is measured by determining the temperature at which the sand begins to melt or fuse.

### IMPORTANCE

If the sand will not withstand the temperature at which the metal is poured into it without melting, the finer particles of the sand, such as the silt and clay, will actually fuse and become included in the surface of the casting. Even if the sand grains are sufficiently refractory some particular mineral in the sand, may possess a low fusion point and form pits in the surface of the casting. The first of these troubles is known as "burning-on", and the latter as "pitting". Both are due largely to the chemical composition of the sand and of the clay substance contained therein.

The effect of the presence of limestone or calcium carbonate in causing pitting has been indicated. If the sand is completely weathered practically all of the calcium carbonate will have been removed. As calcium carbonate is one of the most important fluxing agents found in sands, the color of the sand found in Michigan may be taken as a rough index of its refractoriness, as the deep red sands are leached free from lime and generally the light yellow or buff sands contain lime, either in grains or disseminated throughout the sand.

Because the range of fusion points of sands, from 1350° C. (2462° F.) to 1700° C. (3090° F.) is approximately the same as the casting temperatures of iron and steel, from 1300° C. (2372° F.) to 1670° C. (3038° F.), slight differences in the fusing temperatures of sand are important.

### TEST FOR REFRACTORINESS

Although chemical analysis is indicative of the ability of the sand to resist high temperatures a direct physical test of the fusion point of the sand is far more valuable as many other factors besides the chemical compounds present determines the refractoriness of a sand. Even the interpretation of direct tests of the melting point of sands offers real difficulty, as the sand is used in the foundry under different conditions than ordinarily encountered in furnaces used for determining the melting point.

In foundry practice the sand is in intimate contact with hot molten iron or steel and under reducing conditions, whereas ordinarily in the testing furnaces the atmosphere is maintained oxidizing.

D. W. Trainer[66] prepared a series of specimens by mixing clean silica sand with a glacial clay having a fusion temperature of approximately 1350° C. These samples were prepared in the form of cones and fired in

[66] Transactions of the American Foundrymen's Association, Vol. 34, page 327.



a muffle under oxidizing conditions in the conventional manner for making fusion tests of clays.

The results (Figure 26) show that none of the sand failed until the fusion point of the bonding clay was reached, and that all specimens of sand containing fifty percent or more of clay failed at approximately the same temperature as the pure clay. Similar tests conducted on bars showed that the bars containing the greater percent of clay failed at the lower temperatures.

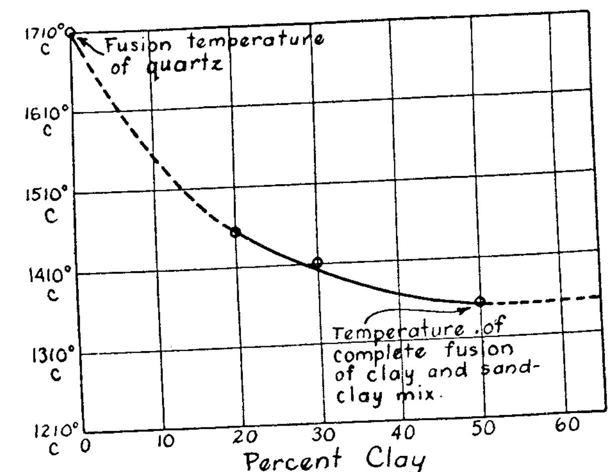



Fig. 26. The relation between the fusion temperature of sand-clay mixture and the percent of clay in the mixture.

### THE EFFECTS OF CLAY AND COLLOIDAL BOND

Although these tests were conducted under oxidizing conditions the results clearly indicate that the refractoriness of the sand is generally limited by the relatively low refractory properties of the clay, and the amount of clay contained in the sand at least up to 50 percent clay.

Trainer calls attention to the fact that in many of the sands tested in his laboratory, it was found that the grains were entirely or partially coated with iron oxide film. He states that this iron oxide adsorbed on the surface of the sand grain may be an important factor in starting the fusion of the quartz, since in such cases, a flux is in very intimate contact with the quartz grains. A. A. Grubb[67] also calls attention to the fact that iron compounds are not as refractory as those of aluminum, but are more plastic, and it is generally believed that high iron sands peel from castings better than high aluminum sands. A consideration of these facts clearly indicates that the refractoriness of a sand as de-

[67] The Instruments, January 1928.

termined under oxidizing conditions or even under reducing conditions in a gas-fired or muffle furnace, is not an accurate indication of the refractoriness of that sand when used in a mold in contact with hot molten metals.

Further contradictory statements of the same kind may be found between these two authors. Trainer[68] states, "Some have thought that the size of the grain may have an influence on the refractoriness of the sand. This in general has been found not true." Grubb[69], on the other hand, basing his conclusions on general foundry experience, rather than laboratory refractory tests states, "It is a well known fact that fusibility depends on particle size as well as on chemical composition."

If we base our conclusions entirely on laboratory tests, no doubt the statements of Trainer are accurate. But, in actual foundry practice, it seems reasonable to expect that the molten iron will flux more readily with the small particles of sand than with the larger because the fluxing must be complete before the iron solidifies, and the larger particles are known to react more slowly. It would seem just as reasonable to expect that the adsorbed film of ferric oxide on the sand particles would act in much the same way as butter or grease in a frying pan and tend to prevent the sand from adhering to the casting as to expect the small amount of adsorbed film oxide on the sand grains to have more effect on the fusibility of the sand than the relatively large amount of molten iron in contact with the sand mold.

Boswell[70] makes a similar statement in calling attention to the fact that molding sands not containing limonite on the sand grains tend to make dirty and poorer castings that those containing the colloidal iron oxide bond.

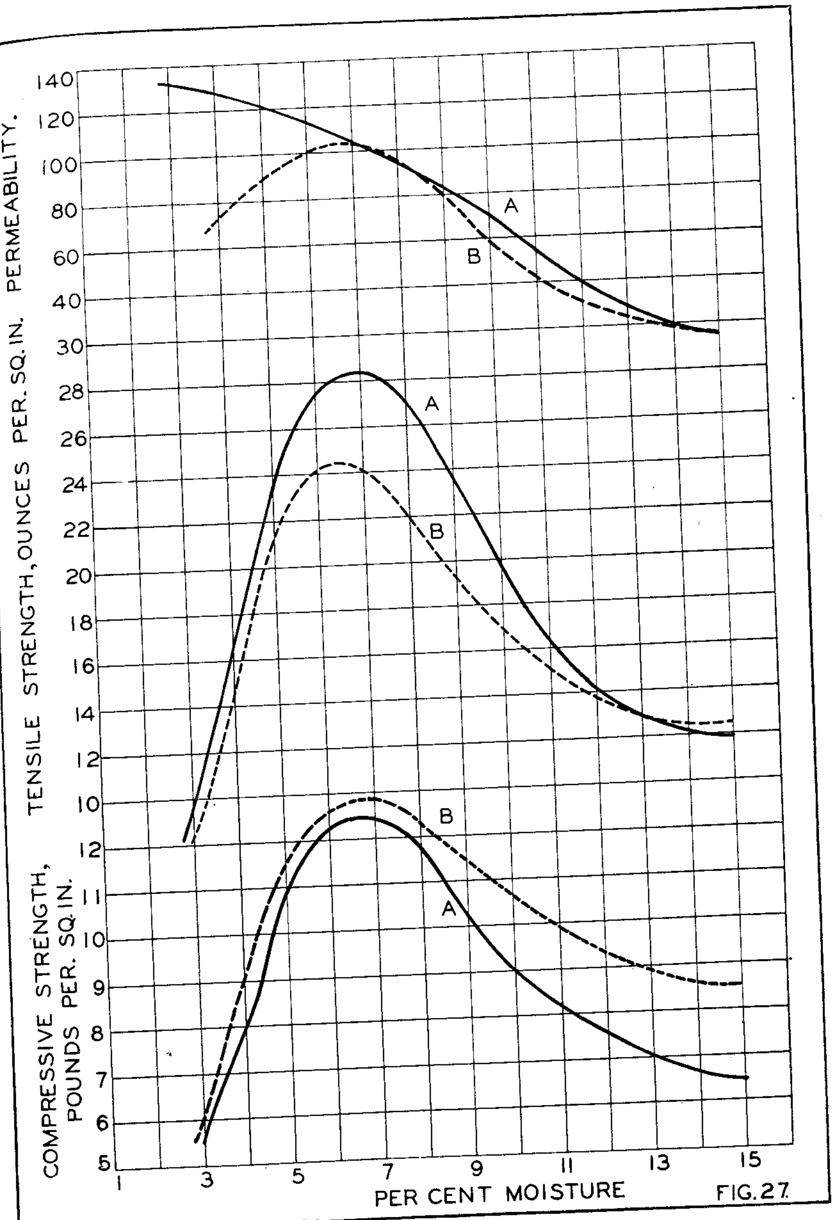
## THE EFFECT OF TREATMENT ON THE PHYSICAL PROPERTIES OF SAND

It is not the purpose at this place to discuss the various factors involved in reclaiming and improving foundry sand, but simply to indicate how the treatment given a sand sample during its preparation and testing may greatly affect the results of the test, and to summarize briefly the important variables determining the physical properties. A. A. Grubb* calls attention to the necessity of carefully breaking up all aggregates, or dusting the sample after drying to prevent the aggregate lumps remaining intact. "If this is not done, abnormally high permeability values result; if it is done, the values are apt to be lower than that of the heap in which it will be used."

[68]Transactions of the American Foundrymen's Association, Vol. 34, page 338.
[69]Instruments, January 1928.
[70]Foundry No. 47, pages 148-150.
*Instruments, January 1928.



Figure 27 illustrates the differences in physical properties that may be obtained depending on the manner in which the sand has been handled. A sample having a grain fineness of 70 and 23 percent clay content was mined wet and passed through a No. 4 riddle with the resulting test data




The effect of method of treatment on physical properties. Solid lines (A) represent riddled sample. Dotted lines (B) represent milled sample.

shown by the solid lines (A) in Figure 27. The sample was then dried, milled and tested again with the results as indicated by the dotted lines (B). This sand is used without other additions in foundry heaps carrying 11 to 14 percent of moisture and the permeability ranges from 60 to 70.

### RAMMING

In preparing sand molds the sand is always compacted by ramming. The degree of ramming or the amount of work expended in compacting the sand is a very important variable in the determining of the properties of the sand mold. Perhaps the most thorough investigation into the effect of ramming on the various physical properties of molding sands is that reported by G. A. Hansen.[71] Qualitatively the general statement may be made that increase in the amount of energy expended in ramming a sand decreases the permeability and increases its bond strength, but general quantitative relations cannot now be stated. As pointed out by Hansen it would seem logical to test the permeability on samples of sand that have been heavily rammed and the bond strength on samples that have been lightly rammed, in order to determine the worst possible behavior to be expected of the sand. Unless the ramming and the moisture content used in making these tests are practically the same as those used in preparing the molds, greater differences between the same sand when rammed differently are evident than between different sands.

In Figure 28 the permeability moisture curves are given of sample No. 289 Houghton County as determined from two different sized specimens but rammed with the same total energy. The solid line and points give results as obtained with the Standard A.F.A. permeability apparatus which rams the sand from one end three times by dropping a 14 pound weight two inches on an area of 3.1416 square inches corresponding to a total energy adsorption of 26.7 inch pounds. The broken line and circled points give the results obtained from ramming a sample of one square inch cross-section once by dropping a weight of 7 pounds 1.91 inches, corresponding to an energy adsorption of 13.4 inch pounds on each end of the specimen as the mold was designed for top and bottom ramming (Figure 11).

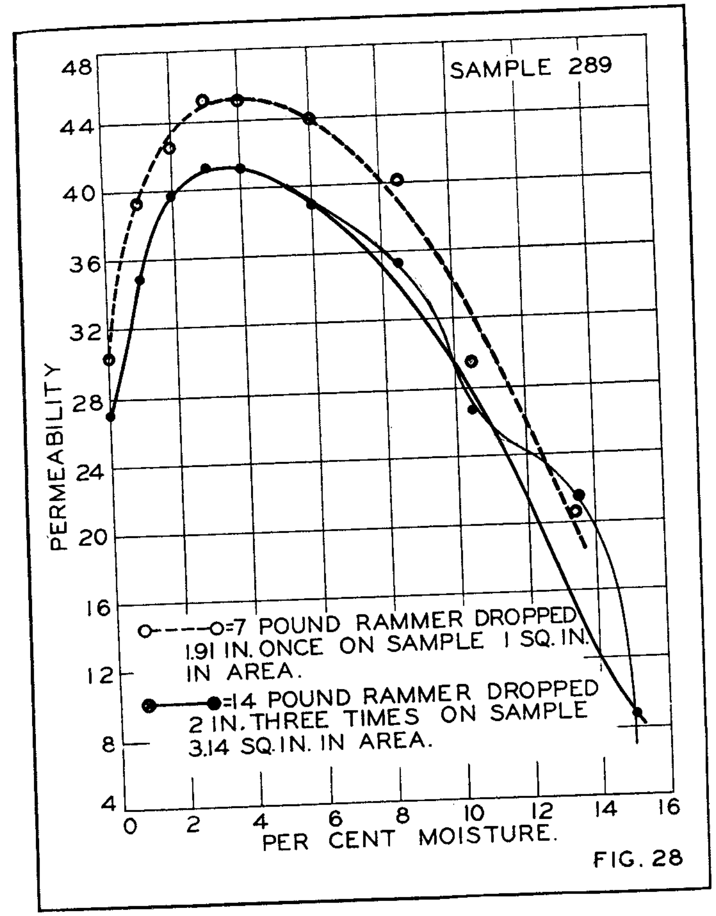
The latter specimen shows a slightly higher permeability indicating that some energy was adsorbed in the mold constructed for top and bottom ramming. But the energy adsorbed by the specimen in ramming seems to be the best criterion of degree of ramming.

[71]Transactions of the American Foundrymen's Association, Vol. 32, Part II, page 57.



### TEMPERING OR MOISTURE CONTENT

Nevin[72] investigated the effect of water on the bond strength and permeability of molding sand. Interesting photo-micrographs are shown which clearly indicate that the colloidal matter and clay substance are not uniformly adsorbed on the sand grains unless the proper amount of




The effect of ramming and moisture on permeability using same relative energy of ramming on different sized specimens.

water is present. As the amount of water is increased the sand particles seem to adsorb the clay and colloidal matter from the spaces between the sand grains, thereby increasing the permeability of the sand and at the same time developing a maximum strength. As the water content is further increased beyond that necessary for the full development of the adsorbed colloid on the particles of sand grains, the bond appears to

[72]Transactions of the American Foundrymen's Association, Vol. 32, Part II, page 168.

become diluted with the excess water which also tends to fill up the spaces between the sand grains.

Exactly the same conditions are indicated in the results reported in the investigation into the cause of the bond in molding sand. Water is absolutely necessary for the development of the colloid structure of the mineral oxides in the sand. The adsorption of the colloid on the sand grains is due to the effect of these colloids on the interfacial tension between the sand particles and water. The water wets the sand particles in much the same way as water wets glass. The colloid particles are then adsorbed in the interface between the sand particles and the water, at the same time adsorbing water themselves and taking on the characteristics of sticky or glue-like properties common to all colloids. The water wets the particles of silt and clay in much the same way as it does the sand grains, thereby serving as a means for uniting or cementing the particles of sand together through the development of the colloid structure which is re-enforced by the particles of silt and clay.

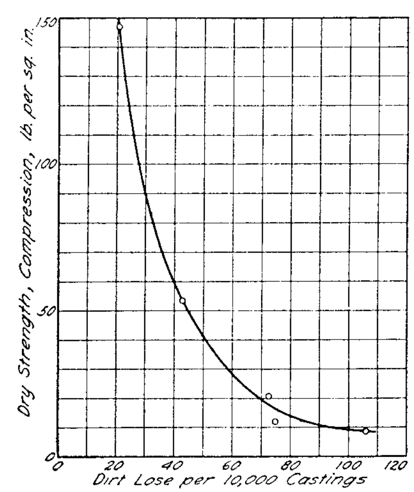



Fig. 29. The relation between casting loss and dry strength of molding sand.

In the absence of water the fine particles of silt and clay tend to fill up the spaces between the sand grains. Upon the addition of water and bonding of the sand grains in this manner the fine particles of silt and clay agglomerate with the sand particles tending to form larger particles with larger and smoother interstices. This allows freer passage of the air, developing a greater permeability as well as an increase in the tensile strength and bond of the sand itself. These properties are increased as the water present in the sand is increased up to a certain



point, beyond which further addition of water tends to fill up the spaces between the sand grains decreasing the permeability of the sand and diluting or weakening the green bond.

Moisture has an even greater effect on the dry strength than on the green bond strength, as is shown in Figure 29. Experience indicates that the moisture content for maximum dry strength is considerably greater than that for maximum green bond strength. If the sand is then tempered with consideration only for the green bond strength, the dry strength of the sand may be so low as to cause the mold to cut or wash during pouring.

Clearly the purpose of tempering the sand is two-fold. First, to obtain the desirable green properties, such as strength, permeability and texture. Second, to obtain the desired dry strength and dry permeability. The importance of the first has been recognized for some time. Figure 29 from Dietert[73] clearly indicates the importance of having the proper dry strength. Dirty castings seem to be due largely to the cutting and washing of the mold caused by a low dry strength.

[73]Transactions of The American Foundrymen's Association, Vol. 34, page 252 (1926).

## Chapter V

# SAND CONTROL AND RECLAMATION IN FOUNDRIES

## CONTROL OF PHYSICAL PROPERTIES

It is not the purpose to enter into a discussion of sand control in the foundry and the commercial problems involved in the economic utilization and reclamation of mold-sands. But, a discussion of the physical properties of molding sand would not be complete without a brief discussion of how these physical properties are influenced or improved by a mechanical treatment of the sand. The effect of moisture and the degree of ramming on the strength and permeability of molding sand have already been indicated.

In actual foundry practice the *degree of ramming* can be maintained fairly constant by a careful check-up of the molding machine or by using the same molders if hand labor is depended upon for this purpose.

### MOISTURE CONTENT

Moisture content can be accurately controlled only by a physical test used as a check on the amount of water used to temper the sand. The importance of controlling the water used to temper the sand can not be over emphasized, because changes in the moisture content cause changes in the bond and the permeability of the sand. If the sand is not properly tempered the green strength and particularly the dry strength of the mold will be affected, causing an increase in the loss of castings. This increased loss is then likely to be blamed on the sand which is then immediately treated by the addition of a large quantity of new sand to bring up the strength. The properties of the heap sand are then greatly changed and the molders have to deal with an entirely different material than that to which they are accustomed. This introduces still further trouble, all of which could be avoided by a careful control of the water used in tempering the sand.

Hansen has investigated in a qualitative way at least, the force required to reduce the moisture content of the sand from that in excess of maximum strength to that slightly less than necessary for maximum strength. This was done by draining the sand on a filter at the end of which treatment it contained 19.1 grams of water per one hundred grams of dry sand. The sand was then centrifuged at the indicated speeds with the results given in Table XXXVI.



TABLE XXXVI.—The Effect of Centrifuging on Moisture Content.

| R. P. M. of Rotaux Machine | Apparent Weight of One Pound of Water at this Point | Grams of Moisture Retained Per 100 Grams Dry Sand After 10 Minutes Rotation |
|---|---|---|
| 0 (Filter drained) | 1 | 19.1 |
| 210 | 5.1 | 16.3 |
| 360 | 14.9 | 13.5 |
| 510 | 29.8 | 8.1 |
| 1000 | 116 | 7.2 |
| 2000 | 464 | 6.05 |
| 2500 | 724 | 5.7 |

Plotting the values of the second column against those in the third column indicates that for this sand water in excess of 8 percent is not held as tenaciously as that up to slightly less than 8 percent. This indicates that the saturation point so far as colloidal conditions are concerned is about 8 percent.

In many ways the accuracy of the Standard Moisture Test is unnecessary for plant control work, and a more rapid method even of less precision is more satisfactory. Dietert[1] describes a satisfactory method for foundry control, using a sample weighing about 860 grams. The larger sample is more apt to be representative of the heap sand than the small sample used in the oven test, and the short time required—2 to 3 minutes —is of great advantage in foundry control work. This method is based upon the principle that the amount of water displaced by the eight hundred and sixty gram sample when placed in a vessel full of water, is directly proportional to the percent of moisture contained in the sand. A dry sample of sand will displace a small amount of water, a wet sample will displace a larger amount. Of course, such a method would be useless in testing sands of different grain size, clay content, and density, but in testing the same heap sand of practically constant grain size, density, and other properties the assumption is justified.

The same author[2] describes a *compression moisture method* which is even more rapid than that mentioned above. For a given sand, the length of a rammed sand specimen is inversely proportional to the moisture content. The procedure uses a sample of sand weighing one hundred and seventy (170) grams, which is rammed in the permeability specimen tube in the Standard manner. The rammer is equipped with an indicating hand which registers accurately the length of the rammed specimen, as described in the section on ramming. If desired, the scale of the indicator may be calibrated in percent of moisture instead of height of rammed specimen. For practical foundry control it is not necessary to

[1]Transactions of the American Foundrymen's Association, Vol. 32, part 2, page 28.
[2]Dietert. Transactions of the American Foundrymen's Association, Vol. 33, page 751.

know the absolute moisture content in tempering the sand, as simply relative moisture content will give equally satisfactory results.

The compression test for moisture can not be used to determine the correct percentage of moisture of a sand for which it has not been calibrated, but only the relative variation of moisture, which is all that is required in a foundry for controlling the tempering of heap sand. Dietert states that this method will give readings varying not more than two-tenths or three-tenths from the correct readings of moisture content as determined by the Standard oven test. As all satisfactory molding sands should possess at least a leeway of one percent moisture for satisfactory tempering it is seen that this method is well within the limit required for foundry control.

### CONTROL OF RAMMING

With controlled moisture content or temper of the heap sand it is comparatively simple to check the degree of ramming actually given in the mold by permeability test of the mold. For this purpose special apparatus may be used[3] or the Standard A.F.A. permeability apparatus may be carried out in the foundry and used for actual testing of molds.[4]

If the permeabilities of the molds vary appreciably it is a direct indication that the ramming of the mold must be at fault, because the moisture and the permeability of the heap sand are accurately controlled by the method described.

## RECLAMATION AND IMPROVEMENTS IN PHYSICAL PROPERTIES

Changes in the property of the molding sand itself are generally brought about by mixing new sand to bring up the bond or permeability of the heap sand, or adding other material such as clay or colloidal matter to modify the properties of the sand so that they will more nearly approach those considered best for the conditions of use. Obviously, in preparing synthetic mixtures of this kind, it is absolutely necessary to know the desired properties, if the mixture is to be made in any really intelligent fashion.

### NEW SAND ADDITIONS

Perhaps the most common method is to add new sand to the heap sand in order to maintain the desired minimum strength and permeability. In adding new sand, the sand grains themselves may be considered simply as carriers of the active bonding material, unless the added sand is of

[3]Harrington, Wright and MacCombe, Transactions of the American Foundrymen's Association, Vol. 32, part II, page 98.
[4]Harrington, Wright and Hosmer, Transactions of the American Foundrymen's Association, Vol. 34, page 307, 1926.



such size distribution as to tend to increase the permeability of the sand. Under these conditions, the addition of the sand particles themselves are the important consideration. It would then seem logical to add simply the active bonding material to a heap sand in order to bring up its bond. But generally, the addition of clay or ordinary colloid matter to the sand, is not satisfactory. Numerous investigators have found that mulling the sand for a relatively long period after mixing clay to improve the bond in this manner, causes an intimate mixture of the clay and the sand which then has the desired property.

### MULLING

One of the first papers reporting the effect of mulling on molding sand was that by Wolfe and Grubb.[5] A number of mixtures as shown in Table XXXVII were investigated, in which local sand No. 1 and No. 2 are those produced in Northern Ohio, and Gallia refers to the red sand in Gallia County, Ohio. Local No. 1 and No. 2 correspond to Albany No. 1 and No. 2 respectively in permeability and bond. The Gallia sand shows a high permeability and high bond with clay content of 27 by the A.F.A. test, and a dye-adsorption of 1700.

TABLE XXXVII.—Effect of Mulling on Various Sand Mixtures.

| Mixture Numbers | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Percent heap sand in mixtures | 100 | 100 | 60 | 60 | .... | 88 | 85 | 80 | 95 |
| Percent refuse in mixtures | .... | .... | 30 | .... | .... | .... | .... | .... | .... |
| Percent Local No. 1 in mixtures | .... | .... | .... | 30 | 90 | .... | .... | .... | .... |
| Percent Local No. 2 in mixtures | .... | .... | 10 | 10 | 10 | 12 | 10 | 10 | .... |
| Percent gallia in mixtures | .... | .... | .... | .... | .... | .... | 5 | 10 | .... |
| Percent Albany No. 2½ in mixtures | .... | .... | .... | .... | .... | .... | .... | .... | 5 |
| Percent Albany slip in mixtures | .... | .... | .... | .... | .... | .... | .... | .... | |
| Method of mixing | S* | S | R** | R | R | R | S | R | S |
| Bond of mixture | 160 | 139 | 134 | 139 | 156 | 133 | 144 | 133 | 138 |
| Perm. of mixture | 20 | 28 | 23 | 26 | 45 | 25 | 20 | 30 | 19 |
| Bond after mulling 10 minutes | 178 | 155 | 190 | 198 | 212 | 169 | 158 | 143 | 178 |
| Perm. after mulling 10 minutes | 19 | 23 | 19 | 21 | 43 | 19 | 19 | 37 | 16 |

*Screen method. **Royer method.

### Strength and Bond

It will be noted that the maximum bond strength is developed only after the mixture is mulled for about fifty minutes or longer, depending upon the properties of the mixture. Mulling alone without the addition of new bonding material serves to restore considerable bond strength to a refuse sand, and has much the same effect on the regular heap sand. It was also noted that the working properties of the heap sand were greatly improved by this treatment and the effect on molding losses was evident for several days.

[5]Transactions of the American Foundrymen's Association, Vol. 32, part II, page 1.

The effect on the strength of the sand as determined by its tensile and compressive tests was similar to the effect of mulling on the bond as determined by the A.F.A. method. The dye-adsorption value was practically unaffected by mulling. This interesting fact leads the author to suggest that the dye-adsorption test probably indicates those characteristics determining the potential bond or the maximum strength that can be developed in a given sample, while the actual tensile compression and bond test indicates the actual strength of the sand existing at any given time.

Grain Size

Mulling seems to have no effect on the average grain size, at least during the first 100 minutes. It is known that dye-adsorption is an equilibrium condition between the surface of the sand grains and clay, and the dye in water solution. The fact that the grain size is not affected by time of mulling, and that the dye-adsorption value remains practically constant, may simply indicate that the active surface of the sand is not changed by mulling. In so far as the active surface of the sand grain determines the potential or maximum bond of the sand, the dye-adsorption value may be a correct indication of the potential bond of the sand, if such a term has any definite meaning.

Permeability

The permeability of the sand was reported to be generally decreased slightly during the first few minutes of mulling, and then to remain practically constant until the sand is mulled for such a long time that the bond strength begins to decrease. In their report Wolfe and Grubb did not state whether or not the sands and mixtures were retempered after mulling. Apparently this was not done, and the loss in permeability was due to a loss in moisture which occurred during the mulling operation.

A later and more thorough investigation by A. V. Leun[6] of the effect of mulling on the physical properties of sand took into account the effect of drying of the sand during mulling. It was found that the water content of the sand was decreased from about six percent to approximately three percent while mulling for one hundred twenty minutes, and that the decrease in moisture is practically a straight line function of the time of mulling. Water content is a very important variable in determining the properties of molding sand, and the earlier results may be entirely contradicted because the proper allowance was not made for this important variable.

[6]A. V. Leun, Transactions of the American Foundrymen's Association, Vol. 34, page 269 1926.



After several unsuccessful attempts to prevent the loss of moisture during mulling, water was added to the sand during the process at the proper rate to maintain practically constant water content. The results of these tests are similar to those reported by Wolfe and Grubb in that in all cases the strength seems to increase with more or less rapidity with time of mulling up to about seventy-five minutes, but, as might be expected, the results regarding permeability are quite different as it was found in the great majority of cases that increasing the time of mulling increases the permeability of the sand if the moisture content is maintained.

The second investigation covering a wide variety of sand clearly indicates that mulling invariably improves the properties of a sand which has been used for some time and is almost indispensable in obtaining the best possible results from such artificial or synthetic mixture as are commonly used.

The effect of moisture content on the sand during mulling is a very important factor. Generally the sand should be mulled with insufficient water rather than with an excess of moisture.

Apparently the increase in permeability frequently noticed in mulling sands is due to the agglomeration of the particles as they are rolled around in the muller. This is generally more pronounced in sands which have a relatively high clay content.

## CLAY ADDITIONS

The bonding and rebonding of molding sand heaps by the addition of clay is not a new problem, as this is the common practice in steel foundries which use a highly refractory sand composed of almost pure silica and a refractory clay. In gray iron foundries the casting temperature is sufficiently lower than in the steel foundries to permit the use of less refractory materials and natural bonded molding sands are usually depended upon even for rebonding heap sand, as described.

Harrington, Wright and Hosmer[7] have found it possible to rebond heap sand by the addition of clay and the use of an effective mixer such as a muller or a paddle-type mixer. In general they found that the paddle type mixer gave higher permeabilities and only slightly lower strength than the muller. However, in treating the heap sand with only clay additions over a period of two or three months, it was found impossible to prevent scabbed castings. The addition of a small percentage of new sand, varying from four to eight percent, was sufficient to produce within the sand such characteristics as to eliminate this tendency to a great extent. It was noted that heap sand rebonded by the addition of

[7]Transactions of the American Foundrymen's Association, Vol. 34, page 307, 1926.

clay showed slightly lower permeability and compression strength than heap sands rebonded by the addition of new sand; also that sand rebonded entirely by the addition of clay seemed unable to develop strength with increased clay content.

Clay Alone Inadequate

These facts indicate clearly that the simple addition of clay for a rebonding material in molding sand, even when the mixture is properly mulled to develop the best working properties, is not adequate to entirely restore the natural bond in the sand. Harrington, Wright and Hosmer noticed a decrease in dye-adsorption with an increased clay content, clearly showing that the clay possesses a lower colloidal value as determined by the dye-adsorption test than the natural sand itself and certainly that bond, clay content, and dye-adsorption are not by any means representative of the same physical property. The results of our work on the relation of colloidal ferric hydroxide to the bond of natural molding sands definitely indicates that the desirable properties possessed by natural molding sand can be duplicated only by supplying a colloidal hydro-jell bond in addition to the clay bond. In adding new sand as a rebonding agent, much colloidal matter is added with the bond carried by the new sand.

Exactly what contribution the colloidal bond makes to desirable properties of the sand is not known. But it would seem to be some effect on the dry strength or properties of the sand in the dry rather than green condition. The tendency toward scabby casting when such colloidal matter is lacking, and the high dry strength of sands bonded by colloidal ferric hydroxide have been noted.

It seems reasonable to expect some relationship between these two facts. The data obtained from an extensive investigation into the possibilities of the use of colloidal ferric hydroxide and clay as a means for rebonding heap sands should prove of practical and theoretical value.

Dry Strength Important

In discussing the scabbing of castings, H. W. Dietert[8] reports that it has been his experience that scabbing is brought about by the use of a sand possessing a too high green strength, and that he has time after time eliminated scabs by simply reducing the green strength of the molding sand. Because it may be the tendency of the molder to increase the green strength in order to lighten his work in ramming or to be sure of getting a good mold, perhaps the increased green strength of the sand causes the molder to use less water or to ram less with disastrous results

[8]Transactions of the American Foundrymen's Association, Vol. 34, page 324, 1926.



to the dry strength. Hansen[9] has clearly shown that the dry strength increases rapidly with increased ramming. It may be that the scabbing is due rather to a low dry strength of the mold, because the mold was insufficiently rammed to develop a necessary dry strength, when the green strength of the sand was excessive.

Use of "Impure" Clays

A. C. Porter[10] reports his experience in using an impure clay from a brick yard added to the burned out sand as a slip composed of about equal weights of clay and water mixed in a muller. After four months of rebonding sand in this manner without the addition of new sand, no difficulty had been observed. This may be due to the fact that the impure clay which was obtained from the brick yard contained sufficient colloidal ferric hydroxide or similar material so that the proper balance between clay and colloid was maintained, or it may be due to the fact that there was sufficient colloid matter in the sand originally to stand the addition of an appreciable amount of clay before any trouble might be experienced as this practice was continued over a longer period.

Our investigation has shown that the bonding power of clay is destroyed more rapidly than that of the adsorbed ferric hydro-jell on the sand grain. This fact may explain why efforts to rebond heap sand by clay additions alone have not been entirely satisfactory.

## SAND HANDLING IN FOUNDRIES

Many practical foundry men in reporting the results of their experience in the transactions of the American Foundrymen's Association call attention to the important advantages in using proper sand control in the foundry. In general, however, the customary method of a foundry does not lend itself readily to treating the sand or keeping it in proper condition by mechanical and chemical treatment. The sand is usually available to the molder in the form of a heap on the foundry floor. The molds are prepared from this heap sand, then the metal is poured, and finally, the sand is returned to the heap where it is retempered and mixed for the next day's operation.

Max Sklovsky[11] calls attention to the fact that under this method of operation, a molder handles forty times as much weight in sand as compared with his production in castings, in the dumping process about nine times the weight of castings, and in cutting the sand, about eighteen times the weight of castings, making a total of sand handled by labor about sixty-seven times that of the casting produced. Not only is this

[9]Transactions of the American Foundrymen's Association, Vol. 32, part II, page 57.
[10]Transactions of the American Foundrymen's Association, Vol. 34, page 325, 1926.
[11]Transactions of the American Foundrymen's Association, Vol. 33, page 708.

a tremendous manual effort but, as the total weight of sand in use in the foundry greatly exceeds that of the casting produced per day, the difficulty of treating this large amount of sand to maintain the desired property for the best production of casting is a real problem.

Sklovsky describes a method of handling and treating molding sands in a foundry, which is radically different from the conventional method and promises important advantages in that the sand is handled entirely by mechanical conveyors which bring the treated sand to the molder and carry the dump sand to the treating equipment. During any one time the number of filled molds is less than five percent of the total daily production. This amounts to about two percent of the total sand in the system.

Such a system not only saves the large amount of labor in handling the sand in the customary manner but offers an important advantage in the ease with which the sand may be treated. It is not necessary to carry the sand by means of the crane to the treating equipment and then back to the heap, as would be necessary in the more conventional type of foundry, as the sand is carried by the conveying system to the treating equipment, and after treatment is carried by a similar system to the molder.

Problems of this kind must always be considered in the light of local foundry conditions. Perhaps in many cases it is still more economical to purchase new sand as required, discarding the old. Present conditions are making this practice more and more expensive, and many foundries are turning their attention to the possibility of reclaiming their old sand and in some cases actually investigating the use of synthetic sand in iron founding. The larger the foundry, and the more sand that is used, the greater the economy in such a procedure.

### SYNTHETIC SANDS

In many ways, preparation of synthetic sands seems to offer the ultimate solution in much the same way as it has been found to be the solution to the problem of casting steel. The differences between the melting point of the iron which is being poured in the mold and the fusing point of the clay bond material is so slight that the differences between the casting temperatures of iron and steel are sufficient to preclude the use of natural bonded molding sand in making steel castings.

# Chapter VI

# CLASSIFICATION OF SANDS

Sands as well as other materials may be classified in a number of different ways. Classification on the basis of origin has already been given in the first chapter. In this chapter sands will be classified according to their uses, and to those physical properties susceptible to classification or description which are most important in determining the practical uses of sand.

## MOLDING SAND

The most important classification of molding sand is that based upon the physical properties determining the utility value of the sand. The need for standardization and classification of these physical properties is generally recognized and such standards are being adopted rather rapidly by the American Foundrymen's Association. The more reliable guide so far has been the results obtained in actual shop practice, as compared to the physical properties determined by the methods of tests enumerated in the previous chapters. At present no entirely satisfactory correlation can be made of the behavior of the sand in molds, with its physical properties, until the necessary information has been accumulated and interpreted in terms of the Standard Tests.

### PHYSICAL PROPERTIES

#### Fineness or Grain Size

The most easily classified property of molding sand is the fineness. For this reason we find that most attempts to grade molding sands are based primarily on fineness.

Perhaps the oldest system of grading sand in this country is the Albany System, or Albany Grade Numbers, based upon fineness or average grain size as indicated in Figure 4. The tentative standard grading classification for foundry sand adopted by the American Foundrymen's Association[1] is based upon a grain fineness number and a clay content classification.

*Relation Between Fineness and Permeability.* Grain size or fineness, and grain size distribution affect the permeability of the sand, its green strength, dry strength and other properties, as well as being a fundamental property of the sand itself.

[1]Transactions, Vol. 35, page 193, 1927.

In grading molding sands, C. A. Hansen[2] has found the average permeability of Albany sands to be fairly well represented by an exponential function of the grain diameter in mills, or of the Rittinger Index as follows:

$$P=3.1\times D^{1.5}$$

or approximately

$$P=3.1\times 2^{n+1.5}$$

where

P is the permeability, D the diameter in mills and n the Rittinger Index.

The permeability of molding sands depends upon other factors than simply the average grain size, and any such relationship must be only approximate.

Another approximation[3] is given by the Sub-Committee of the American Foundrymen's Association on grading sands, which studied a total of seven hundred and twenty-seven natural sands including sixty-four sands from the State of Michigan. The A.F.A. grain fineness number for these samples was calculated, the data assembled and classified in respect to grain fineness, clay content, dye-adsorption value, permeability, and bond. Upon plotting the permeability averages against grain fineness averages, it was found that the points lay very close to a curve represented by the equation:

$$P=\frac{187{,}000}{F^{1.8}}$$

where P is permeability, and F. is A.F.A. grain fineness. Seventy-three percent of the samples studied came within plus or minus fifty percent of the values computed by the formula, which does not take into consideration clay content, distribution of grain size, or other factors, which are important in determining permeability. An alignment chart taking into consideration both grain fineness and clay content is also included which approximates more closely the permeability of new sand.

These two studies indicate that grain fineness is the main factor in determining the permeability of a sand.

## Clay Substance

In many ways *clay substance* and *silt,* may be considered as part of that property identified as *fineness,* as the distinction between sand grain silt and clay, is based fundamentally on differences in sizes of particles. In fact some analyses as reported by the American Foundrymen's Association are based on 100 percent including sand grains, silt, and clay substance; but in classifying sands the A.F.A. grain Fineness Number already described is based on 100 percent excluding the clay substance. The latter plan is preferred because the industry has always so classified sands independently on the basis of grain size or texture, and clay content or bond. The distinction between sands containing a relatively large amount of "clay substance" or "bond" generally classified as strong sands, and sands containing a relatively small amount, classified as weak or lean sands, has been made ever since sands were first used for making metal castings.

[2]Transactions of the American Foundrymen's Association, Vol. 34, page 393, 1926.
[3]Transactions of the American Foundrymen's Association, Vol. XXXIV, page 504, 1926.



Recognizing that the clay content is not identical with the bond of the sand, the classification of sands into groups according to their clay content, as suggested by the Tentative Standard Grading Classification for Foundry Sands of the American Foundrymen's Association, will prove of value in giving some definite numerical scale to the relative terms strong and weak as applied to molding sands. In this classification the clay content is designated by a letter in a series from A through J according to the following classification:

Clay Content Classification

| Class | Clay Content Zone |
|---|---|
| A | 0.0% to but not including 0.5% |
| B | 0.5% to but not including 2.0% |
| C | 2.0% to but not including 5.0% |
| D | 5.0% to but not including 10.0% |
| E | 10.0% to but not including 15.0% |
| F | 15.0% to but not including 20.0% |
| G | 20.0% to but not including 30.0% |
| H | 30.0% to but not including 45.0% |
| I | 45.0% to but not including 60.0% |
| J | 60.0% to but not including 100.0% |

This tentative Standard Grading Classification of the American Foundrymen's Association includes grain fineness and clay content which together determine approximately the permeability and the strength of the sand. With the possible addition of grain size distribution, it does not now seem advisable to complicate further the grading of sand.

*Permeability and Bond Strength* vary so much with moisture content and other conditions of test or use that, for the present at least, it seems better to tabulate this information separately.

## Durability

Another important factor in determining the relative grade of molding sand, is the durability of the sand. It seems that the most satisfactory present method of determining the durability of the bond, is to heat the sand to 600°F. for two hours. The percent of original bond strength remaining after this treatment at that moisture content giving the maximum bond strength in each case, may be regarded as the relative durability of bond.

USES

With this information it is possible to estimate the purpose for which the sand may be used successfully, provided we know the properties of sand which has proved successful in practice.

Although many foundries have determined the properties of sands which may be used successfully in their own plants only little information of this kind has been published. H. W. Dietert[4] gives the properties of sands that are used successfully in the plants of the U. S. Radiator Corporation. For boiler molding sands, the desirable permeability is between 35 and 45, with a compressive strength of from two to three and one-quarter pounds as determined by Dietert's method. The sand should have a fairly wide moisture range giving permeability and bond strength within these limits, with the maximum approximately between seven and eight percent of moisture. Dietert reports that the sand is kept within these limits by the proper addition of an adaptable new sand, as open sand, or bonding sand, and by correct tempering. In purchasing new sand the salesmen are requested to submit representative samples which can be duplicated to within twenty percent of test reading in car lot shipments. These samples are then tested for permeability and compressive strength over the possible working range of moisture content, as well as for clay content, fineness, base permeability, lime, and durability. The percent variation in moisture required to make a change of two and one-half cc. in permeability is regarded as the moisture working range. Sands having a moisture working range of less than one and one-half are difficult to temper correctly in the heap. Some sands have a moisture working range of about seven percent.

Generally a sand which loses not more than twenty percent of its compressive strength when heated to 600° F. for two hours is desired. But this figure may be varied to suit local conditions. For example, if a foundry is located close to a large deposit of molding sand which can be obtained at relatively low cost, it would prove more economical to use this sand even though less durable than other sand not so readily obtainable, to save high freight rates.

Dietert calls attention to the great importance of *base permeability* because it compares the permeability of all sands under similar conditions. Some sands of high clay content show a low permeability due to the presence of a large amount of clay. Yet, when these sands are added to the heap they may have a very open grain structure which will tend to increase the permeability of the heap. This open grain structure giving high permeability is shown on determining the base permeability but not in the natural permeability.

[4]Transactions of the American Foundrymen's Association, Vol. 32, Part II, page 24.



Later Dietert[5] tabulates the permeability values known to give satisfactory results in his foundry for various purposes as follows:

| *Kind of Work* | *Permeability* |
|---|---|
| Light gray iron, hand rammed | 20 to 30 |
| Medium gray iron, hand rammed | 30 to 40 |
| Radiators cored, hand rammed | 30 to 40 |
| Stove plate—Squeeze | 8 to 12 |
| Medium plate—cores or flat squeeze | 12 to 20 |
| Flat boiler section, 200 pound to 900 pound jolt | 40 to 55 |
| Flat boiler section, 200 pound to 900 pound Sandslinger | 50 to 70 |
| Round core sections, closed cheeks, jolt stripped | 55 to 70 |

and compression strength as determined by Dietert's compressive test as follows:

| *Kind of Work* | *Compressive Strength* |
|---|---|
| Squeezer plate sand | 1.0 pounds |
| Sand slinger sand | 0.8 pounds |
| Jolt roll over sand flat work | 2.3 pounds |
| Radiator hand rammed sand | 1.0 pounds |
| Jolt strip for closed cheeks | 0.6 pounds |
| Hand rammed floor molding sand medium work | 1.3 pounds |

These values apply primarily to the foundries under Dietert's control and may or may not properly represent the desirable properties of sand for use in other foundries.

The information on sand gained by these Standard Tests has not yet been accumulated for a sufficiently long time to enable more definite recommendations to be made. As foundrymen continue to test sand carefully under actual working conditions these data will become available and judging or grading molding sands will become more of a science and less of an art.

## OTHER FOUNDRY SANDS

Sand is used in foundries for other purposes than as a naturally bonded molding sand. Sand is used to prepare the cores in the castings, and also to serve as the base of synthetic molding sands as used in the steel foundries.

### CORE SAND

Core sand is composed usually of silica grains but frequently contains from ten to thirty-five percent feldspar and other minerals. It carries

[5]Transactions of the American Foundrymen's Association, Vol. 34, page 244, 1926.

little or no bonding material as in use it is always customary to add this to the sand. In general, the sand should be free from silt, clay, or other extremely fine material, and the grains may be either rounded or angular.

Moldenke[6] claims that cores in general require more strength than molds as they are subject to more and rougher handling, as the cores project into the mold they must not only withstand bending strain through static and fluid pressure, but the gases formed within the cores must be given every opportunity for rapid escape without flowing into the metal. Finally as the cores must be removed after shaking out the mold, the bond of the cores must be such that it is readily destroyed by the heat of molten iron after this has been set. To give the best possible venting of gases a core sand should have uniform size and round grains.

### Bond

Since any clay present would tend to bake the grains together and thus make it difficult to remove the core after casting, the required bond should preferably be a substance with strong adhesive powers so that only a small amount need be used, and it should be able to withstand heat long enough to prevent the metal from cutting the surface as well as entering the pores, and yet be more or less completely destroyed by the heat from the molten iron or metal. Core binders are generally organic substances such as linseed oil, rosin dextrin or mixtures.

### Testing

In testing core sands much the same methods are used as in testing molding sands, except that, as artificial bonds are used, the synthetic mixtures are generally tested to obtain a better working idea of the mixture rather than simply of the natural unbonded sand. As we are not concerned with organic binders for core sands in the present discussion the reader is referred to those readily accessible articles which deal with this matter.[7]

## STEEL SAND

While many of the naturally bonded sands used as molding sands may contain as little as 55 to 60 percent of silica (generally from seventy-five to about ninety percent), sands used for molding steel should consist of practically pure quartz grains either angular or rounded in shape, to

[6]Principles of Iron Foundrying, page 300.
[7]Lane, The Journal of the American Society of Mechanical Engineering, Vol. 33.
D. A. Crosby, Transactions of the American Foundrymen's Association, Vol. 35, page 148, 1927.
H. L. Campbell, Ibid., Vol. 35, page 158, 1927, and Vol. 34, page 558, and page 567, 1926.
Harper and Stevenson, Ibid, Vol. 33, page 817.
A. B. Grubb, Ibid. Vol. 33, page 808.
C. A. Hansen, Ibid, Vol. 34, page 577, 1926.



withstand the higher temperatures necessary in casting steel. Generally steel sands contain more than 90 percent of silica before the addition of the artificial bond which may be fire clay or some organic binder. The most important property of steel sand appears to be high refractoriness.

## FIRE SAND

Fire or furnace sand is silica sand used to line furnace bottoms and wells, especially open hearth furnaces making steel by the acid open hearth process. It is also largely used in forming the bottoms of copper refining furnaces and reverberatory copper smelting furnaces.

A high silica content is usually essential although a small amount of bonding material is frequently desirable to hold the sand in place until the furnace lining has been fired or burned in. If this bonding material is lacking, it is usually added in the form of plastic fire clay. The latter procedure is more desirable than seeking a natural bond in the sand, as the natural bond may decrease the refractory properties of the sand.

Sand as low as 80 percent in silica has been used in some cases[8] but a silica content greater than 95 percent is usually specified.

Generally a product graded from coarse to fine is considered better than one of uniformly sized grain, as the graded sizes assist in bonding, fill voids between the larger grains, and make the hearth more impervious. However, the finer grains sinter more rapidly during firing. Apparently large pieces are not always considered objectionable, as some producers market a crushed sandstone which has passed only a two mesh screen (about three-eighths (3/8) of an inch in diamter).[9]

In many ways fire sands are similar to fine steel molding sand. In some cases silica sand is first used as a steel molding sand, and the spent molding sand then used as furnace sand for the bottoms of the open hearth steel furnaces. This spent sand is reported to give better service than the new sand.[10]

## PARTING SAND

Parting sand is a pulverized fine quartz sand usually passing 100 mesh.

## OTHER USES OF SAND

Although this Bulletin is concerned primarily with the possible use of sands in foundries, it seems proper to include here a brief discussion of the properties of sand used for other purposes. This is particularly appropriate as many of the sands found in Michigan are not well adapted

[8]Barton, Refining Metals Electrically, The Foundry, Vol. 52, page 642, August 15, 1924.
[9]Rock Products, Silica Sand Plant of Newest Type, December 29, 1923, page 77.
[10]Weigel, Department of Commerce, Bureau of Mines, Bulletin 266, page 154.

in their natural state for foundry purposes, but may be used, and frequently are used for other important industrial purposes.

Throughout the country the most important sands in tonnage and total value are those classed under the general head of Structural Sands, which includes all those varieties used in all forms of concrete, plasters, mortars, and similar purposes. A great deal of research work has been done on this class of sands by federal, state, and municipal agencies as well as trade associations, and various specifications and requirements have been formulated to cover the different kinds. This discussion is not intended to be at all complete but simply suggestive of the possible uses of the different kinds of sands found in Michigan. For those readers interested in learning more about the general uses of sand and silica the interesting bulletin by W. M. Weigel[11] is suggested.

## STRUCTURAL SANDS

Specifications for structural sands are not standardized but to a large extent dependent upon supplies available in each locality. In general structural sands may be divided into two large groups: *building sands*, used in engineering and architectural structures, mortar and plaster, and *paving sands* used in all kinds of road and pavement construction.

Practically all specifications for the structural sand requires the sand to be clean and reasonably free from clay coated grains, lumps of clay, flat or elongated grains, vegetable or organic matter, chloride, and extremely fine material.

The upper limiting size of the coarser sands is usually placed at from three-eighths (3/8) to one-quarter (1/4) of an inch.[12, 13, 14] Material retained on a 100 mesh sieve is called sand and that passing 100 mesh, clay, silt or loam. Material removed by sedimentation or elutriation is sometimes called silt and is usually specified not to exceed three percent for all grades. Generally the sand is desired to be uniformly graded from coarse to fine, and is not to contain an undue amount of any one size.[15]

Although some of the earlier specifications usually required sand grains to be angular or sharp, this requirement is omitted in modern specifications because it has been shown that good concrete, mortar and plaster can be made from round grains. The sharp or angular grains do,

[11]Technology and Uses of Silica and Sand, Bulletin 266, Department of Commerce, Bureau of Mines, 40c from the Superintendent of Documents, Government Printing Office, Washington, D. C.

[12]U. S. Bureua of Standards, Wall Plaster, Its Ingredients, Preparation and Properties, Circulars 151, 1924.

[13]American Society for Testing Materials, Tentative Specifications for fine Aggregates, proposed at its meeting June 25-27, 1924.

[14]Edmond Shaw, "What Makes a Good Concrete Sand".

[15]D. A. Abrams, "The Design of Concrete Mixtures", Chicago Materials Research Laboratories, Louis Institute. Bulletin I, and Engineering News Record, Vol. 82, page 759, April 17, 1919.

L. N. Edwards, "Proportioning of Materials for Mortars and Concrete". American Society for Testing Materials, Vol. 18, Part II, page 235, 1918.



however, possess slight advantage in tending to interlock in the concrete or mortar.

### Building Sands

Building sands include those sands used for concrete other than pavement, for mortar in laying stone and brick, and for plastering of all kinds.

#### Concrete Sand or Fine Aggregate

In its tentative specifications for concrete aggregate (C 33-23T) the American Society for testing materials states that *fine aggregate* consists of sand, stone screening, or other inert materials with similar characteristics, or a combination thereof, having clean, hard, strong, durable, uncoated grains, free from injurious amount of dust, lumps, soft or flaky particles, shale, alkali, organic matter, loam or other deleterious substances.

*Screen Analysis.* Fine aggregates shall preferably be graded from fine to coarse within the following limits:

| | |
|---|---|
| Through three-eighths inch sieve | 100 percent |
| Through number 4 sieve | 85 percent |
| Through number 50 sieve, not more than | 30 percent |
| Weight removed by decantation tests, not more than | 3 percent |

The three-eighth inch screen has a square opening of 0.375 inch and a wire diameter of 0.092 inch. The other sizes conform to those specified by the U. S. Bureau of Standards Screen Series (Table III).

*The Decantation Test* consists essentially in placing 500 grams of the properly selected sample dried at 110° F., in a pan or vessel of about nine inches in diameter and about four inches deep, covering with about 225 cc. of water. The whole is agitated fifteen seconds and allowed to settle fifteen seconds, and the water decanted through a 200 mesh sieve. This procedure is repeated with fresh water until the washings are clear. After returning all material retained on the 200 mesh sieve, the sand is dried at 110° F., weighed and the percent lost reported as silt, clay or loam.

*Organic Matter.* The presence of organic or vegetable matter in the sand has an important influence upon the setting time, and on the strength of the finished concrete.

As an indication of the amount of organic matter present, the American Society for Testing Materials recommends the following color test[16]

[16]A. S. T. M. Standard Method, C 40-27.

and that no fine aggregate be used which gives color darker than the standard so determined.

A twelve ounce graduated clear glass bottle is filled to the four and one-half ounce mark with the sand to be tested. To this is added sufficient three percent solution of ammonium hydroxide in water to bring the total volume of sand and liquid to seven ounces after shaking. The bottle is then stoppered and shaken vigorously. After standing for twenty-four hours, the color of the clear liquid above the sand is compared with the color of a standard solution, prepared by adding two and a half cubic centimeters of a two percent solution of tannic acid in ten percent alcohol to 97.5 cc. of a three percent sodium hydroxide solution placed in a twelve ounce stoppered bottle which is given the same treatment as the sand under test. The color of this standard solution is stated as 250 parts per million tannic acid.

### Sand for Brick Mortar

No definite specifications for mortar sand for brick laying has so far been proposed or adopted by either the American Society for Testing Materials, or the U. S. Bureau of Standards. In general, however, the sand used for this purpose should have the same general characteristics as that used for concrete, except that in face work where thin joints are used, the coarsest grain should have a diameter less than the thickness of the mortar joint so that the brick or stone may be properly bedded.

### Plastering Sand

Sand for plastering may be used with lime plaster, gypsum plaster or with a mixture of both. No general specifications are available, but the American Society for Testing Materials has adopted the tentative specifications (C 35-24T) for gypsum plastering sand, which will also apply to sand for other plasters. Such sands consist of fine granular material, naturally or artificially produced by the disintegration of rock containing not less than eighty (80) percent by weight of silica, feldspar, dolomite, magnesite or calcite, and shall be free from alkaline, organic or other deleterious substances.

*Screen Analysis.* The same specifications call for not more than 6 percent by weight on No. 8 sieve, not more than 80 percent on No. 50 sieve, not more than 6 percent through No. 100 sieve (Bureau of Standards Series, Table III.)

The U. S. Bureau of Standards[17] regards the requirement that eighty (80) percent of the sand shall be retained on a number fifty sieve as an ideal to be approached rather than as a rule to be enforced. Johnson[18] also regards these specifications as too severe because they exclude many sands which are thoroughly satisfactory when used with gypsum. In general probably not more than about one-half of the sands actually used for plastering meet the specifications of the American Society for Testing Materials; in fact, only twenty-six (26) out of fifty-three (53) representative samples tested by Johnson, all of which were regarded as good in their respective localities, passed the above specifications.

[17]Wall Plaster, Its Ingredients, Separation and Properties, Circular 151, page 25, 1924.



## Paving Sands

Sand used in paving may be divided into three general classes: (1) that used in concrete pavements, (2) that used in asphaltic or bituminous pavements, and (3) that for grouting and cushioning.

### Sand for Concrete Pavements

Although formerly a different grade was sometimes specified for the wearing surface than for the base if the pavement was laid down in two courses, modern practice now recognizes simply one grade. Preference should be given to sand composed of a mixture of coarse and fine grains, with the coarse grains predominating. In general, the sand should otherwise meet the specifications for concrete or fine aggregate sand. Even small amounts of organic impurities make the sand unsuitable.

*Screen Aanalysis.* The Bureau of Public Roads[19] recommends the following distribution of grain sizes:

| | |
|---|---|
| Through one-quarter inch screen | 100 percent by weight |
| Through one-quarter inch and retained on No. 10 sieve | 5 to 25 percent |
| Through No. 10 and retained on No. 50 | 50 to 90 percent |
| Through 100 sieve, not more than | 10 percent |
| Weight removed by elutriation, not more than | 3 percent |

### Sand for Asphaltic or Bituminous Pavement

This class of sand includes that used for sheet asphalt binder and wearing courses and for bituminous concrete base and wearing courses. In general these sands must be composed of clean, hard, durable grain, free from a coating of clay or loam. The presence of a small amount of organic matter is not objectionable for sands which are to be bonded by a bituminous material, as the latter is itself entirely organic. In specifications covering sand for sheet-asphalt wearing course, it is usually

[18]Sand for lime, gypsum and cement plasters, Rough Products, Vol. 28, page 54, March 21, 1925.

[19]Vashell and Toms, Public Concrete Roads, U. S. Department of Agriculture, Bulletin 1077, page 4, 1922.

further specified that sands be free from lump or balls of clay and that the grain shall be tough, rough surfaced, and angular.

*Screen Analysis.* The tentative standard of the American Society for Testing Materials for sand for sheet-asphalt and bituminous concrete pavements (D 162-23T) requires the following grain size distribution:

| | | |
|---|---|---|
| Passing 200-mesh sieve | 0 to 5 percent | |
| Passing 100-mesh sieve, retained on 200-mesh | 6 to 25 percent | 15 to 40% |
| Passing 80-mesh sieve, retained on 100-mesh | 6 to 25 percent | |
| Passing 50-mesh sieve, retained on 80-mesh | 5 to 40 percent | 30 to 60% |
| Passing 40-mesh sieve, retained on 50-mesh | 5 to 30 percent | |
| Passing 30-mesh sieve, retained on 40-mesh | 8 to 25 percent | 18 to 50% |
| Passing 20-mesh sieve, retained on 30-mesh | 5 to 15 percent | |
| Passing 10-mesh sieve, retained on 20-mesh | 5 to 15 percent | |
| Passing 10-mesh sieve | 95 to 100 percent | |
| Passing ¼ inch screen | 100 percent | |

Hubbard and Jackson[20] approve similar requirements except to recommend that all the grains pass a 10 mesh sieve.

### Grouting Sand

Grouting sand is used for making a thin cement mortar with which the joints between paving blocks or brick are filled. The sand should comply with the same general requirements that govern other mortars.

*Screen Analysis.* As the grouting must flow freely into thin joints, the maximum size of grains permissible is reduced. The American Society for Testing Materials has adopted the following Standard Grading (D 57-20) which has also been approved as Tentative American Standard by the American Engineering Standard Committee:

| | |
|---|---|
| Through a number 10 sieve | 100 percent |
| Through a number 20 sieve, not less than | 80 percent |
| Through a number 200 sieve, not more than | 5 percent |

The sand is also subject to rejection if when mixed with Portland Cement passing the requirements of the Standard Specifications (C9) in a proportion of one part of cement to three parts of sand by weight, the resulting mortar at the age of seven and twenty-eight days possesses a tensile strength of less than seventy-five percent of that developed in the same time by mortar of the same consistency made of one part of the same cement and three parts of Ottawa sand.

### Sand for Sand Bed or Cushion

Sand used for the sand bed or cushion on which paving bricks or blocks are laid should be reasonably clean and free from foreign substances, although this requirement need not be as strict as for sand entering mortar of any kind. It is usually specified that such sand

[20]Typical Specification for non-Bituminous Road Materials, U. S. Dept. of Agriculture, Bulletin 704, 1918, page 12.



should pass a one-quarter inch screen, and not more than 5 percent be removed by elutriation, and that it be well graded from coarse to fine.

### Sand for Cement Mortar Bed

When the sand is used for a cement mortar cushion, instead of loose sand, it should be free from lumps of clay and objectionable foreign matter. In addition to the limiting maximum size of one-quarter inch grain, the A.S.T.M. Specification (D 58-24) requires that at least ninety percent pass a number 10 sieve. That portion of the sand passing the number 10 sieve is also required to meet the same tensile strength test, when used as an aggregate in mortar, as required of sand for cement grout fillers (D 57-20).

The U. S. Department of Agriculture* gives the tentative standard methods for sampling and testing highway materials, including sand, as adopted by the American Association of State Highway Officials and approved by the Secretary of Agriculture for use in connection with Federal aid road construction.

## GLASS SANDS

The quality of sand demanded by glass manufacturers depends largely on the kind of glass being made. Glass may be classified according to chemical composition or the predominating basic oxide, which has no interest for the sand producer; or on the basis of physical characteristics that are largely controlled by the quality of the sand used. On this basis glass may be separated into *optical glass,* requiring sand of the highest purity; *flint glass* for high-grade tableware that is to be polished and cut, requiring sand almost equal to that for optical glass; *plate glass* to be ground and polished, requiring a high grade sand; *window glass,* and plate glass which is not to be polished but used in the form of ribbed or wired glass, requiring a sand of less purity than the above; *green glass* which may contain much more iron oxide than that for the more transparent or colorless glasses, and which is used for containers such as carboys and bottles; and *different grades of amber glass* representing a rather special product for which a sand containing relatively large amounts of iron oxide is permissible and may be used.

### Physical Properties

All glass sand should be screened to remove over-sized particles which may cause stones in the finished glass, as well as to remove pieces of vegetable matter and other rubbish. In general, glass sands should all pass a number 20 sieve. Some technologists and large producers claim

*Bulletin 1216, May, 1924.

that fines, that is material passing 100 mesh, are not objectionable, while others limit the amount of such material. As washing usually removes the excess fine material probably the main objection to fines is that they are likely to contain more impurities than the coarser products. Weigel[21] reports a petrographic examination of the fines obtained from a washed Ottawa sand when screened through a 150 mesh sieve, as showing an abundant amount of pyrite, dratite, or magnesian tourmaline, iron oxide, zircon, and a very small amount of hornblende.

*Screen Analysis.* The following grading of glass sand has been recommended by the American Ceramic Society in conjunction with the U. S. Bureau of Standards, and, although not strictly followed by the manufacturers, may be considered as a desirable grading to be sought rather than required.

| | |
|---|---|
| Through a Number 20 screen | 100 percent |
| Through 20 on 40, not more than 60 or less than | 40 percent |
| Through 40 on 60, not more than 40 or less than | 30 percent |
| Through 60 on 100 not more than 20 or less than | 10 percent |
| Through 100 ..... not more than | 5 percent |

*Shape of Grain.* There has been considerable discussion as to the relative advantages of rounded grains or angular and sub-angular grains, due largely to competition between the Pennsylvania-Virginia and Illinois-Missouri districts, as the former produces a sand with angular grains and the latter a sand with rounded grains. Actually each shape of grain seems to be equally satisfactory in glass sand.

*Chemical Properties.* So far as physical properties are concerned the supply of glass sands would be almost unlimited. However, the chemical properties of the sand are generally far more important than its physical properties, because glass is essentially a chemical product in which the sand is fused with other mineral reagents, and, provided the sand possesses such physical properties as to be used without difficulty, the properties of the glass depends entirely upon the chemical analysis of the materials used.

Perhaps the most important impurity in glass sand is iron oxide because of its discoloring properties on the finished product.

Although no definite standard has been universally adopted for glass sand, as manufacturers have varying opinions on the subject, the American Ceramic Society and the U. S. Bureau of Standards have formulated the following specifications covering the chemical composition for different grades of glass sand.

[21]Technology and uses of Silica and Sand, U. S. Dept. of Commerce, Bureau of Mines, Bulletin 266, page 151.



TABLE XXXVIII.—Specified Composition of Glass Sands. (Ignited Sample = 100 percent.)

| Qualities | Percent by Weight | | | |
|---|---|---|---|---|
| | $SiO_2$ Minimum | $Al_2O_3$ Maximum | $Fe_2O_3$ Maximum | CaO—MgO Maximum |
| 1. First Quality Optical Glass... | 99.8 ± 0.1 | 0.1 ± 0.05 | 0.02 ± .005 | 0.1 ± 0.05 |
| 2. Second Quality Flint Glass Containers. tableware..... | 98.5 ± .5 | .5 ± .1 | 0.035 ± .005 | .2 ± .05 |
| 3. Third Quality Flint Glass.... | 95.0 ± 1.0 | 4.0 ± .5 | .035 ± .005 | .5 ± .1 |
| 4. Fourth Quality Sheet Glass, rolled and polished plate... | 98.5 ± 1.0 | .5 ± .1 | .06 ± .005 | .5 ± .1 |
| 5. Fifth Quality Sheet Glass, rolled and polished plate... | 95.0 ± 1.0 | 4.0 ± .5 | .06 ± .005 | .5 ± .1 |
| 6. Sixth Quality Green Glass, containers and window glass | 98.0 ± 1.0 | .5 ± .5 | .3 ± .05 | .5 ± .1 |
| 7. Seventh Quality Green Glass | 95.0 ± 1.0 | 4.0 ± .5 | .3 ± .05 | .5 ± .1 |
| 8. Eighth Quality Amber Glass containers........ | 98.0 ± 1.0 | .5 ± .5 | 1.0 ± .1 | .5 ± .1 |
| 9. Ninth Quality Amber....... | 95.0 ± 1.0 | 4.0 ± .5 | 1.0 ± .1 | .5 ± .1 |

Frequently first quality optical glass can be made from sands containing less silica, and more lime, magnesia or alumina than specified in the above table provided the iron does not exceed the recommended maximum. In making plate glass and other products a slightly higher lime content seems to be desirable as it aids in making the sand more easily fusible, without having deleterious effect on the finished product. It is also possible to use special reagents to partly neutralize the color due to iron oxide, when necessary. However, manufacturers of high grade glass prefer to obtain a sand with a minimum amount of iron, as iron is almost invariably picked up in other ways during the process. It is difficult to compare different analyses of sands reported from various parts of the world, as methods of analysis differ almost as much as the different requirements found necessary by different plants.

## ENGINE SAND

Engine sand or traction sand is used to prevent the driving wheels of locomotives, street cars or other self-propelled vehicles from slipping on wet or slippery rails.

Engine sand should contain a minimum amount of dust and very fine particles and be free from over-size particles, rubbish, clay lumps, and any considerable clay coating which tends to retain or store moisture and form lumps. These precautions are necessary in order to insure a free flow of the sand through the feed pipes from the sand box to the rails. As the grains are crushed at once to a fine powder under the drivers, a fine pulverized silica would give the necessary tractive effect but would tend to pack, and flow sluggishly through the feed pipe, and be blown away before falling on the rail. Either rounded or angular grained sand is suitable, but the rounded grain seems to have a greater tendency to roll off the rail before being caught under the drivers. Round grains, however, if clean and hard are far more satisfactory than other sands that may contain a natural bond.[22]

The Pennsylvania Railroad system has no definite specification but it requires a high grade non-caking sand containing over ninety-five percent silica, and having sharp, clean grains of such size that practically all of it will pass a twenty mesh sieve, and be retained on an eighty mesh sieve. Actual analyses of sands used by this railroad[23] show from ninety-seven (97) to ninety-nine and six-tenths (99.6) percent through number twenty sieve, with ninety to ninety-eight per cent retained on number eighty. Sand of practically the same screen analysis has been found to be satisfactory by the Southern Railway Systems.

## ABRASIVE SANDS

All grades used for various abrasive and grinding purposes are classified as abrasive sands, including the natural sand grain but not the pulverized quartz or other forms of silica which have been reduced by intensive grinding. The principal uses may be classed into stone sawing sand, glass grinding sand, banding sand, sand paper sand, and sand blast sand.

### STONE SAWING SAND

Sand used for stone and marble sawing should be composed of tough and fairly uniform grains. Flat particles are objectionable, and fines are useless, as the coarser grains support the cutting edge leaving no work for the finer grains. However, unsorted sand is frequently used as it is cheap and readily available. Minerals softer than quartz are waste materials, as they are almost immediately crushed to powder and are of little cutting value. The sand is always used repeatedly by flushing the cuttings into a common sump, from which the sand is pumped. Material finer than 100 mesh is usually removed by flotation or by sedimentation before the sand is re-used.

There are no standard specifications for this material and each plant generally uses the most available material obtainable at a reasonable price. Both round and angular grains are used. It has been suggested[24] that a softer blade should be used with round grains, than for sharp sand as it would have less tendency to ride the round grain.

It is also reported that one company uses a sand of the following screen analysis:

[22]Electric Railway Journal, Vol. 45, page 143, 1915.
[23]Weigel, Special Sands, Serial 2646, Bureau of Mines, October 1924.
[24]W. M. Weigel, U. S. Department of Commerce, Bureau of Mines, Bulletin 266, page 140.



| | |
|---|---|
| Retained on 10 mesh | 3.7 percent |
| Retained on 20 mesh | 12.6 percent |
| Retained on 48 mesh | 83.8 percent |
| Retained on 100 mesh | 98.6 percent |

The same company expressed its preference for clean sea sand as superior to this product if available at a reasonable price.

### GLASS GRINDING SAND

Crude-rolled plate glass requires rough grinding to remove inequalities of the surface before final grinding and polishing. Sand is almost universally used for this purpose. Garnet and artificial abrasives are used to some extent but apply more particularly to the second grinding stage.

Specifications of sand used for glass grinding are not strict. Generally the cheapest available material that will do the work is used. For this reason local supplies of sand are generally used for abrasive purposes.

The sand should be free from rubbish which might choke the pipe used in circulating the sand, and from large grains which may make deep scratches in grinding which are difficult to remove in the finishing process. Very fine sand and clay are objectionable only to the extent that they reduce the amount of quartz grains present.

Frequently the same sand is used for grinding as is used in making the glass mix, except that the latter is not dried or given a final screening. The Pittsburgh Plate Glass Company at Crystal City, Missouri, follows this practice using sand which passes 20 mesh and about ninety (90) percent retained on 150 mesh. The grains of this sand are decidedly rounded.

Chemical composition has no importance, except to indicate the presence of minerals which may be considered waste because they are too soft to do much grinding.

### BANDING SAND

Banding sand is that which was formerly used to some extent for the second or semi-final grinding of plate glass and as an abrasive in beveling glass, but has now been largely superseded by artificial abrasives which cut more rapidly. It is a much finer sand than used for the first grinding of the glass and is also suitable for other than abrasive purposes if a very fine sand is desirable.

The screen analysis of samples of banding sand indicate that not more than four (4) percent is retained on 35 mesh and that at least ninety (90) or ninety-two (92) percent is retained on 100 mesh, and ninety-nine (99) or more retained on 150 mesh.

### SAND PAPER SAND

At one time, sand was largely used for surfacing sand paper. Some crushed or graded quartz grains are still used for sand paper coating, but the introduction of the harder and faster cutting artificial abrasives and garnet, have practically eliminated the use of sand in preparing sand paper.

### STONE AND MARBLE GRINDING SAND

Generally the abrasive sand used for rough grinding of stone and marble on rubbing beds is of the same grade as that used for stone sawing. Sharp angular grains are considered best, but as the cuttings are used over and over, the larger grains become broken so that a well rounded grain sand should prove equally satisfactory in the long run. Different stones and types of finish require different grades of sand, but for all work large grains and pebbles are objectionable and should be screened out. As for other abrasive sands, an excessive amount of clay reduces the efficiency. Generally a sand with hard tough grains which do not readily break down, prove the best.

### SAND BLAST SAND

Formerly use of sand blast sand was confined almost entirely to the foundry to clean and remove inequalities from rough castings. Although this is still the most important application, its use has been extended to many other industries, such as the removal of paint from old surfaces, preliminary glass cutting, cleaning or renovating of walls of stone and brick buildings, preparing the surface of metals for the electrolytic bath, for enameling, and for engraving and carving designs and lettering on stone and marble. An attempt has also been made to use it to channel and cut out blocks of stone in the quarry, but only with partial success.

#### Fineness Grades

In the Midwest where only one fineness grade of sand can be produced from a particular deposit, the natural fineness of the sand deposit, most producers market their products under special trade-names. In the Eastern states, however, some attempts at standardization have been made, and the grades or different sizes are numbered. These grades are commonly classified as number one, two, three and four, number one being the finest and number four the coarsest. A number 0 is occasionally made, but it is too fine for most purposes.

Products of the same number obtained from different producers may vary due to difference in the shape of the grain, slopes of the screen, and variations in the screen mesh. However, tests of numerous samples



sold under the different grade specifications indicate the following to be the average screen analysis of the different sizes:

| Tyler Series | Cumulative Percent Sand Blast Sand | | | |
|---|---|---|---|---|
| Mesh | No. 1 | No. 2 | No. 3 | No. 4 |
| 4 | 0 | 0 | 0 | 2.15 |
| 6 | 0 | 0 | .06 | 73.0 |
| 8 | 0 | 0 | 8.0 | 96.0 |
| 10 | 0 | .02 | 29.4 | 99.3 |
| 14 | 0.1 | 15.5 | 80.5 | 100.0 |
| 20 | 8.0 | 68.5 | 98.0 | |
| 28 | 49.0 | 92.0 | 99.8 | |
| 35 | 85.0 | 98.2 | 100.0 | |
| 48 | 98.5 | 99.6 | | |
| 65 | 99.8 | 100.0 | | |
| 100 | 100.0 | | | |

Decided variations may be noted in the products of different plants, but disregarding small percentages of coarse and fine material, the following limits roughly indicate those of the different sizes:

| | |
|---|---|
| Sand Blast No. 0 | Through 35 mesh and on 100 |
| Sand Blast No. 1 | Through 20 mesh and on 48 |
| Sand Blast No. 2 | Through 10 mesh and on 28 |
| Sand Blast No. 3 | Through 6 mesh and on 14 |
| Sand Blast No. 4 | Through 4 mesh and on 8 |

It would seem advisable for the producers to decide on standard limits for the screen meshes in order to avoid the present confusion. Occasionally, a still smaller size, Number 0, is used but not in general practice. Number 1 is used for light work, and where a comparatively smooth finish is desired as finishing automobile castings, brass, glass, and in removing paint. Generally manufacturers of brass and iron pipe fittings will use Number 1 exclusively. Similar work of a heavier character as for preparing iron bath tubs for enameling frequently require slightly coarser sand such as Number 2. Number 3 and Number 4 are used for the heaviest cast iron and steel work only. In general, very little Number 4 is used.

#### Shape of Grains

There is considerable discussion regarding the relative merits of sharp angular grains, and rounded grains. It is claimed that the sharp grains cut faster, and on the other hand, that the rounded grains give smoother work, and possess a longer life, that is, can be used over more often and make less dust.

The ability to resist crushing or shattering, or toughness of the grains is a very important property and will vary widely with different sands.

However, no method of testing for this property has been developed other than actual tests under plant conditions.

Blasting sand is generally used repeatedly until the grains are reduced to dust. Plants that use large amounts have a separating and feeding system to remove dust and material too fine to be of any use. This material is generally wasted but it has been suggested[25] that it might be used as a foundry parting, mixed with dead core or gang-way sand for thin cores, as a core wash, possibly as a foundry facing, mixed with clay for looting the covers of annealing pots and even in making concrete where discoloration due to particles of iron and steel is not objectionable.

### FILTER SAND

The use of sand for the filtration of municipal water supplies is becoming more important, as most cities that draw water supply from surface sources now use sand filters in their purification system. Sand filters not only remove sediment and suspended matter but also take out most of the bacteria in the water.

Filter sand has been produced in a number of states in varying amounts, but most of the high filter sand is produced in New Jersey with Illinois and Minnesota making an important contribution. Practically all filter sands used in Michigan come from Redwing or Castle Bay, Minn. The production of specially prepared filter sand is not difficult, and any good sand bed can produce suitable sand if it can be washed clean and contains enough grains of the required size to warrant separation.

#### Grain Size and Shape

Good filter sand must be of fairly uniform size and within certain limits. It must be free from clay and organic matter and fairly pure quartz. Early investigations[26] showed that an excess of fine material increased the friction of the water flow and decreased the capacity of the filter bed to an impractical degree, and that the size of the finer particles rather than the coarser determined the effective size.

So far as has been determined, rounded or angular grains are equally efficient provided there are no flat or elongated grains. The size of grain in filter sands and the size distribution are expressed in two terms: (1) The *Effective Size*, expressed in millimeters, and determined as the theoretical size of the screen mesh through which ten percent of the sand would pass, so that ninety percent of the sand is coarser and ten percent of the sand, by weight, finer than the effective size expressed in millimeters. (2) The *Uniformity Coefficient*, the ratio of the size of screen mesh through which sixty percent of the sand will pass to the effective size as determined above.

[25] Abrasive Industries, Possible Uses for a Waste Sand Blast Dust, October 1923, page 305.
[26] Allen Hazen, Analysis of Filter Sand, Massachusetts Board of Health Report, page 541 (1892).



The ordinary method of determining the effective size and the uniformity coefficient is to make a screen analysis of the dry sand. The cumulative percentages are then plotted against the size of the screen opening. The intersection of the curve with the ninety percent line gives the effective size. The size corresponding to the forty percent is read from the plot, divided by the effective size to obtain the uniformity coefficient. This can be done conveniently by use of coordinate paper, on which percentages are laid on the vertical axis and sizes of the screen openings on the horizontal.

Before accurate screens were obtainable it was customary to determine the size of grains passing a given screen by collecting the last grains passing and counting a known weight of the grain and, once their specific gravity was known, their diameters, assumed as spheres, could be calculated.

Specifications usually require that no grain shall be larger than a specified mesh, and limit the percentage of very fine material or that passing 100 mesh. During the washing of the filter bed with counter current flow at a rate of about 2 feet per minute, all material finer than this collect in the top part of the sand bed and clog the filter. Sands with effective sizes of .2 to .7 millimeters are used, but those most commonly specified range from .35 to .65 millimeters. The uniformity coefficients vary from 1.25 to 1.8 with 1.5 to 1.6 as the average. Mr. Hern of the State Board of Health, Lansing, prefers sands of effective size 0.35 to 0.45 inclusive and uniformity coefficient less than 1.5.

#### Chemical Properties

A good filter sand requires a high silica content. Generally specifications require that not more than two percent shall be soluble in hot dilute hydrochloric acid or that the combined lime and magnesia calculated as carbonate shall not exceed two percent. Aside from this the chemical composition is seldom specified.

The amount of filter sand used is small in comparison with building and other sand. It gives satisfactory service for a long period of time and does not require frequent replacements. Sand used in connection with a water softening plant for some time becomes heavily coated with $CaCO_3$ and eventually must be replaced because the grains become too coarse. Preparation requires an extensive plant and careful supervision, and demands a higher price than is obtained for ordinary grades of sand. In many ways it is comparable to sand blast sand in cost and methods of preparation, in fact No. 1 sand blast sand is sometimes marketed as filter sand.

The price of filter sand varies considerably. The U. S. Bureau of Mines gives the average selling price as two (2) dollars per ton in 1924. When bagged and sold in less than carload lots, it sometimes sells for as much as ten dollars a ton, and four to six dollars per ton in carload lots is a common price for specially prepared sand meeting rigid specifications.[27]

### SPECIAL SANDS

In addition to the sands which have been described, there are a number of special sands of considerable industrial importance, but produced in relatively small amounts. Practically no sand producer could confine his production to them alone, and they are usually prepared as the by-product in the preparation of sand used for other purposes in larger quantities. For this reason special sands nearly always command a higher price than the usual grade of building sand; although local conditions may reverse this statement, as what is a special sand for one locality may be the major production of another pit.

### POTTERS SAND

Potters Sand sometimes called *placing sand* is used in the ceramic industry by manufacturers of white ware, wall and floor tile, heavy clay products and refractories, as a packing in the saggers and between the shapes to keep the ware apart. It is of two general types, that used for white-ware and refractories, which must be low in iron and free from other easily fusible minerals, and that used for dark heavy clay ware which need not meet these specifications. There are two general grades, coarse and fine; the coarse being mostly sand between 10 and 40 mesh, and the fine mostly between 28 and 100 mesh. A good grade of glass sand would be suitable for most work. An extreme uniformity of grain is not essential, but coarse particles and dust are objectionable.

### ROOFING SAND

Roofing sand as here defined is that used in coating prepared roofing for which white sand only is suitable, and is not the material applied to

[27]Bargess, Mechanical Analysis of Sand, Journal of the American Waterworks Association, Vol. 2, page 493, 1915.
Fritze, River Sand as Filter Medium, Journal of the American Waterworks Association, Vol. 2, page 390.
Langdon Pearce, The Rapid Filtration Plant at Evanston, Illinois, Journal of the American Waterworks Association, Vol. 2, page 172. 1915.
Smith, Size of Filter Sand at Lima, Ohio, Engineering and Contracting, Vol. 60, page 102, 1923.
True Importance of Filter Sands and Gravel in Filtration Plants, Engineering and Contracting, Vol. 59, page 121, 1923.
Turneaure and Russell, Public Water Supplies, New York, 1908.



roofing built up in place. A rounded grain product is generally desirable but sands of sharp grains are used. The grain size is usually such that all of the sand will pass through the 20 mesh screen, and not more than 5 or 10 per cent through 65 mesh.

### FLOORING SAND

Flooring sand is that used in asphalt flooring, which is made up of asphalt cement, a sand aggregate, and a fine absorbent mineral filler. The Federal Specification board [28] has the following specifications for flooring sand when intended for government use.

"The mineral aggregate shall be sand and small gravel. It shall be clean, hard, and free from clay, silt, organic and other foreign matter and shall be properly graded from coarse to fine, so as to produce a mixture of greatest density and stability, and shall fall within the following limits:

| | | |
|---|---|---|
| Total passing a number | 3 screen ........ | 100 percent |
| Total passing a number | 8 screen, not over | 60 percent |
| Total passing a number | 30 screen, not over | 40 percent |
| Total passing a number | 100 screen, not over | 7.5 percent |

### SANDS FOR CHEMICAL PRODUCTS

Sand is also used in the manufacture of sodium silicate or water glass, and artificial abrasives such as carborundum or silicon carbide. Although both sand and diatomaceous earth are employed in the manufacture of sodium silicate, by far the larger amount is made from sand, as it is suitable for the fusion process and is much cheaper than diatomaceous earth of suitable purity. Only high grade silica sand of especially low iron and alumina is permissible as alumina makes the resulting silicate difficultly soluble, and iron affects the color. A good glass sand is usually considered suitable if low enough in alumina. The general requirements are that the sand must contain at least 99 percent of silica, and over 1 percent of alumina, or over 0.5 percent of lime and magnesia combined, and less than 0.1 percent of iron. It is desirable that the sand should all pass a twenty mesh and remain on 100 mesh, which is approximately equal to the requirements for sizing of a high grade glass sand.

Generally a similar quality of sand is required in the manufacture of silicon carbide. For this purpose the presence of iron is particularly objectionable and more than a trace of lime, phosphorous or magnesia should not be present. Small amounts of alumina should not be par-

[28]U. S. Government Mastic Specifications for Asphalt Mastic Flooring, U. S. Bureau of Standards, 1924.

ticularly harmful. All grains should pass a twenty mesh sieve, and the sand should be free from fines. One manufacturer states that the sand should be fairly free from dust and that material finer than 50 mesh must be removed.

Sand meeting these specifications is obtained generally from Pennsylvania and Illinois glass sand districts.

### SAND FOR SAND-LIME BRICK

In sand-lime brick, sand has a two-fold function. Most of it acts simply as an aggregate making up the body of the brick which is bound together by the cementing material. The remainder supplies silica for the formation of the calcium silicate bond. For the latter purpose a certain amount of quite fine material must be present, as the action of lime on the larger grains under the temperature and pressure conditions is quite slow. Emley[29] gives the practical rule that about 15 percent must pass a 100 mesh screen. The balance should be well graded from coarse to fine to obtain a brick with maximum density and minimum of voids. An excess of large grains gives the brick a high compressive but a low tensile strength. Overlarge grains are objectionable as they make it difficult to mold brick which has sharp corners and edges. Sand for sand-lime brick varies in texture from about 48 percent to zero retained on a 20 mesh sieve, and 5 percent to zero passing a number 200 sieve.

If the fines in the sand do not suffice to combine with the lime, part of the sand must be finely ground before it is mixed.

Extreme chemical purity is not essential, but the sand should be reasonably clean and free from rubbish and other foreign material. Although clay tends to weaken the brick it is not particularly injurious otherwise, and its ill effect can be partly overcome by the use of additional lime. Sharp sand is usually considered better, but there is no reason why a rounded grain product will not make a satisfactory brick if enough fines are present.

### SAND FOR OXYCHLORIDE CEMENT

In compounding oxychloride cement or plaster various aggregates are used in the mix, which usually consists of sand, finely ground silica, and some other material, such as wood flour and a coloring pigment. The sand must be clean and free from clay particles or clay coatings. A sand that is decidedly finer than that used in Portland cement concrete gives the best results.[30] Apparently a sand much like a good glass sand is

[29]Manufacture and Properties of Sand-Lime Brick, U. S. Bureau of Standards, Technological Paper 85, 1917.

[30]Dow Chemical Company, Oxychloride Cement Research, Service Bulletin No. 3, page 31, (1920).



about the proper texture, or one, ninety percent of which will pass a twenty mesh sieve. The following screen analysis is recommended by the Dow Chemical Company:

| | |
|---|---|
| Through 10 mesh | 100 percent |
| Through 20 mesh | 97 percent |
| Through 30 mesh | 87 percent |
| Through 40 mesh | 75 percent |
| Through 50 mesh | 57 percent |
| Through 60 mesh | 47 percent |
| Through 80 mesh | 11 percent |
| Through 100 mesh | 3 percent |
| Through 120 mesh | 2 percent |

### SUMMARY

This brief outline of the properties of sand used for different purposes is intended simply to aid those readers who might be interested in the determination of the probable economic use of those sands described in the last part of this bulletin, and not in any way as an adequate discussion of the various uses of sand.

# PART II—TESTS OF MICHIGAN SANDS

# Chapter VII

## TESTS OF THE MICHIGAN SANDS

### EXPLANATORY STATEMENT

#### MAPS

The two maps, one of the Northern Peninsula and one of the Southern Peninsula were prepared as an aid in locating the deposits from which the samples were taken and in giving a general perspective of the sand resources of the state. The areas of molding sand as indicated on the map must not be interpreted too literally, but simply as a rough indication of the areas where such sand might be found. For these reasons the maps must be considered simply as auxiliary to the more detailed statement in the text.

#### DESCRIPTION BY COUNTIES

Because a classification of the sands of Michigan according to their methods of formation, uses or physical properties would be difficult and of little use to the reader, the following description of the sands of Michigan follows a geographical division of the state into its two natural main divisions (the Northern and Southern Peninsulas), each of which is sub-divided according to counties which are described in alphabetical order. By the use of the map and index, all available information is made readily accessible by this method.

The location from which the sand was taken has been given in as definite and exact terms as possible. Peculiar local conditions have been indicated whenever such observations were made.

#### METHODS OF SAMPLING

In taking the sand samples the methods used were in general those outlined in Chapter II. It is obviously impossible to sample and test every individual pocket or deposit of glacial sand. However, an effort was made to sample so far as possible the representative sands of each district in order to obtain a general idea of the probable characteristics and utility of the sands found in different parts of the state. The samples obtained, by trenching the space of the exposure, from the auger or post-hole digger, or by other means, were generally reduced by careful quartering on a large canvas to about thirty or thirty-five pounds. The reduced sample was bound in a small tightly woven sack of awning material, properly labelled inside and out, and carried in the car until a freight office was reached. The small sacks were then combined in larger sacks and shipped to the laboratory.

### METHODS OF TESTING

Through a cooperative arrangement with the American Foundrymen's Association some samples were tested under their auspices at the Bureau of Standards, Washington, D. C. and at Cornell University, Ithaca, N. Y. Most of the samples taken during the first year's work were tested at these two laboratories. The samples collected during the latter part of the field work were tested mostly in the laboratories of the Department of Chemical Engineering at the University of Michigan. For purposes of comparison, many of those samples forwarded to Washington or Ithaca were also tested in the Michigan laboratories. In one or two cases it will be noted that the test results do not agree at all, obviously due to confusion in the numbers used for purposes of identifying the samples, as all samples shipped to Ithaca were numbered when received at Cornell University.

The methods used for testing have been described in Chapter IV. All three laboratories supposedly used the same method for determining the fineness of grain, and the permeability of the sand. But the method of separating clay as used at the Bureau of Standards was such that most of the pan material and fines were included as "clay" causing the Bureau to report too high clay content and too low fines and pan material. Bond strength was determined by the transverse or cohesiveness test of the American Foundrymen's Association in the laboratories of the Bureau of Standards and Cornell University, but the automatic compression test described in Chapter IV was used on those sands tested in Ann Arbor. As this compression test loads the sample at a low rate, 2.69 pounds or 1220 grams per minute, the compressive strength as determined on these samples is less than the compressive strength determined by Dietert's method described in Chapter IV.

### METHOD OF REPORTING TESTS

A description of the sands found in each county will be found in the text. The actual results of the physical tests are tabulated for convenience at the end of the report. The sample numbers in this table correspond to the sample numbers on the map and are arranged in ascending order corresponding to the order in which the counties and samples are described in the text. The second column giving the laboratory number is the number used to identify the sample as collected in the field and the number used to identify the sample when forwarded to



Washington or Ithaca. All tests are included, the laboratory in which the test was made being indicated in each case.

In addition to the samples collected for the present investigation, the properties of those samples collected by Dr. Ries and reported in the bulletin by Ries and Rosen[1] are also included, Table XLII.

It will be observed that the screen analysis as reported by either the Bureau of Standards or Cornell University includes the clay in figuring the 100 percent. Since the A.F.A. Fineness Factor is based upon the grain size exclusive of clay as 100 percent, the screen analysis as made in Ann Arbor are reported on the basis of 100 percent including only the clay-free sand grains.

### SIGNIFICANCE OF TESTS

It should be borne in mind that the following tests are simply preliminary tests on a particular sample selected from a deposit as located in the description and on the map. The results reported simply indicate the general characteristics, and by comparison with the specifications given in Chapter VI, the possible economic value of the sample selected. Any particular deposit must be carefully sampled and tested before the economic value of such a deposit may be properly demonstrated.

This report is intended simply to indicate the general characteristics of Michigan sands and the possible uses for these sands, but not to prove up any particular deposit for any purpose.

[1] Michigan Geological Survey (1908).

# Chapter VIII

## THE SOUTHERN PENINSULA

The greater industrial development in the Southern Peninsula has stimulated and justifies a far more intensive search for molding sand and other similar materials having an economic value, than in the Northern Peninsula. The Southern Peninsula has been thoroughly investigated and those areas in which molding sand deposits of sufficient extent to have economic value are likely to be found have been indicated.

The lacustrine deposits along the east shore of Lake Michigan from St. Joseph to Grand Haven seem to make satisfactory molding sands when containing sufficient clay to possess the necessary bond. Such deposits are worked commercially at Allegan and Riverside, and Coloma in Van Buren County. Similarly the lacustrine deposits extending inland about twenty miles from the Ohio State line as far north as Port Huron may yield satisfactory sands in some places. Such deposits are worked commercially at Mt. Clemens.

River silts in the glacial deposits seem to be the next most hopeful source of molding sand in the Southern Peninsula. Deposits of this nature have been worked at Dimondale in Eaton County southwest of Lansing for some time.

Small pockets of molding sand may also be found throughout the moraine deposits particularly, on the slopes of the moraines or drumlins. Generally the outwash aprons or plains do not contain sufficient bond to contain molding sand. The till plains may be considered as practically equivalent to the moraine deposits so far as being the source of molding sands.

The river deltas are usually so non-uniform and contain so much fine material classified as silt, as to be generally unsuited for molding sand.

Except for a few sands bonded by iron oxide as found in Houghton County in the Northern Peninsula the durability of Michigan bonded sands when used as molding sand is considerably less than that of molding sands which have been developed by the process of weathering, as represented by the Ohio, Illinois, and New York sands. However, the increasing cost of transportation and the decreasing quality of these out-state sands may tend to encourage the use of local molding sands particularly if their properties may be improved or restored by synthetic or artificial means.

### ALCONA COUNTY

About one-third of the area of Alcona County is sandy till and about one-fourth clayey till. Sample one (1) taken near Spruce about eight or



nine miles west of the Detroit and Mackinac Railroad in section 6 of T. 28 N., R. 8 E. is representative of the sand that may be found in these land laid moraines. It is not well sized as the moraine material contains stones of all sizes, sand, and fine material through clay. As has been indicated in such deposits the sand and clay may be rather well mixed and might possess such physical properties as to be useful as a molding sand. The samples were taken from trenching and from a small pit at the side of a road. As shown in the table of test data this sample possesses a fairly high bond.

Sample two (2) taken on the township line, T. 28 N., R. 8-9 E., five miles west of Black River, represents a light yellow sand somewhat similar to that found on the plains but containing more pebbles and more clay bonding material. This sample was taken from an outcrop where the road cuts through small mounds of moraine deposited material and is believed to be representative of some of the lighter sands found mixed with moraine and boulder clay.

Although some of the sand found in Alcona County may yield usable molding sand for local purposes there is slight chance of any workable deposits of molding sand being found in this county.

### ALLEGAN COUNTY

The surface of Allegan County is about sixty percent sandy or sandy till, representing both moraine deposits and sandy drifts with some sandy lake beds and river silts running about twelve to fifteen miles up the Kalamazoo and Rapid Rivers. In this county the sandy drift seems to be at least partially deposited from the outwash of the glaciers and, where properly mixed with clay from the moraine deposits as south and west of Allegan, may yield commercial molding sand in some areas. At least one such deposit is now being worked by the Clean Cast Sand Company, with offices in the Transportation Building, Chicago, Illinois.

Samples six (6) and seven (7) were taken in 1923 from the pit owned by Mr. Hale in N. W. ¼ Section 32, T. 2 N., R. 13 W., two miles southwest of Allegan on the Pere Marquette railroad. At that time sand was removed by a truck and sold for $1.30 per ton, to C. W. Young Foundry, Allegan, and the Burr Machine Works of Holland, among others. The pit was first opened that year (1923), and as the sand seemed to be fine and smooth and having a good bond, its use as a molding sand was expected to increase. The deposit covers about one hundred acres or more to a depth of one to five feet.

In 1925 this same pit was again visited and sample thirteen (13) collected as representing the molding sand then being shipped from the pit. It was reported that the sand was mixed with coarser sand for use in some foundries. Most of the production was hauled into town by truck, and the daily capacity was rated at fifty tons.

Samples fourteen through eighteen were kindly furnished by the courtesy of Mr. Paul G. Bachner of the Clean Cast Sand Company, representing the material shipped from the pit in 1924. Sample fourteen identified as Clean Cast Company No. 0, is considered to be the basic loam sand of the deposit which is shipped clear if desired or blended with one of two other sands to give it an open structure. Sample sixteen identified as Clean Cast No. 1, sample seventeen identified as Clean Cast No. 2 F, and sample eighteen identified as Clean Cast No. 2, are the blends as shipped from this pit. At the time these samples were supplied the largest sale was of No. 0 and next of No. 2 represented by samples fourteen and eighteen. These sands are used for light automotive castings, light machinery castings of many kinds, for brass and for stove and furniture castings.

Comparison of these sands with Albany No. 1 indicates that the Clean Cast sand has a higher bond, a lower permeability, and lower fusion point. Clean Cast No. 0 fusing at about 2600° F., No. 1 at about 35° higher, and No. 2 at about 2700° F., while Albany No. 1 showed a fusion point of slightly over 2700°. Sample fifteen is Clean Cast No. 0 after it has been heated to 600° F. for two hours. As Clean Cast No. 0 is the bonding sand used in preparing these blends, this was the only one which was tested for durability.

The bond strength was reduced to less than half of its original value.

Sample three (3) taken from Section 25, T. 1 N., R. 11 W., about one mile west of Plainwell is representative of the sharp yellow sand deposited through this region by the glacier. In some places it is free from stone, and in other places it is very gravelly and full of larger stones. Sample four (4) taken two and a half miles northeast of Plainwell in the southeast quarter of Section 8, T. 1 N., R. 11 W., is representative of a deposit of clean sand ranging from white to red in color underlying approximately twenty acres or more. The depth of the sand in this deposit was not determined but it is at least four feet at the bottom of the knoll.

Sample five (5) taken from a small bank of very clayey sand from the pit of the Zeeland Brick Company, Section 8, T. 3 N., R. 14 W., just west of the Pere Marquette Railroad is an interesting sample representing that stage of classification which must be considered as intermediate between clay and sand. Formerly a few carloads were shipped out for foundry use but the bank has not been worked since 1923.

Sample eight (8) represents in a general way the sandy drift and outwash found west of the large moraine deposits in the central part of the peninsula. Sand of this type covers a large area running north through R. 15 W. from the county line to Fennville. Samples nine (9) and ten (10) taken about six miles west of sample eight in Section 10 of T. 1 N., R. 16 W., represents the sand underlying a relatively large area which appears to be an old lake bed which has been weathered to give a somewhat rolling country. The deposit seems to be a mixture of sand with some clay bond and might be used under some conditions for molding sand. Sample eleven (11) from Section 13, T. 4 N., R. 16 W., is an almost white dune sand containing practically no bond and seems to be representative of the dune sand which extends along Lake Michigan shores from Holland to Saugatuck. It is interesting to note that sixty percent of this sand passes a number 40 mesh and is retained on a number 70 mesh sieve indicating the uniform size of wind blown material. Allegan County, and many other counties in the state, afford excellent examples of the relative efficiency of wind, water and ice in separating sand into uniform sized grain.



Sample twelve (12) from Section 14 of T. 4 N., R. 12 W., six miles west of the Lake Shore and Michigan Southern Railroad and about one half of a mile south of Burnet was tested at Michigan and at the Bureau of Standards with somewhat different results for reasons noted. The screen analysis of this sample is also a bit puzzling as it seems to be composed of a mixture of two different sands, one having a grain fineness of 70 mesh and the other somewhere between 140 and 200 mesh. Although such screen analyses may be common in artificial mixtures few natural sands have been observed with this type of grain size distribution.

## ALPENA COUNTY

The surface of Alpena County is composed mostly of boulder clay and moraine deposits with some sandy drift south of Spratt near Nenelon River. About four miles back from the lake shore as far north as the City of Alpena are found sandy deposits from the old glacial lake bed. Sample 19 from Sections 23, 24, 25, 26, of T. 30 N., R. 7 E., is representative of this lake sand to the west of Devils Lake.

Sample 20 from Sections 8, 16, 17, 19 of T. 31 N., R. 6 E., one mile north of Lachine was taken from a layer of mixed white and brown sand about three feet in thickness overlying typical yellow plains or glacial outwash sand. The deposit consists of a few inches of white sand, then a few inches of brown containing chunks cemented together, apparently by iron oxide. These chunks do not exist in definite continuous layers, although generally following the contour of the surface. Indications are that this deposit is undergoing transformation into a naturally bonded sand, but being practically free from clay and possessing little bond cannot now be used for molding sand.

Sample 21 from Section 4 about one mile north of Sample 20 is taken from a thin deposit, a few inches in thickness, which appears to be a weathered boulder clay containing large quantities of sand. It seems reasonable to expect that either Samples 21 or 22 taken from this section is representative of the sand which was formerly used locally as a molding sand in casting brass.

Sample 22 was taken from the same section as 21 but from a formation similar to that shown by Sample 20. Sample 20 represents the white unbonded sand and sample 22 represents the rusty yellow sand occurring in chunks. Samples 21 and 22 are similar in many ways except that sample 21, evidently a boulder clay deposit, is not sized to anywhere near the uniform product as is 22, which is evidently a water deposited sand, probably from some glacial outwash.

Along the lake shore as in Sections 14 and 15 of T. 31 N., R. 8 E., are found large quantities of clean sand somewhat similar to sample 19. This sand is used locally in Alpena as a core sand. The local foundry reported that sand similar to sample 21 and 22 was used as a molding sand and that it was considered superior to molding sand now being shipped in from Ohio.

There are large deposits of clean sand along the lake shore and elsewhere used for building sand and core sand in many parts of the county. Samples 21 and 22 from the glacial deposits are representative of the small pockets of molding sand that may be found in various parts of Michigan. Although occasionally suitable for local use these deposits generally possess little economic value as is evidenced by the present practice of the foundry in Alpena which imports molding sand from Ohio rather than use the inconsistent material found locally.

### ANTRIM COUNTY

About one-third of the surface of Antrim County may be classed as sandy till. Most of it is extremely variable. Sample 23 from Section 6 of T. 31 N., R. 5 W., about three miles west of the G. R. & I. Railroad represents the white clean sand found around Boyne Falls, in a rather limited area, under about three to four feet of yellow sand. The formation is generally pockety, typical of moraine deposits. Sand is found in pockets with clay, gravel and stone to a depth of fifteen to twenty feet and possibly more. Sand also occurs in ridges through the lowlands. The ridges seem to have been deposited either directly under the glacier or at its extremity and are generally similar to moraine deposits.

Sample 24 from Section 4 of T. 30 N., R. 5 W., about three-quarters of a mile northeast of Simmons along the G. R. & I. Railroad is a deposit of clean yellow sand covered by three to four feet of brown sand and containing clay and gravel. Its general formation is similar, to that where sample 23 was taken. The sand is generally similar, although coarser than sample 23. Both of these samples appear to be water deposited, having fairly high distribution factors.



A comparison with sample 21, having a fineness distribution factor of .264, will serve to emphasize the difference in classification brought about by water deposition as compared to moraine deposits as represented by samples 21 and 22.

### ARENAC COUNTY

The surface of Arenac County is mostly sandy, clayey lake beds and contains deposits of sand similar to those found in Bay, Midland and the eastern part of Gladwin County.

### BARRY COUNTY

The surface of Barry County is mostly sandy till laid down by the glaciers. Samples 25 and 26 were taken from Section 9, T. 2 N., R. 8 W., about four miles from the Chicago, Kalamazoo and Saginaw Railroad, along the main highway and Cedar Creek. The sand is fine, light yellow in color and contains little bond. The sample was taken from the cut which here exposes about 30 to 40 feet of sand. The sand is generally covered by three to four feet of sandy gravel and may be found in pockets over an area of four to five square miles.

The differences in screen analyses reported from the laboratories at Ann Arbor and Washington, are probably most evident in comparison of these two samples, taken from the same deposit by the same man at the same time, and intimately mixed before quartering and separating for shipping.

The physical appearance and feel of this sample indicates that it contains much less than thirty percent of clay. Being a fine sand, containing relatively large amounts of silt and fine grained sand particles, the method of siphoning the clay from the sand grain used by the Bureau of Standards carried off a relatively large amount of silt or sand grain with the clay, tending to make the clay content appear high and the pan material and the material on a 270 mesh low.

Sample 27 from Section 28, T. 4 N., R. 8 W., was taken from a bank on the side of the road fifty yards east of the main highway. The sample represents fine sand lying in strata about three feet thick and four feet below the top of the hill. Preliminary investigation indicated that this sand might be found under an area of approximately ten acres.

Samples 28 and 29 from Section 25, T. 4 N., R. 10 W., about one mile east of Middleville and the Michigan Central Railroad, are representative of many pockets of sand found in the till plain. These samples are from a stony, reddish-yellow clay-sand mixture, at least fifteen to twenty feet deep in places. The clay seems to run in streaks over the yellow sand, clearly indicating that the clay and sand were deposited more or less together by the glacier.

In Section 30, T. 3 N., R. 7 W., about four and a half miles east of Hastings, and three-fourths of a mile south of Morgan and the Michigan Central Railroad, is an exposure of about thirty-five to forty feet in a cut made for the highway, of coarse unbonded yellow sand which runs into gravel in places. The deposit is full of stones, typical of moraine deposits.

### BAY COUNTY

Bay County includes considerable areas of sandy lake beds which yield material of commercial value. The industrial development in the Bay City district, is sufficient for a number of local sands to be used for various purposes. The Bay City Electric Steel Casting Company uses a so-called silica sand, Sample 31, which seems similar to sand dredged from the Tittabawassee River (Sample 206) used by the Bay City Iron Works as a core sand. The exact location from which this sand was taken is not known but it was reported to be near Saginaw. The Bay City Iron Works formerly used Michigan City sand exclusively for cores but found it too fine for propeller castings. The sand (206) obtained from the river bed proved satisfactory for this purpose.

For a molding sand this company uses a Zanesville number four molding sand purchased in 1924 at fifty cents per ton f.o.b. and freight charges at $3.15. A sample of this Zanesville sand was collected and is reported as sample 311, laboratory sample 2152.

Sample 32 taken from Section 26 of T. 15 N., R. 5 E., one mile northwest of Kawkawlin, represents a bank of clean sand owned by Mr. Joe Rocarius, and used for making cement blocks. Some sand is also sold in Bay City. The bank is about eight feet thick and covers probably twenty acres. The deposit is evidently a sandy lake bed of well classified material.

The Laetz Foundry Company of Bay City, making iron, brass, and aluminum castings, uses a local sand for core sand and a Zanesville number three for iron castings. Sand received from a small pit, somewhere north of Bay City, was reported as being a fair molding sand.

The Bay City Foundry and Machine Company also uses a Zanesville number three sand for molding and Michigan City and local sands for preparing cores.



### BENZIE COUNTY

Benzie County is more than one-half covered with sand till, sandy lake beds, or sandy outwash plain. Sample 33 from Section 7, T. 26 N., R. 14 W., about one mile west of Honor, and one-half mile from the railroad, is a clean sand found in depths up to twenty to thirty feet in places, and covering about twenty to twenty-five square miles north of Crystal Lake.

Sample 34, from Section 34, T. 26 N., R. 14 W., is a clean white sand, free from bond, found in the glacial outwash plain around Frankfort, and along the Ann Arbor Railroad. Samples 33 and 34 are very similar except that sample 33 has been somewhat discolored and weathered as compared to sample 34. A comparison of the tests reported on sample 33 at Cornell laboratories and sample 34 by the Bureau of Standards, with these facts in mind, may be taken as another indication that the Bureau of Standards separated the clay substance from the sand grains in such a way as to include considerable amounts of fine sand grains with the clay substance.

### BERRIEN COUNTY

The surface of Berrien County is made up largely of glacial outwash and boulder clay, with some sandy lake beds along the river valleys leading back from St. Joseph. An interesting delta formed by the river now known as St. Joseph is found in T. 5 S., R. 18 W. The interesting dunes found along the lake shore in the southern part of the county and also to the north running from the Indiana state line north to Stevensville in an almost unbroken band contain large volumes of well sized sand.

With these deposits frequently in close proximity, it might be expected that some of the old lake beds might contain bonded sand usable as molding sand, as the sandy materials might be washed and mixed with the clay bonding material and then redeposited in quiet bays. This seems to be the method by which the sand near Coloma now used by the Garden City Sand Company and by Kerlikowski was deposited.

Sample 35 taken from T. 7 S., R. 21 W., east of the Pere Marquette Railway, is a light yellow bank sand free from bonding material, and seems to be a water deposited sand. There are large quantities of sand similar to sample 35 in this district, not counting the dune sands which are very plentiful. About six miles east of this locality, in section 36, T. 7 S., R. 19 W., red sand in thin layers about eight inches thick is found under about four feet of clay in what appears to be a boulder clay or till plain.

Sample 36 from section 15, T. 6 S., R. 19 W., represents a glacial deposit in a sandy till plain, containing some stone and clay. The sample was taken from the upper two feet of the deposit. Underneath this layer unbonded sand containing pebbles and bearing water is found. Sample 36 seems to possess most of the properties of molding sand which is removed from this district.

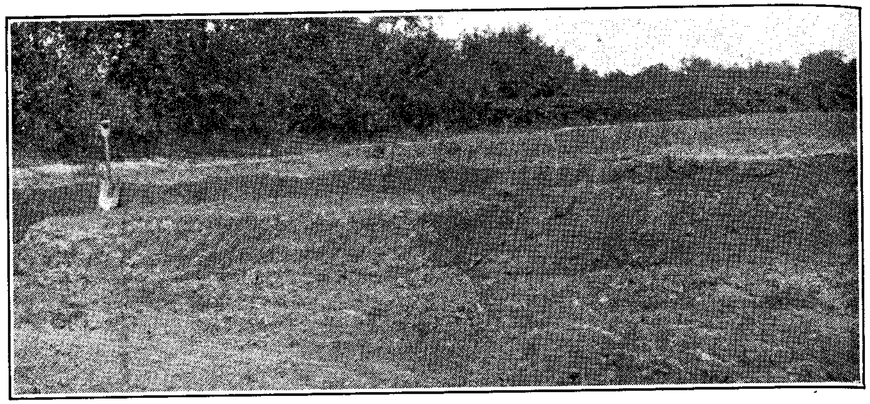


Fig. 30. Pit of Garden City Sand Co. showing top foot of clay loam, indicated by shovel, over brown sand and clay (Sample 37)

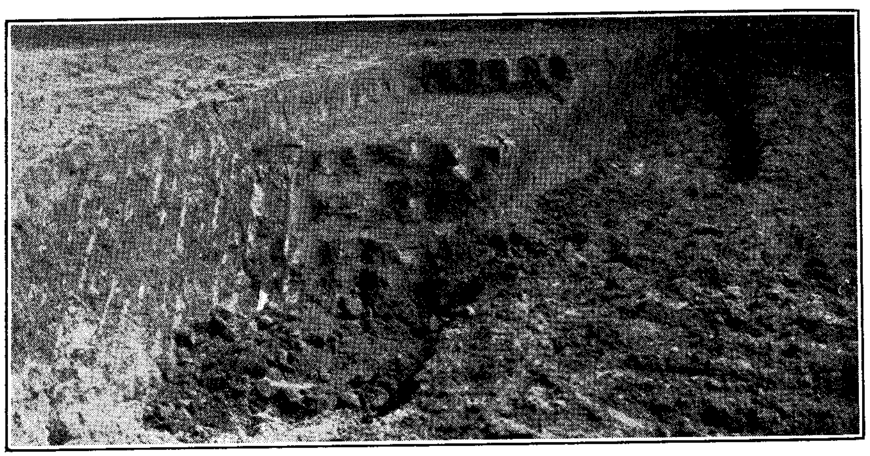


Fig. 31. Pit of Green City Sand Co., showing clay loam thrown into bottom of dug over pit in foreground of right digging. The brown sand (Sample 37) and the white sand (Sample 41) at bottom of pit.

Samples 37 and 41 were taken from the pit of the Garden City Sand Company of Chicago, in section 24, T. 3 S., R. 18 W., in September, 1923. These samples were taken from the old sandy lake bed which extends in a bank about three miles up the Paw Paw River from St. Joseph. The top foot of the deposit is clay loam, which is rejected and shoveled back into the pit, after the sand is removed, as a fill. Under the clay loam is a layer of brown sand and clay mixture about three to five feet thick from which sample 37 was taken. Under the brown sand is found a coarser white sand represented by sample 41. The method of working this deposit is clear from the photographs. Figures 30 and 31. The mixtures of the upper brown sand and the white beach sand below are prepared by loading so many spades of beach sand to so many spades of brown or bonding sand according to the requirements of the purchaser. Usually the mixtures are prepared containing up to 50% of the white beach sand. The mixed load is then trucked about one quarter of a mile across the road to a siding on the Pere Marquette Railroad. Here the truck is dumped and the sand put through a roll crusher and screened to break up the lumps of sand before loading.



In 1923 this pit was shipping molding sand into Illinois, Wisconsin, as well as in Michigan, at a price of $1.25 to $1.50 a ton. About three cars a day were loaded with the six trucks then used to carry the sand to this railroad siding. Over a period of ten years up to 1923 approximately twenty acres of this deposit had been dug over.

Sample 37, representing the upper brown sand found in the pit of the Garden City Sand Company, was tested at the Cornell laboratories with the results as indicated. A duplicate sample, identified as No. 38, was tested in the University of Michigan with similar results. The methods of determining the clay content used at Cornell University and at the University of Michigan give generally concordant results, whereas the clay content reported by the Bureau of Standards is high. Because this sand is the bonding sand used in preparing the commercial molding sand shipped from this pit duplicate samples, numbers 39 and 40, were heated to 600° F. for two hours and fourteen hours respectively, losing 48 and 62 percent of their bond strength and 69 and 63 percent of permeability respectively. This is a rather high loss on heating and indicates that the bond in the sand is not very durable. From practical consideration this may be partly compensated by using a sand containing relatively large quantities of bond as indicated in the discussion of durability.

In 1925 the Garden City Sand Company's pit was again visited. At this time approximately five acres of the deposit were left. Sample 42 taken at that time is representative of the molding sand then being shipped from the pit, apparently about a 50-50 mixture of the brown bonded sand, sample 37, and of the beach sand (41). Sample 42 heated to 600° F. for two hours lost 73 percent of its bond strength and gained 120 percent in permeability. Comparison of sample 42, representing the mixed molding sand as actually shipped from the pit, with sample

39, representing the high bond sand used in preparing the commercial blend, clearly indicates the differences in results obtained from durability tests on different mixtures of the same materials.

There appear to be a number of similar deposits of sand in this area near Riverside. Definite deposits were located about one-eighth of a mile south from the pit of the Garden City Sand Company and about two miles west of the latter deposit.

Sample 43 from section 19, T. 3 S., R. 17 W., one and one-half miles west of Coloma and about one-half mile north of the Pere Marquette Railroad was taken from a bank on the south side of the road, and represents a stratum about three feet thick found one foot below the surface. It is apparently only a small pocket of a few yards in width found in the sandy lake bed and is generally similar to the other deposits worked for molding sand in this district.

The Kerlikowski pit, in section 26, T. 3 S., R. 18 W., has been worked for about nineteen years. The formation and the sand are very similar to that in the Garden City Company's pit, except that the brown bonded sand exists in a stratum about two feet thick. Similar to that of the Garden City Company, this sand is covered by about one foot of clay soil or loam and underlain by beach sand. The deposit is handled in much the same way as that of the Garden City Company's and the sample (44) taken from Kerlikowski's pit has much the same properties as sample 42 taken from the pit of the Garden City Company.

Sample 45, taken from east cut of a country road in section 5, T. 4. S., R. 18 W., about one hundred yards east of the Pere Marquette Railroad and three miles northeast of Benton Harbor, is very similar to the samples taken near Riverside except for the fact that it possesses a coarser grain. Here the formation seems to be about two feet thick as in the Kerlikowski pit.

Another deposit of similar sand is that represented by sample 46, taken from the southeast quarter of section 2, T. 5 S., R. 19 W., on the farm of George G. Clemens, just each of the Michigan Central Railroad tracks. This sample contains more clay than 45 and possesses a higher compressive strength. This deposit has been worked for over thirty years, and in 1925 there appeared to be not more than one hundred car loads left. This sand has been used by the Studebaker Corporation, General Motors, and several Michigan, Illinois, and Indiana foundries, in amounts varying from one to two hundred and fifty cars per year. In this locality the bonded sand occurs in a layer about five feet thick. Another sample (47) taken from the same farm but on the west side of the Michigan Central right of way, represents a layer of bonded sand about six or seven feet thick underlying about one and a half acres which had not been developed when visited in 1925. This sand is finer and contains less clay than that represented by sample 46, but should prove equally satisfactory when properly adapted, or when used for purposes not demanding such a high permeability.



Sample 48 from section 20, T. 3 S., R. 17 W., within the city limits of Coloma, fifty yards north of the county road and about two hundred yards south of the Pere Marquette Railroad, represents a high bonded sand found in a layer about four feet thick three feet below the surface of the ground. It appears to be a large deposit of highly bonded sand. Durability tests as indicated by sample 49 from this deposit classes it as similar to the sands found further west near Riverside.

Sample 50 from section 20, T. 4 S., R. 17 W., taken from the east and west banks of a cut in a county road, represents a finer, highly bonded sand found in a stratum five feet thick, about one foot below the surface. This deposit also appears to be relatively large and to contain considerable quantities of ferric oxide.

Sample 51, Section 29, T. 4 S., R. 17 W., taken from a cut on the county road three miles southeast of Millburg and six miles east of Benton Harbor, is a coarser sand containing less clay, found in a stratum about four feet thick two feet under the surface. This deposit lies on the east side of the road and extends forty or fifty yards along the road and quite a distance eastward. The test indicates that this sand might be used as a molding sand for purposes somewhat similar to sample 46 on the Clemens farm.

Sample 52 is a fine light sand from the pit of E. J. Moody in Section 31, T. 6 S., R. 17 W., about one-half mile south of the Benton Harbor and St. Joseph Electric Railroad, but the owner refused to part with any information regarding the uses of this sand.

Sample 53, section 27, T. 6 S., R. 17 W., three and a quarter miles southeast of Berrien Springs, is a coarser sand containing little bond in a patchy deposit about one foot thick two feet below the surface.

Sample 54 is a fine sand containing about 60 percent of clay, found in a stratum two feet thick and two feet below the surface in section 3, T. 6 S., R. 18 W., on the east bank of the main highway one-quarter of a mile west of the Southern Michigan Electric Railroad and two miles east of the Pere Marquette Railroad. Another similar deposit is represented by sample 55 in section 16, T. 5 S., R. 18 W., on the east bank of the road one mile east of the Southern Michigan Railway and four miles southeast of Benton Harbor. Sample 56 in section 15, T. 6 S., R. 18 W., is another similar sand from a stratum about three feet thick outcropping for one hundred feet along the road. The great similarity between sample 56 and sample 54 indicates that there may be relatively large quantities of sand similar to these samples along this part of the St. Joseph River.

Sample 57 from section 10, T. 7 S., R. 19 W., about a half mile southwest of Glendora and a quarter of a mile west of the Michigan Central Railroad, was taken from a cut on the west side of the county road from Baroda and Galien. It is a coarser sand having a wide working range from about 7½ to 9½ percent moisture. The deposit is about two feet thick and found two feet below the surface. The area of this deposit was not determined although it is apparently relatively small. This sample and also 58 appear to be more like the glacial deposit than the lacustrine deposits found in this county. Sample 58, section 36, T. 7 S., R. 19 W., on the main highway about one and a half miles east of Galien and one and a quarter miles east of the Michigan Central Railroad, was taken from the north side of the highway and represents a deposit about three feet thick four feet below the surface extending for at least fifty yards along the road.

In addition to the samples mentioned above the four samples collected and tested by Ries in the report on foundry sand of 1908 should be included. These samples identified as R. 12, R. 13, R. 23, and R. 56 from Vrooman's pit near Riverside, core sand from Niles, Garden City Sand Company, Vineland, and from Kerlikowski's pit respectively, are included in the table of test data.

### BRANCH COUNTY

The surface of Branch County is mostly clay and sand drift with some outwash sand and land laid moraine. Sample 59 north of Batavia is a gravelly sand running to clean gravel below. Evidently a glacial deposit poorly classified as to grain size, this sample seems representative of the district. Sample 60 is somewhat similar but contains more clay and accordingly possesses a higher bond and lower permeability, Sample 60 was taken from section 18, T. 6 S., R. 7 W., from a pit about three feet deep in the roadside.

The opinion expressed by the foundry foreman in Coldwater, Michigan, that Michigan molding sand had been used due to war necessity as it occurs only in small local deposits, and after first use possesses little bonding power, is perhaps particularly adapted to these sands found in the glacial deposits of Branch County. Foundrymen with this background of experience prefer a heavy coarse Illinois sand for heavy casting or frequently a Zanesville or Ohio sand. The foreman of the Homer Furnace Company stated that this foundry was returning to the use of Albany sand.



### CALHOUN COUNTY

The surface of Calhoun County is largely sandy till. Sample 61 is a stony, yellow, unbonded sand found in mounds of thirty feet or more in height, in section 29, T. 4 S., R. 6 W., on the road between Tekonsha and Burlington and the Michigan Central Railroad and the St. Joseph River. There appear to be large quantities of sand similar to sample 61 in the southeastern part of Calhoun County.

Sample 62 is another sample of similar unbonded sand found in section 21, T. 4 S., R. 8 W., about one and a half miles northwest of Athens near the railroad. Sample 63 represents a somewhat finer sand, also free of bonding material taken from a twenty foot cut in section 30, T. 2 S., R. 6 W., one mile east of Ceresco near the Michigan Central Railroad. The sand in this district appears to be glacial outwash material and is frequently used for structural material in this locality.

Sample 66 from section 12, T. 2 S., R. 6 W., three miles north of Marshall is similar to sample 63. It is covered by dark yellow sand and mixed with streaks of clay. This deposit covers one hundred acres or more to a depth of about twenty-five feet in mounds. The Fleck Foundry Company of Marshall has used this sand for making cores. Mr. Adams of this company reports there is more of the same type of sand on the Jewett farm one and one-half miles southwest of Marshall. When visited in 1923 this foundry was using molding sand from Allegan.

Ries sampled fine grained molding sand from Coldwater Street in Battle Creek, identified as R. 19, and a heavier sand as R. 28. Sample R. 19 seems to be somewhat similar to sample 66 and to samples 64 and 65, but of a finer grain.

In the northwest part of the county, identical samples 64 and 65, as tested by the Bureau of Standards and at the University of Michigan respectively, were taken from section 22, T. 1 S., R. 8 W., about one mile north of Urbandale west of the Wabascon Creek. This deposit of fine grain brown sand containing some bonding material is found mixed with sand and gravel in ridges covered by about one to four feet of coarse sand. In places the formation from which the samples were taken extends to ten or twelve feet in depth.

Comparison of the clay content reported from the Bureau of Standards on sample 64 and reported on the duplicate sample 65 from the University of Michigan again indicates a thoroughly consistent discrepancy due to the Bureau of Standards reporting too high a clay content.

### CASS COUNTY

The surface of Cass County may be classified as largely sandy till and gravelly loam. In many ways the sand found in Cass, Kalamazoo, Calhoun, Branch, and St. Joseph counties are very similar, as these counties are completely covered with glacial drift or morainic deposits. Sample 67 in sections 2 and 3, T. 8 S., R. 13 W., contains some clay and gravel running to more clay at a depth of eight to ten feet. This sample was obtained by trenching the bank on the roadside for a distance of about eleven feet down from the top. Sample 68 from section 12 of T. 8 S., R. 14 W., was obtained from a pit about six feet deep. Here the sand contains some clay near the top and less at a lower depth.

### CHARLEVOIX COUNTY

The surface of Charlevoix County is composed largely of till and moraine deposit. For a short distance back along the lake shore deposits of beach sand similar to sample 90 from Petoskey is found.

Sample 69 in section 27, T. 33 S., R. 6 W., one and a half miles northwest of the center of Boyne City along Pine Lake was taken from an area of yellow clean sand extending to a depth of about thirty or thirty-five feet. Here the sand is generally free from stone or gravel and extends along Pine Lake towards Boyne Falls for about ten square miles. Somewhat similar sand was observed one-quarter of a mile northwest of Sharon along the right of way of the G. R. & I. Railroad. Here the sand is not uniform, running to gravel and clay in some localities. The sand occurs in low ridges and seems to have been deposited by streams running under the glacier.

### CHEBOYGAN COUNTY

The southern part of Cheboygan county is covered with clay and sand till and some moraine deposits. The northern part of the county is largely covered with sandy and clayey lake beds as the old glacial lake shore line south of Indian River.

Sample 70 represents a lake-washed gravelly sand from section 15, T. 37 N., R. 1 W., six miles southeast of Cheboygan on the county road to Grace and Orchard Lake. The sand is probably about thirty to forty feet in depth ranging from red-yellow sand to white sand of a coarse texture and free from bond. The sample was taken from the upper six feet of the deposit on the Apple Growers Association property. This particular deposit covers an area from thirty to forty square miles.

Sample 71 represents the clean white sand found to a depth of six to eight feet over considerable area in the district around Black Lake. This sample was taken from the northern end of the lake in T. 36 N., R. 1 E.

Sample 72 taken from the northeast quarter of section 14, T. 34 N., R. 3 W., about four miles northwest of Wolverine along the Michigan Central Railroad and the Sturgeon River is almost the same texture as sample 71, just described. Sample 72 was taken from the west bank of Sturgeon River which reveals layers of sand and gravel to a depth over forty feet. At the top of the deposit is a layer of gravel about two feet six inches thick underlain by yellow sand about eight or ten feet thick below which is white sand. The sand is composed of smooth round grains and practically free from bond.



Sample 73 is also similar to Samples 71 and 72 so far as size of grain is concerned and is also composed of smooth round grains free from bonding material. Sample 73 was taken from Section 34, T. 37 N., R. 2 W., about one-quarter to one-half of a mile northwest of Mullett Lake Station.

Sample 74 from Section 12, T. 37 N., R. 2 W., was taken along a section road, three-quarters of a mile southwest of the Michigan Central Railroad and two miles by road southwest of the city limits of Cheboygan. The sample was taken from the face of a cut along the side of the road and represents a stratum of about four feet thick of fairly uniform sand lying under a small knoll. Similar deposits under several knolls were encountered in the immediate vicinity. The sand stratum lies about five feet below the surface and covers a determined area of one acre. Probably the deposit covers a much larger area.

A somewhat similar sand not quite so fine, was found in Section 14, T. 34 N., R. 3 W., one-quarter of a mile west of the Michigan Central Railroad, near where Sample 72 was taken. Sample 75 was taken from the face of a cut on the west side of the road. The deposit lies under a small east and west moraine about twenty feet below a top of a hill, and is about four feet in thickness. As this deposit seems to possess molding sand possibilities, a duplicate sample (76) was heated to 600° F. for two hours. The results of this test indicating that the sand loses about sixty percent of its bond strength and about 55 percent of its permeability show the sand to possess little durability.

### CLARE COUNTY

Clare County is completely covered with moraine and glacial till, a large part of which is sandy, generally unbonded, and known as plains sand. Sample 77 from Section 34, T. 18 N., R. 4 W., 9.7 miles southeast of Harrison and 5.5 miles north of Clare on the main highway was taken from the west face of a cut in the road on a hillside. The sample was taken by trenching through the stratum which is five feet thick and four feet under the surface. The sand stratum is very irregular being a mixture of sand and sandy clay. It extends for about fifty yards along the road and probably covers about five acres.

### CLINTON COUNTY

The surface of Clinton County is composed largely of clayey till. Under these conditions it might be expected that where sand is found it is likely to contain clay, particularly if the deposit has been mixed in deposition. Sample 70 from Section 33, T. 6 N., R. 2 W., about one and one-quarter miles northeast of Dewitt, one mile west of the interurban tracks, and seven miles north of the city limits of Lansing, was taken from the face of the west cut on the side of the road and represents a small pockety deposit covering an area of about one acre. The pockets run about twelve to eighteen inches thick and are found generally on the slope of the glacial knob. This is a fine grained sample, containing about ten percent of clay.

Sample 79 from Section 28, T. 8 N., R. 4 W., on the bank of Hayworth Creek, four and one-half miles southeast of Maple River on the county road to St. Johns, represents an exposure of sand deposited in an old lake bed or as a river silt. The sand stratum is about three feet thick and about two feet under the surface. Below the sand is found sandy gravel. This particular deposit covers ten acres but it seems reasonable to expect similar sand in various places throughout a band about a mile and a half wide running along the Maple River and Hayworth Creek up to the point where this sample was taken and then easterly to Duplain where this zone of water-deposited sand again follows Maple River up and down stream to the county line. Similar sand outcropping along the bank of the stream for about two miles, and Sample 80 from Section 8, T. 8 N., R. 3 W., just south of Maple Rapids on the St. Johns Road, exhibit much the same formation and properties except for being much coarser. Sample 80 was taken from the east side of the road and may be classed as a molding gravel. Here the stratum extends almost to the surface and is from twelve to eighteen inches thick covering quite an extensive area, at least one-half mile along the road.

Mr. Handley, Manager of the Industrial Foundry Company of St. Johns kindly furnished samples 320 through 324 representing the sand used in his foundry and shipped in from without the state. As these sands are not Michigan sands they are tabulated separately for purposes of comparison.

Sample 321 is fresh molding sand from Gallipolis, Ohio. The heap sand (about 6 to 12 months old) of a molder using this sand is represented by sample 322. Sample 320 is fresh New Cumberland, Ohio, sand. Sample 323 is the corresponding heap sand (about 4 months old) of a molder who uses about three wheelbarrow loads of fresh sand per week, and sample 324 that of a molder doing the same work but averages about six similar loads of new sand per week. The freight rate on these sands is about $3.15 per ton.



### CRAWFORD COUNTY

Crawford County being entirely covered with glacial outwash plains and glacial till presents much the same formation and type of sand as found in the adjacent county. Sample from Section 6, T. 26 N., R. 4 W., just outside of the city limits of Grayling to the north and near the Michigan Central Railroad represents a yellowish to red sand changing to white at greater depth found on the sides of river banks, road cuts, and similar exposures throughout this district and is generally similar to other deposits of sand in the north central part of the Southern Peninsula.

### EATON COUNTY

Eaton County is largely clay till similar to Ingham County. In such localities small pockets of clay-sand mixtures possessing sufficient bond and permeability to be used as molding sand may be found. Sample 82 from Section 10 of T. 3 N., R. 3 W., within the town limits of Dimondale, one-half mile west of the Lake Shore and Michigan Southern Railroad, on the Grand River, is a clean sand from a stratum in a large gravel pit. The sand layer runs from five to six feet thick, over and underlaid with strata of heavy gravel. The sand is extremely fine and several carloads were sold to the Reo Motor Company of Lansing for use in polishing. In 1925 this gravel pit, owned by Mr. Potts, was worked.

Sample 83 from the same section but just out of the limits of Dimondale about one mile northwest of the Lake Shore Michigan Southern Railroad was taken from a deposit of glacial outwash along the Grand River. This deposit, now owned by Mr. Art Shively, was worked by a former owner and several carloads were shipped apparently exhausting this deposit. Immediately south of the old pit there is a stratum about three to four feet thick, ranging from a clay loam on the surface to what appears to be a light molding sand. The sample was taken from vertical borings through this stratum. The material so obtained was carefully mixed and quartered. The deposit covers approximately five acres with the probability of other similar deposits in the same neighborhood.

Sample 84 from the southwest quarter of Section 2, T. 3 N., R. 3 W., was taken from a deposit owned by Mr. Miller on the Grand River just southeast of the bridge and three miles from the north limits of Dimondale. The deposit is very similar to that represented by Sample 83 but the sand appears somewhat heavier or coarser. About four acres are covered with a thickness of three to four feet underlying six or twelve inches of top soil. Several carloads were shipped out some years ago to Albion. Miller was offered one dollar per ton f.o.b. Dimondale about 1920 but at that time considered the price inadequate.

Sample 85 from the southwest quarter of Section 1, T. 4 N., R. 3 W., about one mile and a half west from Lansing city limits on the north bank of the Grand River, was taken from the farm of C. F. Davis and represents a stratum of sand two to three feet thick underlaid with gravel and overlaid with six to twelve inches of clay loam. The general formation of the deposit and the feel of the sand are very similar to that represented by Sample 84 from Miller's deposit.

Ries has tested a number of these sands as reported in the Survey of 1907. Sample R5 and R52 reported as coming from Ingham County represents the under sand of Cory's pit near Dimondale and considered unsatisfactory by Lansing foundries. The pit was located along the Grand River and the deposit which underlay the lower edge of the slope bordering the river was probably river silt. It was nearly exhausted of molding sand in 1906, having been worked since 1895. Samples R7 as formerly used by the Hildreth Pump and Motor Works, and R 36 formerly used by the Lansing Wheelbarrow Works, are located in Eaton County and described as representing molding sand from Reeve's pit 2½ miles west of Lansing. Samples R44 and R47 are also taken from this district but in Ingham County.

## EMMET COUNTY

The surface of Emmet County is composed largely of sandy till plains and sandy lake beds.

Sample 86 from Section 27, T. 39 N., R. 4 W., about one and one-half miles southwest of the city limits of Mackinaw City near the lake shore is probably a wind blown lake deposited (dune) sand. The yellow to white sand is found in layers about ten to twenty feet deep overlying a reddish clay which comes to the surface in places. The sand is composed of smooth round grains containing little bonding material. The sample was taken from Brook's farm and seems to be generally representative of a large deposit covering three or four square miles.

Sample 87 from Section 24, T. 39 N., R. 4 W., was taken from a similar deposit just south of Mackinaw along the main highway. The sand is composed of smooth round grains, generally similar to that of Sample 86. It appears to be a sandy lake bed rather than dune sand. The sand is at least twenty to thirty feet in thickness and is streaked with limestone which outcrops in a strip about a half mile along the lake shore.

Sample 88 from Section 31, T 38 N., R. 5 W., three miles east of Cross Village, and nine miles west of Levering, is apparently very similar to Sample 85. The deposit here is ten to twenty feet in thickness and covers probably twenty to thirty square miles along Sturgeon and Cecil Bays.



Sample 89, taken one and one-quarter miles south of Pellston, Section 10, T. 36 N., R. 4 W., and Sample 90 from the shore of Little Traverse Bay between Bayview and Petoskey in Section 33, T. 35 N., R. 5 W., are sharper sands of about the same grain size and appear to be deposited in old lake beds rather than as dunes, although the latter may represent dune sand which has been washed by the waters of the lake. The uniform size of grain possessed by sample 89 may indicate that this is the case. The deposit south of Pellston shows about one to two feet of compact brown sand, probably similar to Sample 75 from Cheboygan County, which is underlain by three to four feet of white sand above the main deposit from which the sample was taken. There are large quantities of this sand in the deposit which is at least thirty to forty feet thick.

Sample 90, near Petoskey, is used by the Antrim Iron Company. Samples 86, 88, 89 and 90 all appear suitable for use as core sands and indicate the large quantities of well classified clean sand to be found in Emmet County.

## GENESEE COUNTY

The surface of Genesee County is mostly clay till with some lake deposited sand and probably river silts exposed along the Flint River as far as Mount Morris and Pine Run.

Sample 91 from Sections 5 and 6 of T. 8 N., R. 6 W., about five miles east of the Grand Trunk Railroad, is a light yellow sand found in a fairly uniform deposit about twenty feet deep.

Sample 92, Section 3, T 7 N., R. 5 E., about three hundred yards west of the county road, was taken from borings from the top and side of a knoll. This sand represents a stratum about four feet thick covering approximately one and one-half acres, bearing an overburden of eight inches of clay loam and on top of the knoll about three feet of loose sand. The property is owned by Art. Seymour.

Sample 93, from Section 17, T. 7 N., R. 6 E., about equidistant from Flint and the Grand Trunk Railroad represents screenings from an old gravel pit in a moraine deposit.

Sample 94, from Section 32, T. 8 N., R. 7 E., out Stewart Avenue was taken from the face of a cut on the south side of the road. This deposit represents sand as found in boulder clay plains and consists of four feet of alternating strata of loose sand and compacted (bonded) sand. About one acre was available in 1925, but this has probably been occupied by buildings since then.