Examples of the application of high tensile steel in reinforced concrete slabs

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Examples of the Application of High Tensile Steel in Reinforced Concrete Slabs.

Beispiele für die Anwendung von hochwertigem Baustahl bei Plattenträgern aus Eisenbeton.

Exemples d'application de l'acier à haute résistance dans les systèmes en dalles de béton armé.

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Hitherto the development of reinforced concrete construction in bridges has been concerned almost exclusively with the design of arch and beam bridges, but in view of the great improvement attained in the mechanical properties of concrete, the production of a structural steel of high yield point, and the endeavours now being made to utilise these two high-grade materials consistently, further constructional development of the slab girder is to be anticipated. This is a type of structure with the merit of clear and simple statical conditions, because as a rule the bending moments are in one direction only, while moreover the shuttering work, the arrangement of the reinforcement, and the placing of the concrete are all notably simplified. Again, slab shaped members, in consequence of the great width of the concrete in the tension zone, show much greater freedom from cracking than is the case with the shallow ribs of T-beams.

The structural possibilities of slab girders when account is taken of the increased permissible stresses will be illustrated here in a few practical examples. The bridges in question were designed by the author and were completed as part of the work on the eastern section of the German Alpine Road in the spring and summer of 1936.

Fig. 1 shows a reinforced concrete slab designed as a *Gerber* girder over three openings of 12.4 m span each, with a roadway width of 8.5 m. The piers and abutments make a wide angle with the axis of the road. The thickness of the slab, only 0.60 m at the side and 0.68 m at the axis of the road, shows the extent that the constructional depth can be reduced through the use of high-grade materials. In the present case the proportion of the mix was 300 kg of ordinary Portland cement per cubic metre, and at 28 days the cube strength of the concrete was 405 and 513 kg/cm², allowing a permissible compressive stress in the concrete up to 70 kg/cm², while the permissible stress in the steel in the round bars of St. 62 was taken as 1500 kg/cm². Loading was assumed in accordance with the German regulations for Class I bridges, including a 24 tonne steam

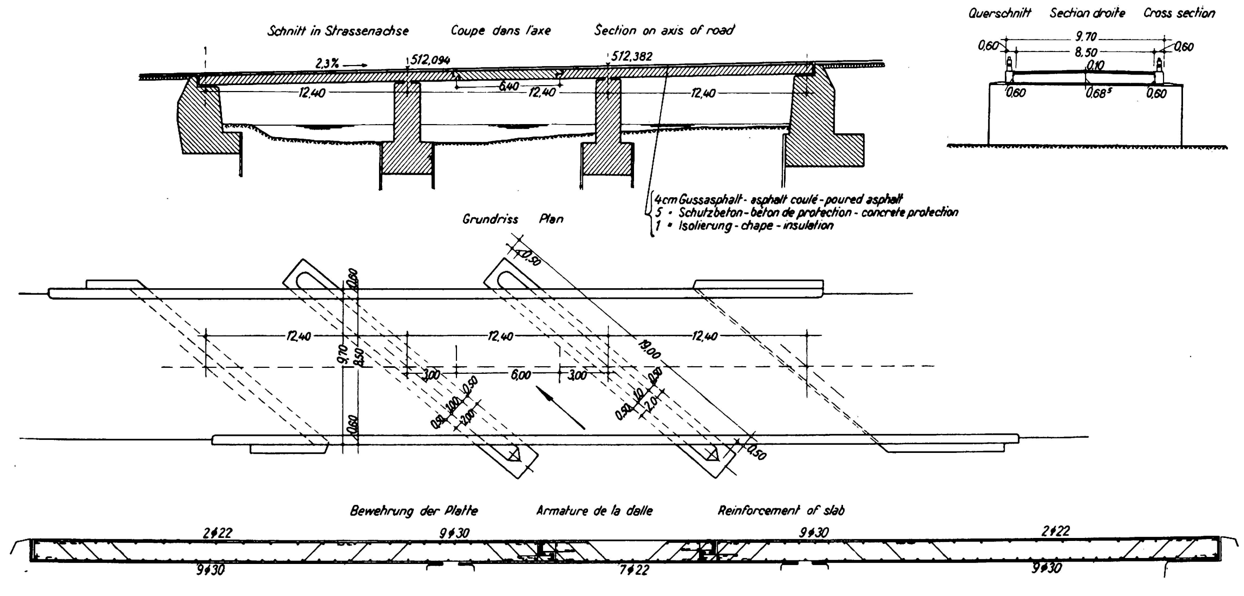

Fig. 1.

Weissbach Bridge II.

roller and a 12 tonne motor lorry uniformly distributed over two lanes of traffic totalling 5.0 m in width, with an impact coefficient of 1.4.

The reinforcement in the direction of the length of the bridge is shown in Fig. 1. With a maximum moment of 51.7 mt/m at the centre of the outside spans and of 60.3 mt/m over the supports, and taking $\sigma = 70/1500$ kg/cm², the design provides nine round bars of 30 mm diameter in each unit of width over the supports. The suspended slab in the central field, which is 6.4 m long and receives a maximum moment of 20.3 mt/m with $\sigma = 42/1500$ kg/cm², is reinforced with seven round bars of 22 mm diameter.

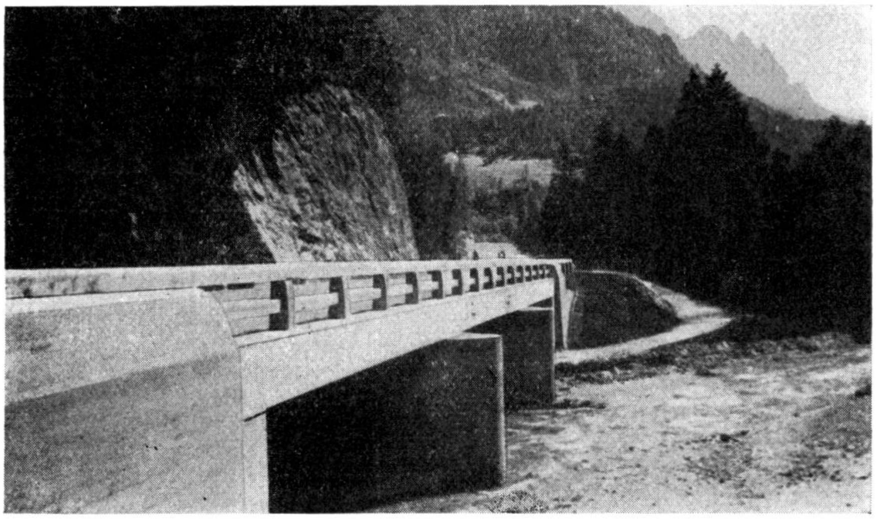

Fig. 2.

Fig. 2 shows the flowing lines in which the bridge crosses the river. The adoption of a timber railing on reinforced concrete posts notably improves the architectural unity of the structure, and this railing runs into massive parapets carried on the wing walls.

Fig. 3 shows another reinforced concrete slab built as a *Gerber* girder over three openings, each of 11.5 m span, with a road width of 8.5 metres. In this case again the two piers and the abutments are askew with the axis of the road. The roadway slab is cambered at 1.5 % and is uniformly 60 cm thick.

Here again the slab was reinforced with round bars of St. 62 subject to a stress of 1800 kg/cm². This stress was justified, among other factors, by the conclusion drawn from the Dresden experiments that such slabs possess notably greater safety against cracking than T-beams, and also by adequate safety against breakage. In the Stuttgart fatigue tests on high tensile steel the further conclusion was drawn that a permissible stress in the steel of 1800 kg/cm² is suitable in slabs, even under moving loads, in cases where the concrete shows a cube strength of not less than 225 kg/cm².

The reinforcement required to resist the standard loading for Class I bridges is shown in Fig. 3. With a maximum moment of 47 mt at the centre of the outside spans and of 45.5 mt over the supports, seven round bars of 13 mm diameter were adopted, the stresses in the cross sections being then respectively

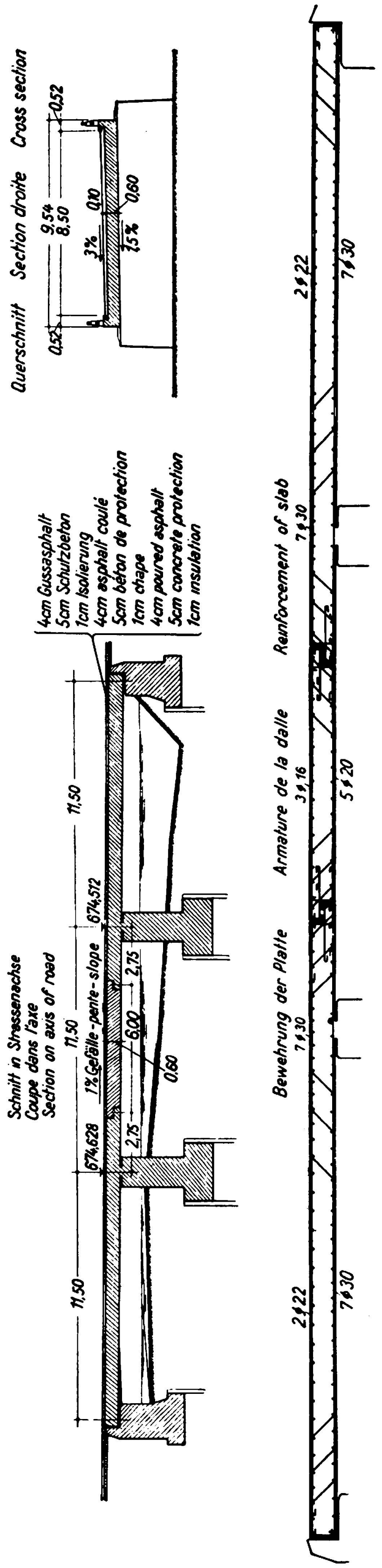

Fig. 3.
Traun Bridge Hinterpoint.

$\sigma = 74/1800$ and $71/1680$ kg/cm². The suspended slab in the central field is of 6.0 m span, and under a maximum moment of 18.8 mt requires five round reinforcing bars of 20 mm diameter for $\sigma = 77/1800$ kg/cm². The cube strength of the concrete made with 300 kg of ordinary Portland cement per cu. metre was 661 kg/cm² at 28 days. This exceptionally high cube strength indicates — as do the cube strengths mentioned above — the particular care with which the concreting of bridges on the German Alpine Road has been carried out. In view of this circumstance the adoption of reinforcing steel of 30 mm diameter was permitted, and provision was made for its firm anchorage in the concrete by means of suitable end hooks.

Fig. 4 shows how well this bridge merges into the surrounding landscape.

By the adoption of framed designs of slab girders it is possible considerably to reduce the constructional depth. Fig. 5 shows a two-hinged slab frame of 10.6 m span with an average depth of 3.25 m. The thickness of the slab of the lintel portion varies from 0.33 m at the side to 0.46 m on the centre line, and the thickness of the side members is 0.60 m. The frame was reinforced with round bars of St. 52 and once again a stress of 1800 kg/cm² was adopted.

Fig. 6 shows the reinforcement of the frame with a maximum moment at the centre of the lintel amounting to 17.9 mt/m, combined with the normal force of 5.5 tonnes, the necessary reinforcement, assuming permissible stresses of $\sigma = 75/1800$ kg/cm², being ten round bars of 20 mm diameter. The fixing of the lintel into the vertical members is calculated for a maximum moment of — 21 mt/m, and taking $\sigma = 50/1800$ kg/cm², eight round bars of 20 mm in diameter are necessary. In the upper portion of the verticals, with $\sigma = 1800$ kg/cm², the necessary reinforcement is seven round bars of 20 mm diameter, and in the middle of the verticals four round bars of that diameter.

Fig. 7 shows the finished bridge, the external lines of which are derived directly from the statical conditions.

By making proper use of the mechanical properties peculiar to high-grade concrete, it becomes possible to construct slab bridges even over large spans, and at the same time the amount of steel required can be much reduced by adopting

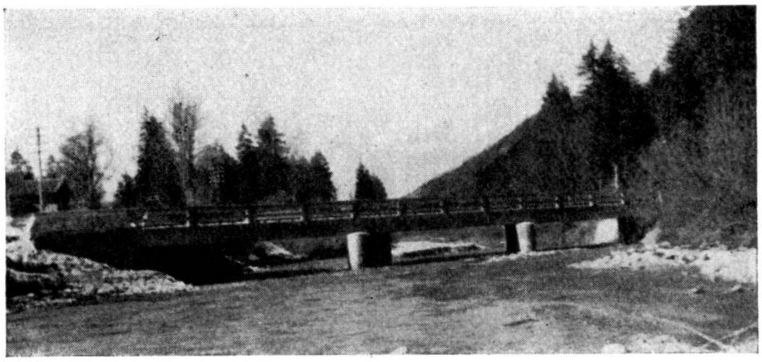

Fig. 4.

high tensile steel and taking advantage of the increased permissible stress therein.

The bridges just described are the first in Germany in which permissible stress in the steel of 1800 kg/cm² has been adopted; this figure exceeds what is

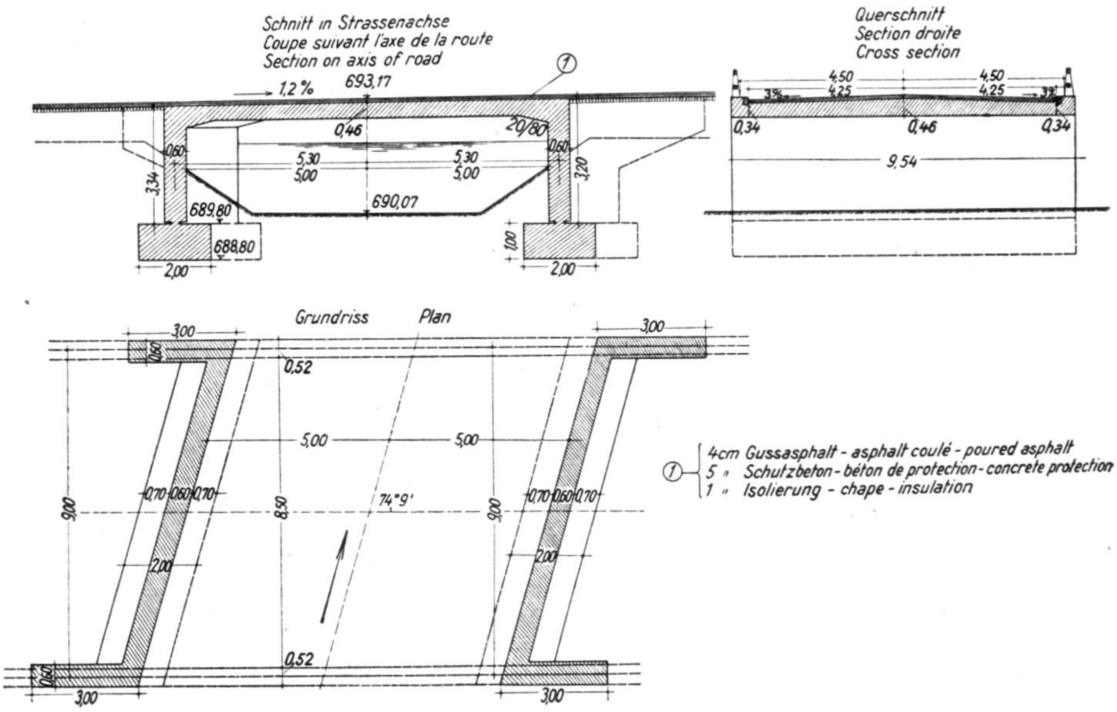

Fig. 5.

Bridge over Grosswaldbach.

allowed by the current regulations, but in view of the knowledge now made available by the testing laboratories its adoption was held to be justified. Moreover the peculiar mechanical properties of high tensile structural steel are confirmed by practical experience in actual work, particularly by the excellent performance noted after six months service under heavy traffic.

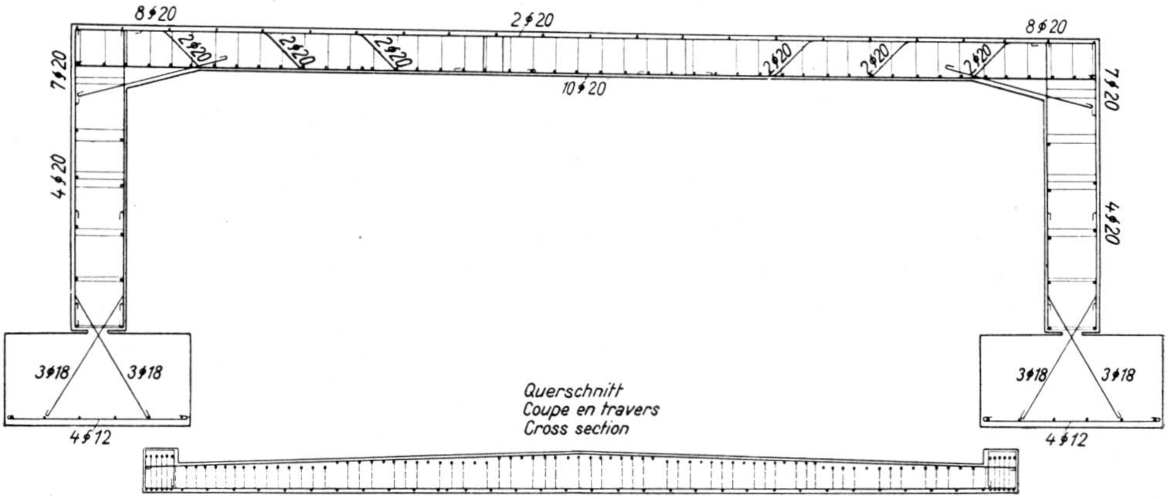

Fig. 6.

Reinforcement of frame.

It may be deduced from these descriptions of structures that slab girders are in fact a method of construction which offers scope for development. Seeing that the scantlings, and therefore the "own weights" of the structure, depend on

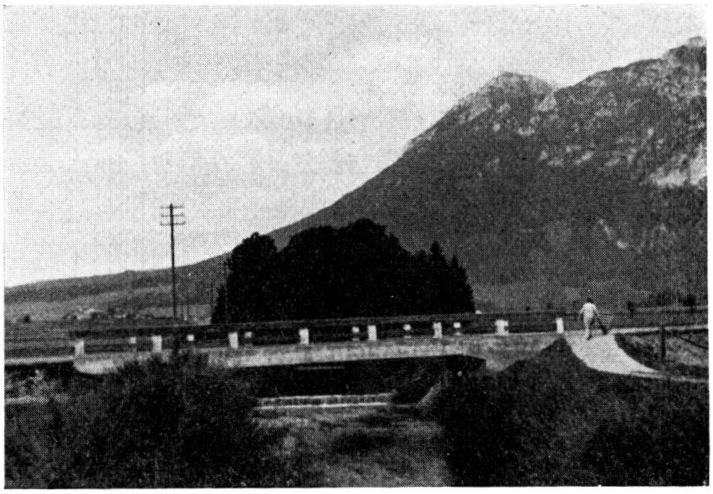

Fig. 7.

the magnitude of the permissible stresses the question arises what is the maximum span to which bridges of this type can be built with constructional and economic advantage; the answer to this depends, above all, on improving the qualities of high-grade concrete and high tensile steel.