MUNICIPAL DEPARTMENT

CEMENT-CONCRETE CULVERTS*

Cement-concrete can hardly be called a new material, for there are viaducts and pavements still in existence which were built by the Romans 2,000 years ago. Its manufacture, however, had until about thirty years ago been numbered among the lost arts. It is of a still more recent period that it has been commonly employed, particularly in Canada.

There is a very general impression among municipal councillors with whom you have to deal that it is too expensive. Councils, nevertheless, are outgrowing that idea, and in one part of the province and another I find waterways of six to eight foot span, built of stone, brick and concrete, at a cost of from $500 to $1,000. The old wooden structures which they replaced may have cost in the first instance only $50, but they were perishable, constantly in need of repairs, an impediment to travel, at times dangerous, and the trend of feeling is towards more permanent and serviceable work.

The limit of span in which concrete can be used is probably quite equal to that of stone arches. This will remain, for the most part, a question of economy in highway work, and its use will show where the steel bridge with concrete abutments steps in. The line is not definitely drawn for all cases, but up to 40 feet the least expensive kind of cement-concrete can be used in arches, and certainly up to that point its use is quite feasible. For the longer spans, arches of the Melan type are being used in the United States and Europe—that is, concrete re-enforced by a skeleton of steel

Arches of concrete may be designed by the formulæ used proportioning arches of stone masonry. But the determination of the line of resistance and theory of the arch, as applied to stone, cannot be applied to concrete arches. The stone arch is designed on the principle that it will remain in place without the use of mortar; while the concrete arch, on the other hand, is a monolith dependent on its cohesive strength points, it appears to me to the necessity of a generous proportion of cement, very great care in mixing the concrete, and the best quality of all materials employed.

My meaning with regard to the proportion of cement can be better understood by glancing over the composition of concrete. A concrete can best be regarded as a mixture of mortar and broken stone, the mortar being formed from a mixture of sand and cement. Given a sample of broken stone in a vessel, the requisite quantity of water can be gauged by pouring water into the vessel until the stone is submerged The quantity of water used will indicate the amount of mortar required to completely fill the voids in the stone. The proportionate amount of cement needed to fill the voids in the sand can be gauged in the same way. The proportions of cement, sand and broken stone obtained in this manner would provide, with perfect mixing, a mortar of which the voids in the sand are filled with cement, and each particle of sand coated with cement; it would provide a concrete in which the interstices of the stone are filled with this mortar, and each stone coated with mortar. This would be the case with perfect mixing, and would provide a theoretically perfect concrete. Perfect mixing is not possible, however, and it is necessary to provide an amount of cement in excess of the voids in the sand, and an amount of mortar in excess of the voids in the stone. With proper mixing and good materials, a satisfactory concrete for bridge abutments can be framed from cement and broken stone in the proportion of one, three and four. But it is recognized that the greatest strength in concrete can be obtained by making the mortar rich in cement, rather than lessening the quantity of stone. This applies to crushing strength, however, rather than to the tensile strength required to some extent in the arch. For the arch proper it will be well to use a rich concrete, in say the proportions of one of cement, two of sand, and three of broken stone. With small arches there will be little economy in changing the proportions of the abutments.

The cost of the abutments may be lessened, where they are of sufficient thick-

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*From a paper read by A. W. Campbell, C. E., Ontario Good Roads Commissioner, before the Association of Ontario Land Surveyors.