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CALCIUM CHLORIDE IN STABILISED SOIL ROADS AND RUNWAYS.

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Mudless, dustless, hard and all weather driving surfaces is a serious requirement of the forces. Surfacings by mixtures of definite amounts of locally available stone, gravel, sand, clay and silt to which calculated amount of calcium chloride is added quickly compact and ultimately harden like concrete. This provides an easy, quick and economic means of meeting the requirement. Necessity of such surfaces, use and action of calcium chloride and resulting effects are discussed. Different methods of construction and application of calcium chloride are briefly related.

Driving surfaces—Our difficulties and requirements

One of the most serious problems for the defence services is to provide firm, mudfree and dustless roads and airport runways and to provide them quickly pending construction and surfacing of permanent heavy duty roads and pavements.

Defence traffic, naturally has to move over many types of highways and the intensity of this traffic varies tremendously in different areas. It will be a physical and economic impossibility in a country like ours to provide paved surfaces on all roads of strategic network. 'Kachcha roads' on the other hand are not only troublesome but dangerous. It has been experienced that civil traffic while crossing military convoys threw up dust and slowed down the convoys, causing trucks to loose their intervals and upsetting the schedules. Similarly anti-aircraft artillery or army groups concealed in groves and trenches near the traffic area get covered with dust during dry periods of manoeuvers, greatly reducing the efficiency of the gunners. In rainy season such roads get muddy. This mud, at places knee deep hinders traffic and frequently causes serious accidents. Besides all this, these roads require constant blade maintenance which is expensive and still very often inadequate. A quick and practical solution consistant with the availability of materials and economy of our country is to be found out which may provide mudless, dustfree, hard and all-weather driving surfaces.

Stabilised soil—What it is and why ?

A very quick and highly practical solution is the construction of stabilised soil driving surfaces. Such surfaces or roads are usually composed of locally available soil materials with aggregates of gravel or crushed stone or other similar hard material for strength, definite amount of sand acting as filler and silt and clay maintained in moist condition to act as a binder. The amount of moisture maintained is definite because there is an optimum[1] value of the moisture which gives maximum density on compaction and therefore maximum shear strength depending upon the type of admixture of the soil materials and the method of compaction. This type of road surfaces if constructed of properly graded natural soil materials firm up under continuous traffic compaction and often attain the density of concrete, become impervious to rain and immune to frost. These should not, therefore, be considered as only makeshift temporary construction. On attaining such a high density and stability, these roads besides being directly used for traffic provide a most desirable base for later bituminous or concrete surfacing. These surfacings are said to hold better on stabilised soil bases. Stabilised surfaces are very useful for shoulder construction on both sides of the permanent strips as they avoid slipings and skidings.

Stabilised soil roads have many constructional advantages ; speed of construction, simplicity, reduction in hauling of materials, avoiding the use of very heavy and complicated machinery, ease of manipulation of the aggregates and allowing stage construction so that surfaces are available during all stages of camp construction. Of course proper proportionating and grading of the ingredients in the aggregate mix with regard to the physical properties of the silts and clays is essential. A few preliminary laboratory test may therefore be required. With experience, however, simple thumb[2] rules often suffice.

Calcium chloride, its use, action and resulting effects.

It has been said above that the aggregates used in constructing the road surfaces must be maintained in moist condition. This is achieved by mixing with the gravel-sand-clay mixture a calculated amount of a chemical possessing specific properties. A very suitable salt is Calcium Chloride.

Calcium chloride is hygroscopic and deliquescent. Hygroscopicity is the process of readily absorbing moisture and retaining it. Deliquescence is the process of dissolving and becoming liquid by attracting and absorbing moisture from the surroundings. In soil stabilisation work calcium chloride is generally used in flake form and absorbs moisture from the air.

It takes up moisture weighing 4 to 10 times its own weight during night and retains ½ to 2/3 of that during the heat of the day. The value of this ability to conserve moisture is most apparent during compaction of the stabilised layer or mat in which the salt is incorporated. The plasticity of the clay component is maintained over a longer time by retarding the loss due to evaporation resulting in ease of manipulation leading to smoother riding surfaces than would be obtained from untreated mix. Fig. 1[3] gives relation of evaporation losses from

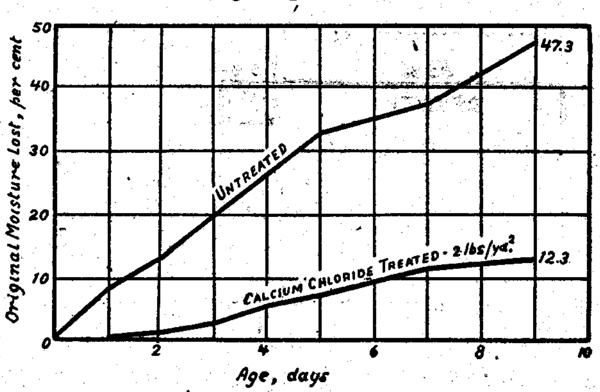


FIG. 1.

treated and untreated mixtures indicating how moisture is held in the road by calcium chloride. Retention of moisture for a longer time in treated soils prolongs the period during which compaction can take place permitting compression of aggregates into denser and stronger mass.

The moisture content necessary to give the greatest density to which an acceptable mixture may be compacted by a specific method of compaction is the most important factor in obtaining a suitable road. The optimum moisture content is generally approximately 8% by weight of the aggregate material.

Calcium chloride increases the viscosity and surface tension of the water in which it dissolves itself. Therefore, in the soil mixtures to which calcium chloride is added the soil particles get moistened and enveloped by a more viscous and lubricating film of water and slide more freely under compacting load to attain greater density. Compaction tests show that the same soils under equal treatment weigh 11 % more (Fig. 2)[4] per cubic foot where calcium chloride is used. This increase in weight is vitally significant, when it is realised that the mass equivalent of the added weight exists as voids in the untreated soils. These voids are open to water penetration an excess of which causes mud and failure under wetting. The salt treatment makes the road less permeable to rain water.

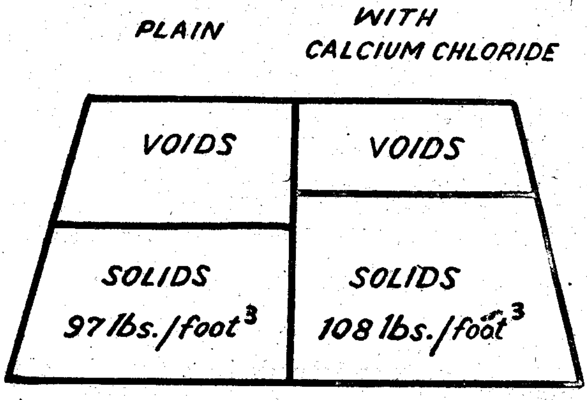


FIG. 2

Due to increase in surface tension of the water greater strength is obtained during shrinkage consequent to seasoning and drying. Fig. 3 shows that 85% of the density is obtained during compaction by a wheel roller and the remaining

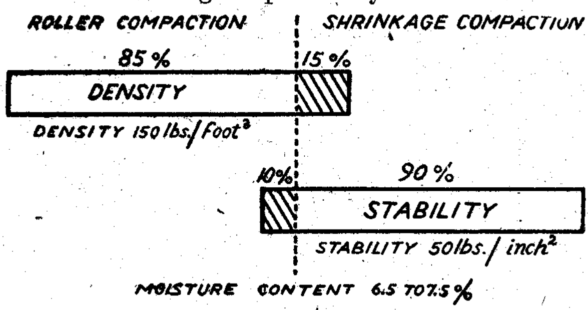


FIG.3

15 % is due to shrinkage compaction or seasoning of the road. On the other hand the roller compaction accounts for only 10 % of the structural stability the remaining 90% being obtained during shrinkage period

The stabilising effects of calcium chloride may be enumerated as below —

(1) Cuts water costs by greatly reducing the quantity of water required in mixing and finishing operation by retarding loss due to evaporation.

(2) Insures against premature drying resulting in cracks etc. and added maintenance costs by retaining moisture.

(3) Facilitates compaction by allowing the compacting particles to move and slide more freely under the load. The compaction time is reduced to approximately one third than with plain water.

(4) Extends compaction period by retaining moisture and keeping the mix in plastic sate for longer time.

(5) Increases the binding action and structural stability during the period of seasoning.

(6) Avoids subgrade water softening or rain water mudding. The increased density makes the stabilised soil layer much less pervious to the water either underneath or above it, which is, therefore, not sucked in.

(7) Reduces the damaging effects of frost action. Because of low voids and impervious structure the mat or layer will not contract or expand under the action of low temperature and moisture of the frost respectively.

Stabilised mixtures, methods of preparing and spreading

In soil stabilisation process proper grading and proportioning of the mixture constituents is an essential requirement. The ratios of ingredients will vary depending upon the type of material available and details of design and specifications of the project. This will be discussed and quantitative values given in part II.

There are mainly three methods of obtaining the desired stabilised mixture plant mixing, road mixing and cut and try method.

In plant mixing calcium chloride is generally added to the soil mixture the plant with enough water to bring the moisture content to about 8 to 10% by weight of dry soil. The mixture is then hauled to the construction site, spread, sprinkled, shaped and rolled.

In road mixing the soil materials without calcium chloride are spread on a previously made even, and prepared base surface to the required thickness. The calcium chloride is then uniformly scattered on it by spreaders in required quantities and thoroughly worked into the soil by harrowing and blading or by travelling mixers. Required amount of water is then sprayed and shaping and compacting operation performed to give smooth dense surface.

In cut and try method chalcium chloride is applied to the road surface after its condition (studied by cutting and trying) indicates that a nearly suitable gradation of the constituents has been obtained. The application of the chloride is made, generally to a part of the whole project. If the surface shows muddiness in wet weather an excess of binder soil is indicated and a light application of coarse sand or fine gravel or crushed stone is made. Behaviour of the surface in dry weather is also studied. A compromised balance between the binder soil and the thicker ingredients is thus established by trial.

Quality of the material required

The volume of the material required will depend upon the area of the surface to be covered and on the thickness of the stabilised layer. Then if,

W=width of the surface in feet.

L=length of the surface in miles.

T=thickness of the mat in inches.

The volume is given by

$$V=\frac{W}{3}\times L760\times\frac{T}{3\times12}=16\cdot3\ WLT\ \text{cubic yds}\ldots\ldots 1.$$

If L be put equal to 1 then we get the volume per mile

$$V_M=16\cdot3\ WT\ yds^3/mile\ldots\ldots 2$$

The dry material in loose state occupies more space than when compacted under moist conditions. It has been found that it reduces in volume by about 2/3 on compaction. Therefore to compensate for this reduction an additional 50% material is required then the total amount of loose aggregate required is given by

$$V=24\cdot4\ WLT/yds^3\ \text{(very approx.)}\ldots\ldots 3$$

It is convenient to collect the material on the sides of the pavements in windrows. The section of a windrow is trepesiam, base being slightly wider than the top. Then if

A=width of the top surface of windrow in feet.

B=width of the base of windrow in feet.

H=height of the windrow in feet.

E=end area in sq. feet.

C=cubic yards per mile per sq. ft. of end area=195·6

V=cubic yards per mile in windrow.

$$E=\frac{A+B}{2}\times H\quad V=195\cdot6\ E\ yds^3$$

substituting from (3)

$$V=24\cdot4\ WT=195\cdot6\ E\ldots\ldots 4$$

We know the values of W in feet and T in inches from our requirements we can find out E and therefore the hight and width of windrow that would be suitable to collect the required material per mile. Table below gives the volume in cubic yards and weight in tons of loose aggregates per mile of the surface at various widths and different thicknesses.

Width of road in feet.	Area per foot length in sq. yds.	Sq. yds. per mile	Average thickness of compacted layer in inch.							
			1		2		3		4	
			Wt.	Vol.	Wt.	Vol.	Wt.	Vol.	Wt.	Vol.
			Tons	C.Y.	Tons	C.Y.	Tons	C.Y.	Tons	C.Y.
10	1·11	5867	330	245	660	489	990	734	1320	78
12	1·33	7040	396	294	792	587	1188	880	1584	1173
14	1·55	8213	462	343	924	684	1386	1026	1848	1368
16	1·77	7387	528	392	1056	783	1584	1073	2112	1563
18	2·00	10560	594	441	1188	880	1782	1320	2376	1758
20	2·22	11733	660	490	1320	978	1980	1467	2640	1956

The weights and volumes in the chart above are based on compaction to 2·03 tons per cubic yards or to 168.4 lbs. per cubic foot.

Graded ingredients and their ratio

The loose aggregate as referred to consists of materials graded from coarse to fine ; crushed stone, sand, silt and clay. It is, therefore, essential to know how much of which is required. It is known from experience that pieces of crushed stone of $\frac{1}{2}$ in. max. size are most desirable. Bigger sizes of $\frac{3}{4}''$ or 1" may sometimes be used but are decidedly not preferable. If we spread a layer of these crushed stones a section of the layer will look as shown in fig. 4 (a). There is a limit beyond which any amount of rearranging will not make the stones occupy less space. The total space occupied by the gravel is only partly filled with strong solid material, the rest being voids containing air. For gravel of $\frac{1}{2}''$ size the voids are about 45% of the total space. Since there will also be pieces of smaller sizes say up to 1/12" the actual voids may be less. The river pebbles or rounded stones are not suitable in place of crushed stone gravel as their smoother boundary does not provide the high internal friction and interlocking so much required in stabilised layers.

These voids are in the form of multishaped gaps. So that these may not get filled up with undesirable matter like dry leaves, dust, peat and water and remain liable to change shape under various loading conditions these need be filled up. As a first step coarse sand passing No. 10 sieve and retained on No. 40 sieve is used to reduce the size of the gaps. The section of the layer will then look like that shown in fig. 4 (b). The earlier voids are partitioned resulting in small pockets. The sand also adds to internal resistance and interlocking. The voids though reduced still exist there. Sometimes when gravel is not obtainable sand is to be used in its place also.

The voids are further filled up by the so called soil fines, fig. 4 (c). It is a material passing No. 40 sieve but retained on No. 200 sieve. Quite often a good amount of silt is present in it as the former is very abundant in agricultural soil.

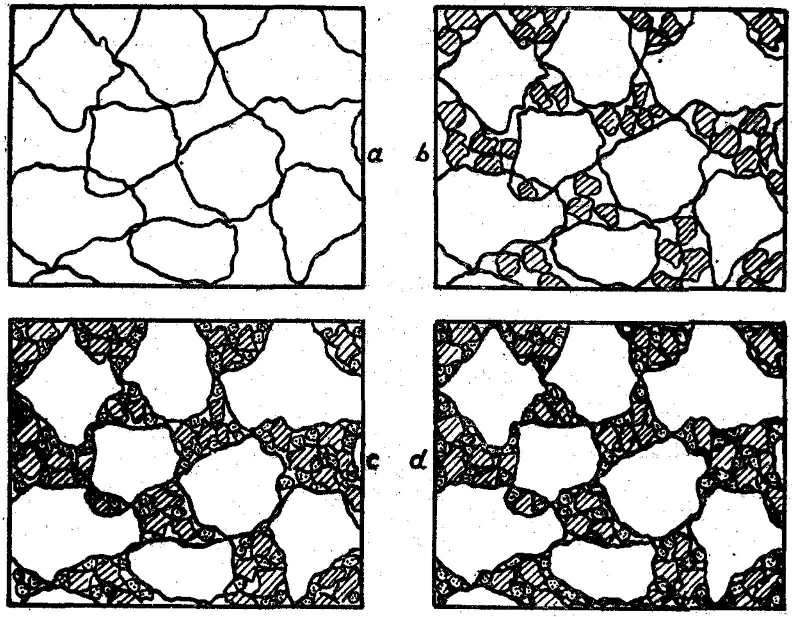


Fig. 4

Silt, however is not desirable due to its detrimental qualities of swelling up on becoming moist, providing capillarity and no cohesion. To this mix is then added the binder soil. This should pass No. 200 sieve and should ideally consist of clay. The clay when made wet by adding 8 to 10 % of water sticks to the boundary of the silt, sand and gravel particles and acts like a binder cement, fig. 4 (d).

In general the ratio of all these constituents may be approximately given as follows :—

	Size	Quantity
Gravel passing ½″ sieve but retained on No. 10 sieve ..	·5″ to ·08″	50 %
Coarse sand passing No. 10 sieve but retained on No. 40 ..	·08″ to ·02″	20 %
Fine soil (sand & silt) passing No. 40 but retained on No. 200 sieve ..	·02″ to ·002″	18 %
Binder soil (clay) passing No. 200 sieve ..	Under ·002″	12 %

The percentage passing No. 200 sieve in the final mix should never be less than 10% and not more than 18% of the total amount. It should further be not more than 2/3 of that passing No. 40 sieve.

The above figures are very general. Quite often variations may be required depending upon the availability of the material and its physical properties. For instance, the amount of binder soil required will depend upon its plasticity and also on the plasticity of the rest of the material passing No. 40 sieve.

Plasticity Index

The stabilisation soil mixture must have some plasticity i.e. ability to flow or roll under load without crumbling and breaking. Without this quality it is not possible to effect and maintain a desirable compaction. It has been found that a plasticity index of 3 to 1 is most suitable for soil mixes to be used as base course. PLASTICITY INDEX PI is the numerical difference between the liquid limit LL and plastic limit PL.

$$PI = LL - PL$$

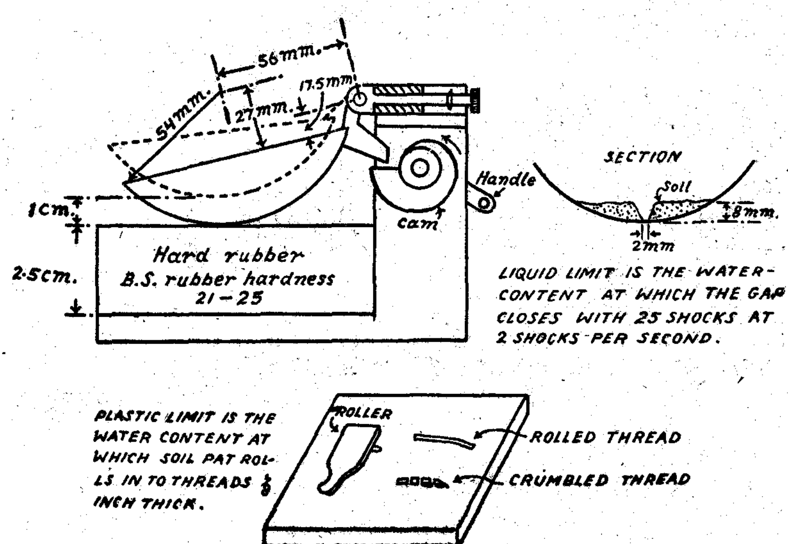


Fig. 5

LIQUID LIMIT LL is the water content in per cent of dry weight at which two sections of a pat of soil having the dimensions shown in the figure barely touch each other but do not flow together when subjected in a cup to the impact of sharp blows from below by a standard device. PLASTIC LIMIT PL or the lower limit of plastic state is the water content at which the soil begins to crumble when rolled out into thin threads. It is to be noted whether the threads immediately before crumbling are very tough like gumbo, moderately tough like an average glacial clay, or weak and spongy like those of organic soil.

Since plasticity is a colloidal property the soil mix will have its plasticity due to the soil fines passing No. 40 sieve and due to the binder soil passing No. 200 sieve: The plasticity index of the windrow fines and the binder clay should therefore be known. If the windrow fines cannot be rolled into 1/8″ thick threads without crumbling the PI for it should be considered zero. The following chart gives the relation between the PI of the binder soil and its percentage weight to be added to the windrow mix when the latter is supposed to have a PI of less than 1.

PI of the binder soil.	Max % passing No. 200 in final mix.
10—16	14—18%
16—25	12—15%
25—35	10—12%
over 35	8—10%

Sometimes a binder soil may have a higher PI and a quantity smaller than specified may result to obtain the required PI for the final mix. In such cases the PI of the final mix is neglected and the quantity of the binder soil raised till it equals the minimum specified value.

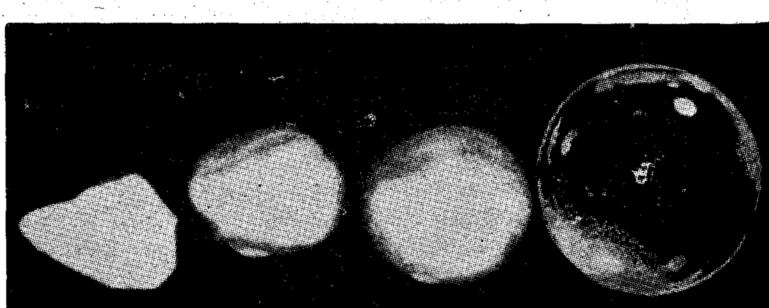
If the proportion of the finer ingredients in the windrow mix is more than specified a binder soil with a higher plasticity is desirable. The binder soil should pass No. 200 sieve but this does not mean that it must be used in such a finely powdered state. Quite good results are obtained by pulverising it to ¼″ to 1/8″ size. Crushing to a finer state will only add to costs.

Water

The stabilised layer should contain 8% by weight of water for effective compaction and subsequent maintenance. This indicates a requirement of about 20 gallons per cubic yard of windrow material. But to keep the water to this required amount more than this has to be added. Experience has shown that 40 to 60 gallons of water per cu. yd. of windrow may be required under dry weather conditions because of rapid evaporation during mixing and spreading operations. There are two ways of adding it. Either it can be added to the soil mix at the crushing and mixing plant and the wet material hauld to the site or it is sprayed on the soil layer which has been evenly spread. This increased amount of water is needed only during process of construction. Afterwards the right amount of water is conserved by the calcium chloride itself which is added to the mix.

Calcium chloride

The hygroscopic and deliquescent properties of calcium chloride cause the absorption of water from atmosphere during periods of high humidity and its retention in the stabilised mat by slowing down the rate of evaporation.



Stage I Stage 2 Stage 3 Stage 4

FIG. 6

Fig. 6, taken from the bulletin of Calcium Chloride Association, Michigan, explains very clearly how the salt grain helps keeping the soil moisture which is the most critical factor in soil stabilisation system.

STAGE No. 1 shows a flake of calcium chloride just as it comes out of the bag—dry, easy to spread on the surface of road, street, driveway or playground.

STAGE No. 2, same flake 24 minutes after exposure to the air at a normal summer temperature of 77° and a relative humidity of 78. At this temperature and humidity, a pond of flake calcium chloride will take up about $2\frac{3}{4}$ lbs. of water.

STAGE No. 3, same flake 48 minutes after exposure at same temperature and humidity.

STAGE No. 4, same flake 180 minutes (three hours) after exposure to same air conditions, having completely dissolved itself in the moisture it attracted, attaining the soluble form it assumes in the road surface material where the surface materials are permiated with the moisture film.

Calcium chloride can either be spread on the layer of the aggregate mix and then worked into it by spike tooth harrows or can be partly mixed in the aggregate before spreading and rest of it spread on the surface. Which method is preferable depends on the conditions of the project. The quantity of water required can be reduced if a part of the calcium chloride which would later be used on the surface is mixed with the soil aggregate at the mixer before spreading. Half a pound of calcium chloride per sq. yd. for every inch of depth will effectively retard the evaporation. Then $\frac{1}{2}$ lb. to $1\frac{1}{2}$ lb. per sq. yd. can be spread on the surface, worked in, sprinkled and compacted. In general 30 to 150 lbs. of clacium chloride per cubic yard of windrow material is used for stabilisation work depending upon the climatic conditions and maintenance arrangements. Shaded roads or roads in moist areas will require less of it than roads constantly exposed to sun.

After the initial application later seasonal periodic treatments may also be required but are of lighter quantities, the amount being determined again by the prevailing conditions.

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