DESIGN AND OPERATION OF PLANTS FOR PRODUCING STABILIZED SOIL-BOUND ROAD MATERIAL

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SYNOPSIS

Because it allows for economy in the use of maintenance equipment, saving in time, and more uniform composition of product, plant-produced stabilized mixtures are favorably considered by the highway engineer Producers are likewise in favor of central plant-mixing because it often makes possible the utilization of accumulated aggregates and sand or clay wastes Although the operations of the plant may vary with local conditions, its essential functions are thorough mixing of the ingredients and covering of the aggregate particles with the binder-soil to which moisture-retaining chemicals are added The simplest method of proportioning the materials is by picking them up with power shovel or clam shell bucket, and placing them in a hopper, after which they are mixed in a pug mill or some other mixing device into which the chemical admixture is fed Preliminary treatment of the binder soil is often advisable, however, to make it coat the coarser aggregate particles more thoroughly during mixing "This may be accomplished by a vibrating screen or by pug mills when the binder soil is a friable sand clay, and by a clay disintegrator when it is a tough and plastic clay The amount of water used in the mixing operation depends on the moisture in the binder and in the aggregate, and also on the method of laying down the material on the road Sieve analyses of the various materials and plasticity index determinations of the binder soil are all that are required to calculate proportions of ingredients necessary to produce a road material which will comply with the usual specifications Costs will depend upon local conditions "

One of the more recent developments of soil stabilization is the combining of several types of soil with a chemical admixture in a centralized plant, thereby producing a road surfacing composition having the soil properties which are necessary to give maximum dry weather and wet weather service Before discussing the design and operation of such a plant, it is only logical first to consider the advantages that such a unit affords, as compared with the more common custom of mixing the soils on the surface of the road to make a stabilized mixture

The highway engineer considers plant-mixing favorably in producing stabilized road material for the following reasons:

1 By means of thoro mixing and accurate control of the composition, there is provided a product of uniform composition, and hence uniform properties
2 Expensive and much-needed maintenance equipment is not tied up for mixing operations in construction work
3 Dust nuisance and annoyance to traffic by construction operations on the road are eliminated
4 Expense of delays due to waiting for materials to dry after periods of wet weather are abolished
5 The season during which stabilized roads may be built is materially extended in many parts of the country
6 Towns, villages, or counties that do not own equipment suitable for carrying on stabilization operations on the road may obtain a complete mix which will give them the desired road properties
7 Shoulders are somewhat difficult to stabilize in place, but may be made safer and more serviceable by surfacing with the plant-mixed materials
8. Roads and detours may be put into

service more rapidly, due to the speed and ease with which plant material consolidates This is of great importance where flexible type paving surfaces are to be applied in the same year

Producers of aggregates are likewise favorably disposed toward central plant-mixing for the following reasons:

1 Frequently it is possible to utilize at a profit, excessive accumulations of a certain size aggregate by combining them with other available materials
2 Easily available over-burdens of clay and sand frequently may be incorporated in the plant mix, thereby in many cases profitably getting rid of waste material which has become a nuisance
3 In areas of large population a substantial retail business may be developed for private drives, cemeteries, parking lots and similar uses

DESIGN OF PLANT

In relatively rare instances nature itself, at some time in the prehistoric past, has served as the mixing plant for producing the correct proportions of clay, silt, sand and gravel In doing so it has provided a road surfacing composition which requires only the addition of a chemical product which will aid in consolidation and moisture retention in order to answer all requirements of a stabilized road material A simple gravity feeder with a plate shut-off may be used satisfactorily to dispense the chemical uniformly to such a soil at some point in the ordinary process of obtaining it from the earth

Plants for stabilizing soils may be either stationary or portable and their operations may vary, depending on local conditions, but essentially their function is to mix the ingredients thoroughly so that the particles of frictional material, such as sand, pebbles, crushed stone or slag, will be coated completely with a film of binder-soil particles which are dampened with the moisture-retaining chemical which is added in the process. In general, the scheme of operations involves preparing the binder-soil by putting it through a mechanical device to reduce it to a fine state of subdivision, and mixing this with the proper proportions of fine and coarse aggregate, to which water and chemical have already been added

The quality of the binder-soil which is to be used in a stabilization plant usually governs its design If a highly cohesive clay, free from sand and silt, is to serve as the bonding medium in the product, the problem of equipment is somewhat complex If, however, the binder soil is a friable sand-clay having a plasticity index close to that desired in the ultimate product, the design of the plant becomes quite simple This latter type of plant is found in several places in Michigan where several feet of over-burden having a plasticity index of 4 to 10 may be stripped off the gravel and used in combination with coarser aggregate to form a satisfactory mixture

The simplest plant using such materials as these, is one in which a power shovel or clam shell bucket is used for proportioning the materials The proper quantities of binder soil and aggregate are picked alternately from separate piles and placed in a hopper or in another pile, from which the combination is then taken to a pug mill or other efficient mixing device The chemical admixture is fed into the mixer at a uniform rate and water is added as necessary, depending on the moisture content of the other materials Such a plant is shown in Figure 1

In general, however, it is better that the binder-soil receive some preliminary treatment to make it coat the coarser aggregate particles more thoroughly during the mixing operation One method of accomplishing this, which has been used with success, is by putting the sand-clay through a vibrating screen as illustrated in Figure 2. The power shovel dumps the soil on an inclined vibrating screen having openings about one inch square. In the case of higher plasticity index sand-clay, the power shovel which digs the strippings may raise and drop them once or twice to shatter the large lumps of soil and thus prepare them to break up easily on the vibrating screen. If large stones are present, these may be removed by means of grizzley bars or by a screen having about $2\frac{1}{2}$ in. openings. The bars are stationary, whereas the coarse screen may be mounted on the vibrating frame above the one with smaller openings. This equipment will break up about 90 percent of the binder-soil of relatively low plasticity index in such a form that it can easily be combined with coarse material in a pug mill, into which water and chemical admixture are also added.

If a vibrating screen is not already available in an aggregate producer's plant, investment in such equipment to enable production of stabilized road material is not usually considered as a questionable expenditure, since it also will find much other service in such environment. Such a screen, operated by a 10 H.P. motor, will prepare the low PI binder-soil for a plant having a capacity of 50 to 60 tons of finished product per hour.

Another common device for preparing the binder-soil, particularly if it is highly cohesive, is the so-called disintegrator, which is common to the clay-products industry. In this machine, shown in Figure 3, the binder-soil is fed between two rolls which rotate toward the center. One of the rolls is smaller in diameter than the other, the smaller one being operated at a higher speed and having cutting bars or blades set lengthwise in the roll. This unit will cut the binder-soil and shred it when the material is damp, and if dry, will more or less powder it. If the clay binder-soil which is being used is deficient in silt, this latter material, in proper amount, may be put through the disintegrator along with the clay.

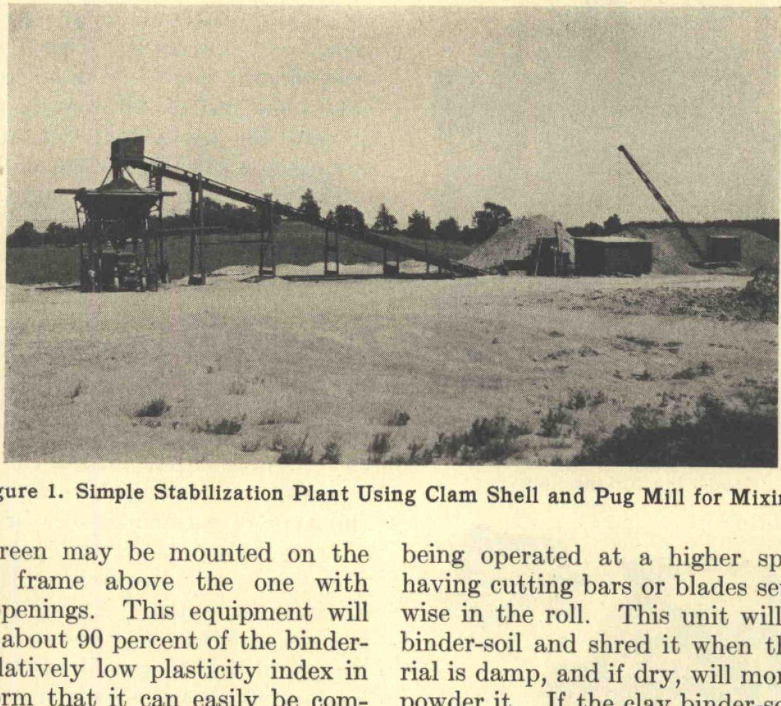

Figure 1. Simple Stabilization Plant Using Clam Shell and Pug Mill for Mixing

In plants where it is necessary to handle a very cohesive clay, such as one having a plasticity index of 30 or more, the combination of a disintegrator and a smooth roll crusher works to very good advantage. Such a pit-run clay, after leaving the disintegrator, is likely to contain small damp lumps which will not be

Figure 2. Vibrating Screen Breaking up Sand-Clay Binder-Soil

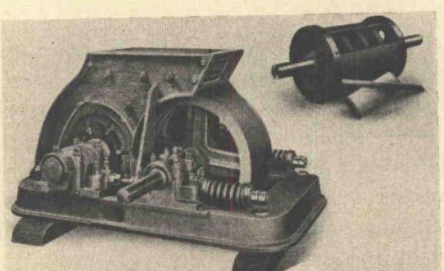

Figure 3. Disintegrator for Preparing Highly Cohesive Clay

further broken up to any appreciable extent in subsequent mixing operations. Hence if this clay is put through a pair of smooth rolls, set with a small clearance and rotating in opposite directions, any dry pieces are thoroughly pulverized and the damp lumps will be reduced to the form of thin flakes which are more easily cut up by pug mill blades and which are also broken up by abrasion through the grinding action of the coarse aggregate in any further mixing operation.

Pug mills have been used to break up the binder-soil, but unless the latter is quite friable, it is necessary to use equipment which has a greater disintegrating effect. Ordinarily hammer mills are satisfactory for thoroughly dry binder-soil, but since most plants operate on pit-run material, only a few special types can be used. These must be exceptionally high speed machines and have some sort of self-cleaning device to prevent the sticky material from accumulating on the inside of the mill.

The clay products industry also uses another piece of equipment which prepares clay in a more or less granular form. This is the so-called dry pan, which has a very heavy steel wheel running in a rotating pan. In the bottom of the pan is a slotted plate through which the clay is forced. The plant-stabilized gravel which was put down on the streets of the city of Ames, Iowa, during the past two seasons, was made with clay prepared in this type of equipment in a brick plant.

At some point in the process it is necessary to measure and feed the binder-soil into the system. One method which has given satisfactory results is to drop charges of the binder-soil into a rectangular box which has slowly moving screw feeders at the bottom. Such a piece of equipment is shown in Figure 4. The screws are arranged so as to draw the material through an adjustable gate which, together with the speed of the screws, controls the quantity and delivers the material, directly or by means of a conveyor belt, to the next piece of equipment. Pit-run clay and silt may be fed to grinding equipment, or prepared binder-soil may be fed to mixing machinery, by this apparatus. When using pit-run material which may contain occasional stones of large diameter, it is well, either to screen out such stones by means of bars across the top of the feeder, or to provide shear pins or a slip clutch on the shaft driving the feeder to prevent breaking or twisting of the ribbon screw blades in case such a stone becomes wedged between the screws and the bottom of the feeder. To save time in emptying the feeder when this occurs, a hinged door cut into the side of the feeder has been found very valuable.

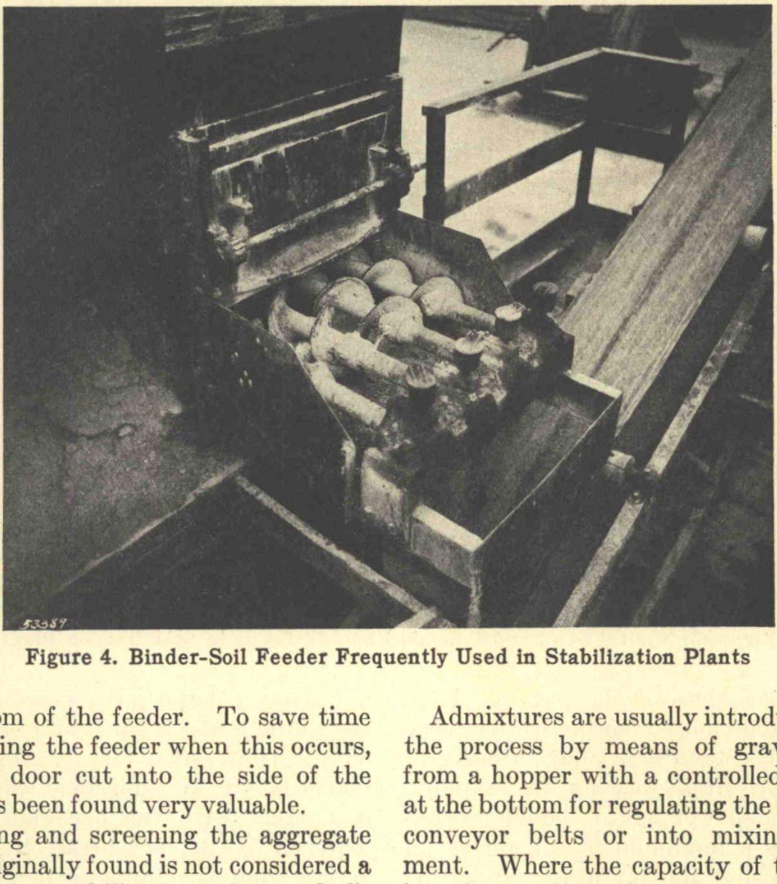

Figure 4. Binder-Soil Feeder Frequently Used in Stabilization Plants

Crushing and screening the aggregate as it is originally found is not considered a part of the stabilization plant. Ordinarily, the only operation with respect to aggregate is conveying it in measured quantity to the mixing unit. In some plants the sand will be found incorporated with the coarse aggregate, while in others there will be enough in the binder-soil. In still others, sand or other type of finer aggregate must be added as a separate constituent. In this case feeding from bins and measuring are the only operations. Screw feeds or a moving belt along the bottom of the bin will satisfactorily feed such material onto another conveying belt or into hoppers. In either case an adjustable gate to regulate the flow of fine aggregate from the bin has been found a satisfactory method of measuring. Such an arrangement may be seen in Figure 5.

Admixtures are usually introduced into the process by means of gravity feed from a hopper with a controlled opening at the bottom for regulating the flow onto conveyor belts or into mixing equipment. Where the capacity of the plant is rather small, so that the feed of admixture is very light, an agitator or mechanical finger is sometimes necessary to maintain continuous flow. The bottom of a calcium chloride hopper, together with sprocket for operating a feeding device, is shown in Figure 5.

The pug mill, with revolving horizontal shaft having cutting knives on it, is the most common mixing device. The knives are set at an angle so as to forward the material from one end to the other, delivering it at the exit end to hopper or conveyor. The pug mill ordinarily is the gauge of production in the stabilizing plant; in other words, the other pieces of apparatus usually have a wide range of capacity, whereas the pug mill operates most efficiently, and hence has most steady operation, at a definite rate. The knives of the pug mill have to be composed of, or surfaced with, very abrasive resistant steel alloy in order to keep them from wearing too rapidly. A 40 horse-power motor should be considered as a minimum for operating an 8-ft. pug mill for producing about 50 tons of stabilized road material per hour. The pug mill used in the plant illustrated by Figure 1 is shown to better advantage in Figure 6.

The amount of water which is added to the material in the pug mill during the mixing operation depends on the moisture in the binder and in the aggregate, also on the method of laying down the material on the road. Where the various ingredients are exposed to the weather, they pick up considerable quantity of water in rainy weather and it is frequently unnecessary to add any water to the mix. In periods of dry weather, a water hose adjusted to introduce a stream of water into the mixture is desirable. In the case of the pug mill it has been found advantageous to add the water at about the center of the unit. This permits some dry mixing by the blades before the additional water comes in contact with the materials. If the material is to be spread by fanning action from the tail-gate of the truck, the moisture content should be lower than if it is to be dumped by the load on the surface of the road and spread by motor graders. This latter method is perhaps a little more expensive, but due to the increased moisture which may be

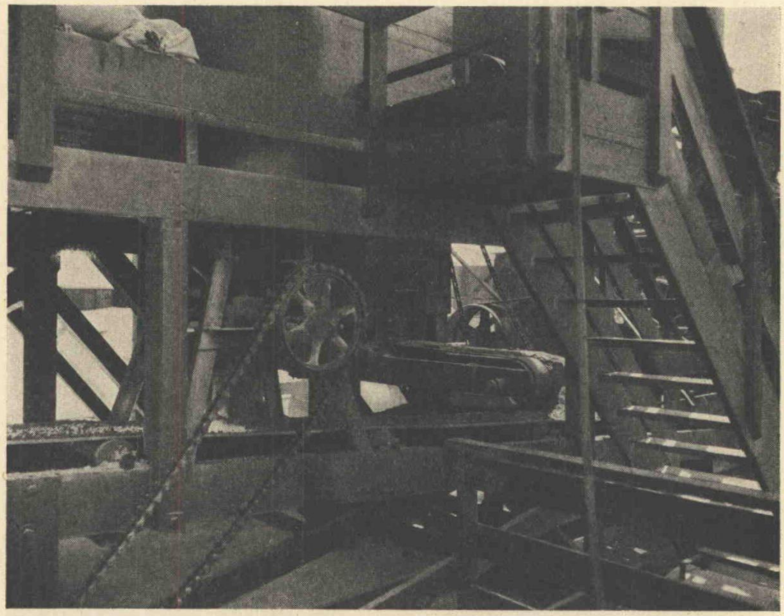

Figure 5. Typical Sand and Calcium Chloride Feeds in Stabilization Plant

present, it facilitates consolidating the material on the road, particularly in hot, dry weather.

In operating the equipment which has been described, the lower the moisture content of the binder-soil, the more satisfactory the operation. In the large plant in Detroit, which turns out 1500 tons of stabilized slag per day, it was found that in order to get this capacity it is advisable to put the pit-run clay through a pug mill, adding sufficient water to give a thick paste. This is then put through the disintegrator rolls along with the entire amount of aggregate. The rolls are set a couple of inches apart, but with such large quantities of material going through them, the aggregate and binder-soil are pressed together, thus giving them a preliminary mixing. Two twelve-foot pug mills, operating with 75 and 100 H.P. motors, are then used to complete the mixing of the materials. The calcium chloride used in this mix is added to the first of these pug mills at the rate of 16 lb. per cu. yd. The finished mix is quite damp and is loaded out of the pit, below the second pug mill, by means of a power shovel.

Probably the first central mixing plant for producing stabilized soil-bound road material is the one designed and constructed by The Dow Chemical Company at Midland, Michigan. This is shown in Figure 7. It was built as a demonstration plant for the purpose of studying the various factors which are pertinent to the successful operation of such a plant. It has a maximum capacity of 30 tons of finished mix per hour, but has been operated mostly at 20 to 25 tons per hour. In the two seasons it has been used it has produced more than 25,000 tons of stabilized gravel, as well as approximately 1,000 tons of stabilized limestone and slag.

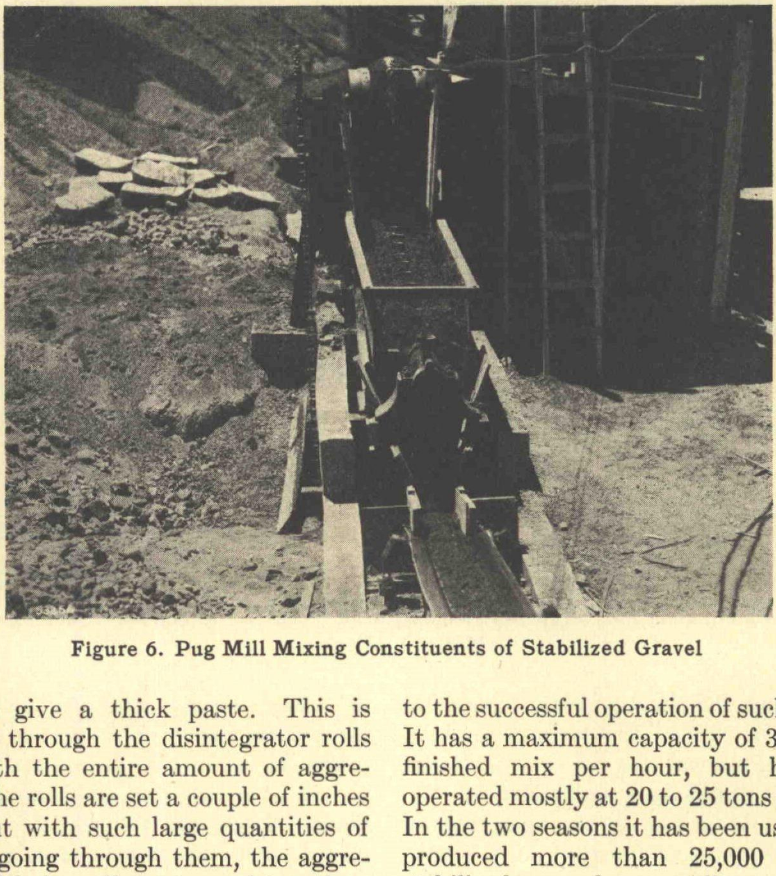

Figure 6. Pug Mill Mixing Constituents of Stabilized Gravel

In the demonstration plant the clay which is used has fairly high cohesiveness and the quantity used is regulated by the spiral screw feeder mentioned above.

Both disintegrator and roll crusher are used to prepare the binder-soil, which is then combined with sand and coarse aggregate (usually pea gravel) in a 7-ft. pug mill. Up to the point of loading the finished material into the storage hopper, wide rubber belts are used for conveying the various constituents; a bucket conveyor is used on the completed mix. In a small preliminary plant an attempt was made both to mix the ingredients and convey the finished composition by means of a ribbon screw conveyor in a trough. This was not successful as the damp mix built up a hard mat on the bottom and sides of the trough, causing a binding action which resulted in breaking sprockets, drive chains and even the conveyor shaft itself.

It is believed that the first portable stabilizing plant is the one built by the Pioneer Gravel Equipment Manufacturing Company of Minneapolis, Minnesota for the highway department of that state. It combined, on a frame on wheels, the same equipment mentioned in the previous paragraph. A later model, as shown in Figure 8, has dispensed with the smooth roll crusher. Such a portable unit has also been used with considerable success by road construction contractors in Illinois and other states.

Another interesting stabilizing plant is the type used in 1935 and 1936 in preparing materials for streets in the City of Ames, Iowa. The clay which was used was a highly cohesive material, prepared in a finely granulated form, by means of a dry pan, in a nearby brick plant. Local gravel was used and was mixed with the binder-soil in a 15 cu. ft. concrete mixer the first year, and in a 21 cu. ft. mixer the next year. Calcium chloride was added from a measuring bucket to the materials in the skip of the mixer. The plant had a capacity of 30 to 40 tons of stabilized gravel per hour. Figure 9 shows the complete

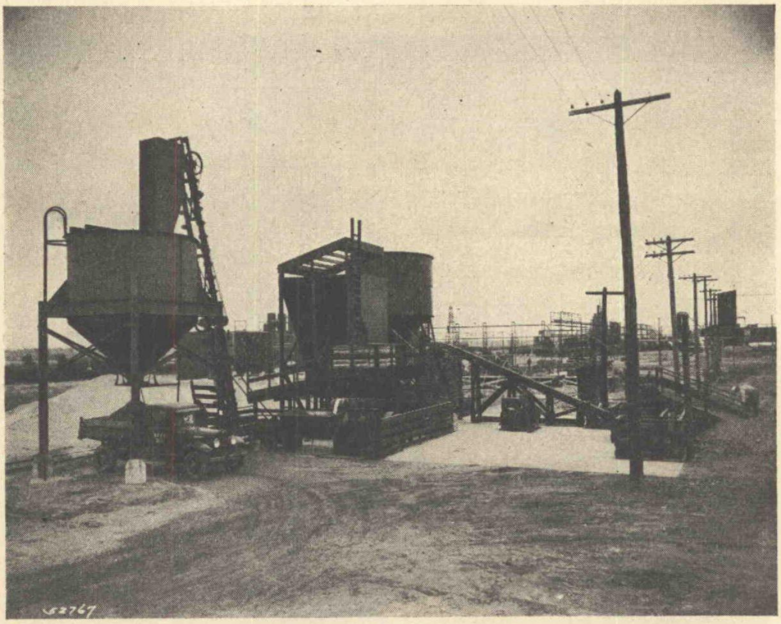

Figure 7. Stabilization Plant Built for Demonstration Purposes by The Dow Chemical Company, Midland, Michigan

1936 plant set-up for crushing and screening the gravel, mixing the clay and calcium chloride with it, and loading the product into trucks. Figure 10 is a view of the mixer. In this plant the materials were dry-mixed only, and water was supplied from fire hydrants after the mix had been placed on the street. Blading and rolling operations served to produce a smooth, densely compacted wearing course.

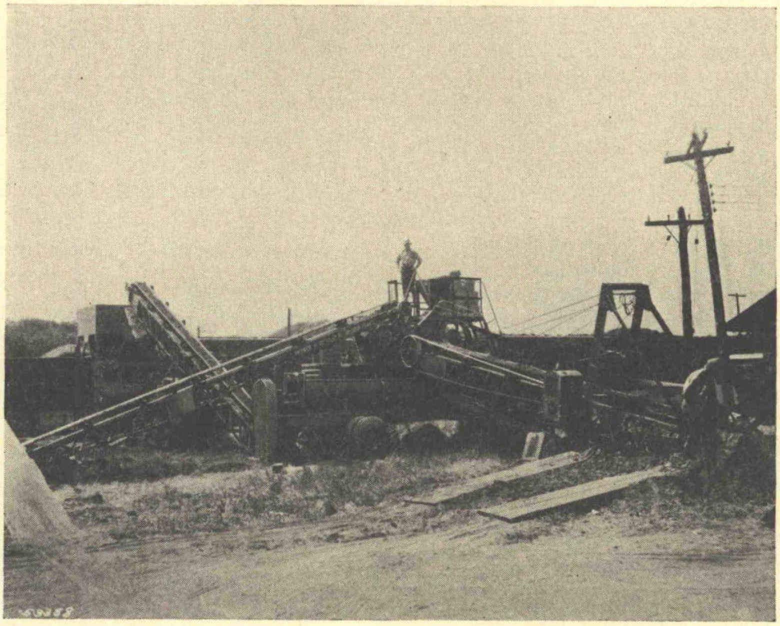

Figure 8. Portable Stabilization Plant as Built by Pioneer Gravel Equipment Manufacturing Company, Minneapolis, Minnesota

Figure 9. Plant for Producing Dry-Mixed Stabilized Road Material at Ames, Iowa

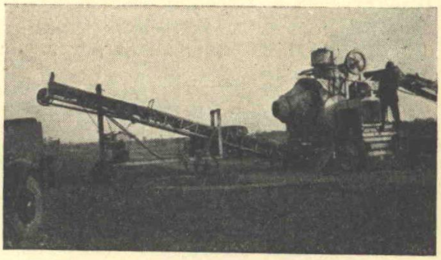

Figure 10. Concrete Mixer Set-Up in Plant Shown in Figure 9, at Ames, Iowa

COMPOSITION AND CONTROL OF FINISHED PRODUCT

The plant operations that have been described will produce mixtures in accordance with the design essentials of stable soil mixtures recommended in the 1935 and 1936 Progress Reports of the Project Committee on Stabilized Soil Road Surfaces of the Highway Research Board, which are as follows:

Materials falling within the following composition limits, by weight, should produce good results

Passing	Percent
1-inch sieve	100
¾-inch sieve	85–100
No 4 sieve	55– 85
No 10 sieve	40– 65
No 40 sieve	25– 50
No 270 sieve	10– 25

Material larger than one inch can be used under certain conditions but the amount should not exceed 10 percent Also the maximum size should never exceed ⅓ the thickness of the stabilized layer

The fraction passing the No 270 sieve should be less than two-thirds of the fraction passing the No 40 sieve

Generally plasticity indexes of about 3 or less indicate sufficient binder cohesion for roads to be constructed on locations subject to unusually wet conditions, 4 to about 8, for conditions of average moisture; and 9 to 15 inclusive, only for the dryer or the arid conditions Plasticity indexes exceeding 15 indicate soils not suitable for this type of construction

The presence of the undesirable micaceous, diatomaceous, peaty or other organic substances is indicated by liquid limits greater than those indicated by the expression

$$LL = 1.6\ PI + 14$$

The more the liquid limits exceed those values, the more unsatisfactory the soil binder is apt to be due to detrimental sponginess and capillarity Elimination of such properties in detrimental amount from the final road mixture may be accomplished by keeping the liquid limits from exceeding about 35

Suggested limits for base or lower course are as follows

Passing	Percent (By Weight)
1½ inch sieve	100
1 inch sieve	85 to 100
¾ inch sieve	65 to 95
½ inch sieve	30 to 85
No 4 sieve	25 to 70
No 10 sieve	20 to 50
No 40 sieve	15 to 30
No. 270 sieve	17 to 20[1]

The fraction passing the No 270 sieve should not be more than two-thirds of the fraction passing the No 40 sieve

The material passing the No 40 sieve should have a plasticity index between 4 and 14[1] and a liquid limit not exceeding 35 as determined by the physical test methods of the United States Bureau of Public Roads (31), or the American Association of State Highway Officials, Standard Specifications for Soil Testing, Method T-89, T-90 and T-91 (31)

In order to prevent the undesirable combination of a high amount of soil fines and a high plasticity index the Calcium Chloride Association recommends further that the sum of the percentage of the material passing the 40 mesh sieve and the plasticity index of this fraction shall not exceed 40

In proportioning the materials which are combined to form a mixture complying with the above recommendations, the particle size grading of the binder-soil and of the aggregate govern the ratio of the quantities which are used Sieve analyses of the various materials and plasticity index determinations of the binder-soil are all that are required to calculate the proportions In general, sandy clay requires clean, non-sandy coarse aggregate, whereas highly plastic clay binder requires fine sand as well as coarser aggregate, and in many cases the stability of the final product is improved if silt is also incorporated in the mix It is of particular importance that the recommendation of the Calcium Chloride Assoc be observed, which states that the sum of the percentage of the material passing the 40-mesh sieve and the plasticity index of the fraction shall not exceed 40 This insures a material which will not become unduly sloppy on the surface of the road under traffic in wet weather

The laboratory testing which is necessary to control the operation of a stabilization plant satisfactorily is relatively simple Sieve analysis of the dried product, using ¾-inch, Numbers 4, 10, and 40 sieves, and a quick method for determining the plasticity index are all that are necessary to check the uniformity of production Of course an occasional sample should be subjected to complete physical and mechanical tests This is particularly true if the source of binder-soil is changed

[1] From recent observations in Indiana it appears that for stabilized bases the percentage passing the No 270 sieve should be from 7 to 15 and the plasticity index should be less than 9

There is no particular short-cut in making the control sieve analysis except oven-drying at 110° and using only the four sieves mentioned above The quick method which we have developed for determining plastic and liquid limits, the difference of which is the plasticity index, may be worth mentioning at this point The actual manipulation of the moistened soil sample in each of the soil tests is the same as the standard A S T M and A A S H O methods The benefit lies in the elimination of the time, effort and equipment required for oven-drying and accurate weighing in the usual method of determining quantitatively the moisture present in wetted soil samples

In these rapid tests a sample weighing 33 3 g is taken from the dry, thoroughly mixed portion of the material passing the No 40 sieve, and subjected to the standard test operations When adding the water, however, it is measured from a burette in increments until the end point of the test is reached The test value being sought is equal to three times the number of cubic centimeters of the water which is used

The end-point of the tests should be approached from the dry side and if it is exceeded the sample must be discarded and a new one prepared, with less water added With a little experience, however, the technique can be developed so there will be no need of repeating the operations Preliminary tests on samples, the test values of which are known, will aid in developing this technique To be reasonably reliable, each test should not take longer than four minutes and there should be no appreciable breeze blowing across the mixing dish, or some drying may take place which may increase the test value somewhat

Costs

The cost of producing plant-mixed stabilized soil-bound road material will depend on local conditions, both from the standpoint of investment and of operating costs Often an aggregate producer will build such a plant to use either strippings or aggregates, which otherwise are of limited value to him Hence he must figure to off-set the investment in any new equipment with the increased income from such raw materials Often such savings also make it possible for him to include the chemical admixture at little or no increase in price of finished product, as compared with material which he has sold previously for road purposes

If an easily prepared sand-clay binder-soil can be obtained cheaply, a pug mill with a motor and a home-made feeder for the chemical admixture is about all the new equipment he may need and it will cost less than a thousand dollars Storage bins and conveying and handling equipment, when not already available, involve an extra investment of several hundred dollars When a vibrating screen or disintegrator is required for preparing the binder-soil, and a screw feeder is used to regulate its flow into the process, another couple of thousand dollars are likely to be involved by the time these units are fitted up with motors and conveyor belts

The labor required to operate a stabilization plant necessarily will vary, depending upon the amount of equipment required to handle the local materials Usually one man can operate the equipment other than power shovels and trucks If a vibrating screen is used for breaking up the binder-soil, this is likely to be located at the pit, which may be some distance from the rest of the plant and may require the services of an extra man In general, however, the labor costs, as well as costs of power and materials, will be such that the product can be sold for 65 cents to one dollar per ton at the plant, and can compete favorably with material sold under specifications which were adopted before the benefits of stabilization became so widely recognized