Akkar Bridge - the first all-concrete cable-stayed bridge in India

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The first all-concrete cable-stayed road bridge in India across the Great Rangeet River in the picturesque valley of Akkar near Nayabazar, Sikkim, is nearing completion. The bridge comprises of two 77-m long symmetrical spans, whose decking is supported by 17 pairs of cable-stays from a 55-m high central pylon. The most significant aspect of this bridge construction is the development of staycables indigenously and their fabrication to the requisite standards at job site, the latter being done probably for the first time in the world. The authors briefly describe the salient construction features of this bridge.

The bridge across the Great Rangeet River in the picturesque valley of Akkar near Nayabazar, Sikkim, provided the best opportunity for an all-concrete cable-stayed road bridge. A valley, 150-m wide and nearly 20-m deep, required a bridge

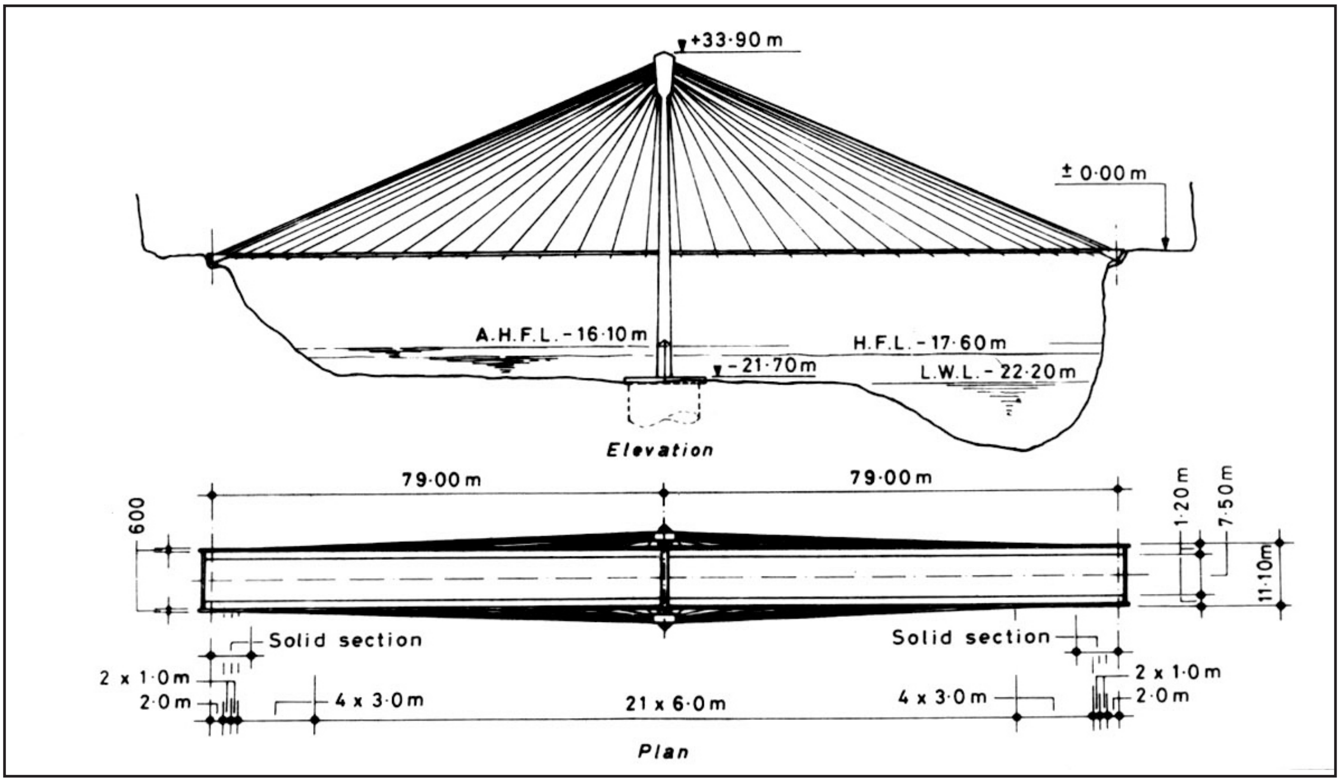

Figure 1. General arrangement of the Akkar Bridge which has two symmetrical spans of 77m each. The decking is supported by 17 pairs of stay-cables from a single pylon

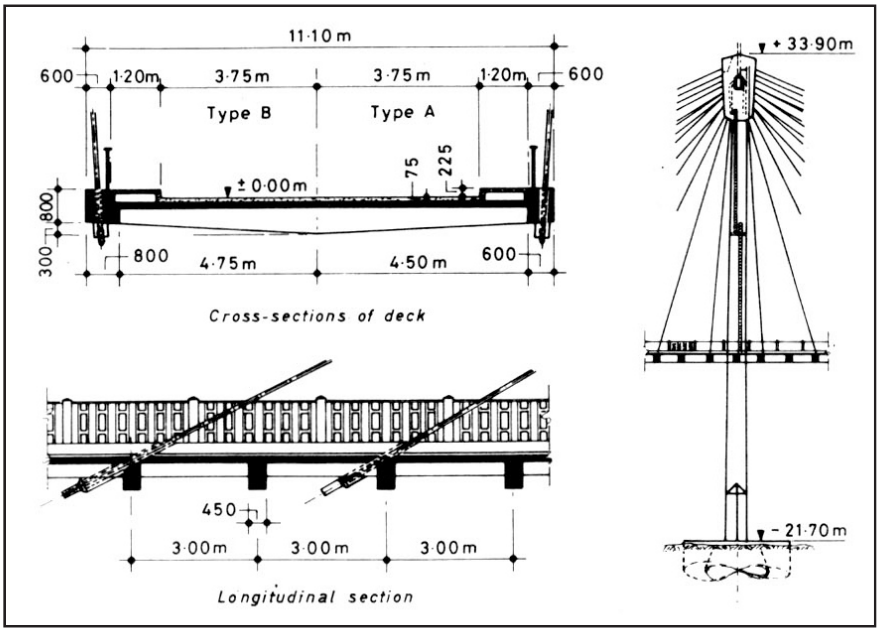

Figure 2. Sections of the decking and its part elevation with pylon

with a minimum number of foundations and a slender substructure to reduce the obstruction to an otherwise ferocious river currrent. The severe seismic zone of the location
also demanded a lightweight superstructure.

Proposal

The initial proposal for the bridge, which consisted of a double cantilevered deck with a single central pier, gave way to an all-concrete cable-stayed bridge, though being tried for the first time in India. The bridge presently nearing completion consists of two symmetrical spans of 77.0m each, supported from a single central pylon, Figure 1. The 55.0-m high pylon supports the decking at 21.0m above the bed by 17 pairs of stay-cables.

The superstructure deck, which provides for a 7.5-m clear roadway with two footpaths of 1.2m each on either side, consists of a 180-mm thick reinforced concrete slab supported from transverse cross beams spaced at 3.0m centres. They are integral with the main longitudinal girders of 600-mm width x 800-mm depth, which anchor the cable-stays. The variable depth transverse beams are 450-mm wide. The abutment end of the deck structure is thickened and is socketed into the abutments. Figure 2 shows sections of decking and part elevation of pylon.

The pylon consists of two numbers interconnected cellular columns of size 2.5m x 2.5m at base and reduced to 1.61 m x 1.61 m at the pylon head, Figure 3. The pylon head of variable width is 7.5-m high and houses 17 sets of cablestays in each direction arranged in a fan shape. The 1.0m x 1.6-m deep cross beam at pylon head helps in portal action for transverse forces and also stiffens the system to cater for torsional effects.

The trapezoidal-shaped pier, supported by the 12.0-m diameter single circular reinforced concrete well foundation, helps in smooth transfer of loads and forces from the pylon legs spaced 14.0m apart.

Foundations

The reinforced concrete well required sinking through bouldery strata which required heavy blasting, and hence had to be strengthened at the bottom with M.S. plate liners, Figure 3. With a view to aid sinking as also to stabilise the foundation

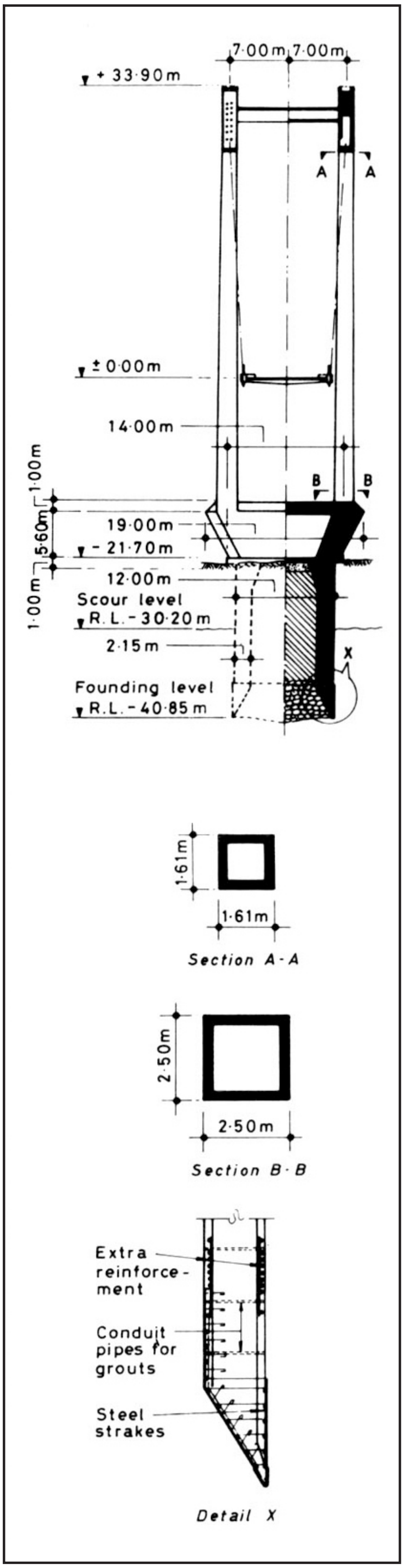

Figure 3. General arrangement of pylon and well foundation details

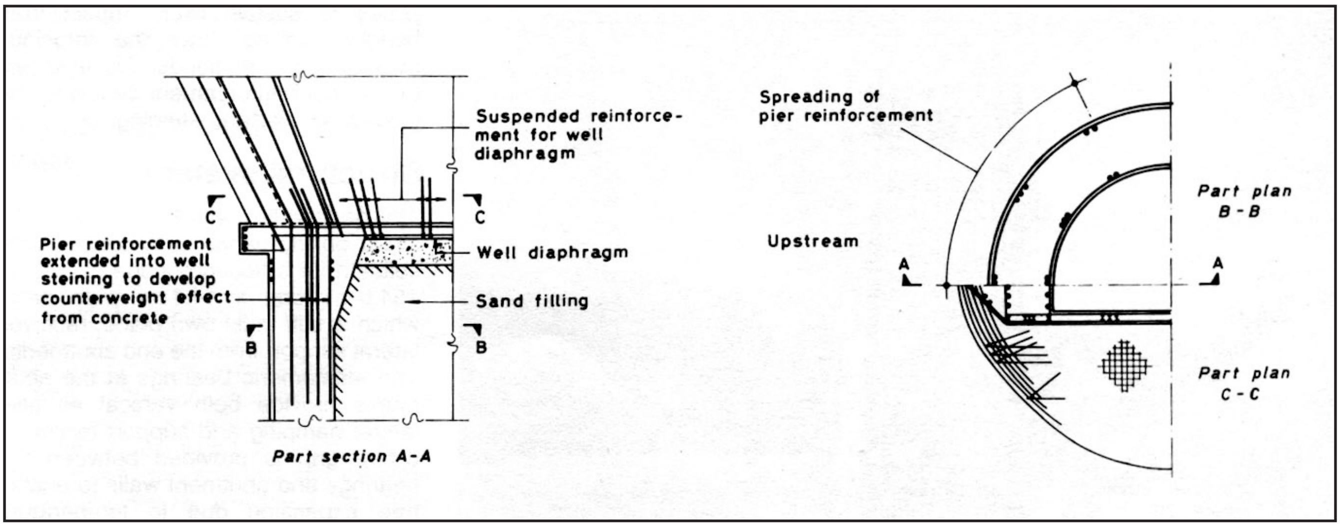

Figure 4. Typical reinforcement details at the junction of pier and steining

strata, holes were provided at the lower part of the steining, just above the curb.

These holes were used to jet water around the periphery of the well to reduce friction and improve sinking effort. The same holes were also used, following sinking and plugging of the well, to inject the cement grout around the well, so that an intimate contact between the well and the surrounding soil was established. In this manner, full passive support from the substrata below the scour level was realised. The importance of this stabilisation would be evident, if one examines what would happen if a small tilt of the well, under the action of longitudinal and transverse forces, occurs. In the absence of such support, the tilt would get maximised at the pylon head, with consequent loss of geometry of the deck system and the entire structure could become unsafe.

This would be specially important during construction, when the total load on the pylon and the deck would act as a free cantilever without any lateral and longitudinal support from

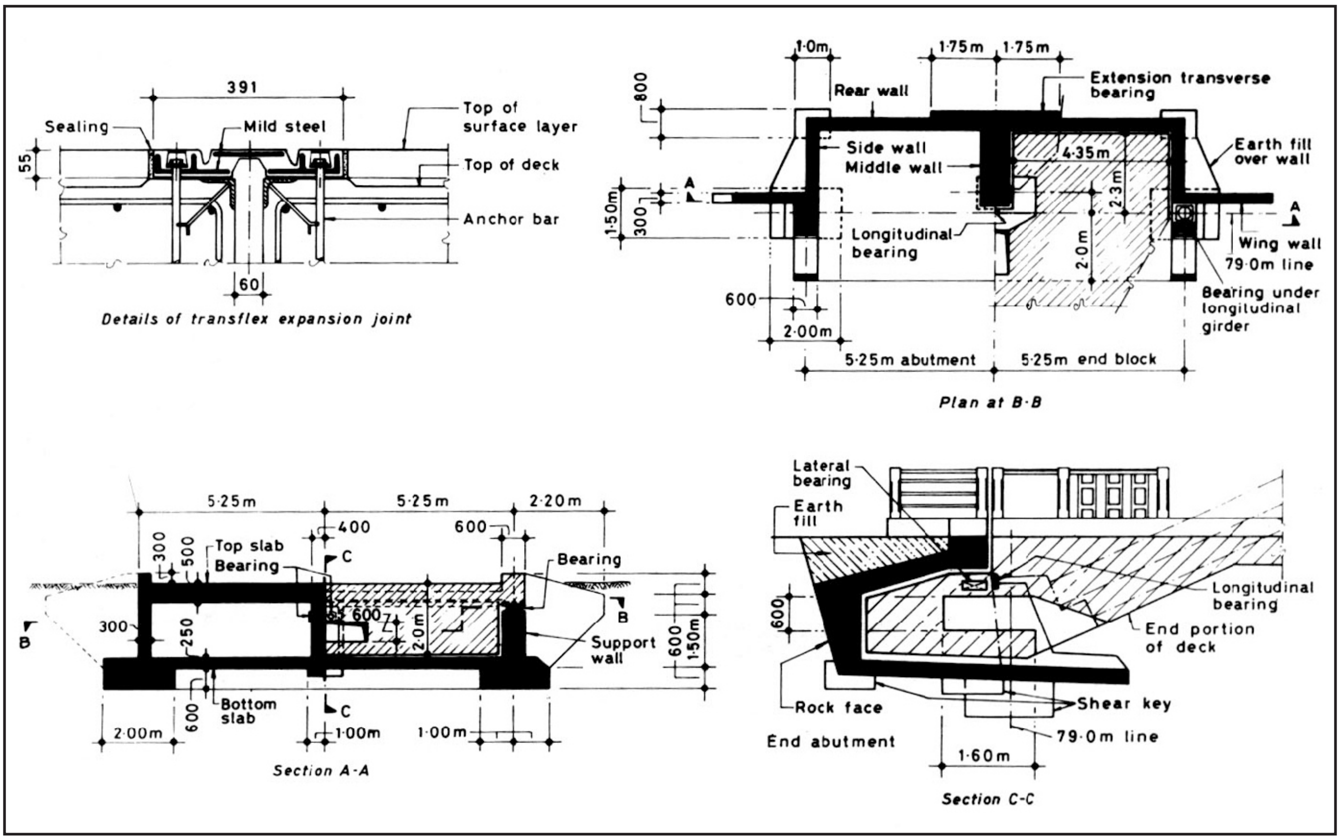

Figure 5. Details of expansion joint and abutment end block. The geometry of the abutment had been cleverty conceived to meet the force and load-transfer requirements

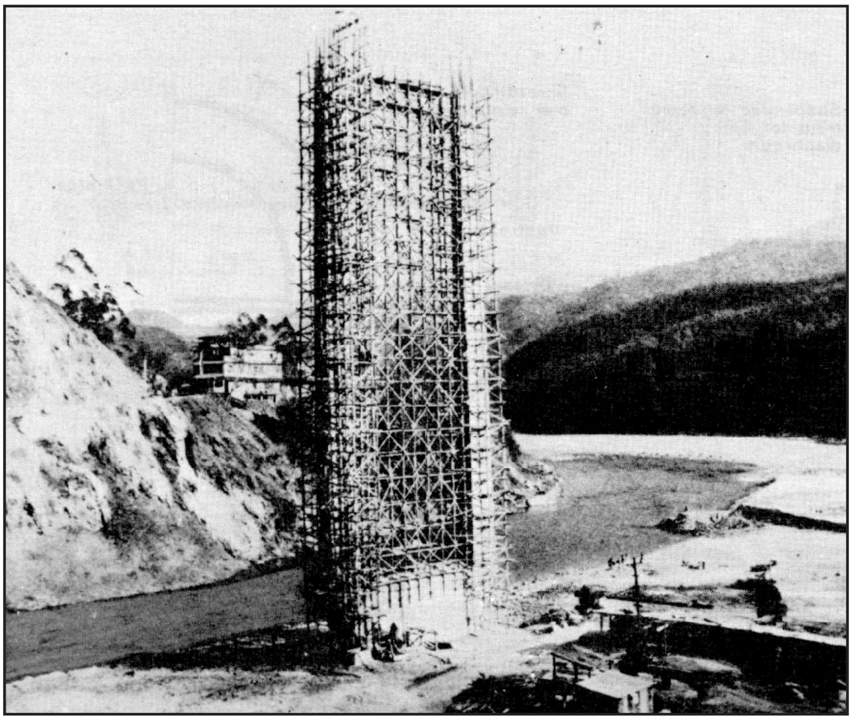

Figure 6. A view showing completed pier and pylon, with staging adopted for casting the pylon

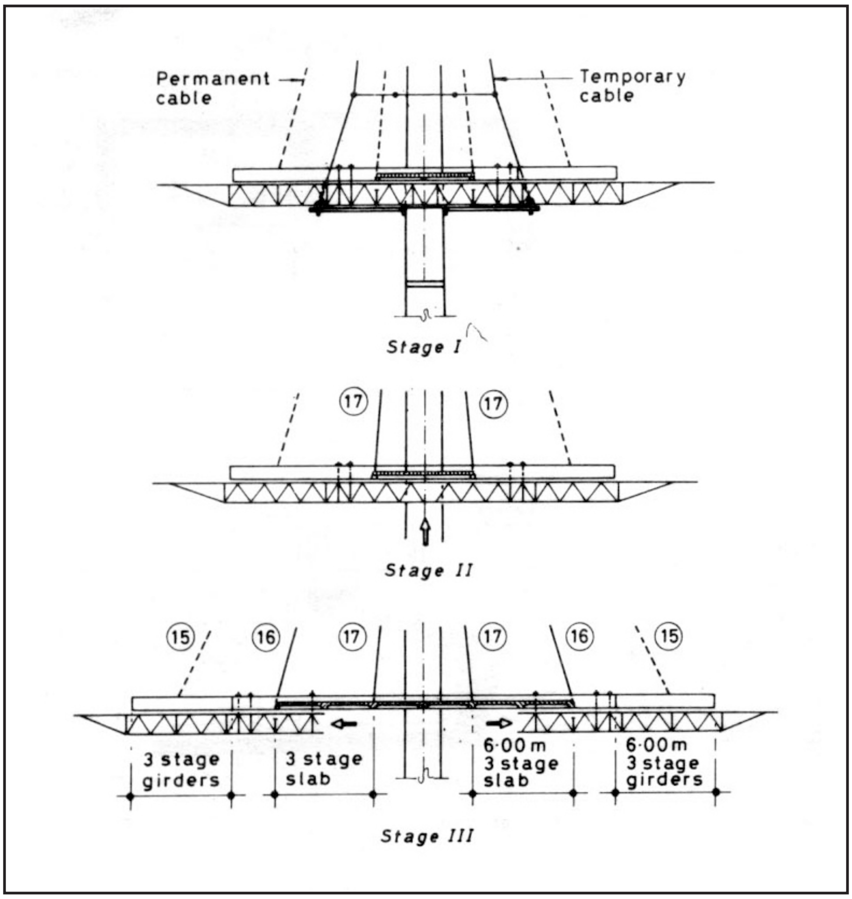

Figure 7. Sequence of deck construction. Stage I: casting decking on suspended gantries, Stage II: decking with gantry suspended from first set of stay-cables, Stage III: deck construction with gantries separated

the abutment. The proper plugging of the well was, therefore, a critical operational requirement from the standpoint of safety of the structure itself and demanded special attention.

The upstream faces of the pier and the well cap have been lined with M.S. plates to sustain likely impact from boulders rolling down the ferocious river during high floods. Figure 4 shows the typical reinforcement details at the junction of pier and steining.

Structural system

The deep valley with fairly good rocky strata on the banks, provided an ideal solution for a floating bridge deck. The 154.0-m long x 11.1-m wide deck, which is stiff in its own plane, receives lateral support from the end abutments. The elastomeric bearings at the abutments provide both vertical as also lateral damping and support facility. A 6-mm gap is provided between the bearings and abutment walls to enable free expansion due to temperature effects without sacrificing the primary requirement of absorbing braking forces, seismic and wind effects after initial small movements. Though major vertical loads are carried to the pylon by the stay-cables, a portion of unbalanced dead load and transient loads are transmitted to the end abutments.

Abutments

To meet the force transmission and absorption requirements as detailed above, the geometry of the abutment on either side had to be such that the forces in the cartesian direction are absorbed in the abutment block at the most appropriate level and transmitted to the back-up rock through it. Figure 5 shows the details of expansion joint and abutment end block.

The abutment projects shear keys into the rock and derives positional stability, especially against transverse forces. The deck forks into a projecting arm of the abutment extending from the back wall of the abutment along the longitudinal axis of the bridge. The root and flanks of the fork accommodate the longitudinal and lateral bearings for absorption of forces. In addition, the longitudinal girders are supported on an extension of the abutment side-wall along the axis of the girders, by another pair of elastomeric bearings, to take up the unsupported dead load and transient loads.

The abutments were cast directly against the excavated rock surface and this ensured that the force transfer to the rock was certain and effective.

The geometry of the abutment had to be cleverly and carefully conceived to meet the forces and load-transfer requirements, in a manner such that the deck and the abutments acted in unison for gradual dissipation of the effect of external forces on the deck structure.

Pylon and deck construction

The construction of pylon legs required utmost care to ensure its verticality and alignment. As the sun transits at an angle to the bridge axis, the problem is somewhat accentuated. The conventional staging system with leap-frogging of the shuttering was considered appropriate. Although a slower process compared to the slipforming technique presently advocated, it ensured precision monitoring and enabled the verticality of pylon head within ± 6mm tolerance against much higher permissible limits. This required measurement of alignment in the early hours of the morning, when the temperature variations are minimum. Figure 6 shows a view of the pylons under construction.

The deck construction needed casting of the concrete by the cantilever system. As the pylon acts as a slender, free-standing cantilevered column, load balancing is most important to ensure that the desired deck levels do not get vitiated by pylon deformation. It was, therefore, necessary to keep the erection stage loads to the minimum. With this aim in view, a lightweight gantry of weight not more than 25t was designed, which can take a limited amount of load, viz., 6.0-m long main girders and the two cross girders.

Figure 7 shows a sequence of deck construction. The concreting of the deck commenced from the centre of the pylon and proceeded symmetrically on either side towards the abutment. For this purpose, a gantry of length 16.5m was lifted to position and was supported by temporary cables from the pylon head. The first length of 11.3m of the longitudinal girder was cast on this gantry alongwith the related cross girders, Figure 8. The girder was thereafter supported by permanent cables. The gantry was further extended and the support to it

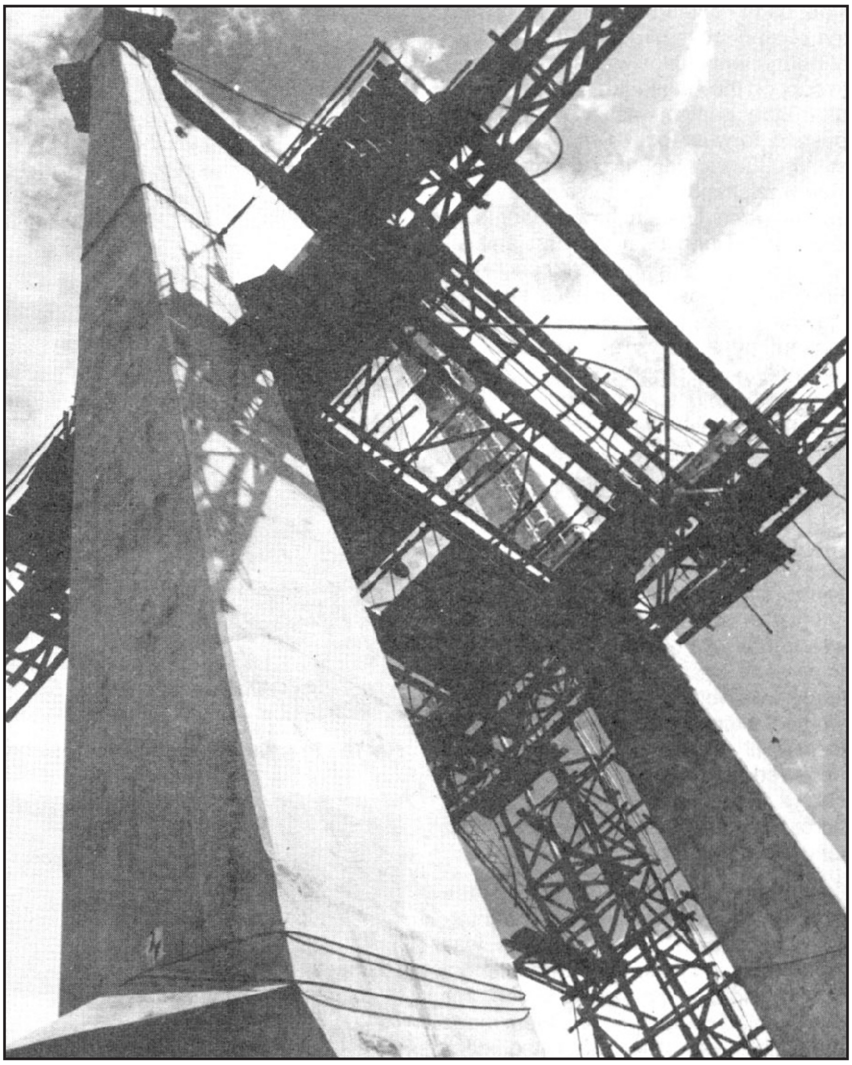

Figure 8. A view showing finished pylon and position of gantry for casting first unit

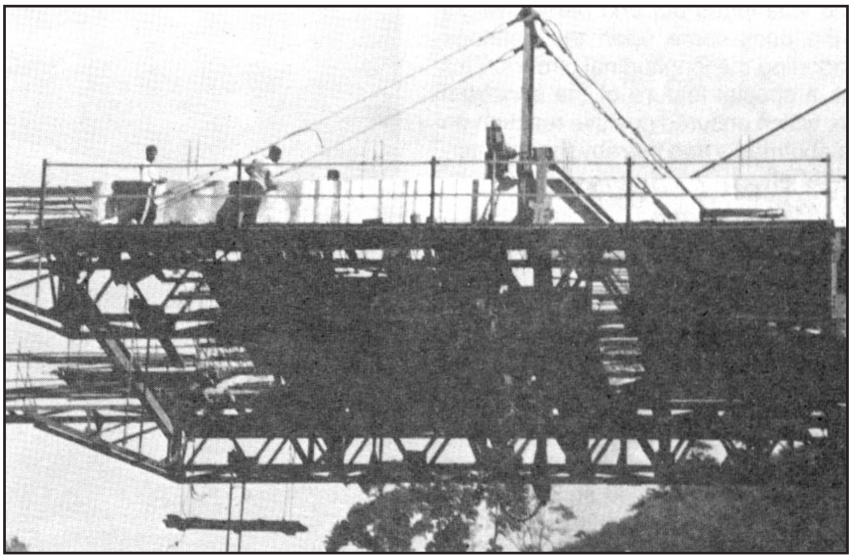

Figure 9. View showing gantry and a completed 6-m long longitudinal girder with side shutters stripped. Note the position of the cable-stay, in position on previous unit

was transferred from the temporary cable to the already-cast longitudinal girder by means of a system of rollers travelling on the girder. The gantry was so designed that stresssing of cables could take place from below the longitudinal girder, without interference.

The deck slab was then completed for a length of 3.0m on either side of the pylon. This was followed by the casting of 6.0-m additional length of longitudinal girders on either side, on the extended gantry, alongwith the related cross girders. The next pair of permanent cables was then stressed to support the longitudinal girder. Thereafter, the gantry was bifurcated and pushed forward by 6.0m to the next station. Further length of 6.0m of deck slab was cast on the previous bay and, at the same time, a further length of 6.0m of the longitudinal girders and related cross girders were also concreted. Following stressing of cables supporting the girder, the gantry was moved forward by a length of 6.0m and the operation was repeated. Figure 9 shows the gantry with a completed 6-m long longitudinal girder with side shutters stripped.

The casting of the deck slab was accomplished by laying precast slabs with projecting reinforcement supported on the cross girders. Together with the in - situ slab of 120-mm thickness cast integrally over these precast slabs, which measure 60mm in thickness, the total deck slab capacity for imposed loads was obtained. This arrangement worked excellently well with available local skill and a rapid progress was achieved with least efforts. Figure 10 shows a view of precast slabs placed across cross beams which connect longitudinal girders.

A length of decking of 5.1m at the end, thickened to provide counterweight and mass for force transfer, was cast on a sand layer over the abutment portion and over the staging beyond the abutment. The girder was then made monolithic with the concreted deck supported by cable-stays. Back-stay cables were introduced and a limited force was applied to these cables. The sand was jetted out and partial weight of the deck came upon the bearings supporting the longitudinal girders. This was a special feature of the construction, which ensured positive reaction on the abutments and thereby the counterweight effect.

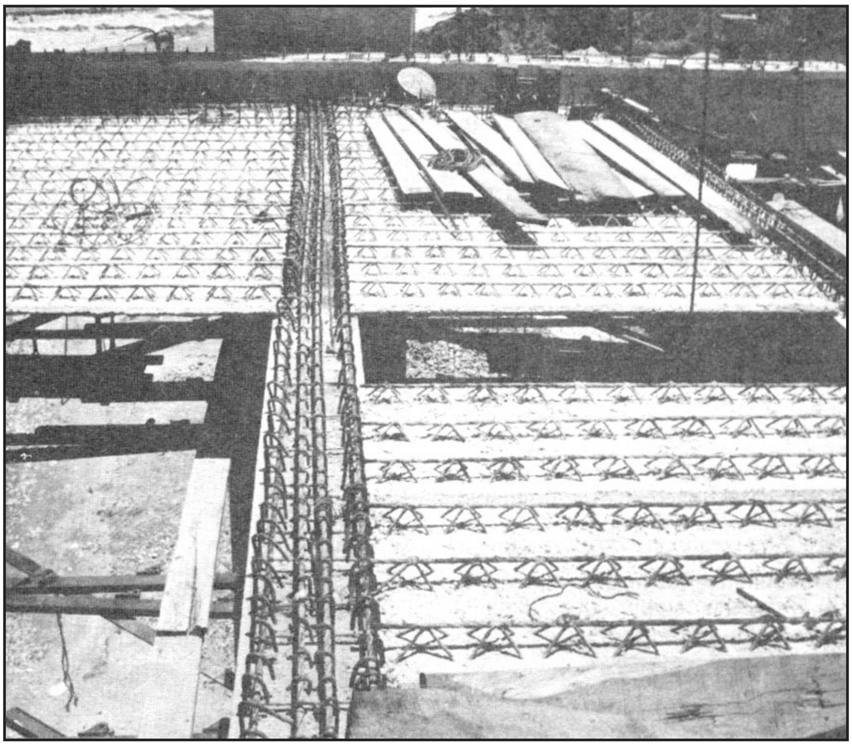

Figure 10. Precast slabs placed across beams connecting longitudinal girders

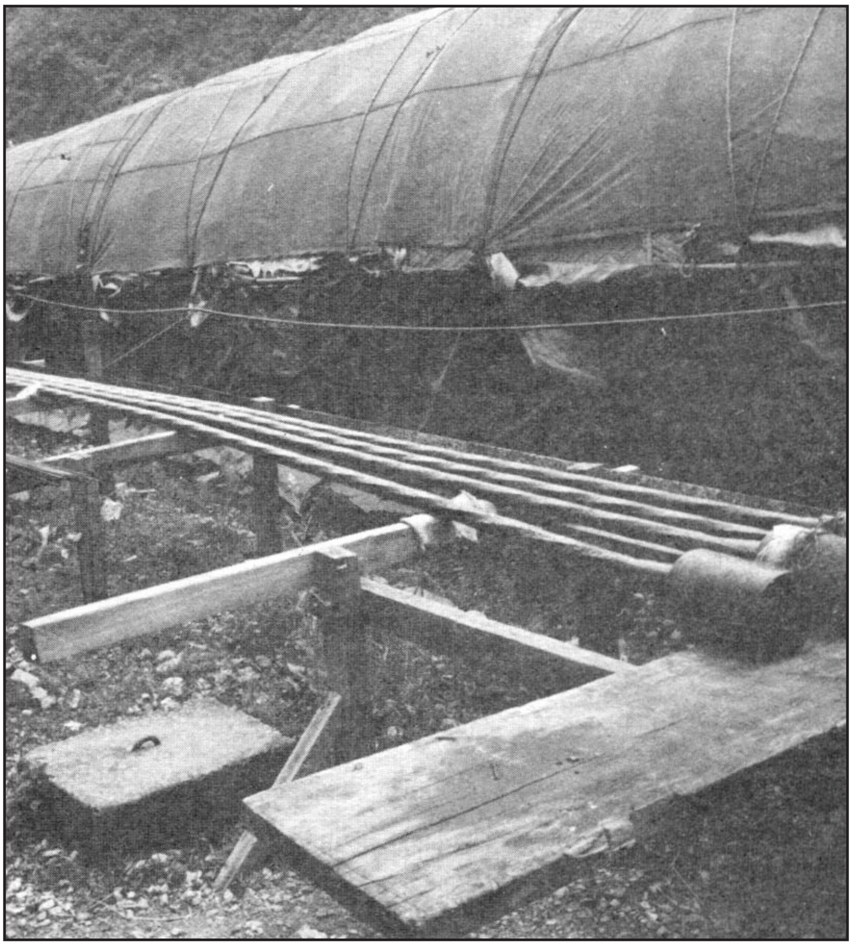

Figure 11. View of the shed alongside the river, used for fabricating the cables. Finished cables are also shown stacked outside

During the construction stage, all unbalanced vertical loads and lateral forces are resisted by the pylon. Hence, temporary steel brackets were provided between the pylon legs and the deck to prevent oscillation.

The deck has been provided with a precamber so that it progressively attains its designed profile, as a result of shortening due to creep and shrinkage and relaxation of stay-cables. Fourteen sets of cables are stressed from bottom of the deck and the last three sets of back-stay cables from the top to suit operational requirements. The deck profile is planned to avoid readjustment of the cable forces after the entire deck is built. The finer adjustments in the level of the deck were achieved by introduction of shims of varying thicknesses ranging from 1 mm to 25mm. The manufacture of shims in different thicknesses itself required parallelism and perfect matching of the contact surfaces; this is to avoid concentration of stresses in the shims and consequent misalignment of cables. The levelling measurements were always carried out in the early hours of the morning, taking care to ensure that the pylon was in true vertical alignment during the stressing and levelling operations. The location of the M.S. preturbes for the cables in the main girders demanded extreme care to achieve precision alignment in the cartesian coordinates.

Stay-cables and their development

The cost economics of cable-stayed bridges largely depends upon the availability of dependable cablestays, which have an acceptable level of corrosion protection, ease of manufacture, transport, erection and handling plus prerequisite physical characteristics. With this end in view, indigenous production of stay-cables was initiated in technical collaboration with our Consultants, Messrs Schlaich + Partners, West Germany. Large-scale testing for development of anchorages, which have high fatigue-resistant qualities coupled with corrosion-protection assurance, was undertaken. The efforts culminated in a lightweight cable of 37 Nos. of 7-mm diameter high tensile (H.T.) wires of 1600N/mm^2 ultimate tensile strength, and a modulus of 200,000N/mm^2; the ultimate strength of the cable is evaluated at 200 tonnes.

The cable so developed was manufactured in an 80m X 4m X 3-m high shed built at site, with all necessary precautions and quality-control. For this purpose, a wooden bench of workable height was erected, on which 37 Nos. of treated H.T. wires were laid in a series of prefixed metal clamps, Figure 11. The bundle was passed through specially-formulated polyurethene resin, before twisting to required lay-length.

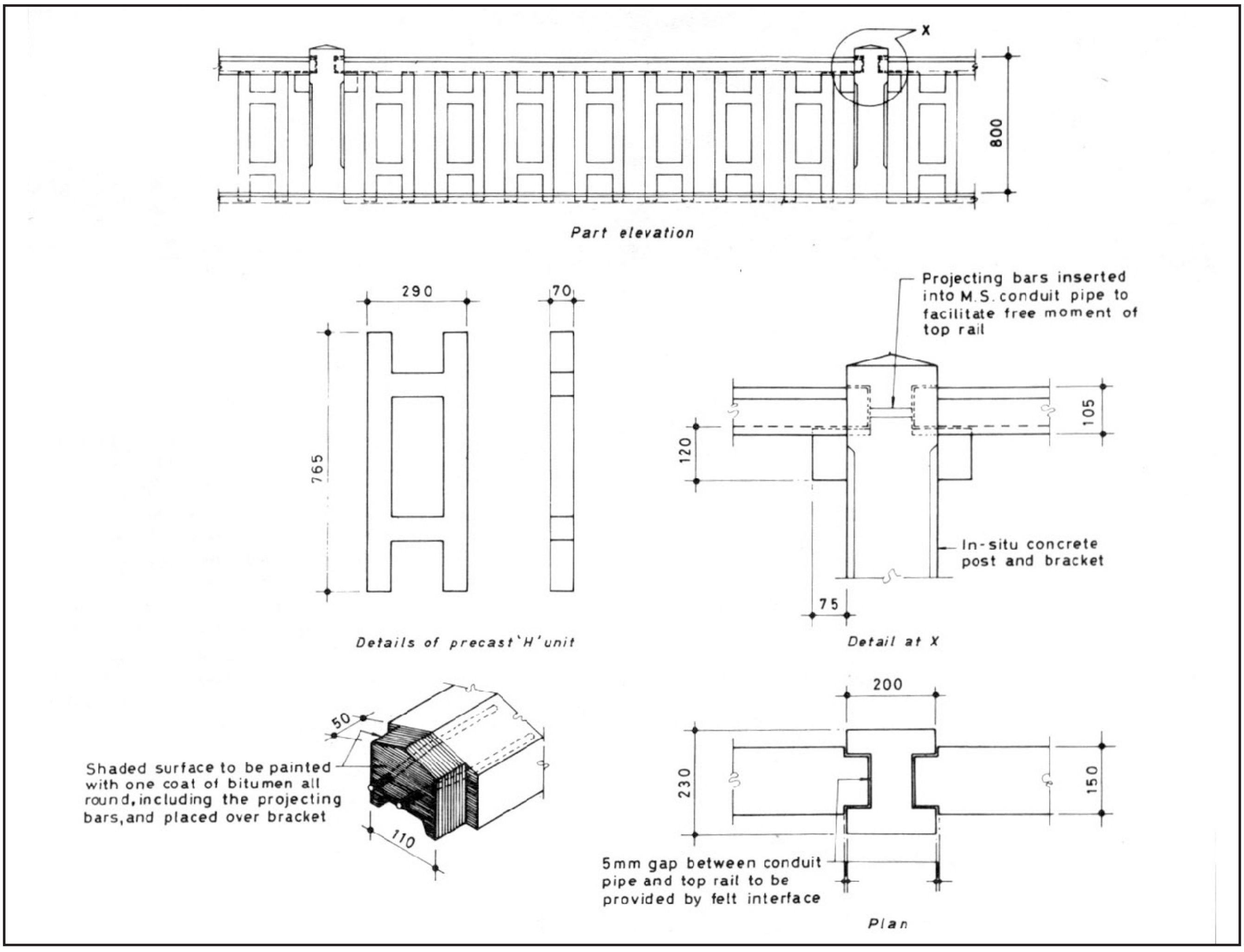

Figure 12. Typical details of handrails, which consist of in-situ concrete posts and precast vertical 'H'-type railing units

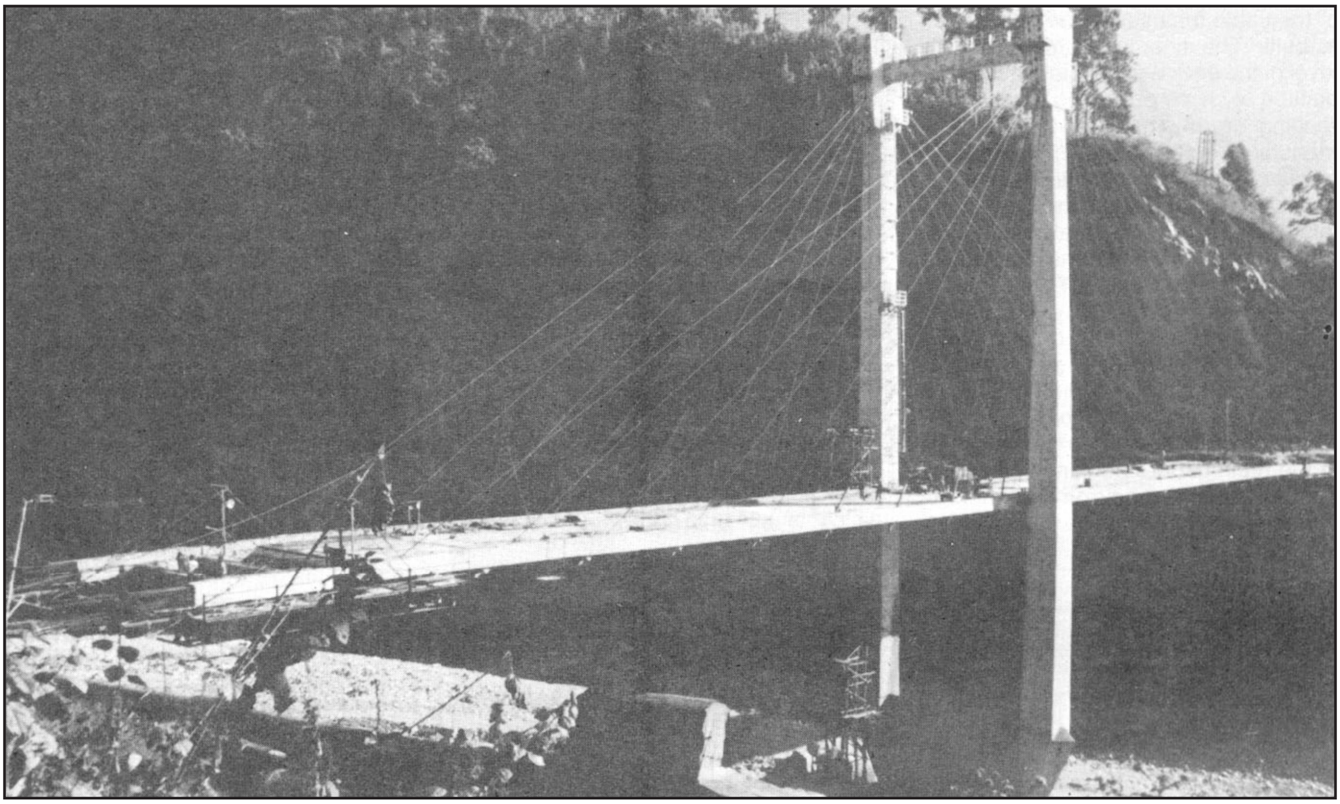

Figure 13. View of the bridge during the construction of the deck. In the foreground, the shed for making cables is seen. The ladder system with intermediate and top landing as well as arrangements to traverse from one pylon head to another over top beam of portal is evident

This procedure ensured proper, thorough and all round coating of resin, besides helping the ends of the cables to fan out into the metallic socket of the anchor. The socket was then filled with metallic alloy of tested quality. The anticorrosive treatment provided has a high abrasive property and exhibits good resistance. It also cuts out ultraviolet rays.

The cables do not require any other external protection or grouting around the covering. They are also readily observable for any distress or failure of coating due to external impact or other causes. The covering could be repaired with little effort, should any defect be noticed. With periodical inspection, the cable should give an excellent performance for years.

It could be said that this is perhaps the first time that cable-stays have ever been manufactured at job site. It has eliminated transportation of the cables, which could be quite expensive and problematic in countries like India.

The important outcome of this cable development is that the apparent modulus, related to the sag, could be evaluated more accurately under all loading conditions, unlike those protected externally by grout cover.

The flexibility and rationality in regard to the performance of these cables is expected to promote manysided applications of these cables, besides their use on cable-stayed bridges. The ease of inspection, repair and replacement are their principle merits.

Railing, wearing coat and expansion joint

A 75-mm thick lightly-reinforced concrete wearing coat is laid over a waterproofing membrane provided over the deck. The railing consists of in-situ concrete posts and precast vertical 'H'-type railing units, with movement capacity for the top rail in each panel at either end. The typical details of this solution are shown in Figure 12. The expansion joint at either end of the bridge is of 'Transflex' type (Figure 5) which permits longitudinal movement and also vertical flexing with little resistance. Figure 13 shows a view of the bridge during the construction of the deck.

Acknowledgement

The realisation of this cable-stayed bridge with onsite cable-stay manufacture to international standards owes much to the encouragement and cooperation given by the Public Works Department of the Government of Sikkim. Equally significant is the almostascetic dedication to the cause of state-of-the-art technology promotion in India by the firm, Messrs Schlaich + Partners, West Germany. Their free and selfless involvement at all stages is one for which mere gratitude is insufficient. The cooperation extended by Gammon India staff, especially Messrs S. Gupta, S.K. Khatri, M.S. Bhumber, V.M. Dharap and S.A. Reddi, is in the best tradition of the Company.

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