Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

Band: 2 (1936)

Artikel: Steel in hydraulic engineering, and model experiments

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DOI: https://doi.org/10.5169/seals-3351

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Steel in Hydraulic Engineering, and Model Experiments.

Stahlwasserbau und Modellversuche.

Constructions hydrauliques en acier et essais sur modèles.

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In the paper by *Burkowitz* and in all the contributions to the discussion on "Application of Steel in Hydraulic Construction — Movable Plant" reference is made to hydro-dynamical effects, vibration, etc. It is proposed here to develop that section of the subject which relates to the design of steel hydraulic structures on the basis of model experiments for studying the hydro-dynamical effects.

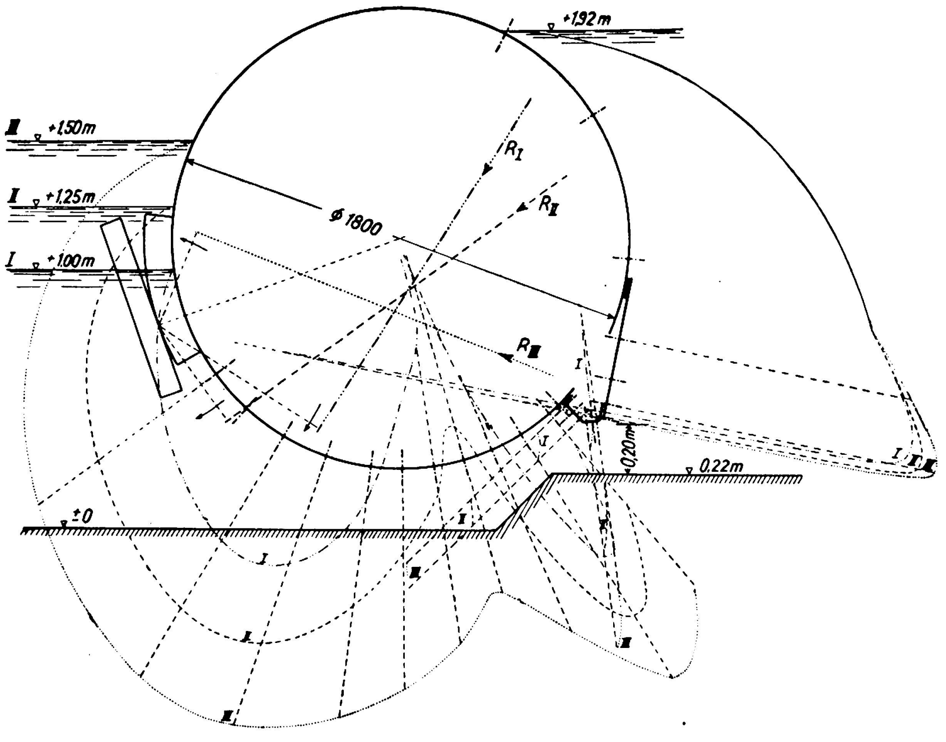

Fig. 1.

This study was first embarked upon as the result of certain diseases of infancy in the hydraulic plants which had to be cleared up by experiments on models, and the second phase was to use such experiments as a means of deducing principles capable of application for measuring the forces and dimensioning the openings and operating gear in plant designed in the ordinary way. From this it was easy to pass to the next stage, namely that of using model experiments to develop forms which would offer the most favourable possible hydro-dynamical qualities. A few examples will now be given.

Among the earliest roller weirs there were some which consisted merely of a supporting cylinder with a small attachment for stop planks. On one occasion such a weir was seen to be in a vigorous dancing motion, which finally led to the destruction of the whole gauge house and to the roller coming out of its guides. As it was difficult to explain this occurrence otherwise than on the assumption of some outstanding fault in operation, experiments on models were undertaken (Fig. 1). These showed that with a roller and crest of that shape the current of water shooting over the top experienced violent variations of pressure with the result that the roller was subjected alternately to pressure and suction effects. As a result of this knowledge all rollers were subsequently made with larger shields (Fig. 2). The most favourable relationship between the diameter of the roller and the height of the inlet was also experimentally determined.

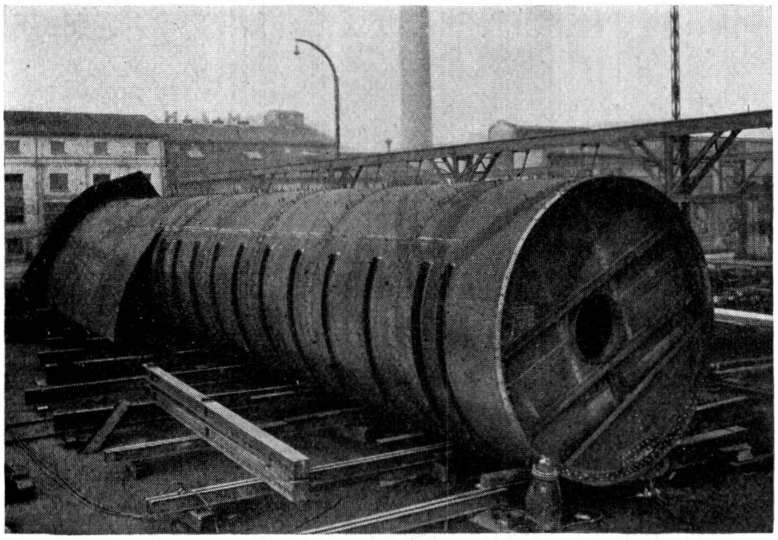

Fig. 2.

In the double gates of a large weir the upper gates were provided with a cover which the overflow water was discharged when the upper shields (upstream) were lowered. This cover consisted as shown on the left of Fig. 3 of a flat wooden sill inclined downstream. After every period of high water it was found that these overflow sills were to some extent damaged and required renewal. The wooden sill was replaced by a steel sill, but before doing so experiments were carried out to a scale of 1 in 5 to determine the proper shape for the plate, whereby a curved shape was decided upon, as shown on the right. The original inclined shape was found to cause an entirely irregular distribution of pressure, with numerous suction hollows, and the form finally decided upon for the overflow plates gives a harmonic distribution of pressure without any such suction hollows. At the same time it was found possible to incorporate two further impor-

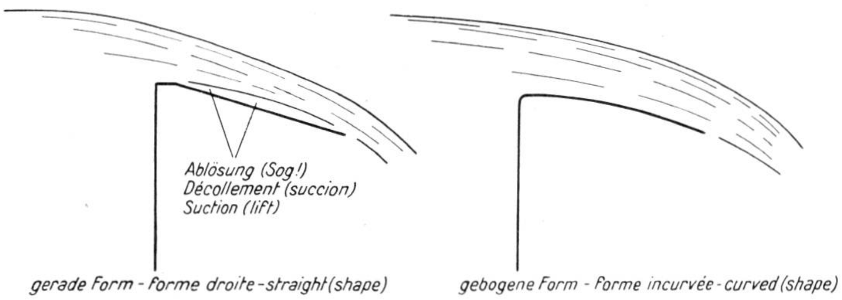

Fig. 3.

tant improvements in the new design: the water pressure load on the wall was reduced from 82 tonnes in the old to 38 tonnes in the new form, with a corresponding reduction in the power required for operation, and at the same time the discharge capacity was increased by some 20 %, showing that with the aid

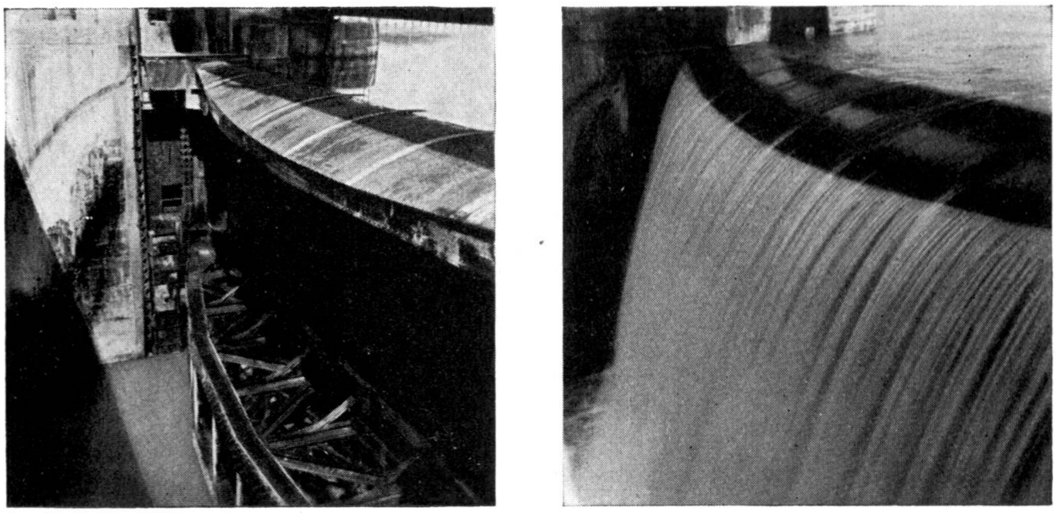

Fig. 4.

of a suitable overflow sill it is possible to economise in the length of the weir. Fig. 4 shows the constructional arrangement of a weir with one of the M.A.N. "hook gates" at Ryburg-Schwörstadt with the overflow shutter of the upper stoney-sluice. With a total height of 12.5 m these gates allow the upper gate to be dropped by 4.5 m. Their dynamical behaviour thus calls for very careful study.

A further problem was that of the vibration experienced by weirs when water flows underneath where only a small opening exists, an effect which was apt to lead to damage when the retained head became large. It was soon found by experiment that the cause of these vibrations lay in the design of the wooden sill and that by taking suitable measures the trouble could be mitigated (Fig. 5). Here again it is a question of obtaining a positive and stable line of pressure.

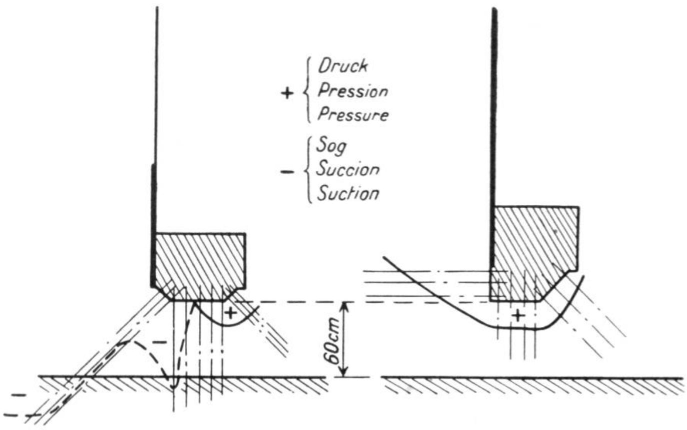

Fig. 5.

In yet other weirs of the stoney-sluice or bear-trap type vibrations were found to occur where there was an excess flow, especially where the height was limited. First of all, by experiment, ample ventilation of the space between the gate and the overflow was ensured, but this did not always cure the trouble, for it was found that the thin, coherent stream of water flowing over the flat sill was extremely sensitive to every impulse, and thus in itself tended to cause vibration. The experiments also showed however that this sensitiveness of the water stream is destroyed if cohesion is disturbed throughout its length, as by cutting it up or making it wavy (Fig. 6). This was accomplished by the introduction of

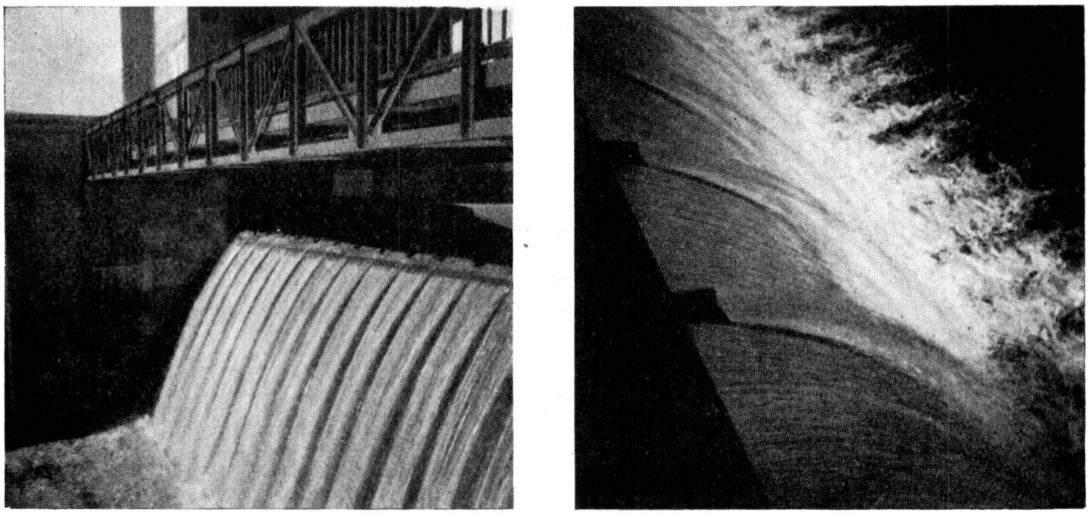

Fig. 6.

dovetailed strips of plate on the sill of the weir, and the illustration shows the stream flowing over the gate after this had been done.

Again, in the M.A.N. "fish bellied shutter", the chief feature of which is the operation from one side (Fig. 7), a current interrupter of this kind has been introduced. The example shows a sill of this kind in the weir at Heinbach measuring 18.0×4.0 m.

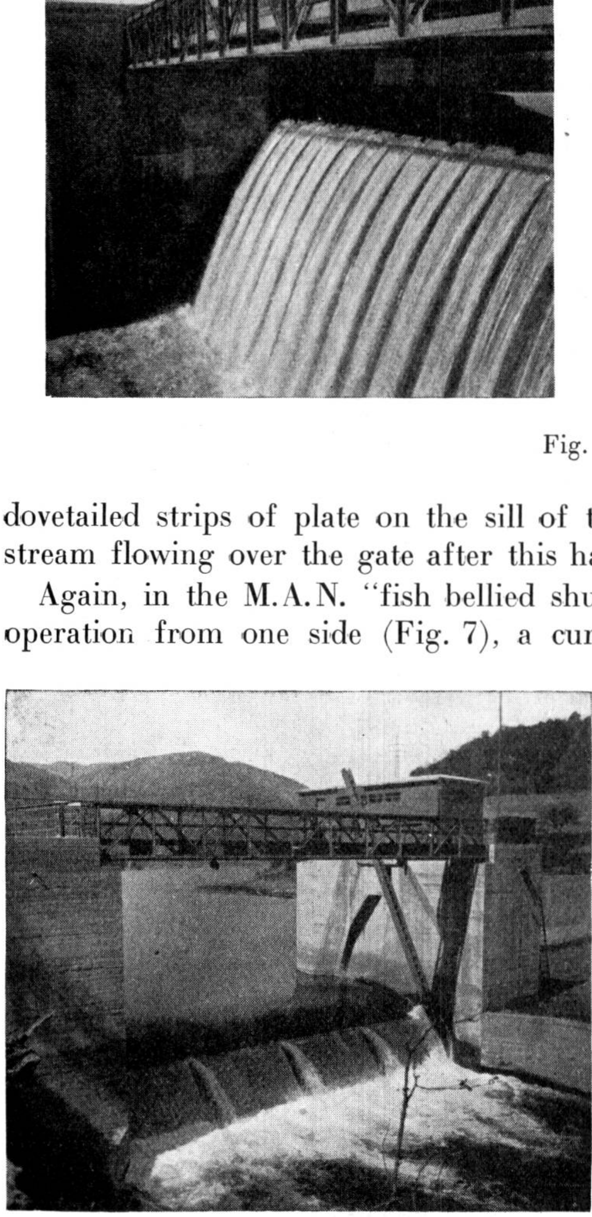

Fig. 7.

In the case of trap weirs it is also found that when the tail-race water rises, with the barrage down, alternating forces are set up therein, and in the lowest position these may easily tend to develop vibrations. The idea arose of so forming the barrage that in all cases its weight, together with the pressure of the water, would produce a positive moment in the direction of overturning on the body of the weir thus holding it steady (Fig. 8). The curves in the diagram give the turning moment due to the water pressure in the different positions of the gate, the small negative portion below the abscissae being compensated by the moment due to the own weight of the structure which always acts in a positive direction. The problem was solved only after numerous measurements of pressure had been carried out in the testing laboratory. Indeed it is essential, if accurate work is required, to carry out a fresh set of experiments for each new weir, since the shape of the fixed portion of the weir and of the tailrace, the depth of water in the latter, and the possible height of water over the sill, are always different and all affect the result. In the course of these experiments accurate determinations were also made of the turning moment due to the pressure of the water to be carried by the body of the barrage, and also of the operating pressure on the turning gear; at the same time the installation was calibrated, that is to say the discharge over the weir was measured for each stage of water level.

A particularly difficult problem arises in the design of under water closures (Fig. 9). Here the M.A.N., with the aid of their laboratory resources, have achieved several successful new solution during the past few years. This entailed

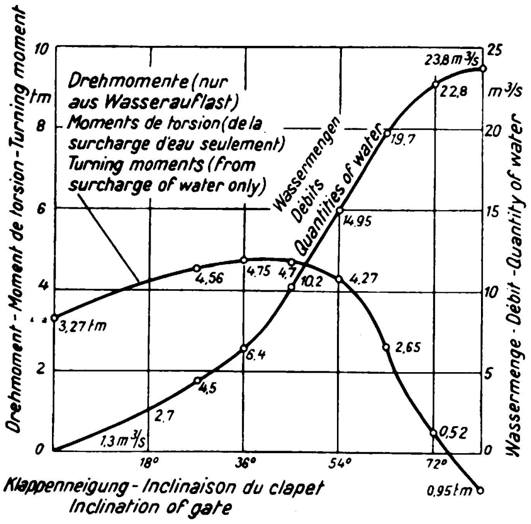

Fig. 8.

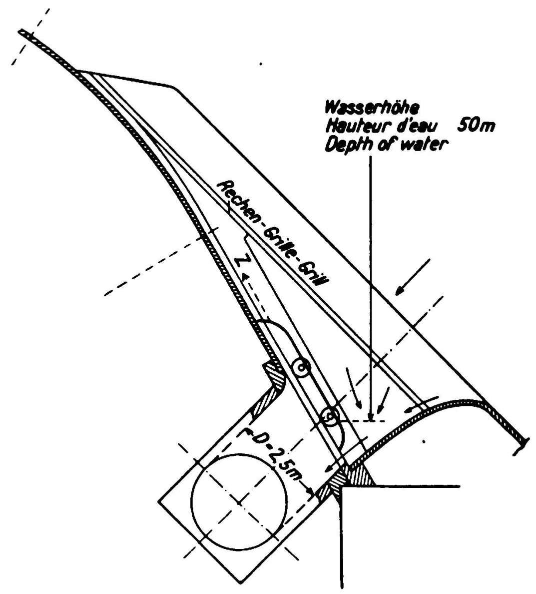

Fig. 9.

working in the laboratory with very considerable pressures in order to enable the transition to be made to full scale. The illustration (Fig. 10) shows the under water gate used in the Odertal dam in the Harz mountains, which is designed to withstand a head of water of some 50 m. As the weir is required closed under its own weight when subject to the full pressure of water, very extensive experiments were necessary to determine the design of the weir and of the structure as a whole.

The contest with vibration, and the study of the effects of moving water which it entailed, has had yet other repercussions on design, for these are factors which influence not only outward arrangement of the design but also its detailed dimensions. Flowing water must always be opposed by a definite mass, but the possibility suggests itself of reducing the moving masses in movable weirs by more suitable construction or by the use of high grade materials. Considerations of cost either of the construction or of the electric current required for operating the weirs should not be allowed to interfere with such developments, for in weirs where such operation is seldom required this factor is of no importance, and in the cases of sluices or lifting gear the same consideration applies. The choice of St. 52 as a material would not appear to be very appropriate in the construction of weirs unless special local considerations make it necessary, for the elasticity and therefore the tendency to vibration become greater in structures where this is used. The permissible stresses, moreover, should not be as high as in ordinary steel work, having regard to corrosion. For instance in steel applied to hydraulic engineering St. 37 should not be stressed in excess of 1200 kg/cm².

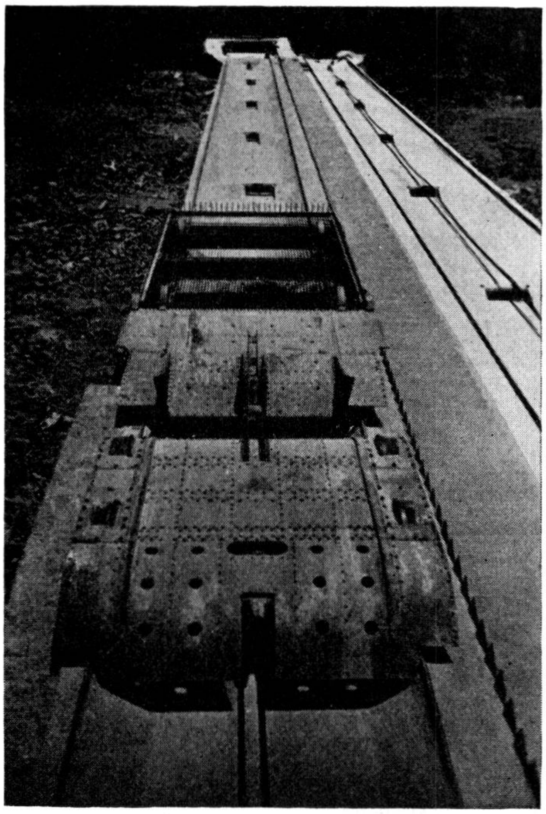

Fig. 10.

Finally, a few illustrations from workshops and finished weirs may be given as indications of the magnitude now attained by steel structures in application to hydraulic work. Two of these examples will be drawn from the numerous large weirs on the Main and Neckar canalisation. Firstly Fig. 11 shows a barrage with three-boom framing and fish-bellied shutter for the installation of Faulbach in the Main-River during the process of erection. This barrage 35.0 m weir width and 6.7 m high, of which 1.60 m is taken up by the movable member. Among the Neckar weirs the installation at Heidelberg (Fig. 12) is especially notable, both on account of the pleasing way in which it has been incorporated in the landscape of the

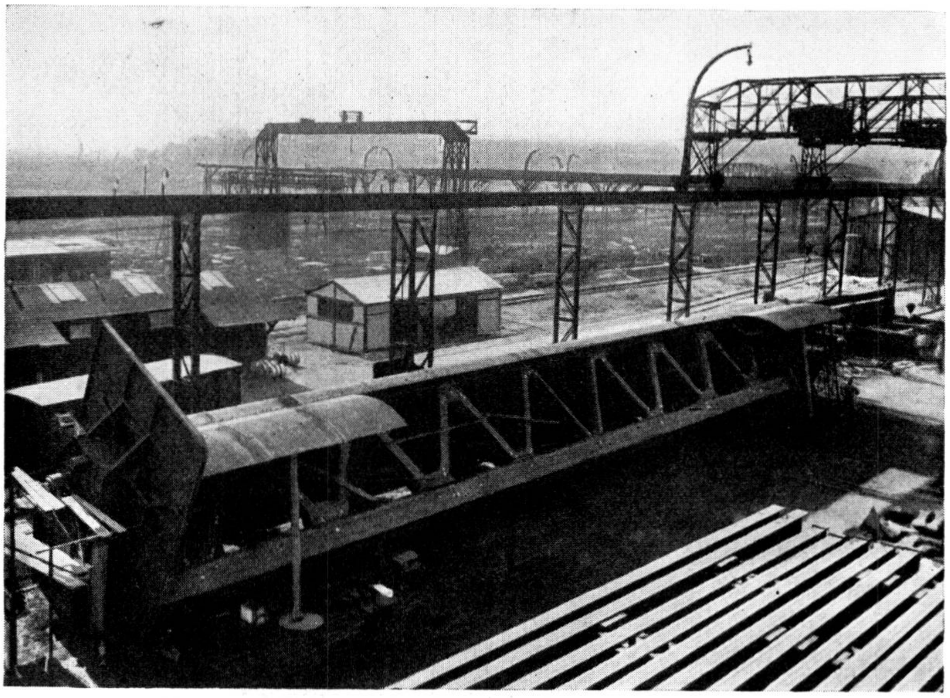

Fig. 11.

town — here so important — and on account of its dimensions. The three rollers at Heidelberg, for a retained head of only 4.10 m, have a clear width of 40.0 m and can be dropped through a depth of 0.60 m.

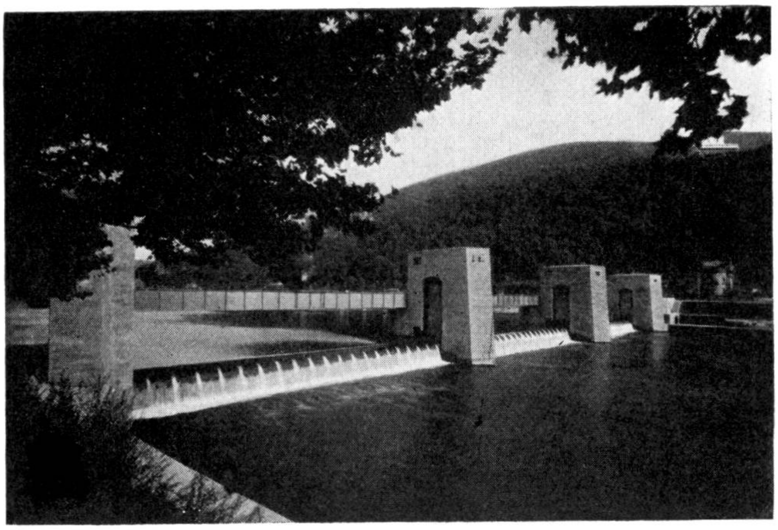

Fig. 12.

Fig. 13 shows an example of a roller weir in course of construction, intended for Solbergfoos in Norway; one of the three rollers is shown in course of being

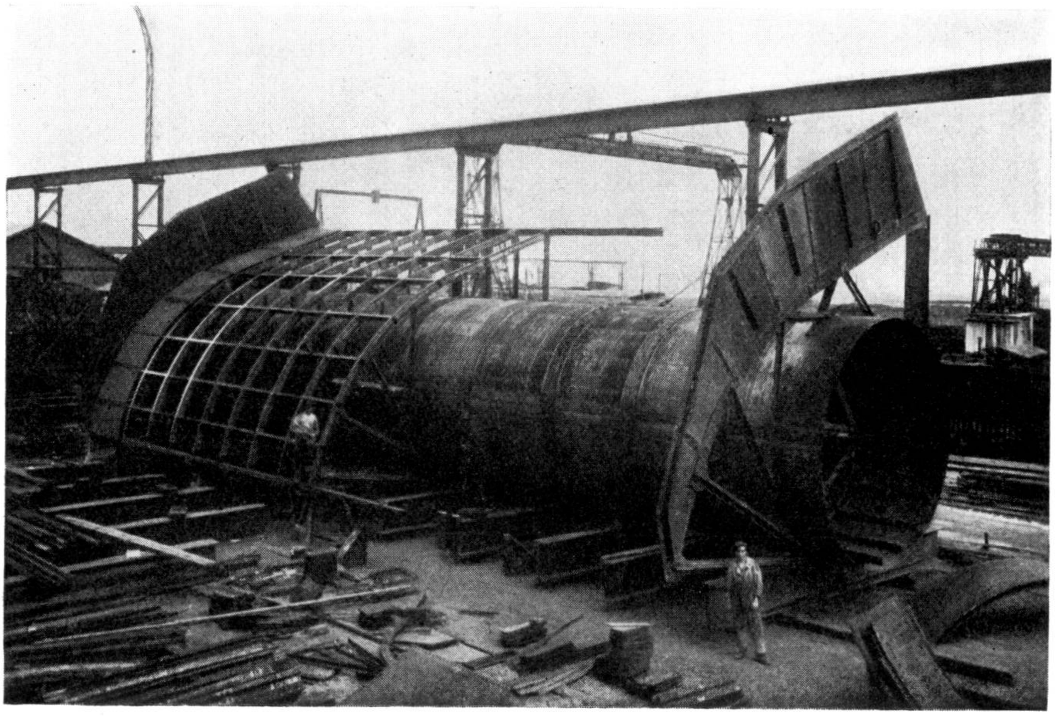

Fig. 13.

erected in the workshop. This method is economical as in the case of all roller weirs where large heads of water are to be retained and where the widths are relatively small. For instance the installation at Solbergfoos will have three rollers each of 20.0 m clear width with 8.75 m retained depth (Fig. 14).

The Ryburg-Schwörstadt installation has already been cited as an example of large weirs with double shutters or "hook gates". The M.A.N. double gate has

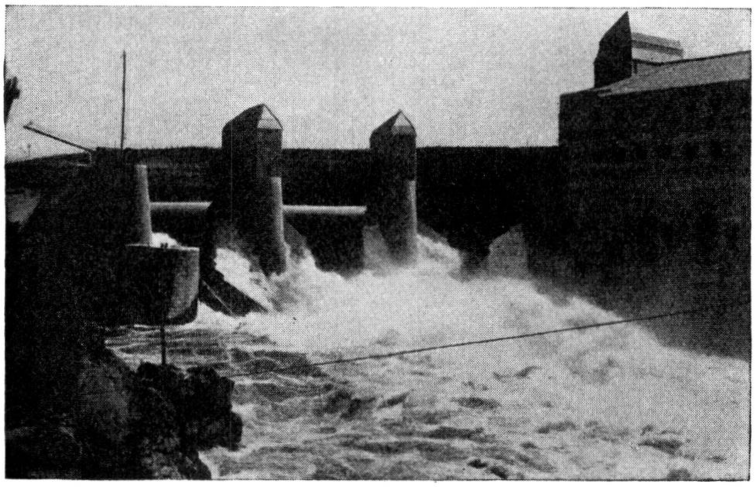

Fig. 14.

also been adopted in the large weir installation at Donau-Kachlet, which has six such gates of 25 m clear width and 11.5 m height, this being one of the largest installations anywhere in the world. Finally Fig. 15 shows the installation at

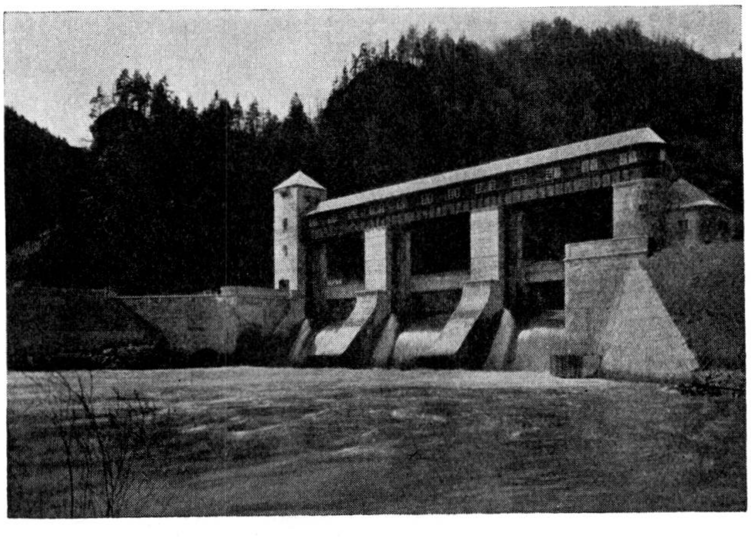

Fig. 15.

Pernegg in the Mur district, which again is a good example of the way that modern barrages are made to blend with the landscape. This includes three double openings measuring 15.0 m by 11.60 m. The extent that the double gates can be dropped amounts, as a rule, to one quarter of the total height, but the "hook gates" can be sunk as much as one third of the total height.