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The Use of Steel of High Yield Stress Limit in Reinforced Concrete.

Anwendung von Stahl mit hochliegender Streckgrenze im Eisenbetonbau.

L'emploi de l'acier à haute limite d'écoulement dans le béton armé.

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The carrying capacity of reinforced concrete structures is not only dependent upon the quality of the concrete, but also upon the grip and quality of the reinforcing bars. In view of the fact that the use of good-quality cements and good aggregates produces high-grade concrete, an appropriate use of steel of high yield stress limit for reinforcing bars in reinforced concrete construction means, for the same degree of safety, an economic improvement of the reinforced concrete — an improvement that can only be welcomed in the interest of the public purse.

All reinforced concrete structures subjected to bending are calculated on the assumption of a definite ratio "n" between the elasticity of steel and that of concrete. When the steel reinforcement is stressed beyond yield limit, its co-efficient of elasticity drops in consequence of the great elongation produced, to such an extent that the ratio "n" is reduced to the vicinity of *1*. The distance of the neutral axis from the extreme compressive fibre is again dependent on "$n\,Fe$", "Fe" being the cross-sectional area of the tensile bars. The stressing of the reinforcement beyond yield point therefore acts, apart from its tensile strength, in the same way as would a reduction in cross section of the reinforcement in the same proportion as a decrease in the value of the co-efficient of elasticity. However, the smaller the cross-sectional area of the reinforcement, the lower is the pressure zone and the greater the pressure exerted upon the concrete. On the displacement of the neutral axis towards the compressive fibre, however, the leverage with which the internal forces act becomes greater and the stresses exerted upon the steel are thus not increased to any great extent. When the yield limit has been passed considerably greater compressive stresses are produced in the concrete; these lead to failure (breakage) even when the steel is not stressed more than 10 %, or at the very most 20 %, beyond yield point. Only when concrete of comparatively high strength is used, or when elongation of the steel is not very great after the yield limit has been passed, will the steel stand up to still higher stresses. Thus it is always the height of the yield point, and not the tensile strength, that determines the permissible stresses and also, in consequences, the degree of safety in reinforced concrete structures.

Using ordinary C 38 mild steel, a yield limit of 2300 kg/cm² is now being guaranteed. With permissible stresses of 1200 or 1400 kg/cm², the degree of safety is therefore 1.92 to 1.64. Permanent elongation at the upper yield limit amounts to about 0.2 %.

For high-grade steels the yield limit and permissible stressing are corresondingly higher. The ultimate load for reinforced concrete beams, which is comparatively independent of compressive strength, is generally determined by the height of the yield limit of the steel used for reinforcing bars. When the first cracks appear considerably greater stresses in the steel have also to be calculated with. Beams reinforced with high-quality steel, in consequence of the small cross section of their reinforcement, undergo, however, considerably greater deflection than beams reinforced with ordinary C 38 steel of the same carrying capacity.

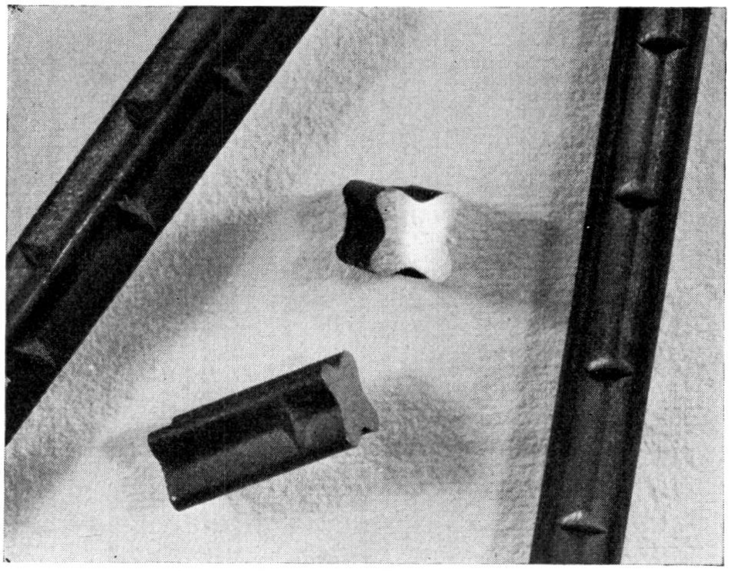

Fig. 1.

The raising of the permissible stresses in steel offers great advantages from a constructive as well as from an economic point of view. The advantages of higher permissible stressing in steel involve a reduction of the cross sections required, thereby decreasing the dead weight of reinforced concrete structures and permitting the construction of larger spans.

A high yield point in steel can be attained either in a natural manner *during production at the rolling mills,* or artificially *by cold stretch processing.*

A reinforcement bar belonging to the first of these two groups is the so-called "Roxor" type, which possesses a minimum yield limit of 3800 kg/cm². Greater grip is attained by means of cruciform cross section (Fig. 1), the surface of which is provided at intervals of about $1^1/_2$ times the maximum diameter with transverse ribs. The latter are so dimensioned that they are sufficiently impervious to injury when the bars are withdrawn from the concrete, and at the same time add as little as possible to the weight of the bars. The action of the ribs is to increase to a considerable extent the grip of the reinforcing bars in cooperation with the shearing strength of the concrete, for when the bars are withdrawn the space between two adjacent ribs remains filled with fine-grained concrete. At the same time the cross-section contour of these reinforcing bars is such as to prevent their being mistaken for any other type of steel.

The main data required for calculating the cross-sectional area and girth of these bars is the following:

Diameter of circumferential circle of "Roxor" bar

$$D = 1.2715\,d;$$

diameter of round bar equivalent to "Roxor" strength

$$d = 0.7856\,D;$$

girth of "Roxor" bar

$$U = 3.1106\,D = 3.9551\,d;$$

circumference of corresponding round bar

$$u = 2.4708\,D = \pi;$$

cross-sectional area of "Roxor" bar

$$F = 0.4816\,D^2 = 0.7786\,d^2.$$

By a round bar equivalent to "Roxor" strength is to be understood a round bar of the same weight per metre length. As the weight of the ribs amounts to 0.86 % of the total weight, however, the cross-sectional area of the corresponding round bar is 0.86 % greater than the actual cross section of the "Roxor" bar.

Mean values obtained by quality tests are classified in Table I:

Table I.

Quality test on reinforcing bar of	C 38 Steel	Roxor
Coefficient of elasticity in t cm²	2050	2092
Yield point stress in kg cm²	2718	4037
Strength in kg/cm²	3889	5259
Ratio of yield point stress to strength in %	70	77
Elongation	30	26
Constriction in %	64	55

The measured length in these tests amounted to ten times the diameter of the corresponding round bar. All test bars stood the cold bending tests carried out round a pin of the same diameter as that of the circumferential circle of the "Roxor" bar.

Comparative grip tests on "Roxor" reinforcing bars and others of ordinary C 38 steel were carried out by withdrawing the test bars from cubes of concrete in which they had been imbedded for periods of various lengths. When calculating grip strength it was assumed that the tensile stresses were evenly distributed throughout the whole length of the imbedded metal, whereby the circumference of the corresponding round bar was entered instead of the actual girth of the "Roxor" bar. The results of about 160 tests[1] made will be found in Table II.

[1] All tests and observations were carried out in the test house of the Czechoslovakian Institute of Technology in Prague under the guidance of the two engineers Prof. *F. Klokner* and Dr. *B. Hacar*.

Table II.

Cube strength of concrete		Grip strength of reinforcing bars in kg/cm² C 38 steel	Roxor
minimum 250 kg/cm²	min. value	42	59
	mean value	54	98
	max. value	68	161
minimum 350 kg/cm²	min. value	48	64
	mean value	69	121
	max. value	110	200

The above figures show that the grip strength of "Roxor" reinforcing steel is app. 80 % greater than that of ordinary C 38 steel bars. Calculating the actual girth of "Roxor" bars as 3.1106 D, the increase of grip strength amounts to about 43 %.

When testing ordinary C 38 steel bars, sliding was first observed at a tension somewhat less than half that of actual grip strength. In the case of "Roxor" reinforcing bars this took place at a tension somewhat below that of half grip strength; on the other hand, "Roxor" bars offered great resistance to further withdrawal.

By comparing the test results it was ascertained that grip strength

1) increases with the quality of the concrete,
2) increases with the setting time of the concrete,
3) decreases as the amount of water added is increased,
4) decreases as the imbedded length increases,
5) decreases as the diameter of the imbedded bar increases,
6) increases but little when stored dry as against storage under varying conditions. It therefore appeared that the conditions under which the test cubes were stored made little difference.

On the basis of 80 beam tests and subsequent calculations carried out in accordance with the respective regulations, it was ascertained that breakage was caused by stressing the steel reinforcement beyond its yield limit. In this connection beams whose reinforcement was not provided with hooks possessed the same carrying capacity as beams whose reinforcing bars were provided with the usual hooks. The total deflection of the beams reinforced with "Roxor" bars only amounted, under the same loading, to about 20 % more than that produced in beams reinforced with ordinary C 38 steel, though the reinforcement of the former was $^1/_3$ less. The elastic character of the steel was hereby transmitted for the greater part to the whole of the construction, so that the total deflections were for the main part composed of elastic deformations. Permanent deformations for beams reinforced with "Roxor" bars were approximately the same as those occurring in beams reinforced with C 38 steel.

Sixty-eight column tests, some for centric, others for eccentric pressure, were carried out and showed that "Roxor" reinforcing bars were considerably superior to C 38 steel bars. Thus it is possible to calculate for "Roxor" bars a correspondingly greater cross-sectional area, which comes to the same thing as increasing the permissible stresses. This enlargement factor can, with an adequate margin of safety, be put at 1.5; calculations for stressed sections can therefore be effected with 1.5×15 Fe $=$ *22.5 Fe,* instead of the usual 15 Fe. Permissible stressing now remains the same as for C 38 steel reinforcement bars. The greater use made of the compressibility of concrete, however, makes stronger transverse reinforcement necessary.

If the factor of safety for C 38 steel with a permissible total stressing of 1400 kg/cm^2 is 1.64 or 1.94, according as the yield limit of 2300 kg/cm^2 guaranteed by the steel works or the effective yield limit of 2718 kg/cm^2 is calculated with, then permissible stressing works out at 2317 kg/cm^2 or 1960 kg/cm^2 for "Roxor" reinforcement bars, working with the same safety factors and a guaranteed yield limit of 3800 kg/cm^2. After the first cracks had appeared in the concrete, however — at approximately 850 kg/cm^2 for C 38 steel reinforcement and at about 1200 kg/cm^2 for "Roxor" bars — the *permissible tensile stressing* of "Roxor" reinforcement was determined at round *1900 kg/cm*^{2}.

Consequently, in special cases — water reservoirs, for instance — absolute safety against cracking can be attained by a reduction of the permissible tensile stresses of the "Roxor" reinforcement bars to 1200 kg/cm^2; for C 38 steel reinforcement this can only be effected by reducing the permissible tensile stressing to 850 kg/cm^2.

In consequence of their greater grip strength, "Roxor" reinforcement bars can also be employed *without hooks* and with a comparatively slight increase of the usual concreted length. This valuable property will particularly appeal to the designer for portions of the structure where an overcrowding with steel is liable to ensue.

"Roxor" reinforcement bars are rolled in strengths ranging from D $=$ 8 mm to D $=$ 70 mm and in lengths of 35 m and 25 m. The standard price per 100 kg works out on an average at Cz. Kr. 178, that of C 38 steel at Kr. 147.

Steel of high yield stress limit can be manufactured not only in the actual steel-works by a combination of suitable materials; it can also be produced mechanically from ordinary mild steel by cold stretch processing. This fact could for a long time not be utilised in reinforced concrete construction, because the single bar could not be stretched uniformly along its whole length and throughout its entire cross section. It only became possible to eliminate these deficiencies almost entirely througth the introduction of *Isteg Steel* (Fig. 2).

Two ordinary C 38 steel bars placed side by side with their respective ends rigidly clamped, are twisted cold by a special machine in such a manner that the pitch of the twist and the length of both bars remains constant, causing a certain amount of prestretching. The stretching takes place uniformly along the whole length of the individual bars and can be ascertained at any stage of the process from the pitch of the twist. As an elongation of the axis of the twisted bar does not ensue, the effective cross section of the latter is constant and equal to the total section of the two round bars before twisting took place. This process thus ensures even strength and uniformity throughout the material, and is at the same time a test of quality, since on inferior material this treatment would produce visible signs of damage.

A whole series of tests showed that this twisting process causes a raising of the yield stress limit by about 40 to 50%, grip strength simultaneously increasing by app. 10%. The coefficient of elasticity, however, decreases with the amount of twist applied, and for a pitch equivalent to 12.5 times the diameter of the single round bar works out at app. 80 % of the coefficient of elasticity of the straight rod. The ultimate yield elongation for "Isteg" Steel is about half that of ordinary C 38 steel. When judging the coefficients of elasticity of "Isteg" and ordinary C 38 steels it must be borne in mind that in the former not only the changes in length but also certain relative changes of position between the two individual bars (roping) plays an important part. This probably explains, too, the observation made that the lowering of the coefficient of elasticity at low tensions is somewhat more rapid than when the stresses become greater.

As the yield stress limit of "Isteg" Steel under steady increase of the stress-strain curve does not appear so pronounced as for ordinary C 38 steel, and as fracture only ensues at a total elongation of 0.4 %, the figure 0.3 % total elongation was taken as being decisive for the yield limit of "Isteg" Steel. The surge-load strength of "Isteg" Steel at a load frequency of two million (350 per

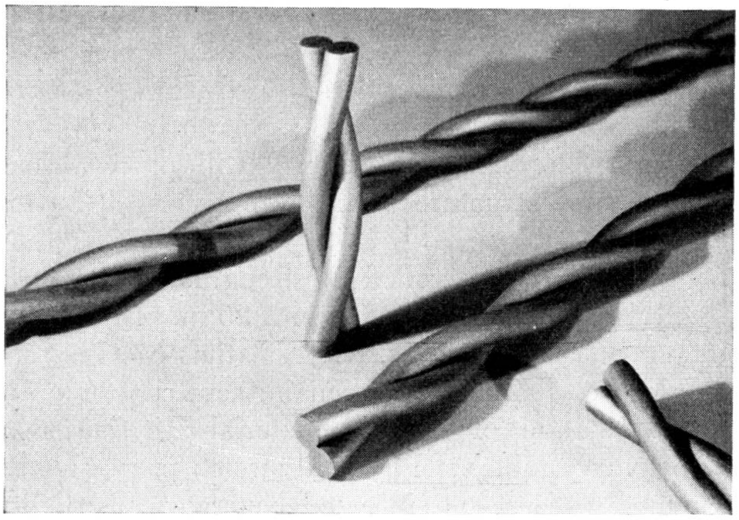

Fig. 2.

minute) amounts to from 2400 to 2500 kg/cm². The apprehension that the stretching of "Isteg" Steel under repeated impact action might have a deleterious effect, is therefore unfounded. The mean grip strength of "Isteg" Steel was also found to be about 25 % greater than that of ordinary round bars of C 38 steel. As regards safety against cracking, the tests carried out show that "Isteg" Steel is superior to the ordinary C 38 steel reinforcing bar, although great caution has to be observed when employing in practice the results obtained from ascertaining the first appearance of hair-cracks in reinforced concrete constructions. It is, however, a fact that with "Isteg" reinforcement the cracks were evenly distributed over the whole length, and even when the load was increased proved to be very much finer than in the case of C 38 steel. Here single cracks appeared, which widened more and more as the load was increased.

On the strength of the tests made, therefore, taking as a basis a *minimum yield stress limit of 3600 kg/cm²* at a total elongation of 0.3 %, a minimum strength of 4000 kg/cm² and a minimum ultimate elongation of 10 %, *a permissible* *tensile stressing of 1800 kg/cm²* could be prescribed for "Isteg" Steel. In this connection, when dimensioning the cross-sectional area, the ratio of the coefficients of elasticity of steel and concrete has to be assumed as being $n = 15$, while elastic changes of shape and statically undeterminable dimensions have to be calculated with $n = 8$. Welding and hot bending are not admissible. Apart from this, the same principles of construction (grip length, formation of hooks and so forth) apply for "Isteg" Steel as for ordinary reinforcing rods of C 38 steel.

Reinforcing bars of "Isteg" Steel are manufactured in diameters of from 5.5 mm to 30 mm, in lengths up to 30 m. Their average standard price per 100 kg is Cz. Kr. 168, that of C 38 steel bars Kr. 147.

In view of the above qualities and properties possessed by the two types of reinforcing bar *Roxor* and *Isteg*, they may claim both economic and technical superiority over the normal type of reinforcement with round bars of C 38 steel. Their high yield stress limit increases the carrying capacity of concrete constructions and effects a considerable saving in cross section and weight of the

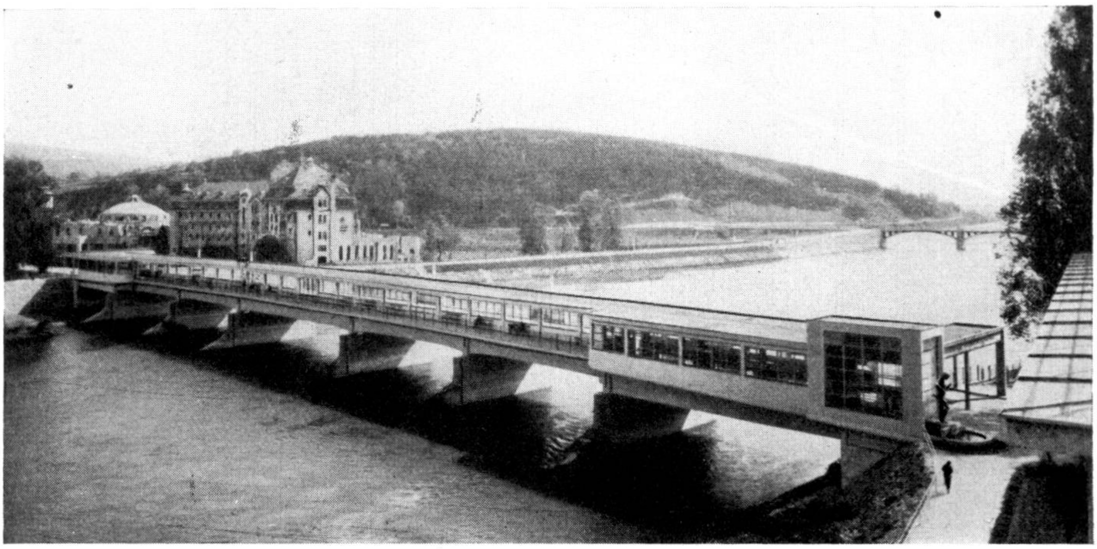

Fig. 3.

reinforcement, together with a corresponding economy as regards freight expenses and cutting, bending and laying wages. On account of their lighter weight and the impossibility of confusing normal and superior building steel, it is more advantageous to lay these bars at site; nor is high-quality cement an absolute necessity for these types of reinforcement steel. *In spite of their relatively higher unit price, they save the public purse at least 20 %.*

The far-reaching development of the use of high-quality building steels in the construction of reinforced concrete bridges began in Czechoslovakia on the introduction of "*Isteg*" Steel in 1931.

One of the first structures in which it was used was the *bridge across the River Waag in Piešťany* (Fig. 3), which links the town of Piešťany on the right bank of the river with the thermal springs and baths on the island and is exclusively used for the traffic of the Spa. The whole planning of the bridge, from beginning to end, is in itself extremely peculiar, for the structure is partly a covered bridge whose roofed-in portion forms a colonnade used by visitors to the Spa (Fig. 4).

The bridge is 148 metres long and composed of seven spans, the middle of which is 28 metres long, all the others are of 20 metres. The superstructure is built of continuous T-beams over three spans each. With the exception of the end bearings, the structure is monolithically connected with the piers. The beams are cantilevering at both ends, with a projection of 4.3 m over the end bearings. The central span is also provided with cantilever arms to carry a hinged portion 20 metres long.

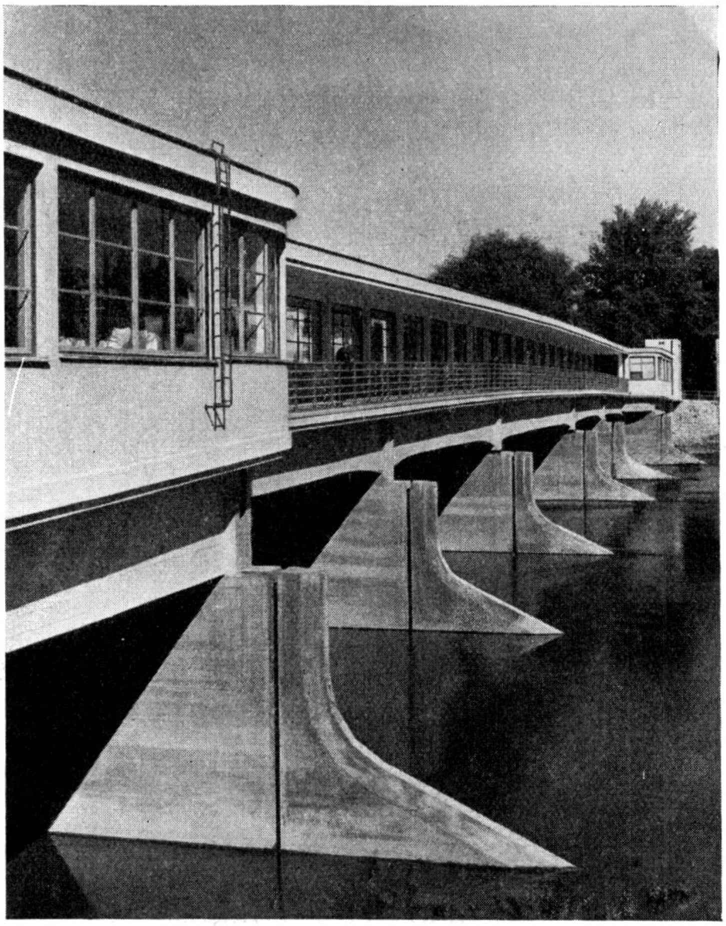

Fig. 4.

The clear width of the bridge for the five middle spans is 12.34 m, of which 5 m comprises the asphalted roadway and 6.40 m the useful width of the covered colonnade (Fig. 5). The columns are situated at the middle of the wide walk at 5 m intervals; they are connected at the top by a beam supporting the reinforced concrete roof. The covered colonnade is divided by glass partitions into two independent parts, so that when crossing the river visitors to the Spa may use the sheltered half, i. e. the leeward side. Over each end-span the two colonnades merge into a single hall, enclosed on all sides and containing permanent exhibitions of Czechoslovakian arts and crafts. For this reason 2.5 m was added to the width of the end bays of the bridge by insertion of a T-beam.

Apart from the live load of 4-ton wagons, i. e. 400 kg/m², the structure of the bridge is under extremely heavy load owing to the great weight of its superstructure. The employment of *"Isteg"* Steel as reinforcement (Fig. 6) thus

Fig. 5.

enabled the over-all dimensions of the reinforced concrete structure to be reduced and a considerable saving to be effected.

Fig. 6.

The total consumption of building materials amounted to about 30 wagons of steel, 10 wagons of Bauximent and 100 wagons of Portland cement. About 4000 cubic metres of concrete and 1000 cubic metres of timber were used.

One of the most interesting structures for which "Isteg" Steel has been used as reinforcement in bridge-building, is the State Road Bridge over the River

Strela at Plasy, near Pilsen (Fig. 7), where a new reinforced concrete girder bridge of 30.58 m span was erected to replace the old iron lattice-work construction.

The superstructure of this bridge consists of solid web girders, with sunk road construction. The over-all width of the bridge between the two main girders measures 6.00 m, of which 5.20 m comprises the paved roadway and twice 0.40 m the kerbs at either side. Outside of the main girders and borne on brackets, a footpath of 1.30 m clear width is arranged at each side.

The suspended girders have a width of 76 cm and a height of 2.80 m, i. e. approx. 1/11 of the span. The main girders are 1.30 m higher than the footpaths and kerbs, so that for the most part they are hidden by the 1.10 m high parapet. The structure itself is a skew bridge and the cross-girders are placed at right angles to the two main girders and at intervals of 1.39 m. To keep down the dead weight, openings were arranged in the middle parts of the main girders.

Fig. 7.

Decking slab and cross-beams are reinforced with ordinary round bars of C 38 steel, while the tensile reinforcing of the main beams was carried out with "Isteg" Steel bars of 30 mm diameter. The reinforcement was delivered to site in full-length bars, so that no splicings were necessary. The longest one-piece "Isteg" bar built into the structure measured 38.59 m.

Decking slab and cross-beams were dimensioned with due regard to the impact coefficient, on the basis of a permissible stressing for the concrete of 48 kg/cm² and a permissible tensile stressing for the steel of 1200 kg/cm². In the main beams the greatest tensile stresses measured 69.4 kg/cm² (permissible stressing 70 kg/cm²), and 1662 kg/cm², (permissible stressing 1800 kg/cm²), respectively. In order to avoid tension cracks in the main beams wire-netting was laid around the tensile reinforcement in addition to the stirrups, the object being to increase the tensile resistance of the concrete cover over the bars. When laying down the loading conditions, the Czechoslovakien regulations for the loading of 1st class road bridges were adhered to, viz, the use of a 22-ton steam plough and a human crowd equivalent to 500 kg/cm².

The specified cube strength of the concrete after 28 days curing was 170 kg/cm² for roadway and footpaths, and 330 kg/cm² for the main beams.

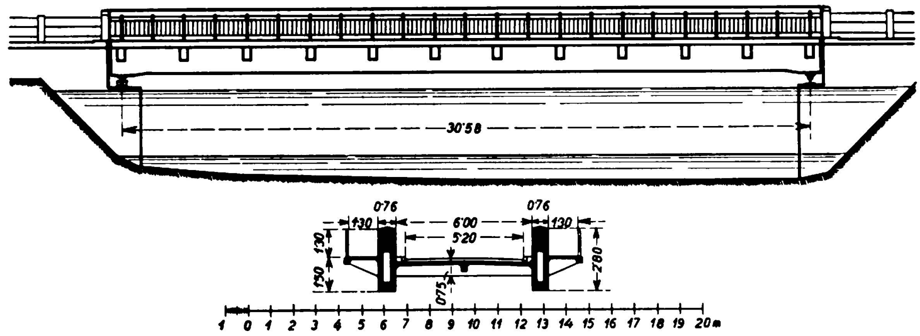

Fig. 8a.

The effective strengths attained in actual construction were 334 kg/cm² and 486 kg/cm² respectively for 250 kg and 420 kg respectively of Portland cement per cubic metre of dry sand-and-shingle mixture and a grain-size proportion of aggregates 5.70 and 6.30 respectively.

The results of quality tests carried out with the types of steel used are classified in Table III.

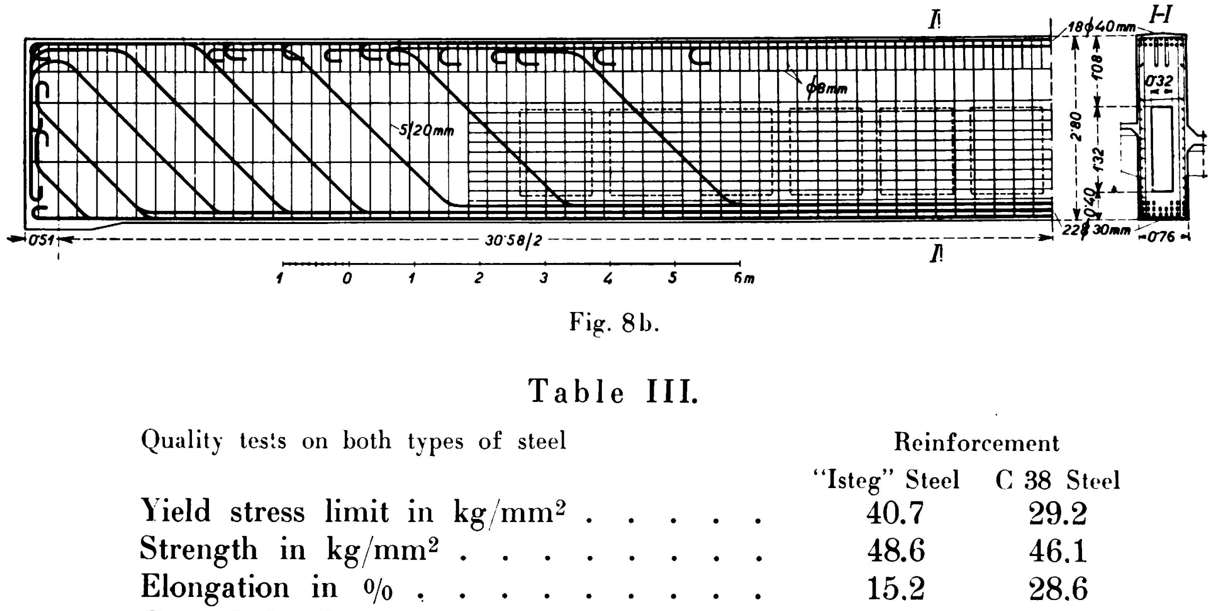

Fig. 8b.

Table III.

Quality tests on both types of steel	Reinforcement "Isteg" Steel	C 38 Steel
Yield stress limit in kg/mm²	40.7	29.2
Strength in kg/mm²	48.6	46.1
Elongation in %	15.2	28.6
Constriction in %	52.6	58.6

The loading tests on the bridge were carried out with 4 twelve-ton vehicles. The greatest elastic deformation undergone by the main beams measured 2.60 mm, as against a calculated figure of 3.10 mm; that of the cross-beams amounted to 0.15 mm as against the 1.30 mm calculated. No permanent deformations were recorded.

The total consumption of concrete per sq. metre covered area of the bridge is 38.5 cm, the total steel consumption 133 kg. Of the latter figure 48 kg is "Isteg" Steel, the remainder being ordinary round C 38 steel bars.

Besides "Isteg" Steel, which is produced artificially from ordinary building steel by cold-stretch processing, "Roxor" Steel, manufactured in a natural manner in the actual steelworks, has been employed as reinforcement in reinforced concrete structures in Czechoslovakia since 1933.

One of the first constructions in which "Roxor" was used was that of the *Bridge over the Svratka in Brunn* (Fig. 9) on the Vienna-Brunn highway. This bridge has a clear skewed width of 31.20 m.

When deciding upon the type of construction to be employed, and in working out the project as a whole, two factors had to be taken into particular consideration, viz. the limited constructional height, and the fact that the bridge had to be capable of being widened on both sides and that the municipal tram-lines could be laid as desired. Finally, it was specified that all reinforcing bars had to lie above high-water mark.

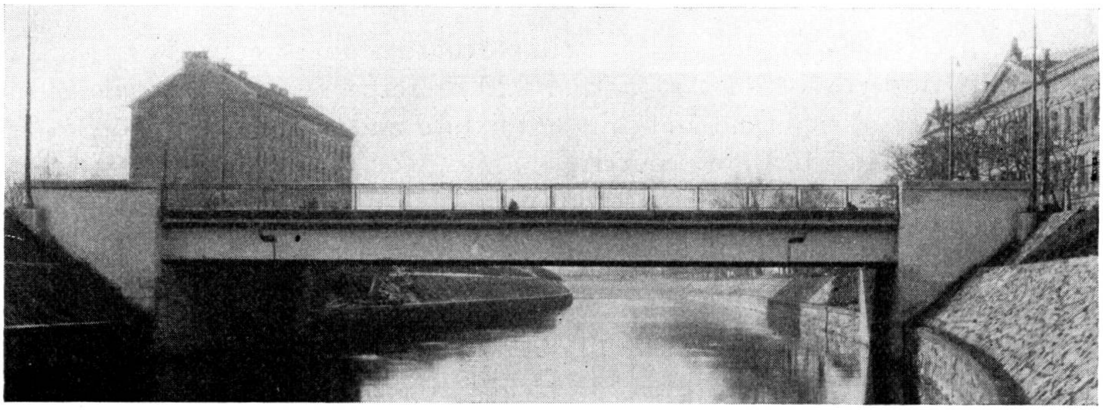

Fig. 9.

With the object of suiting the appearance of the bridge to its surroundings, the type of structure chosen was that of continuous T-girders over three spans with hinges in the middle span (Fig. 10 a b c). In this manner the advantage, offered by continuous girders, in reducing of the bending moments in mid-structure could be maintained, whereas the disadvantages that might be feared from subsidence of the supports were eliminated.

The suspended girder in the 32.30 m long middle span has a length of 22.80 m. The position of the hinges in the middle bay, as well as the length of span in both end bays — which had to be filled up in consequence of the river correction scheme — were so chosen that the positive moment in the span of the suspended girder became equal to the negative moments over the two middle supports. This yielded cantilever arms of 4.70 m and a 13.00 m span for the end bays. Thus it was possible to limit the constructional height to only 1.80 m, i. e. about $^1/_8$ middle span length, or $^1/_{13}$ that of the suspended girder. In order to secure a safety factor of 1.4 against overturning when the middle bay is under full load, those portions of the end bays not required to carry conduits were constructed with box-type girders weighted with concrete filling.

The clear width of the bridge measures 17.60 m, of which 11.50 is allotted to the paved roadway and 3.00 m on each side to the two footpaths. The whole arrangement comprises 8 T-beams at intervals of 2.20 m.

The tram-line base consists of a 13 mm thick shock-absorbing "Contravibron" slab between layers of 3 mm thick lead sheeting.

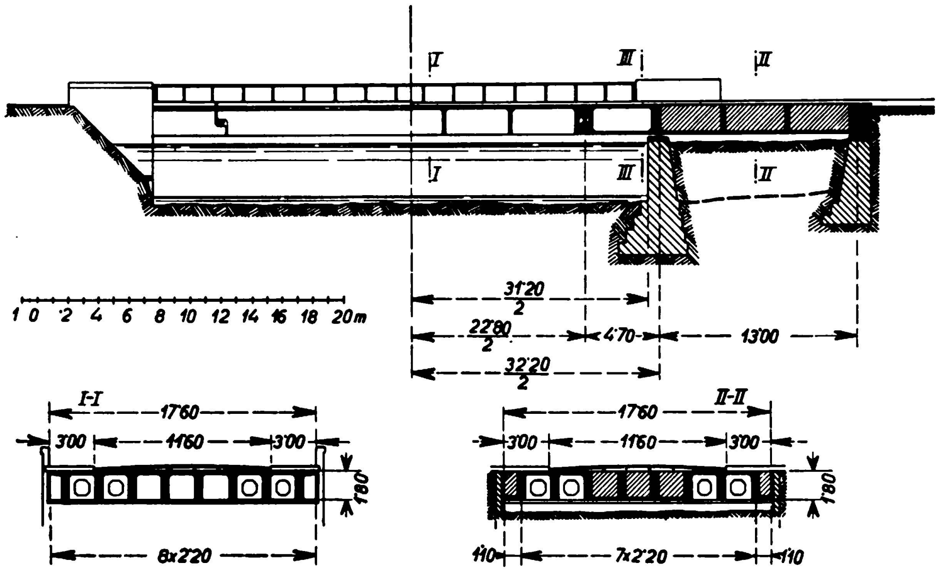

Fig. 10a.

The statical calculation of the bridge was carried out not only in respect of the loading of 1st class road bridges in accordance with the regulations in force in Czechoslovakia, but also for 22-ton railway wagons hauled by electrically driven locomotives, and then for 21-ton watering cars or motor-driven vehicles with 13-ton trailers — all rolling stock of the electric tramways. In addition, the

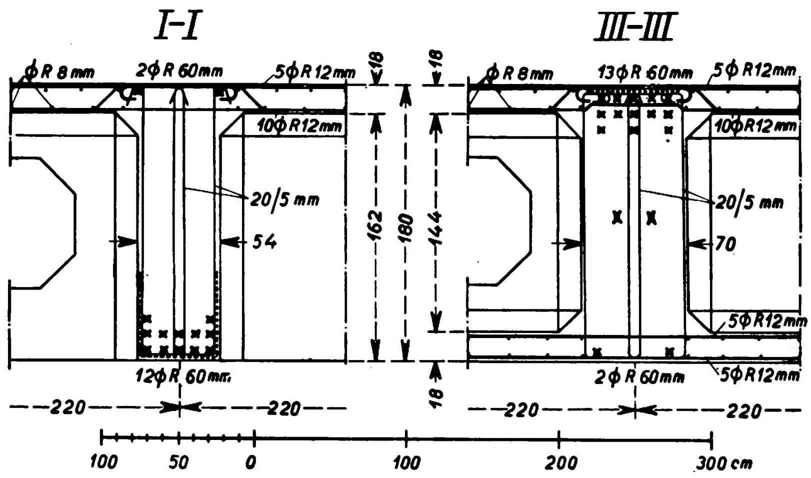

Fig. 10b.

bridge carries three water mains, the gas main, and electric power and telephone cables. For this reason, and in order to render the hinges in the middle bay accessible, openings were left in the cross braces.

With the exception of the stirrups, all the reinforcing bars used in the bridge are of "Roxor" Steel (Figs. 11 and 12). The advantage of employing this high-quality material is that it effects a reduction of the cross-sectional area of the reinforcement required and allows the constructional height available to be better utilised, since at least four rows of reinforcing bars, would have been required had ordinary C 38 reinforcement been employed and the ideal cross-sectional height thus reduced.

The greatest stressing of the 18 cm thick decking slab is 42.2 kg/cm^2, that of the steel 1623 kg/cm^2. In the main beams the greatest tensile stresses amount to 69.2 kg/cm^2 (permissible stressing 70 kg/cm^2), and 1750 kg/cm^2 (permissible stressing 1900 kg/cm^2) respectively.

To prevent the occurrence of tension cracks welded steel-wire mesh was placed around the reinforcing bars at the points of greatest tensile stress, viz. in the lower portion of the suspended beam, and in the upper part of the beams over the middle piers.

The regulation cube compression strength of the concrete used in the structure was 330 kg/cm^2 after 28 days curing. In actual construction, with a concrete mixture of 350 kg Portland cement per cubic metre of dry aggregates, grain-size proportion 6.06, a cube strength of 431 kg/cm^2 was attained.

The results of the quality tests carried out on the "Roxor" steel employed were as follows:

Yield stress limit average . . .	41.1 kg/mm^2
Strength average	59.2 kg/cm^2
Elongation average	24.4 %
Constriction average	54.2 %.

When planning execution of the bridge it was borne in mind that the scaffolding would settle under the weight of the concrete. For this reason the concreting work was proceeded with in such a manner that cross sections situated at points of greatest bending moments were concreted last. This applied chiefly to the cross sections over the two middle piers, and to the central cross section of the suspended beams. The bridge being a skewed structure ($d = 81^0\ 30'$) and relatively wide, the suspended beams in the middle bay were only concreted after the form-work of the end bays and cantilevers had been removed. This was done to prevent any torsion that might take place from being transmitted to the middle span.

When carrying out loading tests on the bridge the following vehicles were employed: two 21-ton watering cars belonging to the electric tramways, two 20.5-ton motor-driven cars, one 14-ton petrol-driven roller, one 12-ton naphtha-driven roller, besides 85.5 tons of paving stones on the footpaths. The total test load thus amounted to 180.5 tons. The greatest elastic deflection recorded for the main beams below the tram-lines was 2.35 mm, as against the 4.47 mm calculated; that of the other main beams was 2.05 mm as against 2.90 mm. The result of the loading test was therefore extremely satisfactory.

Total concrete consumption, including concrete filling, amounted to 79 cm per sq. metre of covered area; total steel consumption only 128 kg, of which the stirrups-ordinary C 38 building steel, accounts for 10 kg, the remainder being "Roxor" Steel.

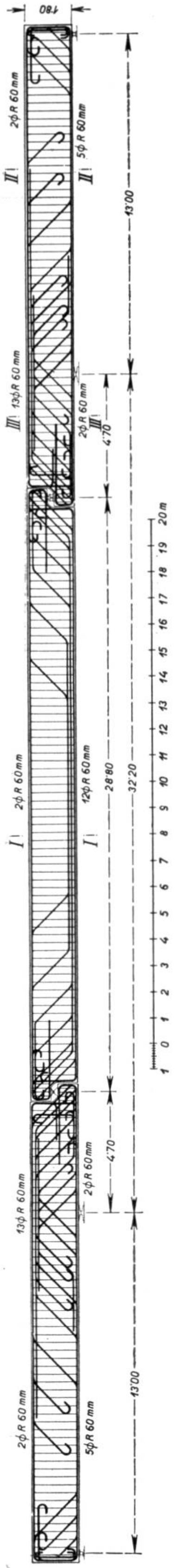

Fig. 10c.

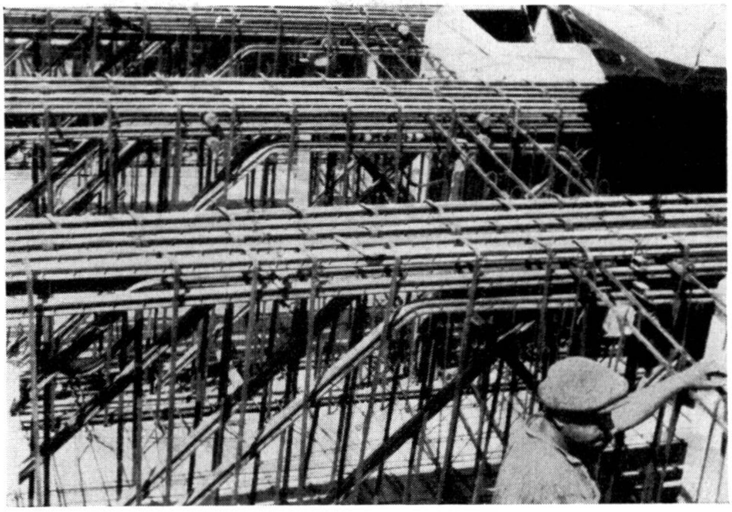

Fig. 11.

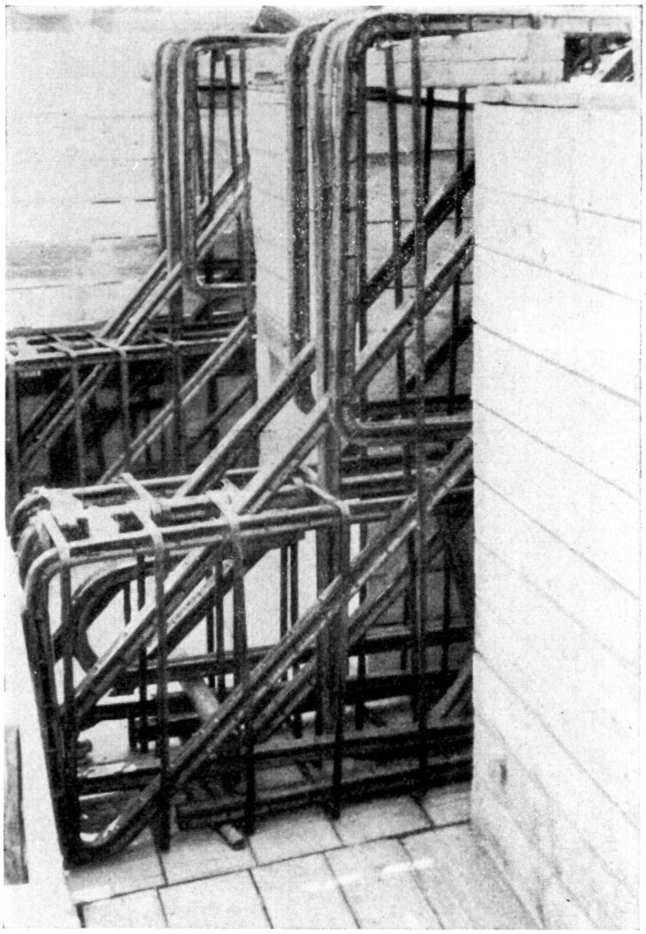

Fig. 12.

Summary.

The report considers from a theoretical standpoint the two high-quality types of steel, "Roxor" and "Isteg", employed in reinforced concrete construction in Czechoslovakia. The high yield stress limit of "Roxor" Steel is attained in a natural manner during actual manufacture in the steel-works, that of "Isteg" Steel by artificial cold stretching.

The report further describes the application of "Isteg" and "Roxor" Steel in the construction of some State Road bridges.