will be observed that the mixture used in these tests was a rich one, corresponding roughly to a 1: 2: 3 mix by volume proportioning. Yet, with such a mixture, strength as low as 700 lbs. per square inch, and as high as 4400 lbs. per square inch are obtained by simply varying the quantity of the mixing water. Other workers, as well as Prof. Abrams, have shown the detrimental effects of the use of too much water in concrete mixtures, but Prof. Abrams has gone into the matter very fully indeed. The writer is at a loss to understand how it is possible to make the mixtures up in all this water. If cement were a material like glue which could be thinned down to an extreme degree and hold all the water added, a continuous reduction in strength would be expected, as the amount of cement in a given volume of mix was gradually decreased, due to its replacement by water; but since water is rejected from concrete mixtures, even when plastic consistencies are used, the limit at which any additional water is thrown off surely must be reached at a percentage of water only slightly more than is present when the mix is in a plastic state.

On making up neat cement paste with different percentages of water and allowing the paste to set, the writer has observed that water is rejected by the paste before a very wet consistency is reached, and it would not seem possible to make the cement hold more than a very limited amount of water unless the cement were prevented from setting by being beaten up into a collodial state, in which form it would of course take up large quantities of water. But for ordinary method of mixing by hand, the writer has been able to obtain only a slight variation in the amount of the cement required to make a cubic foot of paste. It is hard to see how Prof. Abrams gets cement paste into the condition he speaks of in which the cement particles are so far thrust apart by the water that there is no cohesion between the particles, and the mass offers no resistance to stress. This is a matter which I am sure has not been clear to many readers of his work.

About the same time some work was published by Capt. Edwards, of Toronto, who had been working on a "cement to surface area idea. See Figure 8. In these tests Capt. Edwards endeavored to always have the cement at normal consistency and used an amount of water to guage the sand which was always a certain proportion of the surface area of the sand. In this way he was able to eliminate to a degree variations due to the consistency factor. He found that when he kept the ratio cement to surface area constant, he obtained practically the same strength for all sands tested. On examination of the figures in the table originally published, it is evident that another reason why his strengths were all the same is that the water to cement ratio of the mortars is constant.

So that it would appear that his work is in complete accord with that of Prof. Abrams.

It seems to me that a considerable amount of the poor concrete work poured in this country has been due to the use of pit run gravel. Most samples of pit run material which have come to my notice have contained at least 55% fine aggregate which will pass a ⅛-in. screen. The effect of the sand content on the strength and density of concrete is shown in the table on p. 421. Note increase in density and strength when sand content is reduced. One class of material was used throughout these tests. The strength is proportional to the density only when the materials are the same for the mixes compared. It is obvious that the bond of cement to a rough surface aggregate would be greater than in the case of a smooth, polished material.

The limit in the reduction of a sand content is dependent on the workability of the mix. The mix must not be too stony or it will be hard to place, and will cause the production of stone pockets devoid of mortar; but as much stone should be added as possible consistent with the production of a workable mixture. The amount of cement to be used depends on the class of work. If strength is the primary consideration, sufficient cement should be used to give the desired strength as determined by making up compression specimens with various percentages of cement; bearing in mind also that the mixture must contain sufficient fine material to make it smooth working. If strength is a secondary consideration, some of the cement can be substituted with a fine sand or dust to supply the necessary amount of fine fattening material, thus giving workability to the mix and economizing cement. Although such fine dust cannot be considered in any degree as a substitute for cement, its presence in a concrete mixture provides the necessary effect of richness in the mix, minimises the risk of the formation of stone pockets, helps to hold the cement evenly distributed throughout the mix and makes it possible to make workable mixes with a less ratio of water to total dust cement. If lean mixes are poured without the addition of such fine dust, the amount of cement paste or lubricating medium in the mix is small. To make such mixes flow into corners, excess water is usually added. The excess water tends to wash the sand grains free of cement and the result is a mass of concrete full of porous areas.

It has been pointed out by Mr. Feret that for a 1:3 mortar the highest density and strength was obtained when the granulometric composition of the sand was about 80% coarse grains and 20% fine grains. It is obvious that in a richer mortar, such as a 1:2, for the same density the amount of fine material in the sand must be reduced or the coarse increased. In fact it is generally agreed that in practical concrete mixtures, when mortars as rich at 1:2 are used, no fine sand or dust is necessary either from the point of view of strength, density, or workability.

It has been pointed out by Wm. B. Fuller, in his chapter on concrete proportioning, that a finer sand is permissible in the case of a concrete than in a mortar. Dividing a sand into three grades (by Mr. Feret's plan) coarse, medium and fine grains, for maximum strength and density, we require a high percentage coarse grain and in the case of a rich mortar very little fine grains, and preferably no medium grains. In the same way, grading a concrete on three corresponding screens, the stone portion now corresponds to the coarse part of the division. The coarse grains of sand become the medium grains in the concrete. It would therefore appear that a finer sand would be used for a concrete than would be indicated by making tests on mortars. It is pointed out that by using a mortar with a relatively fine sand the small voids in the stone portion of the mix are more readily filled with mortar than in the case of a similar mortar with coarse sand; the coarser particles of the latter getting between the stones and thrusting them apart, and decreasing the density.

But the following facts must also be borne in mind: the mortar with the finer sand is less dense than that made with the coarse sand, thus offsetting to a certain degree any benefits to be gained by the use of the finer material. Also that in practical concrete an excess of mortar is usually used, so that the condition where the use of a coarse sand will thrust apart the stone portion of a mix to a greater degree than the same bulk of finer sand is not usually met with. The influence of the grading of the fine aggregate or sand on the volume of mortar produced from the same proportion of cement to sand using sands of different grading, is well illustrated by the curves in Figure 5.

It is obvious that the sand marked "Indian Bay Sand" will produce concrete of greater bulk or less density than, for example, will the coarse sand marked "Sand from Lake Francis gravel." This is especially the case when excess mortar is used in the concrete.

As far as is known at present, the best way to secure concrete which will resist alkali attack is to use a mixture relatively rich in cement, with a carefully selected aggregate. In the case of a rich mix the aggregate should contain as little sand (and that preferably of a coarse nature) and as much stone as possible consistent with the production of a workable concrete. In this way we have a rich mortar produced. The ratio cement to surface area of aggregate is high with such coarse material, thus producing a very strong and impermeable concrete. As little water as possible should be used in the mixing and the concrete should be thoroughly spaded and worked to enable entrapped air to escape and to work the mortar into all pockets in the

(Concluded on page 429)