IId. Influence of concreting and dilatation joints

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Influence of concreting and dilatation joints.

Einfluß von Betonierungs- und Bewegungsfugen.

Influence des reprises de bétonnage et des joints de dilatation.

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IId 1

Reduction in Shrinkage and Expansion Stresses by the Systematic Use of Concrete Joints. — Application to the Philippe de Girard Bridge, Paris.

Verminderung der Wärme- und Schwindspannungen durch systematische Anwendung von Betonierungsfugen. — Anwendung für den Bau der Philippe de Girard-Brücke in Paris.

Diminution des efforts dus au retrait et à la dilatation par l'emploi systématique de reprises de bétonnage. — Application au cas du pont Philippe de Girard, à Paris.

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The Philippe *de Girard* bridge, crossing the railway tracks outside the Gare de l'Est at Paris, consists of a concrete arch of 41 m opening (Fig. 1). The metal centreing was not erected underneath the arch but inside it, and later embedded in the concrete — an arrangement that was necessary in order to allow the passage of traffic while work was in progress.

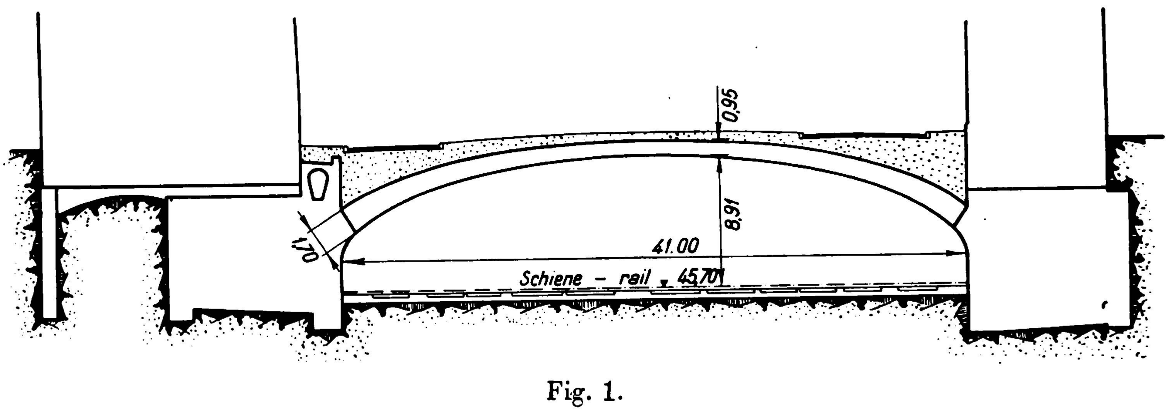

Fig. 1.
Philippe de Girard Bridge. Cross section.

The design of the arch was first attempted with due allowance for shrinkage on the assumption that the effect of this could be represented by a variation of temperature of 27° C. This implied considerable fixing moments at the springing, amounting to something of the order of 350 tonne-metres per m width of arch, and a considerable amount of reinforcement would have been necessary to resist them (Fig. 2). Such a design would have been complicated by the need to accomodate the reinforcing bars in the spaces left free by the ribs and bracings carrying the arch (Fig. 3), and the cost of the work would have been considerably greater in consequence.

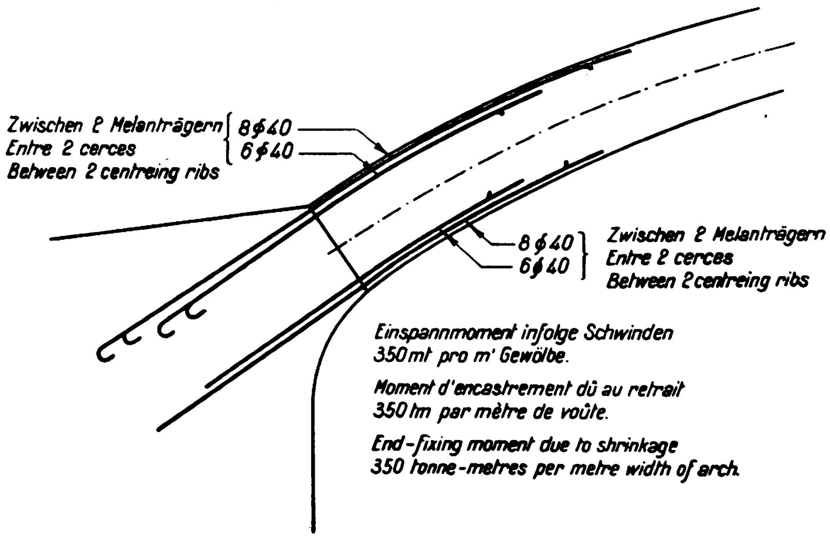

Fig. 2.
Section through haunch.

Ultimately, however, it was found possible to avoid the need for reinforcement by reducing shrinkage to a minimum, this being done by taking advantage of the fact that most of the shrinkage associated with the drying of the concrete occurs

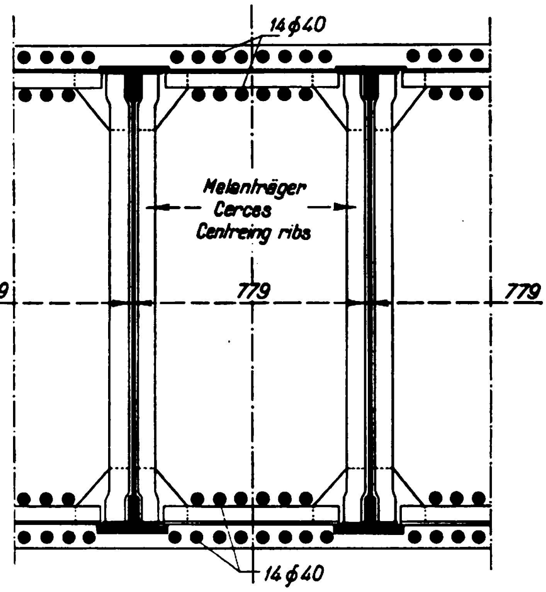

Fig. 3.
Section of arch.

when it first begins to harden: instead of pouring the whole of the arch in a continuous operation the latter was divided into voussoirs (Fig. 4), and these were concreted separately at a sufficient interval to allow of shrinkage taking place in each voussoir independently: in other words no concrete was placed in any given voussoir until a definite time had elapsed after completing the adjacent ones, during which the greater part of the shrinkage might be assumed to have occurred.

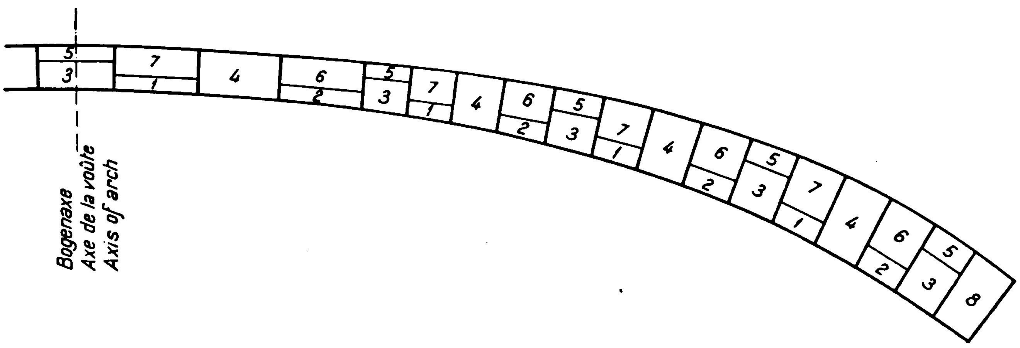

Fig. 4.
Sequence of concreting the voussoirs.

Moreover, the final closing of the arch at the haunches was delayed until the last voussoir was old enough to justify the assumption that its shrinkage had been practically finished.

By suitably planning the sequence of concreting on these lines it becomes possible considerably to reduce the effects of shrinkage, to lighten the construction, and to reduce its cost.

IId 2

The Effect of Concrete Joints.

Einfluß von Betonierungsfugen.

L'influence des reprises de bétonnage.

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This effect has two principal aspects:

1) its effect on strength, and

2) its effect on weather resistance, water tightness, rust protection, etc.

The answer to the problem is essentially a practical matter and can never be reached entirely from considerations of theory; neither is any definite solution to be expected from laboratory experiments.

There is no uniformity of opinion among reinforced concrete engineers on this very important question, and the differences of opinion that exist find expression also in the regulations as to the treatment of construction joints that operate in various countries; regulations which may be looked upon as condensed experience. On this matter they all agree to the extent of requiring that the joints should be cleaned, roughened and wetted, and in reference to subsequent treatment they may be divided into two categories.

The first category — which includes Germany, Austria, Holland and Czechoslovakia — prescribes after-treatment on these lines: immediately before the new layer of concrete is placed a thin layer of mortar of the same composition as the mortar in the concrete is to be laid down; or in Italy the joint has to be wetted with cement grout.

In the second category — which includes France, Belgium and the United States — no such treatment is required.

As regards the French and American regulations, it would not be correct to speak of this matter having been overlooked but it should rather be assumed that the requirement has deliberately been omitted — and, in the present author's opinion, rightly so.

It may well be the case that when a thin layer is deposited the presence in it of a considerably higher proportion of cement than in the concrete itself may somewhat strengthen the bond, but on the other hand in placing this rich layer encouragement is given to the lifelong enemy of concrete, namely "shrinkage". Even if no overwhelming indictment can be sustained against a really thin layer, it will in most practical cases be impossible to deposit this uniformly over concrete which has already hardened, and usually it is necessary to be content with pouring the mortar or the cement grout from some distance away, through the reinforcement, onto the concrete already in place, making it impossible to avoid the collection of rich mortar at certain points which later show much more intense shrinkage than the normal concrete in the structure. Several instances are known to the author where, on the shuttering being struck, such layers spalled right off, so that with a pocket knife it was possible to scratch out long flat flakes which were glass hard in themselves. In this way the cure is worse than the disease. As a rule there is no great evil in a slight reduction in the bond, because in most cases concrete serves to transmit compression, and between two surfaces which are completely in contact with one another this is possible even without any bond at all.

In exceptional cases where the tensile strength of the concrete is taken into account it is always better to avoid the presence of concreting joints altogether — or, should this be quite impossible, to insert steel at the place where the joint occurs. As regards shear stresses, it is to be observed that the joints should be arranged at the point of minimum shear (a requirement specifically laid down in the American regulations), and further that it is now almost the universal practice for the whole of the transverse principal tensile stress at places where heavy shear loads occur to be taken by steel, so that even in this case only purely compressive stresses in the concrete come into question. In small jobs, provided ordinary care is taken (by roughening, cleaning, and wetting) the presence of a working joint in the concrete need cause no diminution in strength.

The problem of working joints in concrete is frequently affected by considerations other than those of strength which may be of great importance to the engineer: as, for instance, the questions of weather resistance and water tightness. It is well known that the denser the concrete the better its resistance to atmospheric influences, and the greater possibilities of weathering in a joint in the concrete can be attributed only to the smaller density at the joint, seeing that mechanical properties of the cement and aggregates are the same as elsewhere. Assuming that both masses of concrete are weather resistant, it is not a matter for apprehension that a small opening for attack may exist at the joint for all it means is that the neat surfaces in question are exposed like all neat surfaces to accelerated weathering. What may be dangerous, however, is a relative lack of density in the lower layers of the lift of concrete deposited last in order such as may result from improper workmanship. Apart from the usual unmixing process which occurs through the coarse aggregate falling to the bottom when the water content is too high (a matter to which insufficient attention is paid in most jobs at present) there may be a further weakening through loss of the fine materials for the first layers in the course of transport owing to the means of transport being in a cleaned condition. Such loss may be very considerable, but provided the necessary precautions are taken to avoid this defect, the presence of a working joint in the concrete is not attended by any risk whatever even as regards length of life.

There is not always complete assurance as to the water tightness of a joint in the concrete even if the work has been carefully done, particularly where heavy hydrostatic pressures occur as, for instance, in cellar work. Where the precautions against unmixing are adequate it is desirable to place as large a mass of concrete at one time as possible. But often it is not possible to erect the shuttering to above the water line, and in any case there nearly always has to be a joint in the concrete between the floors and the walls. The many large and deep cellars which have been constructed in recent years in Rotterdam have offered opportunities for studying this circumstance more closely, and have led to the conclusion that if the work is in other respects carefully carried out any lack of watertightness at the joint in the concrete is to be attributed to shrinkage.

In one of the earliest of the large cellars it was found that despite the great thickness of the walls, and the exceptional care taken to roughen and wet the joints and to cover them with a thin layer of mortar, the walls of the cellar became leaky at several places.

In a structure built shortly after this the cellar was formed of thinner but heavily reinforced walls, and special precautions were taken to ensure good watertightness by incorporating in the joints a continuous thin steel plate, in addition to extra shear reinforcement. In this way it was found possible to make the construction joints in the concrete quite watertight, but the method is attended by practical difficulties. The large amount of steel, including the plate, present in the middle of the surface to be cleaned, made it difficult to clean out the joint completely. The same objections arise to the method recommended in the American regulations in which the lower portion of the concrete is required to be dovetailed, and it is obvious that in heavily reinforced cellar work the execution of this dovetailing would be attended by great difficulties. Where such a method is suitable, however, it offers the advantage that the risk of shear is eliminated without necessitating extra reinforcement. At a later stage the method depending on the use of a steel plate was no longer applied, but in spite of this it was found possible to make large cellars, poured in lifts 1 to 2 metres high, completely watertight without the need for any subsequent treatment.

In Rotterdam all these cellars are founded on piles which have their heads in very yielding ground, with the result that the floor of the cellar carried on them has complete freedom to move. No cracking ever occurs in these floors.

If no special precautions are taken, the floor already deposited will have undergone a very large percentage of the total shrinkage to be anticipated in it during the time required for erecting the shuttering, placing the reinforcements and depositing the concrete on the next lift, and in the first few days after the new lift has been placed the old concrete will shrink considerably less than the new. It may be assumed that at the end of two weeks the shrinking will attain to 0.2 $^0/_{00}$, after four weeks to 0.3 $^0/_{00}$, and if the two layers are poured at an interval of two weeks there will, therefore, be a shear stress in the joint of the concrete, corresponding to a difference in length of 0.1 $^0/_{00}$. In very stiff construction of somewhat larger dimensions, the effect must necessarily be to displace one layer of concrete relatively to the other, and with greater dimensions still the tensile strength of the fresh concrete may be exceeded, with the result that vertical cracks will be formed at regular distances originating at the joint in the concrete. These cracks must necessarily be accompanied by horizontal cracks in the joint itself, due to the relative displacement of the layers, in exactly the same way as when the steel is loose in concrete subjected to tension. The presence of such cracks has, in fact, been confirmed, as is shown in the attached illustration which refers to two cellars approximately 25 m long wherein the cracks occurred in the walls at each end. At the joints they were as much as 1 or 2 mm wide, diminishing gradually upward, and it was established when the cellar was filled with water that horizontal cracks also occurred (although they could not be noticed with the naked eye) at the concreting joints on either side of the vertical cracks.

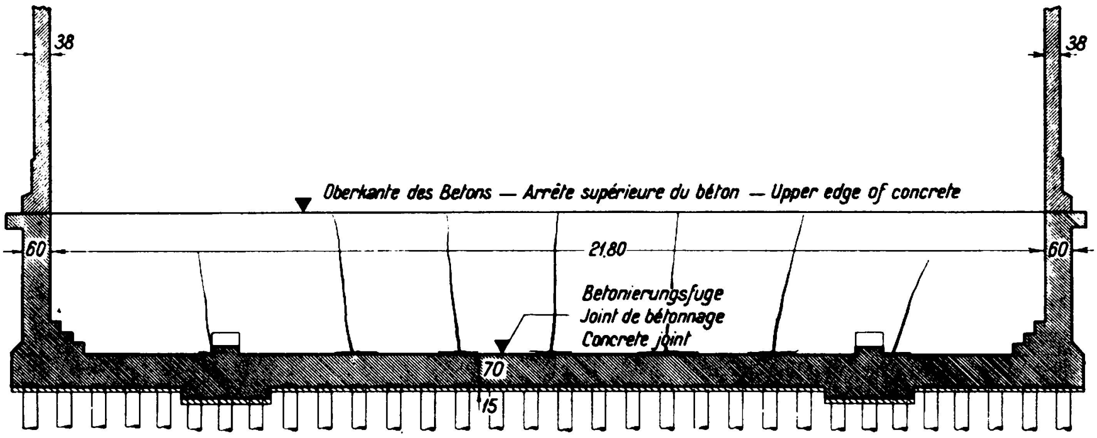

Fig. 1.

The proper precaution to take is, therefore, to let one stage of the work follow upon the other as quickly as possible, and to avoid shrinkage of the portion already deposited as much as possible.

In the construction of two cellars having exactly the same dimensions as those in which the cracks mentioned above occurred, using the same brand of cement and the same concrete mix, this principle was followed with notable success: the layer deposited first was not merely wetted just before the second layer was added but was kept sodden throughout the whole period from its production to the deposition of the next layer. An alternative (which is quite feasible in the case of the floor, for instance) is to keep it under water.

Conclusion.

In small jobs a joint in the concrete need have no effect on the safety of the structure, provided ordinary care is used. In large and stiff structures precautions must be taken to avoid irregular shrinkage, or where this is not possible, to combat the consequences of the latter.

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