range plans call for a second bridge, which would keep the heavy traffic from the center of the city. Normal widths will suffice for long-distance traffic in the near future. Four lanes of 3 m each, making a total width of 12 m were selected. The bicycle paths again are 1.5 m wide, each; the sidewalks are 3 m each ... [end of original text].

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