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Practical Application of Surface Area Method

Of Proportioning Materials for Concrete, as Used by the Hydro-Electric Power Commission of Ontario—Economy of Different Aggregates Can Be Compared, as Workability and Strength, Formerly Variables, Are Now Reduced to Constants

By RODERICK B. YOUNG
Engineering Materials Laboratory, Hydro-Electric Power Commission of Ontario

CERTAIN fundamental considerations must be borne in mind in developing any method for proportioning concrete. Each element of a structure is designed to perform certain work, to accomplish which it must be constructed of materials having physical and mechanical properties at least equal to those assumed in the design, in order that the safety of that structure will not be endangered. Concrete is no exception, and therefore any method of proportioning, to be satisfactory, must be capable of producing concrete of the class required by the design of the structure in which it is being used.

This is not, however, the only requirement which has to be met in practical proportioning; other elements enter which must be taken into account. The materials vary from day to day, and these variations should be provided for with a minimum of interference with field operations and methods. Account must also be taken of the fact that the same consistency is not universally applicable, because different conditions, even on the same piece of work, may require concretes of different plasticity. The method must, therefore, permit of obtaining mixtures of any desired plasticity, and do this without sacrificing the quality of the concrete.

The attitude of the field engineer and contractor toward any method of proportioning to which he is not accustomed, must be borne in mind. The type of man found in construction work has, of necessity, a practical turn of mind, and is ordinarily impatient of involved methods. His business is to obtain results at a reasonable cost, and he is interested only in those methods which will do this with some certainty. He resents being hedged around with restrictions which hamper his operations, if reasons for these restrictions are not apparent. Therefore, any method to be applicable to field conditions must be simple in theory and easy of application. No other method, however complete and meritorious it may be, will get his support, and without his support it is impossible to get results.

Field Conditions Are Considered

In the method of proportioning developed by the Hydro-Electric Power Commission of Ontario, an attempt has been made to take these features into account. The method combines simplicity of theory, the requisite flexibility to fit field conditions, and a certainty of results. Its basic principles have been subjected to extensive experimental investigation and found sound.

In the finished concrete, strength is usually the prime consideration and is thus taken here. During construction another property is demanded of the concrete, and that is workability. The concrete must be sufficiently plastic and mobile to be handled and placed properly. Economy of materials and labor must also be considered. Other factors enter, but primarily the problem of proportioning concrete materials is to obtain in the most economical manner a workable mixture which will produce, in the specified time, concrete developing the required strength.

The binding material of a concrete is the product of the union of cement and water, which, before it can combine, is mixed to form a cement paste. This paste is used to coat the surfaces of the particles of aggregate, forming a film of cementitous material about each particle which binds the whole mass into one unit. The strength of this bond and therefore of the mass depends largely on the quality of this cement film, and this is, in turn, dependent on the concentration of the cement paste.

The quantity of paste which is required to bind any given mass of aggregate depends upon the quality of the paste, the mobility of the mixture, the combined surface areas of the particles of aggregate and, to some extent, on the character of their surfaces. However, with a given aggregate, if the quality of the cement paste and mobility of the mixture are fixed, the quantity of paste then becomes a function of the surface area of the aggregate.

Applicable to Workable Mixtures

The foregoing is closely analogous to paints and painting, for the service or protection given by a paint depends, generally speaking, upon its quality, while the quantity required for any particular job depends upon its "covering power," the area of the surface to be painted, and the character of that surface. This analogy has been found very useful in explaining our methods in the field.

It was first noted by Professor Abrams, as the result of his experiments at the Lewis Institute, that, within the range of workable concrete mixtures, the compressive strength of a concrete bears a very definite relation to a value which he has called the "water ratio" of the concrete. The "water ratio," or "water-cement ratio" as we prefer to call it, is the ratio between the volume of water and the volume of cement contained in the concrete mixture; or in other words, it is a measure of the concentration or quality of the cement paste.

Abrams has shown that for any given set of conditions—same aggregate, same cement, same age of concrete, etc.—this relationship is fixed within narrow limits, and that so long as the mixtures are practicable and workable, concretes having equal water-cement ratios will have approximately equal strengths. Our own experimental work further supports this conclusion. This, then, furnishes us with a means of obtaining concrete of specified quality, for if in any case the relationship between the desired compressive strength and the water-cement ratio is known for the set of conditions governing that case, it is only necessary to proportion the water and cement in the concrete mixture so as to give the necessary water-cement ratio and, if the mixture comes within the bounds of workable concretes, the required strength will result.

I have referred in my last paragraph to "workable" concrete mixtures; a concrete mixture must possess a certain degree of plasticity or mobility before it can be handled and placed. The second problem, therefore, in proportioning is to obtain in mixtures of the desired strength the necessary mobility, and to maintain this mobility with every change in the aggregates. This problem cannot be fully solved until plasticity or mobility can be expressed in definite units and a satisfactory means of measuring it devised, but a partial solution, which answers practical requirements, is possible.

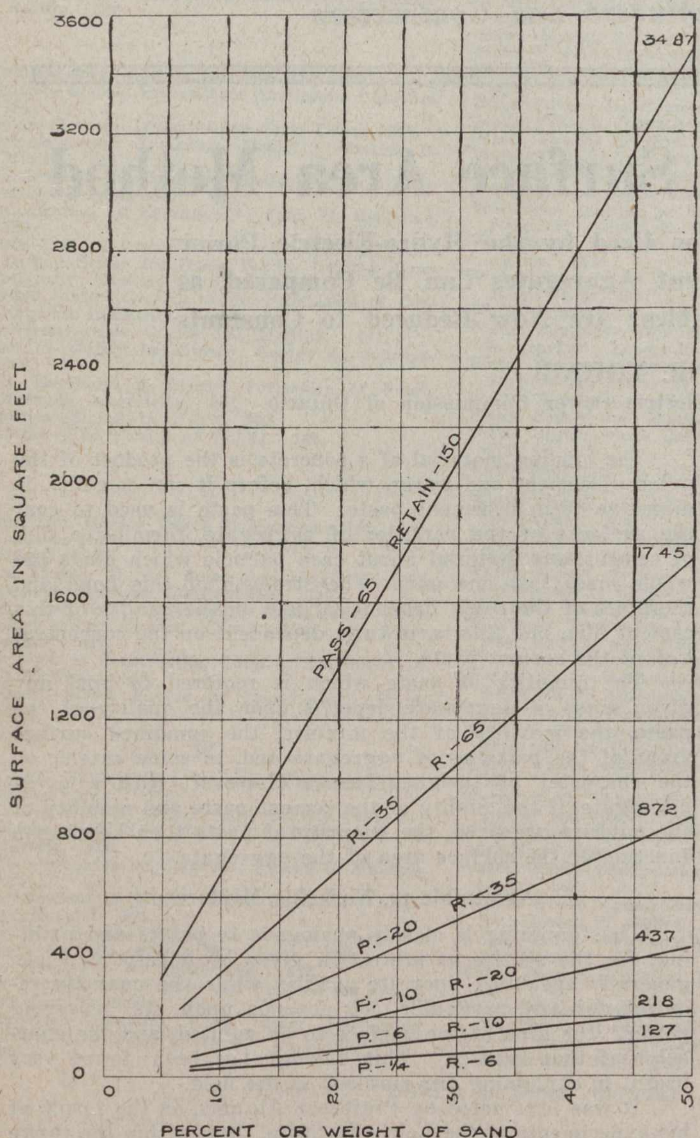


FIG. 1—NIAGARA INVESTIGATION, SURFACE AREA OF SAND PORTION OF PIT RUN

Mobility or plasticity depends upon several factors: The character of the aggregate, whether gravel, crushed stone or some combination of these; the grading of the combined aggregates; the quality of the cement paste; and the relation between the volume of the cement paste and the surface area of the aggregates which it coats.

The first factor can seldom be controlled; the materials cheaply available to the job must be used. However, the materials will probably be the same throughout any one piece of construction, and hence the effect of this factor is usually constant.

Our studies have shown that the second factor, the effect of grading, is approximately this: Mixtures in which coarse aggregate predominates, and which lack the finer particles requisite to density, are unworkable, lack mobility and do not flow well. For such it is difficult, if not impossible, to develop a method of proportioning which gives mixtures of equal mobility, as the cement paste is called upon to act as a filler of voids, a function not within the province of the cement paste but rightfully belonging to the finer aggregate.

This introduces a new variable which materially modifies the problem, and for which it is not easy to compensate. Further, such mixtures are undesirable from several standpoints, and are to be avoided. In mixtures which contain a sufficient proportion of fine aggregate, and those in which the fine aggregate is in excess, the function of the cement paste is almost altogether that of a paint,—at least that required as a filler seems to bear a constant relation to the total quantity of paste used,—and here it is possible to ignore entirely the effect of grading on mobility except as it affects the quantity of cement paste required to supply a given thickness of paste film on the surfaces of the aggregates.

The third and fourth factors may be considered together. It seems from such evidence as is now at hand, that, leaving out of account the first two factors, the mobility of a mixture depends on the relation of the surface area of the aggregate to the water present in the cement paste in excess of that required to properly moisten the cement. The excess water available in a paste depends upon its quality, or concentration of the paste, as well as upon the quantity or volume in use. Hence the two factors mentioned.

In proportioning for strength, it is necessary to know the relation between quality of cement paste and compressive strength. In proportioning for workability, it is necessary to know the relation between mobility and the volume of excess water per unit of area. As before noted, mobility is a term not yet quantitatively defined, and hence the latter is impossible to obtain. However, the volume of excess water per unit of area for some one degree of mobility can be

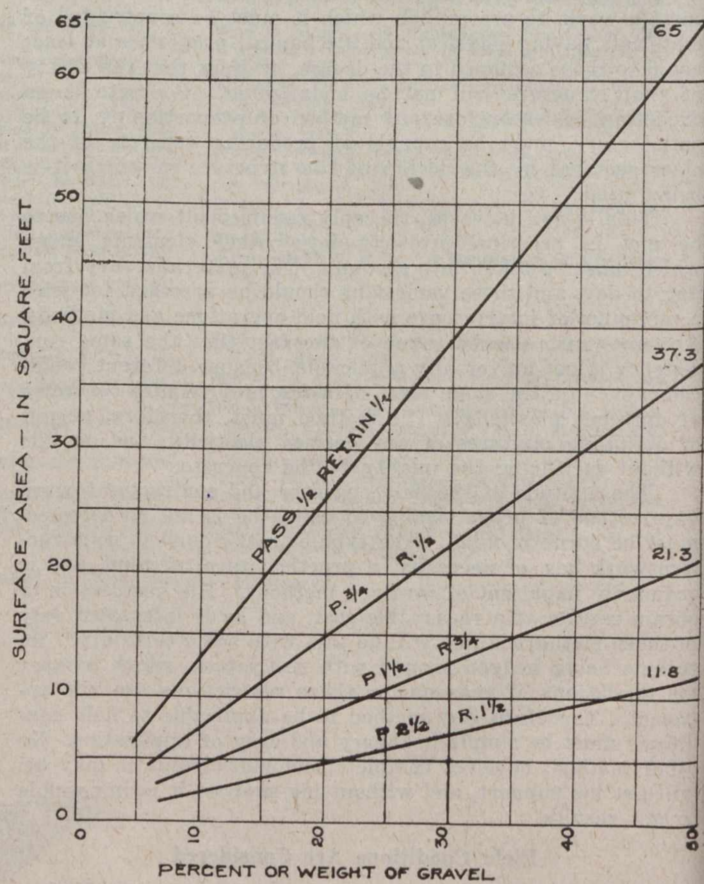


FIG. 2—NIAGARA INVESTIGATION, SURFACE AREA OF GRAVEL PORTION OF PIT RUN

ascertained by experiment; and by maintaining this ratio constant, the same mobility can be obtained under varying conditions of water-cement ratio and grading of aggregate. By using this degree of mobility as a base, all other mobilities can be referred to it in terms of relative consistency; that is, in terms of the relation between the volume of cement and water in the new consistency to that in the normal or test consistency, both having cement pastes of equal water-cement ratios. Thus a 1.10 consistency is one having 10% more cement and 10% more water than has the normal, or 1.00, consistency.

If the volume of cement is determined from the surface area to be coated, then some method of determining these areas is necessary. It is apparent that it is impossible to determine exactly the true surface area of the aggregate particles because of their irregularity and the uneven condition of their surfaces. However, it is not necessary to know the true surface area, for if a value can be determined for each case which has a constant relation to the true surface area, it is equally useful.

In the work of the Hydro-Electric Power Commission, the method employed to obtain this surface area variable is the same as that used by Mr. Edwards in his original investigations of the surface area method of proportioning. The aggregate is separated by means of testing sieves into its component sizes, and the number of particles per unit weight of each size obtained by count. The assumption is made that these particles are spheres. It is then possible from these counts and the specific gravity of the material to calculate for each size of separation the surface area of the average particle, and hence the total surface area in a pound of particles. This information is tabulated as in Table 1, or put into the form of charts (see Figs. 1 and 2).

In calculating the surface area of a particular aggregate, it is necessary to sieve it into the same sizes of separation as those used in obtaining the above data. While usually in reporting such a mechanical analysis, the percentages either passing or retained on each sieve are given, for this work the percentages lying between the adjacent sieves are

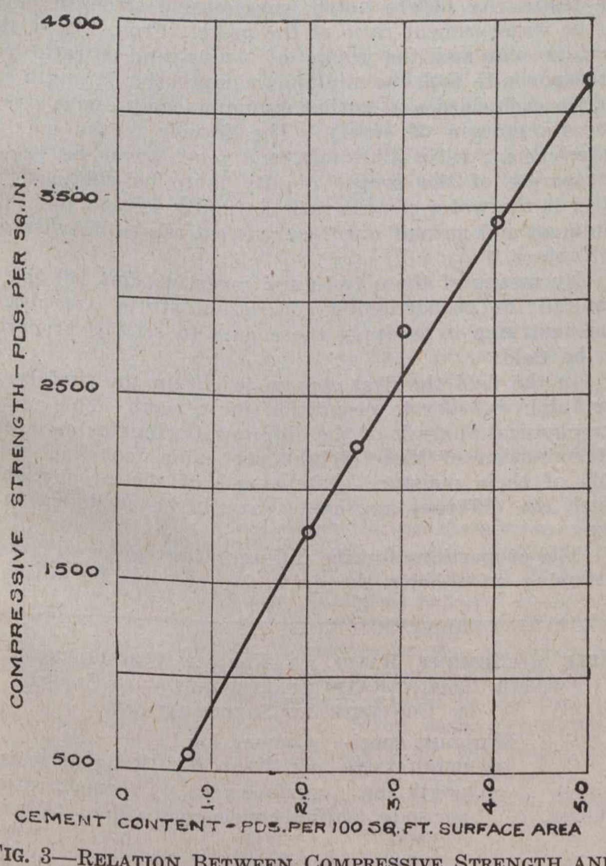


FIG. 3—RELATION BETWEEN COMPRESSIVE STRENGTH AND CEMENT CONTENT AT NORMAL CONSISTENCY

required. These percentages are translated as so many pounds of each size of material in 100 lbs. of aggregate. The surface area corresponding to the weight of each size is read from the surface area charts or calculated from the tabulated data. The sum of the different values thus obtained is the surface area per 100 lbs. of aggregate. This may be changed by simple calculation into the surface area per cubic foot or other unit as found desirable.

Our experience has shown that the finer portion of the aggregate, the silt or dust, must be treated differently than the coarser portion. This finer material is more comparable to the cement than to the aggregate. Investigations now under way indicate that it would be more correct to consider this dust as a dilutent or extender of the cement, and that where this dust does not exceed a few per cent. of the total aggregate, this could be done without affecting the strength of the mixtures. At the present time it is our practice to ignore entirely that portion of an aggregate finer than the No. 150 sieve. Our choice of this sieve is purely arbitrary, and it may be that the dividing point between dust and aggregate should be elsewhere. This method has, however, given good results. With fine aggregates the silt

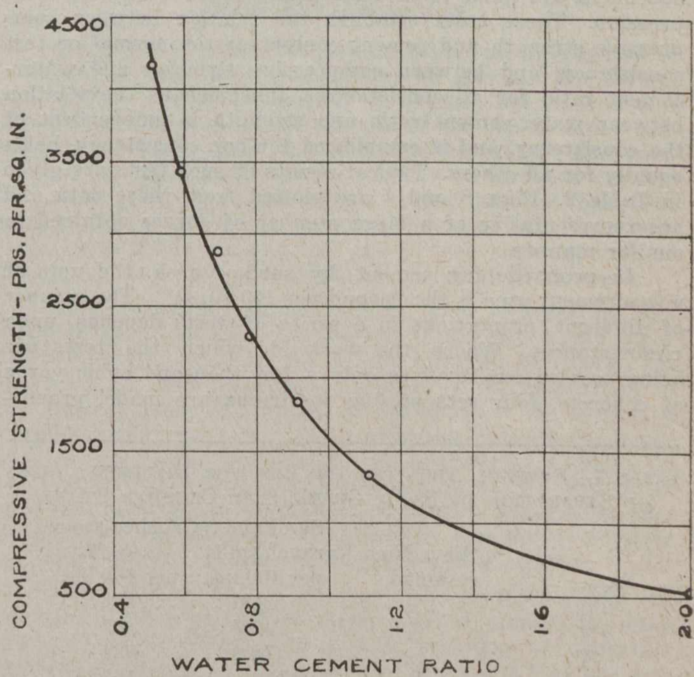


FIG. 4—RELATION BETWEEN COMPRESSIVE STRENGTH AND WATER-CEMENT RATIO

content of which is 5% and under, the above practice of ignoring the dust will be found satisfactory.

This brings us to the practical application of the foregoing and the system of judging and proportioning concrete aggregates based thereon now in use by the Hydro-Electric Power Commission of Ontario.

When a piece of construction involving concrete is contemplated, a combined field and laboratory investigation is first made to determine the most suitable and economical sources of supply for the necessary aggregates. The extent of this investigation depends on circumstances, but usually it consists of reports on deposits, samples from these deposits and field and laboratory tests of these samples to determine their quality. This work is undertaken as far as possible in advance of actual construction.

Once the source from which the aggregate is to be taken has been determined, a quantity of the material, usually from 3,000 to 5,000 lbs., is shipped to the laboratory for detailed investigations into its concrete-making properties. The first study undertaken is to determine the mechanical analysis of the combined fine and coarse aggregate which will give the most economical mixture, workability and economy of materials being balanced. The most economical mixture is one containing the lowest surface area per cubic foot of material which can be successfully handled and placed. These studies are checked in the laboratory by making concrete mixtures of different gradings and observing their mobility and flowing properties. However, the quantities of concrete handled in the laboratory are too small to allow of their exhibiting the same characteristics as do large masses of concrete, and the final determinations as to what is a workable mix must be made in the field.

Coincident with the laboratory work, the necessary grain counts and calculations are made to obtain the surface area per pound of each size of these materials, and these results are charted.

The next step in the laboratory investigation is to determine for these materials the relation between cement content at normal consistency, water-cement ratio and compressive strength.

Using the combination of fine and coarse aggregate giving the grading already determined as most suitable, a series of tests are made in which the cement is proportioned according to the surface area of the aggregate. Water is added to give mixtures of the same mobility. Concrete test specimens are made from these mixtures and tested in compression. These tests establish the relation between compressive strength and cement content at the normal or test consistency, and between compressive strength and water-cement ratio for all consistencies, inasmuch as the relation between water-cement ratio and strength is independent of the consistency, and if established for one consistency, holds equally for all others. Typical results of such tests are given in Table 2. Figs. 3 and 4 are plotted from these data and are representative of a large number of curves obtained in similar manner.

In proportioning cement by surface area, the unit of measurement used is the "pound per 100 sq. ft." The number of different proportions in a series of tests depends upon circumstances. Where the work for which the tests are being carried out involves only a few thousand cubic yards of concrete, four sets of five specimens are made, proportioned 1.5, 2.0, 2.5 and 3.0 lbs. of cement per 100 sq. ft. of area, and tested at 28 days. Where the yardage is considerable, six sets of ten specimens, with a range of cement from 0.75 to 4.0 lbs. per 100 sq. ft. of area, are tested at both 28 and 90 days. Where the yardage is very large, even more extensive investigations are warranted. In any case, less than four sets are inadvisable, and more are always to be recommended.

TABLE 1—SURFACE AREA PER 100 LBS. FOR DIFFERENT SIZES OF SEPARATION OF SAND, GRAVEL AND CRUSHED STONE

Pass.	Sieve No. retained.	Sand and gravel, sq. ft. per 100 lbs.	Crushed stone, sq. ft. per 100 lbs.
2½	1½	23.6	36
1½	¾	42.7	62
¾	½	74.6	124
½	¼	130	163
¼	No. 6	255	
No. 6	" 10	437	
" 10	" 20	875	
" 20	" 35	1,744	
" 35	" 65	3,490	
" 65	" 150	6,975	

In proportioning water, the simplest way is for the operator to add the water until in his judgment the mixture is of the required mobility. With an experienced operator, this method can be made to yield satisfactory results, even with a wide range of cement ratios and differently graded aggregates.

In the work of the Hydro-Electric Power Commission, a formula is used for determining the correct amount of water required to bring a mixture to the proper mobility. This formula is based on a theory as yet only partially established, and its discussion is without the scope of this article. It is not general in its application, and its constants have to be determined for each different class of material. They are derived from the tests made when studying the relative mobility of the different combinations of aggregates. With this formula, mixtures have been obtained the mobility of which were so nearly equal that no difference could be detected by any means at our disposal.

Our concrete specifications provides for four classes of concrete, designated A, B, C and D. Class A concrete is required to be of such quality as to show a minimum compressive strength of 2,500 lbs. per sq. in. at the age of 28 days when tested in accordance with the Commission's standard methods of testing. Classes B, C and D are required to have minimum compressive strengths of 2,000, 1,500 and 1,000 lbs. per sq. in., respectively, under the same conditions. This form of specification has been adopted because it is considered more logical to specify the desired property of concrete, than to give a formula for the mixing of its ingredients.

In designing concrete mixtures to fulfil these specifications, it is customary to allow a margin of from 300 to 500 lbs. per sq. in., to take care of field conditions. A 300-lb. margin should be ample, however, if the operations of proportioning and placing are subject to careful inspection. Allowing a 300-lb. margin of safety, the ratio of cement to surface area which corresponds to each of the above classes of concrete would, in the case of the materials used in the tests of Fig. 3, be those shown in Table 3. These, however, hold only for concretes of the same plasticity as that used in the tests. As before noted, compressive strength depends on the water-cement ratio of the paste. From Fig. 3, therefore, is obtained the range of water-cement ratio which corresponds to both the minimum compressive strength specified for each class, and to that minimum compressive strength plus its margin of safety. The former is the maximum water-cement ratio allowable, and must never be exceeded if concrete of the proper quality is to be obtained. The latter is the water-cement ratio normally worked for. These minimum and normal water-cement ratios are likewise given in Table 3.

TABLE 2—RELATION BETWEEN CEMENT CONTENT, WATER-CEMENT RATIO AND COMPRESSIVE STRENGTH

Cement, lbs. per 100 sq. ft.	0.75	1.5	2.0	2.5	3.0	4.0	5.0
Water-cement ratio	1.994	1.118	0.915	0.780	0.697	0.590	0.526
Compressive strength, lbs. per sq. in.	548	1,337	1,791	2,290	2,851	3,426	4,158

By means of these tests and investigations, all the data required for proportioning concrete mixtures are obtained. The next step is to apply these data to setting proportions in the field.

In the field the first step is to obtain the surface area per batch in order to proportion the cement. This requires a mechanical analysis of the different aggregates used, and a determination of their weight per cubic foot and if possible of their moisture content and of the proportions in which the different aggregates are to be combined in the mix.

The proportions for the different aggregates are worked out using as a basis the data obtained by the laboratory in the preliminary studies of the most economical mixture. The aim is to get the leanest concrete which is workable, gives a good surface, has the requisite density, and at the same time fulfils the requirements for water-cement ratio, and hence for strength.

TABLE 3—CEMENT RATIO AT NORMAL CONSISTENCY AND WATER-CEMENT RATIO CORRESPONDING TO CLASSES OF CONCRETE IN SPECIFICATIONS

Class.	Minimum specified compressive strength, lbs. per sq in.	Cement, lbs. per 100 sq. ft. surface area, normal consistency.	Range of water-cement ratio. Min.	Max.
A	2,500	3.18	0.68	0.74
B	2,000	2.58	0.78	0.86
C	1,500	2.08	0.91	1.04
D	1,000	1.48	1.14	1.37

Although the laboratory's preliminary studies are of great value in obtaining this, the final proportions should actually be set in the field, because to some extent they depend on the type of structure being built (whether mass or reinforced), on the amount and spacing of the reinforcing, on whether the sections are thick or thin, on the maximum size of stone used and the quantity of this maximum size present in the coarse aggregate, on the consistency, on the quality of labor, etc.

The sieve analysis and other tests referred to are carried out by the field engineer with equipment supplied him for the purpose. The sieve analyses and weight-per-cubic-foot determinations are performed similarly to those in the laboratory, except that the latter is made without drying the aggregate as in laboratory practice. From the data of these tests and the surface area charts of Figs. 1 and 2, the surface area per 100 lbs., per cu. ft., and hence per batch, are determined.

The weight of cement required for normal or test consistency is found by multiplying the surface area by the proper cement factor (Table 3) for the class of concrete it is sought to obtain. This weight is usually given in terms of bags of cement.

Moisture in Aggregate

The quantity of gauging water is then calculated from the minimum water-cement ratio (Table 3) corresponding to the same class of concrete. In calculating the water, allowance must be made for moisture contained in the aggregate in its natural state. This has been found to be seldom less than 2%, and is usually between 3 and 4%. This last figure is a safe figure to use, except directly after rain, when allowance should be made for 6 or 8% moisture. It is better practice, where circumstances permit, to determine the moisture content of the aggregate by actual test, but this is not always possible.

Experience has shown that if these tests are made a few times under different weather conditions, the engineer can then judge the proper moisture corrections for his aggregate so closely that only occasional check tests become necessary. Moisture tests do not have to be made upon the coarse aggregate unless it is mixed with considerable fine aggregate, as the amount present is negligible.

If the normal or test consistency is too dry for the work in hand, cement and water in the same proportion are added until the required mobility is obtained. If the consistency is wetter than necessary, the cement and water are reduced. The new consistency is defined in terms of its relative consistency, as before explained. In further proportioning in which the same mobility is desired, the cement content for normal consistency is multiplied by the consistency factor; that is, by 1.10, 0.90, etc., as the case may be, and the water proportioned to give a cement paste of the proper water-cement ratio.

Natural aggregates are subject to changes in their grading, and it is therefore necessary to test them frequently and to alter the proportions of the concrete mixtures to suit. This involves a repetition of the mechanical analyses and calculations for surface area described before. However, it is not usually necessary to change the combination of the aggregates except where the variation in the materials is considerable, such as when, in using a mixture of bank sand and crushed stone, the percentage of gravel in the former changes from, say, 25% to 40%. When such occurs, and changes in the proportions of the aggregate are necessary, the combinations which give the nearest approximation to the ideal grading are re-determined, as was done in fixing the original proportions.

Testing Samples from Job

Finally, samples of the actual concrete produced are taken periodically, made into standard test cylinders and sent into the laboratory. It is our practice to take these directly from the forms, to take two or three samples at a time, and to test these at 28 days. Samples are taken whenever it is necessary to change the proportions, and oftener if deemed advisable by the engineer in charge. Careful record is kept of the portion of the structure represented by the samples, the proportions used, the approximate water-cement ratio, and all other pertinent data.

Certain features peculiar to the use of this method bear emphasis. If the contractor is required by the specification to produce concrete of definite quality, then it is evident that to do so he must use concrete mixtures having water-cement ratios not greater than those corresponding to the minimum requirements of the specification. Where this is insisted upon, the question of the proper consistency to use under any given set of conditions is one that can be left to the contractor for solution. The wetter mixes require more cement, the drier more labor to handle and place. The contractor will balance these two factors and may be depended upon to use the consistency that is cheapest. This will almost always be found to be the driest consistency practicable for the work in question.

Bank Run Aggregates

The method allows the use of bank run aggregates or mixtures of these with crushed rock or gravel. The former are seldom, if ever, economical in cement, but their use is sometimes advisable where the size of the job or other consideration makes their treatment unprofitable. The commission have regularly used a mixture of screened crushed rock and bank sand and gravel. This practice has been found entirely satisfactory and the mixtures used have been economical in cement, nor has any trouble been experienced with them in getting concretes of the required strength.

Under ordinary conditions, the only changes in proportions to compensate for changes in the aggregate occur in the cement. This is the easiest material to handle, but it is also the most expensive. Changes in the proportions of the aggregates usually involve a disruption of the system of handling materials, give rise to confusion amongst the workmen, and increase the difficulty of inspection. Changes in the quantity of cement involve a change in the routine of only one man, whose intelligence is usually superior to that of the laborers handling the aggregate, and the proportions are more easily checked and inspection is simplified.

Proportioning by the surface area method allows the use of a smaller margin of safety than is permissible when the proportions must cover a wide variation of materials. To take advantage of the economies in cement that are possible where this smaller factor of safety can be used, it is necessary to proportion the cement more closely than is customary in the field. Splitting a bag of cement in half is as fine a division as is ordinarily considered feasible in practical work. This is not enough, and some provision should be made to further subdivide a bag. Such an arrangement is not hard to devise and saves its cost many times over. If a quarter of a bag of cement can be saved on each one-half yard batch in a day's run of 160 cu. yds., it means a saving of 40 bags, or from $25 to $40, which would pay handsomely for the extra labor and equipment involved, but on large mixers the saving might not warrant the extra trouble and expense. The commission have under consideration the proportioning of cement entirely by weight, eliminating, wherever possible, the bag as a unit of measurement.

Cost of Investigations

The cost of the necessary investigations as above outlined are moderate. It is hardly debatable whether an investigation of the concrete materials should be made prior to any work of importance. Experience has too often shown the danger of neglecting this precaution. Few will quarrel with the statement that tests should be made of the concrete produced. These precautionary measures are common to all methods, only here the laboratory investigations are carried out differently. Our experience, which covers the usual methods as well as those described here, has demonstrated that the studies and investigations for the latter cost less and yield more valuable information than those for the former. The cost runs from $400 to $1,000, depending on the size of the job and its location, and on the experience and organization of the laboratory making the tests. These costs are moderate considering the benefits to be gained. We are making an endeavor to develop approximate methods for use on the smallest jobs,—even those of just a few hundred cubic yards. We believe that it will soon be possible to make such studies as are necessary for these at a cost of from $25 to $50, and still retain the essential features of the method. It will usually be found that the cost of such investigations as are required will be offset by the savings effected by the more accurate proportioning possible.

It will be of interest here to cite a recent experience of the Hydro-Electric Power Commission. On a job upon which the surface area method is being regularly used, a structure is also being built by the commission for an outside firm, using methods specified by their engineers. On the same job a similar structure, in which concrete of the same quality is called for, is being built by the use of the surface area method. Materials for the two structures are from the same sources and are mixed and placed by similar equipment. The following results, from seven consecutive tests of field concrete specimens, some of which were from each of the jobs and which represent concrete placed simultaneously, illustrate the kind of results obtainable with the two methods:—

Cylinder No.	Class of concrete.	Proportions.	Compressive strength, lbs. per sq. in.	Method.
90	B	1:2:4	2,000	H.E.P.C.
91	B	do.	2,480	do.
92	B	do.	1,960	Outside
93	B	do.	1,470	do.
94	B	do.	1,800	do.
95	B	do.	1,510	do.
96	B	1:2½:5	2,090	H.E.P.C.

In the pouring represented by the last specimen, the mix had been changed to a 1:2½:5, yet the quality and mobility of the concrete were maintained at the standard desired.

The surface area method here described has been found in actual practice to have the characteristics laid down in the opening paragraphs of this article. It takes well in the field and the laboratory studies involved in its use are cheaper than those required for other methods, and obtain information of wider application. The method has been found to give a means of estimating the relative economy of different aggregates, because two factors, workability and strength, which were formerly variable, have now been reduced to constants. The success so far obtained in its use has been so encouraging that it is now expected that it will be used on all work undertaken in the future by the Hydro-Electric Power Commission of Ontario; and in the next three years alone, the Commission's work will total over 500,000 cu. yds. of concrete.

SASKATOON LOOKS INQUIRINGLY UPON REGINA AND MOOSE JAW WATER SCHEME

WHAT will be the effect on Saskatoon's supply of water, if the towns and cities in the southern part of Saskatchewan obtain their supply from the South Saskatchewan river? This is one of the twenty questions concerning Saskatoon's future which are answered by C. J. Yorath, city commissioner, in his annual report for 1919. Mr. Yorath says:—

"A committee of one hundred, representing the municipalities of the southern part of the province, recently waited upon the provincial government to discuss a proposal to take a water supply from the Saskatchewan river at the Elbow, to serve the cities of Regina and Moose Jaw, and other towns.

"This is a proposal which will have to be very carefully watched by the urban centres and residents in the north part of the province. There will be no objection to the southern municipalities obtaining their water supply from the South Saskatchewan river, provided that in doing so, they do not prejudicially affect the supply of those who do at present, and will in future, by virtue of their location, rely upon their supply of water from this source.

"This matter is brought to the attention of the citizens, as it may very seriously affect the development of the northern part of the province if certain precautions are not taken.

"The Saskatchewan river, according to the records of the Irrigation Department, showed the lowest flow of water on January 10th, 1913—i.e., 1,130 cu. ft. per sec.

"During the non-irrigation season, October to April, the following maximum diversions are already authorized by the Department of Irrigation:—

"From the Bow and Elbow rivers

"(Tributary to the Saskatchewan river)

"Canadian Pacific Railway, 700 sec. ft. for irrigation.

"Canada Land and Irrigation Co., 1,500 sec. ft. for irrigation.

"City of Calgary, 120 sec. ft. for domestic and industrial purposes.

"General reserved, 100 sec. ft.

"From the Oldman river

"(Tributary to Saskatchewan river)

"Lethbridge, 25 sec. ft., industrial and domestic.

"General reserved, 100 sec. ft.

"Lethbridge northern project, 900 sec. ft. for irrigation.

"Other diversions, 150 sec. ft.

"During the irrigation season (May to September), the above amounts may be approximately doubled.

"The following is a note appended to information supplied by the Commissioner of Irrigation:—

"'I feel sure that I ought to call your attention to the fact that care should be taken in making use of the above data, especially with regard to drawing conclusions as to available water supply, as all water is subject to many conditions of administration, which are liable to materially affect the results.'

"The present maximum daily requirements of Saskatoon, during the winter months are 3.25 sec. ft.

"The present maximum daily requirements of Regina, during the winter months are 4.70 sec. ft.

"The present mavimum daily requirements of Moose Jaw, during the winter months are 1.83 sec. ft.

"Of course, these requirements will largely increase as the population increases.

"No definite project for supplying southern Saskatchewan from the Saskatchewan river has yet been decided upon. The lowest estimated cost of carrying out such a project is $12,000,000, based on 1913 prices, which to-day would probably be increased to at least $16,000,000.

"The fixed charges on an expenditure of $16,000,000 would be made up as follows:—

"Interest on $16,000,000 at 5½%	$ 880,000
"Sinking fund to repay loan in 50 years	104,800
"Total	$ 984,800

"In addition to the above, there would be an annual charge for maintenance and operation of approximately $200,000, so that it will be readily realized that considerable revenue will be required from the southern municipalities to make the project self-supporting and not a charge upon the province as a whole. Some idea of the revenue derived from water works utilities will be obtained from the annual revenue earned by this city's water department, i.e., approximately $120,000.

"The above information is given to the citizens of Saskatoon so they will realize how important it is that steps should be taken to safeguard their interest in respect to:—

"1. The future water supply of Saskatoon;

"2. That their burden of taxation is not increased in order to supply water to cities in the southern part of the province which have been less advantageously located."

About a mile of sewers were laid in Dundas, Ont., last year at a cost of $235,778. This comprises 3,005 ft. of 30-in. segment block, 210 ft. of 30-in. vitrified tile, 828 ft. of 24-in. vitrified tile, 658 ft. of 18-in. tile, and 300 ft. of 8-in. tile. Twenty manholes have been constructed.

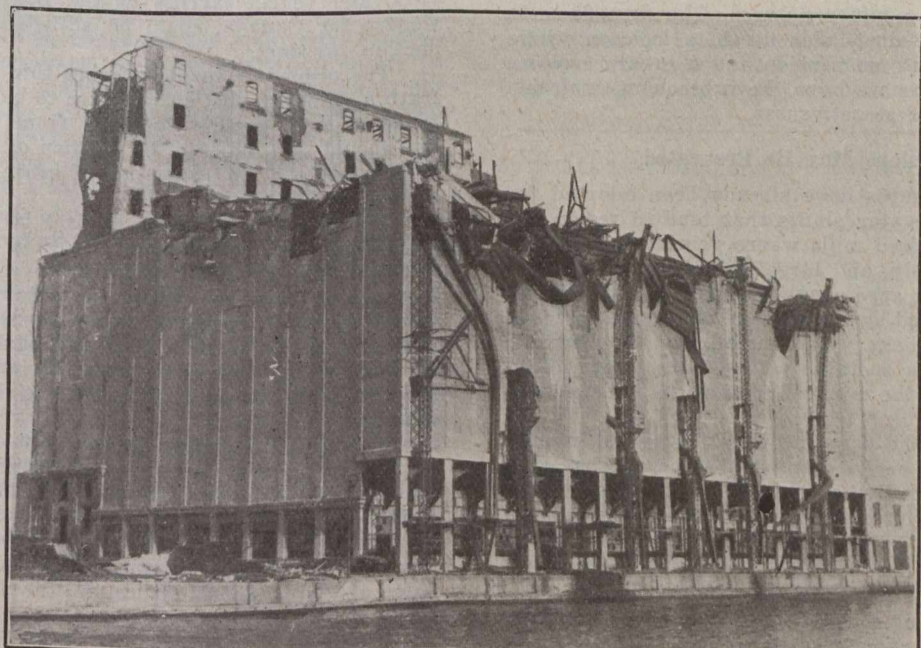
It is estimated that about $250,000 is being expended in Orillia, Ont., in street improvements, as follows: $34,604 for storm sewers; $4,406 for relaying water services and renewals of sidewalks; $198,147 for bituminous paving; and $12,786, estimated cost of engineering, interest during construction, etc.

DUST EXPLOSIONS

By Hon. Ralph B. Chandler
C. D. Howe & Co., Consulting Engineers, Port Arthur, Ont.

When the cupola of the Canadian government's transfer elevator at Port Colborne, Ont., was completely demolished last summer by a dust explosion, resulting in loss of life and much property damage, as well as heavy losses due to the plant's being out of commission, attention was again called to the tremendous potential destructive forces in dust accumulations.

The explosion at Port Colborne is but one instance of many similar disasters that have occurred during the past decade throughout Canada and the United States. The writer has been keenly interested, from an engineering point of view, in the problems of dust extraction and disposal, particularly those met with in grain elevator plants, and has had opportunities of supervising the installation and checking up the actual performance of dust-collecting systems in the elevator plants most recently erected at the head of the lakes and on the Canadian prairies, and he is of the opinion that the systems installed do not adequately take care of the situation.



Port Colborne Grain Elevator After Dust Explosion

Undoubtedly, these systems perform the functions for which they were designed—namely, to collect the dust and chaff from the grain during cleaning operations, to dispose of it to a dust bin (either in or outside the building), and to provide a means for the removal of sweepings from the floors. But this is not enough. The constant discharge of large quantities of dust into the atmosphere on the various work floors throughout a plant should be prevented.

This dust, settling on the exterior frame of the building, on the spouting and on the machinery, often is allowed to accumulate for years, storing up the fuel supply for the flame of a dust explosion. To-day the conservation of food supplies, of property, and of life itself demands the attention and support of all interested parties towards the determination of the most efficient and practical methods of preventing dust explosions.

The United States government, through the medium of its department of agriculture, is at present carrying on an active educational campaign by pamphlet and lecture tours, dealing with dust explosions and preventive methods. Our own government should put its shoulder to the wheel and take the full share of its responsibilities in this important matter.

Dust explosions occur principally in industrial plants of the following types: Grain elevators, feed grinding plants, flour mills, starch works, sugar refineries, wood working industries, coal mines and coal-handling plants, breakfast cocoa plants (chocolate dust), and paper mills.

Explosions are due to the dust in air coming into contact with an external source of ignition, under favorable temperature and humidity conditions. The factors that combine to give explosions of destructive violence are briefly as follows:—

1. Degree of fineness of dust particles. Susceptibility to ignition increases as the fineness of the dust particles in suspension.

2. Moisture content of dust. Dampness retards and dryness expedites rate of flame propagation.

3. Atmospheric conditions. Periods of high temperature and low humidity are most favorable for dust explosions.

From this it follows that fine dry dust such as grain elevator dust, coal dust, starch dust, sugar dust, etc., in suspension in a large volume of air, will, under certain conditions, ignite with ease and explosive violence.

The sources of ignition, which investigations have proven conclusively to have caused explosions, come under the following classifications:—

1. *Open Flame.* Striking of a match, pipe smoking, etc.

2. *Mechanical Causes.* (a) Choke-ups in elevator legs where the head pulley keeps turning inside the belt until the temperature produced by the resulting friction passes the ignition point. (b) Hot bearings and belt slippage.

3. *Electrical Causes.* (a) Sparks from motors. (b) Blowing of fuses. (c) Open switch throwing. (d) Carbon lights (old type incandescent lighting).

4. *Static Electricity.* A large percentage of dust explosions have had as their ignition factor static electrical discharges. Static currents, with voltage as high as 50,000 volts, have been recorded in the operation of grain threshers. It has been stated that during a single crop year in the western United States, four hundred explosions resulted in connection with threshing operations. Investigations proved that these smut-dust and grain-dust explosions were caused by static electricity igniting the dust-laden air. The friction of the straw over the teeth in the cylinder on the shaker shoe and in the exhaust fan, created the current, and the proper grounding of these danger zones eliminated further trouble. Static electricity frequently manifests itself in elevators during elevator leg and conveyor belt operations.

5. *Spontaneous Combustion.* The slow process of destructive distillation or charring that is commonly known as spontaneous combustion, has been looked upon by indifferent investigators as the cause of many dust explosions, but no case as yet has been found directly attributable to this reaction.

Theory of Dust Explosions

The ignition point of dust particles varies. Some ignite at lower temperatures and with greater speed of propagation than others. Glowing red heat will ignite sugar dust, ranking this particular type as one of the most inflammable.

Of the percentage of dust that must be in suspension in order to create an explosive mixture, certain available data give a fair idea. It is a well-known fact that fire-damp explosions in mines and tunnels occur when the percentage methane in the air lies between 5½ and 14%. With mixtures outside these limits the menace does not exist.

Coal-dust explosions require a dust suspension of from two to three hundredths of an ounce per cubic foot of air space. As grain dust is made up of finer particles, it is natural to conclude that a smaller quantity by weight would be required to create an explosive mixture.

The theory advanced at present is that dust explosions are caused by rapid propagation of flame from one particle to another with a speed that builds up heavy pressures. In the case of coal dust we have the formation of large volumes of highly heated gaseous products of combustion taking place in an infinitesimal period of time. The created gases occupy 2,600 times the volume of space taken up by the dust particles themselves. It is evident under these conditions that since the expansion is practically instantaneous, it must occur with explosive violence.

The rate of flame propagation has been measured. Gas explosions travel at the rate of 9,000 ft. per sec.; coal dust combustion at 6,600 ft. per sec.; and grain dust practically the same. The resulting unconfined pressure from coal and grain dust explosions, which has been fixed experimentally, plainly shows the impracticability of erecting structures that will stand up under such bursting pressures.

Dust explosions may occur singly or in pairs, and sometimes three distinct concussions have been felt. The initial explosion is usually of a minor nature. The first flame is propagated through the dust-laden air to a location where dust has been stirred into suspension and a greater volume of air is available. Here we have the subsequent explosion of greater violence and destructiveness.

How Explosions May Be Prevented

Precautionary measures have already been adopted for feed mills and grain elevator plants that tend to reduce the explosion hazard. In feed mills where grinding operations are going on continuously, and large quantities of dust are always in the air, great care should be exercised to prevent sparks from being created by the passage of foreign material through the grinding disks. The installation of magnetic separators to remove the metallic refuse, and proper cleaning devices to separate the mineral content, have been most beneficial.

The prevention of the flame propagation to the interior of the plant has been arrived at by the installation of a revolving damper in the discharge from the grinders to the elevator leg or screw conveyer taking care of the finished product. The machine section in front of the damper is vented to the outside air, and explosions taking place inside the grinder can then be safely discharged to atmosphere.

An air separation of foreign matter from raw grinder material is now being experimented with in several large feed mills. The principle of the grain trap has been adopted from the well-known dust-collecting system used in many elevators. The air current which is partially supplied by fan and partly created by suction from the grinder, is gauged to carry through into the feed box grain only, all the metallic and mineral content being removed during the sudden air expansion in the trap.

In grain elevators the danger from static electricity can be successfully coped with by grounding all elevator and conveyor head spouts. Friction of the grain passing over the steel spouting produces the static currents under these conditions.

The danger from belt slippage, hot bearings and leg choke-ups is one which can only be eliminated by greater vigilence on the part of the operating staff.

The use of vapor-proof lamp globes, replacing the old carbon types, should be universally adopted. The introduction of carbon filament lights into dusty grain bins has caused explosions. The dust coatings that always form on light globes throughout an elevator plant, in the case of the carbon types will heat to a very high temperature and often char. The sudden displacement of this heated coating to the dusty floor has caused explosions, but none have as yet been attributed to the modern mazda lamps.

It has been noted that in plants kept reasonably clean, explosions, when they do occur, have not the destructive powers they attain in others where no attempts have been made to remove the dust accumulations. It would appear from this fact that to prevent dust from discharging freely into the interior of a plant, would be the proper course to follow to reduce the explosion hazard.

The dust-collecting systems at present installed in modern houses could be easily improved upon to take care of this added feature. It is universally agreed that suction is the prime factor in dust removal; but suction requires power and therefore costs money. The ideal in grain elevator operation would be to provide suction at all points where grain is handled or thrown. This would prevent accumulation inside the plant and assist greatly in keeping a clean interior.

Government regulations at present do not provide an incentive to the elevator operator to keep dust out of his plant. Should an average allowance be made to the operator for dust removed from all incoming cars, based upon a loss in weight observed from a series of actual tests, which has already been determined at approximately 8 lbs. per car, and regulations requiring the installation of adequate dust-collecting and disposal systems be passed, then and only then will the operators move to improve existing conditions.

The existing allowances for invisible loss and shrinkage, as set forth in the provisions of the Canada Grain Act, 1912, and yearly tarriffs of the Board of Grain Commissioners for Canada, could be adjusted to take care of deduction for dust.

The order-in-council covering this regulation should set forth a standard suction pressure to be adopted and the distance of such suction openings from the grain in motion, and should also indicate the location of points of application. This would put the prevention of grain-dust explosions upon a working basis.

The regulations might at first be confined to elevators of medium and large capacity, with a reduction in the dust allowance as the grain passes from a shipping terminal to a receiving terminal where both have proper systems of dust elimination operating under government inspection. In this way, a car lot of a thousand bushels would lose 8 lbs. of dust at the lake-head terminal, and, say, 50% of this amount upon passing through the lower lake receiving houses.

The two outstanding factors that combine to cause dust explosions, namely, dust and some external source of ignition, which have in the past taken toll to the extent of scores of lives, millions of dollars' worth of food supplies, and untold property losses, are factors that can be eliminated by keeping plants clean and educating operating staffs to a knowledge of their responsibilities and the danger of carelessness.

BEATTY PLANT AT WELLAND PURCHASED

ANNOUNCEMENT has been made of the purchase by the Mead-Morrison Mfg. Co., East Boston, Mass., of the plant and business of M. Beatty & Sons, Ltd., Welland, Ont. The new firm will continue the business along the same lines as previously followed by this old-established Canadian firm, and it is said that the change in stock ownership will not involve any changes in policy.

In 1906 M. Beatty & Sons, Ltd., erected new reinforced concrete buildings on the Welland canal, and they now have large facilities for the manufacture of their present lines of electric hoists, hoisting engines, buckets, dredges, derricks, pumps, locomotive cranes, ditchers, steel scows, etc., but it is understood that the new owners of the plant will extend it and will manufacture coal-handling machinery and other lines.

The Mead-Morrison Mfg. Co. were established in the United States about 75 years ago, and besides their works and executive offices at East Boston, they have branches in New York and Chicago.

It is understood that Harvey L. Beatty will retire from the presidency of M. Beatty & Sons, Ltd., and Alvin O. Beatty from the vice-presidency, but that the following present officials will remain with the new organization: R. M. Beatty, superintendent; Geo. Day, secretary and sales manager; G. O. Norton, treasurer; and J. McCarter, purchasing agent.

Activities of Provincial Sanitary Engineers

Along What Lines Should the Work of State and Provincial Boards of Health Be Extended?—Review of Six Main Functions—Should the State Design Structures?—Address to the American Society for Municipal Improvements

By FRED. A. DALLYN
Sanitary Engineer to the Ontario Board of Health

STATE supervision of municipal sanitation is a matter calling for wise consideration. At best it should guide or supplement municipal activities, without destroying local initiative; at worst it may be onerous enough to destroy all spirit of co-operation, and signally fail through lack of support. The present paper is written with a desire to illuminate the activities of the engineering services of state and provincial boards of health, especially those connected with the control or supervision of water works, water purification works, sewerage, sewage disposal and the design and location of incinerators and abattoirs.

War time revelations suggested the many advantages of a great forward movement in state sanitation under the direction of specially qualified servants. A beginning was made a few years ago, and it was most interesting to note public men and engineers continuing the discussion as to the qualifications of medical officers of health at the last meeting of the American Public Health Association.

The employment of full-time sanitary engineers at salaries ranging from $2,000 to $5,000 in the following thirty-three states is a promising sign that the movement is in the right direction:—

California, North Carolina, Connecticut, Indiana, Kentucky, Maine, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Vermont, Washington, Wisconsin, Alabama, Arizona, Arkansas, North Dakota, Delaware, Florida, Illinois, Iowa, Kansas, Louisiana, Nebraska, New Mexico, Oklahama, Texas, Virginia and West Virginia.

In a few notable instances the state boards are now guided by the experience gained in the operation of small, state, sewage and water experimental or testing stations, supplemented by the observations of municipally controlled testing stations.

TABLE 1—SHOWING EFFECT OF SYSTEMATIC EFFORTS TO CONTROL TYPHOID BY PROTECTION OF PUBLIC WATER SUPPLIES, PROVINCE OF ONTARIO

Typhoid death rate per 100,000 population

	1918	1917	1916	1915	1914	1913	1912*	1911	1910	1909	1908
Rural and county ..	5.09	6.58	8.1	9.45	10.0	13.3	10.9	16.1	22.0	25.1	20.5
Cities	9.6	7.50	12.1	9.43	12.4	17.3	27.7	35.8	51.5	34.3	37.8
Towns (5,000 to 10,000)	17.2	31.4	52.2	38.0	47.4	46.0	47.0	62.3	56.4	67.7	107.1
Total deaths from typhoid	208	232	335	298	358	446	483	637	706	669	662
Average rate	7.52	8.4	12.5	10.7	13.5	15.7	18.7	25.3	31.5	29.9	29.7
Rate in U.S.A.	....	...	13.3	12.4	15.4	17.9	16.5	21.0	23.5	21.1	24.3

*Chlorination adopted for the major foci in 1912 and 1913. Protection insisted upon for the points of potential danger, 1913 to date, as sanitary surveys progress.

The activities of the state boards of health to-day are handicapped (and this is becoming more and more evident) not so much by lack of power or legislative authority, as by lack of direction and inadequate appropriations. It is because of this latter restraint, which is slow of adjustment, that I suggest consideration of the activities of their engineering departments as to whether there are not certain functions of the office of paramount national importance, the exercise of which should draw to the state board the needed financial support so that its operations may expand into one or more of its other logical branches.

The first duty of the state board, or its engineering subdivision, is the location for the state or province of the major foci of water or filth-borne diseases. Returns of deaths and deaths from specific causes are obtainable. These must be examined and reduced to a common denominator; for instance, death rates are usually compared on the basis of deaths per 1,000 of population living, and typhoid fever is commonly compared on the basis of deaths per 100,000 of population living. Divergencies above the state or continental averages almost invariably indicate foci of disease transmission. Divergencies not only indicate the infective centres or foci, but in addition frequently suggest the occasion of endemic conditions and the extent to which improvement can be immediately carried. A persistent high winter rate for typhoid fever in our northern states almost invariably is due to sewage-polluted water supplies.

TABLE 2—DIARRHOEA AND ENTERITIS IN ONTARIO, 1902-1914 (Under 2 years)

Yearly deaths per hundred live births

Class of Municipality.	Max. Individual year.	Max. Aver. 1902-14.	Min. Individual year.	Min. Aver. 1902-14.	Average Max.	Average Min.	Average Aver.	Group of the lowest averages.	Group of the highest averages.
*County (rural)	10.6	5.1	0	.46	3.44	0.54	1.89	0.88	2.73
Towns (5,000-10,000)	12.9	7.8	0	1.6	7.1	1.27	3.59	2.30	4.86
Cities (10,000-500,000)	11.5	6.9	0	1.7	5.9	1.44	3.37	2.20	5.36

*For one of the smaller municipalities included in the county rate, the exceptional year ran as high as 22.9%, and the average for 1902-1914 was 11%.

Fortunately a great many investigations have already been made and comparative statistics and illuminative suggestions with reference to vital statistics are available for portions of almost all the civilized countries of the globe. The work of an engineering division consists largely, therefore, in assembling existing data and calculating averages for purposes of comparison. But even without the aid of outside data the divergencies encountered within the statistical divisions of the state or province are sufficient in themselves to locate major foci and suggest the course to pursue.

The second duty of the state is to ameliorate or safeguard all major foci and in addition to stop-gap all potential danger as is made apparent by sanitary surveys.

This portion of the program appears simple enough but in actual practise it is far from that. It presupposes the existence of reasonably complete and accurate mortality and morbidity statistics. Unfortunately for the engineer, these are not always available. Of the states having appointed sanitary engineers, 41% were not in the registration area of the United States in 1916, including Alabama, Arizona, Arkansas, North Dakota, Delaware, Florida, Illinois, Iowa, Louisiana, Nebraska, New Mexico, Oklahama, Texas and West Virginia,—an open avowel of the incomplete character and unreliability of their mortality statistics.

Your foci have been located, the zero hour is given and then the real struggle begins. Organization counts for much at this stage of the proceeding. On the one side you have some unadorned statistical facts and the information that a certain number of unnecessary deaths occur annually in this and that town, and many cases and deaths distributed all over the state and continent; on the other side is represented an unwelcome capital expenditure for water purification works, an already high tax rate and a municipal council uncertain of re-election.

It is a situation worthy of the best efforts of a fighter and a diplomat, and not infrequently the diplomat fails and the exercise of coercive or mandatory powers remains as a possible solution. Granting the existence of such powers, their exercise without a campaign of education is rarely politic, having in mind the mixed personnel not only of municipal councils but also of the state assemblies.

If it is the water supply which is polluted, supervised chlorination will substantially control the situation whilst a determined action for the objective is being carried on. A great deal, fortunately, can be accomplished by even half-way measures. Experiments along such lines as supervised chlorination yield gratifying results. Table 1 shows the typhoid fever reduction following systematic efforts in the province of Ontario.

TABLE 3—JACKSONVILLE, FLORIDA, TYPHOID FEVER, 1908-1918

Year.	1918	1917	1916	1915	1914	1913	*1912	1911	1910	1909	1908
Cases reported	144	106	56	92	119	85	94	158	329	102	...
Deaths	27	18	9	14	28	22	18	40	60	42	41
Basis of 15 cases to one death ...	405	270	135	210	420	330	270	600	900	630	615

*Outhouses 100% screened in 1912.

The rates for 1918 and 1917, Table 1, show a marked improvement over the endemic conditions prevailing prior to 1912.

Endemic typhoid is customarily distributed one-third water, one-third milk and one-third contact and food. Lacking a common continuing source of infection, such as a sewage-polluted water supply, the portion of the rate attributed to milk, food and contact also shows a marked improvement. This must be owing to the fact that lacking a general distribution of the disease through major foci, the minor foci, sometimes referred to as potent sources of infection, do not realize their complement of the general transmission of the disease.

Considering the great advantages that can be immediately gained and the great reduction in deaths that can be immediately accomplished, it appears that the first two items of the program are the paramount functions of the engineering service, and that next to detection and protection stands the continued supervision of the agencies of protection by the municipal and state authorities.

Before leaving the question of the use of vital statistics to locate major foci, I should like to impress on state and provincial organizations the fact that we must dismiss once and for all the old fallacy of believing that there is no matter for inquiry if, when considering the country as a whole, a good average is obtained. The figures for each municipality must be considered, even in counties or other statistical divisions exhibiting excellent rates. To illustrate this, Table 2 has been borrowed from an old report of the writer's on diarrhoea and enteritis in Ontario, 1914. The table shows the wide divergencies displayed by the major divisions of counties, towns and cities in Ontario.

TABLE 4—TOTAL DEATHS IN ONTARIO, 1908-1918, FROM CERTAIN COMMUNICABLE DISEASES, ALSO INFANT DEATHS

Year.	Population.	Typhoid.	Scarlet fever.	Diphtheria.	Measles.	Whooping cough.	T.B. lung.	Smallpox	D. & E. under one year.	Total under one year.	Births.
1918 ..	2,711,620	208	84	335	95	305	2,129	2	719	6,402	64,729
1917 ..	2,769,850	232	59	396	58	228	2,014	1	566	5,791	62,666
1916 ..	2,776,886	335	49	461	411	341	2,148	5	1,026	7,000	65,264
1915 ..	2,767,350	298	42	341	145	193	2,088	2	999	6,839	67,032
1914 ..	2,749,840	358	111	443	61	196	1,982	1	1,075	6,835	66,225
1913* .	2,677,600	446	137	339	166	272	1,955	4	1,751	7,597	64,516
1912 ..	2,582,500	483	152	371	111	419	1,921	2	979	6,494	58,870
1911 ..	2,523,274	637	290	427	169	169	2,035	3	1,188	6,421	54,772
1910 ..	2,239,621	706	237	435	304	186	2,013	2	1,239	6,649	53,664
1909 ..	2,233,264	669	200	430	167	262	2,017	3	1,184	6,932	52,629
1908 ..	2,226,860	662	163	450	38	246	2,129	2	1,223	6,895	55,388

*Improved registration.

The next item is a survey of municipal sewerage systems and inquiry as to the protection and collection of night soil.

The fact that a sewer exists on a certain street is generally accepted as meaning that every premise is connected with that sewer. This, unfortunately, is very far from the case and I know that if our municipal engineers would make an investigation of conditions existing to-day they would find that the number of unconnected premises lies generally between 10% and 15% and rarely less than 5%. The existence of this condition is generally only revealed through surveys initiated by state or federal health bodies. The influence of the out-house in cities, especially as much as 15% of the total premises, is most marked in high infant mortality rates, high typhoid rates and the prevalence of fly nuisance.

Improvement can only be brought about by systematic education and coercion. Legislation can sometimes be evoked to assist by expanding municipal powers so that the cost of connecting unsanitary premises to sewers may be carried over an interval of years and collected as taxes. This method has been used successfully in some of the Canadian cities. In one instance I have in mind—the city of Toronto—some 12,000 unconnected premises were connected to sewers in the course of some four years' work initiated by the local officer of health. The benefit was almost immediately evidenced by the lowering of the infant mortality rate and a decided improvement in the fly nuisance.

I should say, then, that the encouragement of sewer extensions, the promoting of surveys for determining the extent of unconnected premises, and the enlargement of legislation to promote the general use of sewers, are included in the third major activity of an engineering service.

TABLE 5—DEATHS FROM D.&E. (UNDER 2 YRS.) AND INFANT MORTALITY (UNDER 1 YR.) IN TORONTO, ONT., 1902-1918*

Year.	Population.	D. & E. under two years.	Deaths under one year.	Infant mortality rate.	Births.	Year.	Population.	D. & E. under two years.	Deaths under one year.	Infant mortality rate.	Births.
1902..	208,040	138	713	146	4,873	1911..	376,538	361	1,442	151	9,545
1903..	219,002	197	827	172	4,844	1912..	414,000	366	1,582	144	10,960
1904..	226,365	192	903	179	5,028	1913†.	454,000	557	1,858	135	13,722
1905..	238,642	232	935	168	5,553	1914..	475,000	259	1,507	108	13,949
1906..	253,720	274	918	160	5,708	1915..	475,000	248	1,398	109	12,806
1907..	272,600	215	976	153	6,343	1916..	470,000	258	1,355	108	12,498
1908..	287,201	238	1,215	153	7,924	1917..	475,000	173	1,112	92	12,110
1909..	325,302	349	1,410	187	7,531	1918..	490,000	170	1,238	105	11,779
1910..	341,991	327	1,420	166	8,555						

*Compiled from the returns of the Registrar-General of Ontario.

†Outside privies declared a nuisance and connection to sewer required. About 12,000 privies done away with from 1912 to 1916.

Pending the general use of sewers, measures should be taken to guard against disease transmission from exposed faecal matter. This means the adoption of screening, standardizing the outdoor toilet, and facilitating frequent and regular removal of night soil. By "frequent" is meant an interval less than the seasonal breeding period of the common house-fly.

The campaign against hook-worm disease involves the early destruction of all human faecal matter. The screening of privies in Jacksonville, Fla., and the coincident reduction of typhoid fever are well set out in Table 3 and demonstrate the value of what is termed "half-way measures" in controlling typhoid.

The next activities might be those having to do with the promoting of garbage collection and the disposal of it. These activities have their advantage in minimizing the fly nuisance and in improving municipal sanitation at a less expense than attends individual effort.

Municipal collection of garbage is a necessity in all our large cities. Frequently, however, outlying areas are not included, and this applies especially to small foreign sections of our larger municipalities. Garbage collection and disposal hereto has been one of the activities least promoted by state boards, but it is one which amply repays any effort, for both hygienic and economic reasons.

The fifth item, sewage disposal, is a subject which has agitated state boards of health for the last fifty years. It is perhaps the one subject which unfortunately demands the greatest amount of time and, both from a statistical and monetary standpoint, shows least return.

Many sanitarians of late contend that sewage disposal is not a problem until the discharge of sewage into a stream imperils the safety of public water supplies. The limit of permissible pollution, however, is without definition so long as it is contended that even heavily polluted water supplies can be treated so that they are fit for domestic consumption. The worst, or best, example of the latter might be Niagara Falls, N.Y.

It would appear that, lacking definition of what one might call tolerable pollution, the individual case must control the situation. The state regulations defining the standards of sewage effluents almost invariably arise through requirement for water of acceptable purity for industrial rather than domestic use. This indeed is the history of the Rivers Pollution Prevention Act although the opposite was true for the Thames Conservancy Act.

Generally speaking it is not to the advantage of any state to issue arbitrary regulations defining the standard of sewage effluents. The individual situation should be given consideration in all cases. Certain areas will have their own standards, depending upon the general uses to which the water is put. Treaty obligations, inter-state commerce obligations and general public health must all be considered before reaching a conclusion.

Management of Experimental Stations

So much for the major activities of the engineering service of a state or provincial board of health. There remain the special functions grouping themselves around the main five vested in such boards. It is only a few years ago since ardent disciples of the septic tank could convince state boards of health that here at last was a solution of all difficulties with reference to sewage disposal. This day is fortunately past and lip service is now at a discount, which may be largely attributed to the magnificent service to the country of the various state and municipal experimental and testing stations investigating sewage and water purification problems.

There exists a question as to whether the operation of experimental stations is the function of a state board of health or of a state university. It must be admitted that the experience gained during the operation of such plants is of the greatest assistance to the board's engineering service. Naturally, being more cognizant of these problems, it would appear that the sanitary engineer is the logical person to direct the activities of such stations, but on the other hand the benefits of research should not be withheld from the educational institutions. The proper arrangement doubtless would be for the stations to be jointly operated by the engineering service and by the educational institution, the state board of health having the majority representation so that it may direct the activities along the lines most beneficial to the state. I think this might even be cited as the sixth item on the program for engineering services of state and provincial boards of health,—that is, the joint operation with educational institutions of testing and experimental stations with reference to processes for the purification of water and sewage. This might be expanded to include methods for the reduction of garbage and disposal of privy wastes.

Should the State Design?

In the activities which have been outlined, the engineering service very soon becomes a well of information and an inspiration to the young municipal engineers. The fact that many of the smaller municipalities and almost all of the larger ones are now more fully appreciating the value of trained municipal engineers, leads me to raise a question: May we anticipate that the engineering services of the state boards of health will become consultative bodies, especially as to the design of water-purification and sewage-disposal works?

There can be no doubt that with reference to those things demonstrated in the experimental station, the state is, in fact, capable of designing. More especially is this evident when the staff and organization of the municipal engineer may be used for detailing. The question arises: Is it right or advisable for the state to assume this function?

This question is bound to be very acute in the course of the next few years. On the part of the state and municipality there is a certain long-suffering due to a good deal of encroachment on the field of consulting engineers by those advertising as such and lacking the specific qualifications. On the part of the consulting engineer there is a feeling that he cannot well enter into competition with the state, especially where the state is prepared to offer its services free or at a nominal charge. If the consulting sanitary engineer is to be superseded, there should be a definite forward movement of municipalities in favor of state offices assuming consultative capacities, and coincident with this the announcement of a definite program for the exchange of information.

The logical consummation of such a function on the part of the state would be for the engineering service to organize the co-operative effort by which the state becomes the repository of the collective efforts of its municipalities.

MINERAL AGGREGATES FOR BITUMINOUS PAVEMENTS*

Serious Shortage of Suitable Sands and Fillers—One-Third of all Failures Likely Due to Unsuitable Mineral Aggregate—Requisite Physical Properties

By Wallace L. Caldwell

Director, Department of Roads and Pavements, Pittsburgh Testing Laboratory, Birmingham, Ala.

ENGINEERS in charge of road and pavement construction are to-day facing a vital problem which must be solved if great road-building programs are to be carried out. That problem is the serious shortage of road-building materials, particularly aggregates for bituminous pavements. We must encourage in every possible way the development of new supplies of such materials, but, at the same time, we must not overlook the quality of these materials. This shortage has already resulted in the development of new sources of supply, but the slightly increased production has by no means met the demand. Some of the new materials being sold and used are far from satisfactory, and will undoubtedly cause a number of failures within the next few years.

The writer is connected with a number of current projects, and on nearly every contract difficulty is being experienced in securing sufficient supplies of satisfactory aggregate materials. In order to overcome the delay caused by this shortage, available but inferior materials are being offered. Delays are costly and inconvenient, and, therefore, a decided tendency to permit the use of unsuitable aggregate materials has been noted on the part of both contractors and city officials. It will invariably be found that the use of such materials will eventually be much more costly than any ordinary delay.

The public, and even some city officials, consider the bitumen to be the one important element in a bituminous pavement, but engineers familiar with pavement construction are aware that the mineral aggregate is of much greater importance. Many failures can be attributed to the use of inferior aggregates, but only a comparatively few to the use of an inferior bituminous cement.

The writer has investigated a large number of failures of different types of bituminous pavement, and has endeavored to differentiate the causes and percentage of failure. The percentages given below are not of universal application, but represent approximately the causes of failure encountered in the writer's investigation. The failures considered are failures of the wearing surface as distinct from failures caused by improper subgrade and foundations.

*Paper read at the last meeting of the American Society for Municipal Improvements.

Unsuitable mineral aggregate	30%
Improper manipulation at mixing plant	25%
Poor workmanship on street	15%
Bad weather conditions	15%
Bitumen of improper consistency	10%
Bitumen unsuitable for paving	5%
	100%

In spite of its importance, it is only recently that general attention has been given to the physical testing of aggregates for bituminous pavements. Even to-day, most specifications are extremely vague and indefinite as to the quality of aggregate materials. The specifications of the United States Bureau of Public Roads, of several state highway departments and of a few cities have recognized the value of such tests, and have made their requirements as definite as the present state of our knowledge of physical testing permits. Hundreds of specifications are being prepared every year in which even the data available at present are not recognized. The only definite test commonly specified is the mechanical analysis as determined by laboratory sieves. Aside from this test, the acceptance of aggregate materials is ordinarily based upon visual examination and personal opinion, both of which have their value, but some more definite standards are needed, especially in these days when many inferior materials are being used, often under the supervision of men of limited experience.

In this article only the aggregate materials commonly used in mixed method pavements will be discussed. The essential properties of sand, filler and the usual coarse aggregates will be described briefly.

Sands for Bituminous Pavements

Sand is the water-worn detritus of crystalline rocks, and is largely composed of quartz, although calcareous and feldspathic sands are known. It is the writer's opinion, and the experience of others seem to bear this out, that for paving purposes satisfactory results are in general obtained only from quartz sands.

Sands may be classified, as to source, as beach, river and bank sands. A great variety of sands are found in each class, but in general the sands of greatest value are secured from rivers and banks, although many sands from the beaches of the Great Lakes have been used satisfactorily. Sea-beach sands are sometimes used, but as a class are not so satisfactory as the other sands mentioned.

Before discussing the physical properties which are necessary in a sand, it may be stated that very little real quantitative data regarding the physical properties of sands for bituminous pavements are available. This is a fruitful field for research and is well worth the time of qualified investigators. Prof. Abrams and others have ably investigated the properties of concrete sands, and if our knowledge of bituminous pavements is to be advanced, it is essential that similar investigation be made as to essential properties of sands for use in bituminous pavements. This is a complicated field of research which offers many practical difficulties, but nevertheless the problems which need solution can and will be solved.

Investigating Properties of Sands

The writer is glad to report that certain investigations have been under way in his laboratories for some time, and that progress is being made. In due time results will be secured which will be of value. In the meantime, we can best secure satisfactory results by availing ourselves of the information which has been accumulated through experience and observation. Although this information is largely empirical, it serves as a useful guide.

Both theory and experience have shown that sands having angular grains are best suited for bituminous pavements. Rounded grains do not have as many points of contact as angular grains, and, therefore, a mixture in which such grains are used is not stable and is more readily displaced by traffic than a mixture containing angular grains. This applies to sand used in both fine and coarse aggregate pavements.

In order that a film of bitumen of sufficient thickness may adhere to each sand grain, the surface of the grain should be somewaht rough or pitted. Sands with smooth and polished grains are frequently encountered, but their use should be avoided, because the individual grains are sometimes so thinly coated with bitumen that a proper bond between the different particles of the mineral aggregate cannot be secured.

The sand grains should be hard and tough, so that the individual grain will not readily wear away under the abrasion of traffic nor fracture under impact. Of course, the small size of the sand grains and the cushioning action of the bituminous cement so largely reduces the danger of fracture that toughness is a much less important factor than in the case of aggregate of larger size, such as gravel and crushed stone. Several failures have been attributed to the use of sands with soft grains.

Hardness and Toughness

As yet no satisfactory means of ascertaining the hardness and toughness of sands have been devised. There is, however, a need for such tests, and in connection with the investigations previously mentioned the writer has developed certain methods for making these tests. Before arriving at any definite conclusion as to the value of these tests, it will be necessary that many check tests of several hundred different sands be made.

The amount and character of the impurities found in a sand largely determine its value. Clay, loam, mica and organic matter are common impurities, and in sufficient amount each one is a most important factor in determining the quality of a mixture.

Clay is found either finely divided and evenly distributed through the sand or in the form of small clay balls. If only a small percentage of clay is present in a finely divided state, and the clay itself is not plastic, little harm will be done; in fact a large percentage of the clay will be removed by the fan on the heating drum of the asphalt plant. However, if the clay is plastic and present to the extent of more than 5%, the sand grains will be coated with a hardened film of clay after passing through the drum. This film will prevent the bitumen from adhering to the actual surface of the sand grains. The film of bituminous cement is easily broken away from the sand grains, permitting water and traffic to disintegrate the pavement.

Clay, Mica and Organic Matter

Clay balls, when present in any appreciable quantity are a source of even greater danger than evenly distributed clay, and engineers should take a decided stand against the use of sands containing such material, because disintegration is quite certain. The clay balls at the surface of the pavement are removed by water and traffic. This allows water to gradually work down into the pavement, softening the clay balls scattered throughout the mass. Eventually this results in serious disintegration of the pavement surface. This condition is of more common occurence than is often realized.

In certain localities where the sands have been formed by disintegration of granites and gneisses, mica is almost a universal constituent of the sands. If present in any appreciable amount, trouble may be experienced, since the mica grains cannot be satisfactorily coated with bitumen and will not resist traffic. In practice the writer has ordinarily rejected sands containing over 3% of mica, as estimated with the microscope.

Organic matter, usually in the form of roots, twigs and leaves, is found in many sands. When the hot sand is screened through an 8-mesh screen, as in the case of sheet asphalt, the greater portion of such material will be removed, but when the type of pavement requires the use of a larger size screen, the roots and twigs will pass through into the mixture. Such material in the mixture is a source of weakness, and either the sand containing it should not be used or else it should be screened out.

(Continued on page 114)

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PRINCIPAL CONTENTS

SHOULD PROVINCIAL BOARDS OF HEALTH DESIGN SANITARY STRUCTURES?

MAY we anticipate that the engineering services of the provincial boards of health will become consultative bodies, especially as to the design of water-purification and sewage-disposal works? This question, asked by F. A. Dallyn, sanitary engineer of the Ontario Board of Health, in an article on another page of this issue, should be answered emphatically in the negative.

"There can be no doubt that . . . the state is capable of designing," says Mr. Dallyn. "More especially is this evident when the staff and organization of the municipal engineer may be used for detailing. . . . If the consulting sanitary engineer is to be superseded, there should be a definite forward movement of municipalities in favor of state offices assuming consultative capacities."

We strongly suspect that Mr. Dallyn is guilty of Shavian humor, and that he is merely having a little fun at the expense of his fellow sanitary engineers in Canada, otherwise he surely would not place himself in the position of appearing to advocate Bolshevistic doctrines of this sort. Surely no man who has been to Russia to fight Bolshevism, as has Mr. Dallyn, and no man who has acted as consulting sanitary engineer to any Ontario municipality of late years, would advocate seriously the superseding of consulting sanitary engineers and the acquiring by the state of a monopoly in sanitary design.

The office of provincial sanitary engineer would, indeed, be a very important one were he to be required actually to design all water works and sewage disposal plants. But we think that Mr. Dallyn would not care to remain in office long under such heavy responsibilities for a province the size of Ontario and without the benefit of the advice of any consulting engineers—they would have been "superseded," of course, just as all private enterprise has been superseded in Russia. His clients, the municipalities, might require too much. They might expect a solution of the sewage sludge problem, or a cheap method of sterilizing water without the addition of chemicals, and Mr. Dallyn might wish that he were once again in the position of a judge of the engineering merits of others' designs rather than of one who was being held directly responsible for the designs.

It may be quite proper for a provincial board of health, or local government board, to give advice within certain definite limits, and to pass upon the efficiency and safety of any plans submitted to it, but it is certainly beyond its functions actually to design a water purification or sewage disposal plant for a municipality, either free of charge or by giving its sanitary engineer permission to do the job "on the side" as a personal venture. Such a program would, indeed, cause the consulting sanitary engineers to be superseded, and incidentally would retard progress in the sanitary art, for we challenge Mr. Dallyn to point out contributions to sanitary engineering which have been made by any engineers while in the employ of any state or provincial boards of health, that will compare with the advancements that have been due to private initiative.

The King can do no wrong, but this immunity from error does not extend to the King's servants. The state is a glorious institution,—when its servants serve the people, but not when they attempt to crush private initiative and become despots. Mr. Dallyn should recall his tentative invitation to the municipalities to join in a "forward movement" in favor of state offices assuming consultative capacities,—a movement in which the engineering service of the provincial board of health is to become the leader by "organizing the co-operative effort" by which the state is to acquire its sanitary knowledge. But again we state that we suspect that Mr. Dallyn, who is an able engineer and an energetic (though sadly underpaid) worker in the interests of sanitary progress, is having a little joke on the profession in appearing to sponsor such an invitation.

THE WATER-RATIO-SURFACE-AREA METHOD

RESULTS that show the value of the surface area method of proportioning concrete materials when that method is combined with the use of Prof. Abrams' water-cement ratio, have been obtained by the engineering and construction departments of the Hydro-Electric Power Commission of Ontario.

In his article upon another page of this issue, Roderick B. Young, of the Commission's laboratory staff, gives an interesting comparison of the results obtained in some work where the Commission built a structure by this method and another similar structure by the old methods of proportioning, the same materials being used in both structures. The tests showed greater strength in the concrete proportioned by the water-cement-ratio-surface-area method than in the concrete proportioned in the present usual manner, even when less cement was used in the Hydro's proportioning than was used in the work done under the outside specifications.

In work done at High Falls, the Hydro obtained strengths far in excess of those normally secured by the use of the same quantity of cement.

The formula for obtaining uniform mobility, at which Mr. Young hints, will be of great value if further tests prove its accuracy under a wide range of conditions, and it is hoped that the Commission will vigorously pursue its investigations along this line. The suggestions regarding proportioning by weight and saving fractional parts of bags of cement are also noteworthy, and no doubt the next few years may see some radical changes in construction methods when contractors and construction engineers fully realize the definte savings that will result from taking the guess-work out of concrete-making.

PERSONALS

Lewie Dewar Walker, who was recently appointed water works engineer and inspector for the Canadian Fire Underwriters' Association, Toronto, was born May 9th, 1879, in Stirling, Scotland. He was educated at the Stirling High School and the Royal Technical College, Glasgow. In 1900 he was apprenticed to Crouch & Hogg, civil engineers, Glasgow, and was employed on the construction of railways, water works, bridges, etc. He joined the Clyde Navigation Trust, Glasgow, early in 1905 as assistant engineer on dock and harbor construction, mainly in connection with the improvements to the channel. Coming to Canada in 1907, Mr. Walker was on the staff of the C.P.R. at Montreal for a few months, in the maintenance-of-way department, but resigned in order to go with the G.T.R. at Fort William, on the construction of the Fort William terminals and the Lake Superior branch. From the spring of 1909 to the summer of 1911, he was in the chief engineer's office of the G.T.P. Ry., at Winnipeg, and for the following two years he was an assistant engineer on structural design in the chief engineer's office of the Algoma Central Ry., at Sault Ste. Marie. From the end of 1913 to the beginning of 1916, when he received a commission as lieutenant in the Canadian Engineers, he was in the Sault Ste. Marie office of the Department of Public Works of Canada. He went overseas in 1916 with a draft, but was detained in England for some months by the War Office, and was attached to the staff of the Administrator of Works and Buildings. Among other constructional work, he supervised the erection of the armament school for the R.A.F., at Uxbridge, Middlesex. Mr. Walker joined the 8th Canadian Engineers in France in 1918 and returned to England in February, 1919, and received his discharge in Canada towards the end of the following month. He joined the British American Nickel Corporation at Deschenes, near Ottawa, in June, assisting in designing the new nickel refining plant, and resigned that position only a few weeks ago upon receiving an offer from the fire underwriters. Mr. Walker is an associate member of the Institution of Civil Engineers of Great Britain.

John G. G. Kerry, of Kerry & Chace, Ltd., consulting engineers, Toronto, has sailed for England on a six weeks' business trip.

C. P. Disney has been appointed acting bridge engineer, eastern lines, Canadian National Railways, with headquarters at Toronto.

A. H. Harkness, consulting structural engineer, Toronto, and T. R. Loudon and C. S. L. Hertzberg, both of the firm of Loudon & Hertzberg, consulting engineers, Toronto, have entered into partnership, the agreement to take effect toward the end of this month. The firm name will be Harkness, Loudon & Hertzberg.

J. G. Mingle, who has been associated with the Rust Engineering Co., of Cleveland, Ohio, has been appointed Detroit representative of R. Winthrop Pratt, consulting engineer, specializing in sewage disposal and water supply. Mr. Mingle is a graduate of Purdue University, class of 1913. His territory will include all of Michigan and Ontario.

MINERAL AGGREGATES FOR PAVEMENTS

(Continued from page 112)

The grading of sand is, of course, one of its most important properties. In fact, experience and theory have demonstrated most clearly that the grading must be within certain narrow limits if satisfactory results are to be secured. Sand is used in several types of pavement, both by itself and combined in various percentages with several kinds of coarse aggregate, but in every class of pavement the grading of the sand is an important factor. From the standpoint of the practical asphalt man, sands are often classified as fine, medium and coarse.

The fine sand contains a high percentage of 100 and 80-mesh grains, the medium a high percentage of 50 and 40-mesh material, and the coarse a preponderance of 30, 20, and 10-mesh grains. In most localities, medium and coarse sands of proper quality are more readily secured than the fine. Sands containing a sufficient percentage of the fine 100 and 80-mesh grains must be found, since without these fine grains a satisfactory pavement will not be produced, regardless of the type of pavement. An engineer is fortunate, indeed, who can find one sand which will fill all requirements as to grading. Such sands are found but they are rare. Ordinarily mixtures of two, three and even four sands must be made in order to produce a properly graded aggregate.

Specifications customarily fix the percentage of 200-mesh sand at a maximum of 5%. This limitation is based upon sound reasons and should be invariably followed, in fact, it has been the writer's practice to limit the 200-mesh sand to 3% whenever possible. The 200-mesh material in a bituminous mixture should be composed of filler, and not sand. Sand grains, even though they pass the 200-mesh sieve, are much coarser than the greater portion of a properly ground dust, and do not function as a filler in any respect. Sands containing up to 10 or 12% of 200-mesh grains have been used with little or no filler, it being assumed that since the percentage of the 200-mesh material was within the required limits, no other material of this size was needed. Such mixtures are unstable and invariably result in failure.

Too frequently, the sands most readily available, even though not entirely satisfactory, are used. Usually a brief investigation and a sand survey will locate other supplies within reasonable shipping distance. Quite commonly the new supplies will be better than those previously available, particularly in those regions where suitable sands have not been developed owing to lack of demand. Before deciding upon the sands to be used on any job the writer has invariably investigated all possible sources of supply, both developed and undeveloped. The results obtained have usually justified these investigations.

(Concluded in next week's issue)

It is stated that 50,000 acres in Southern Alberta will be placed under irrigation next spring and thrown open for farm settlement by the Canadian Land & Irrigation Co.

The Dominion Public Works' Association, Toronto, has elected the following officers for the ensuing year: M. McCarthy, president; E. Hewitt, vice-president; C. Crowe, treasurer; and Robert M. Patterson, secretary.

Work has commenced in the erection of a power transmission line to carry 4,000 h.p. from Winnipeg to Portage la Prairie, Man. The line will be 60 miles long and the estimated cost is about $350,000.

At a meeting of the Hamilton Town Planning Commission held last month, the legislative committee was instructed to prepare a draft bill along the lines advised by Thomas Adams, of Ottawa, enabling the city to deal with its own development problems in a modern way. The bill will be submitted to the city council this month, and will be introduced into the Ontario legislature at the coming session. The commission will also support the Southwestern Ontario Town Planning Association in its endeavors to have the Town Planning and Development Act amended.