Effect of petrographical properties of aggregates on the strength of concrete

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Effect of Petrographical Properties of Aggregates on the Strength of Concrete.

Einfluß der petrographischen Eigenschaften der Zuschlagstoffe auf die Betonfestigkeit.

Influence des propriétés pétrographiques des matériaux additionnels sur la résistance des bétons.

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Arising out of the papers published in Section IIb of the Preliminary Publication of the Congress, it would appear useful to refer to some straightforward but characteristic series of experiments on concrete which have been carried out in the Materials Testing Laboratory of the Technical Faculty of the University of Ljubljana in Yugoslavia, with a view to closer investigation of the stone found in large quantities within the jurisdiction of the Banat of Drave, from the point of view of its suitability for making high quality concrete.

The district in question lies at the north west corner of the country and includes the eastern chains of the southern limestone mountains in addition to the northern or Carinthian region of the Dinaric Alps. From these orographical characteristics it will be at once apparent that the whole region contains mainly limestone with some dolomite. In the central Drave valley and in the transition to the eastern central mountains there exists, however, a fairly pronounced massif of foothills known as the Pohorje which consists mainly of primary rocks, and which in addition to some softer sedimentary rocks contains an excellent plutonic rock known as *Tonalite*, which is a special form of diorite and is typical of the boundary region between the central and southern alps. This rock differs from granite in having a smaller quartz content, varying between 16 and 31 %; its main constituent is plagioclase. The stone is uniformly of medium to fine grain and is well compacted.[1]

In the alpine chains there occur porphyritic intrusions, notably *Keratophyr*, which are intermediate in quartz content between the granitic and syenitic groups, and are classed as magmatic rocks; these show a fine porphyritic structure. In the spurs of the alps which form the boundary of the Panon plain many veins and blocks of andesite occur; here again the main constituent is plagioclase with occasional grains of magnesite and volcanic glass. The structure varies from fine-grained to amorphous, and as a result of the low degree of crystallisation and of

[1] This and all the following mineralogical and petrographical details have been supplied through the great kindness of the Mineralogical-Petrographical Institute of the University of Ljubljana under Professor *V. Nikitin*.

the presence of the volcanic glass the stone is fairly brittle, but apart from this it must be regarded as a good material which is suitable for the purpose named.

In the past, use has been made not only of these local magmatic rocks but also of a basalt, found in the Lavan Valley of Carinthia in immediate proximity to the Yugoslav frontier, although in Austrian territory. The existence of favourable railway connections has made possible a fairly extensive use of this material in Yugoslav territory; the stone shows the usual characteristics of a material of normal quality, is very uniform, and has a fine grained structure.

These four kinds of magmatic rocks were the subject of the experiments mentioned above, and two further limestones and two dolomites were examined at the same time for purposes of comparison. The first of these limestones comes from the northern edge of the Carinthian region at Verd, south of Ljubljana; it is a palaeozoic material with a fairly high content of silicate admixtures. The second limestone comes from Trbovlje and belongs stratigraphically to the trias formation; it is mainly pure and contains only very small admixtures. The two dolomites also come from triassic strata in the foothills of the eastern alps, and differ only as regards their origins at Trbovlje and Senovo respectively.

The sand and small material obtained from these rocks was put together as far as possible in accordance with *Fuller's* sieve curve. In the tonalite, and in one series of tests with basalt, pure quartz sand of less than 1 mm gauge was added as a filler. High grade cement to the following specification was employed: —

At two days 27 kg/cm^2 tension, 377 kg/cm^2 compression.

At seven days 36 kg/cm^2 tension, 636 kg/cm^2 compression.

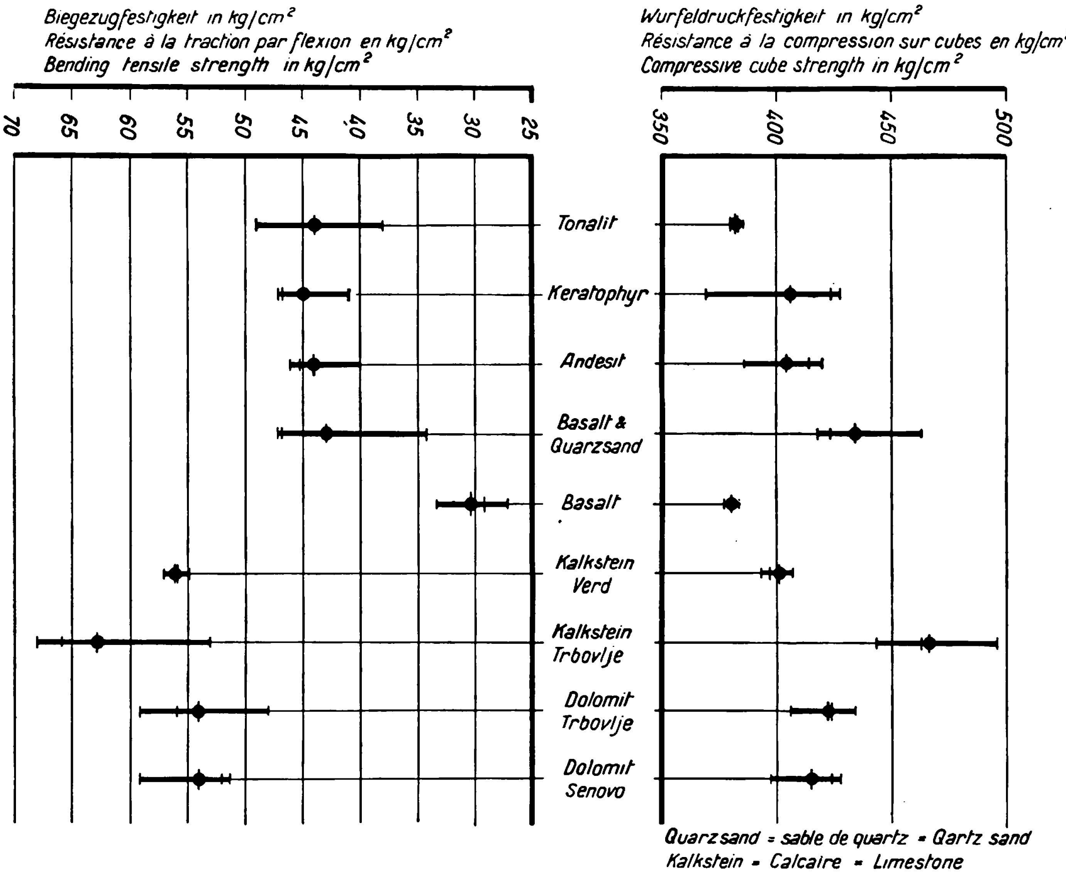
The test specimens were prepared in accordance with the Yugoslav standards using the *Tetmajer-Klebe* tamping apparatus.

The cement admixture of 400 kg/m^3 of concrete was made with a water-cement ratio of 0.5; and the consistency was further controlled by the American slump method, in order to ensure the greatest possible uniformity of the concrete made with all kinds of stone.

From the wide range of experiments carried out with these materials, only the cube and bending strengths at 28 days are given below, in a graphical form for the sake of convenience in perusal. Despite the relatively small scope of the statistical data, the following conclusions may be drawn:

From the point of view of compressive strength no appreciable difference is disclosed between the concrete made with magmatic rock and that made with calcareous rock, most of the average values being 400 to 450 kg/cm^2 and the deviations from the average being for the most part less than 10 %, or in many of the series of experiments inappreciable. The diagram of tensile strength is more instructive: the tensile strengths of concretes made with magmatic rock all lie close to the average value of 45 kg/cm^2, whereas it is clearly apparent in the case of the limestone groups that the tensile strength averages close to 55 kg/cm^2. Even the relatively large scattering of values for the bending strength here obtained cannot impair this interesting indication, and the minimum strengths in the calcareous groups are also noticeably higher than the maximum strengths in the magmatic groups.

A further interesting comparison may be made between the strength of the concrete made from the Verd limestone and that made from the Trbovlje limestone. The whole of this region, the geography of which was explained at the beginning of this note, lies in the region of contact between the Alps and the Dinarides. Owing to the orogenetic processes which are known to have taken place there the earth's crust has been violently compressed, and this is clearly apparent in the microscopical structure of the rocks in question. They all show consequences of such pressure having been exerted in a variety of orientations, and throughout the region the cohesion of the stone depends to a large degree on whether this orogenetic pressure has been exerted on it from all sides at a great



depth or whether, on the other hand, it has been the result of later infiltrations of calcite into the cracks and cleavages by a secondary process. The Verd limestone being older, and having clearly been produced in lower strata by pressure in addition to having undergone this secondary infiltration of calcite, is better bonded and much more uniform than the Trbovlje limestone, but on the other hand the latter is a good deal purer. This is the probable explanation of the higher strength obtained in the latter material and also of the greater scattering of values both for compressive and bending strengths. The diaclase apparent in its micro-structure shows every sign of having been a further disturbing cause in the coherence of the concrete mass.

In spite of this lack of uniformity, it seems justifiable to conclude that calcareous rocks offer a higher degree of adherence for cement mortar than is afforded by the otherwise stronger magmatic rocks, and the result of this is a higher tensile (though not compressive) strength in the concrete for which they form the mineral skeleton.