# SCOPE OF SOIL-CEMENT IN RUNWAYS CONSTRUCTION IN INDIA

by

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**ABSTRACT**

The subject of soil-cement has been dealt with at some length. Developments in other countries in runway construction embodying soil-cement are reviewed and an account of Heavy Duty military airport having soil-cement runway is furnished. Soils of India have been examined to determine their suitability for cement stabilisation. It is proposed that a percentage water stability of 80 should be a good criterion of suitability of a given soil. Salient features of soil-cement construction are presented here and large scale field trials prior to adopting construction of soil-cement runways in the near future have been recommended.

## Introduction

The engineering practices of runway construction have been undergoing many changes commensurate with the various developments that have taken place in the realm of aircraft design. Starting from turf surfaces in 1930 when all-up weights of the then aircraft ranged between 10,000 and 25,000 lb with tyre pressures varying between 25 and 40 psi, we are now confronted with most military aircrafts having gross weights well in excess of 150,000 lb with tyre pressures of about 150 psi. Figures as high as 400,000 lb (weight) and about 300 psi (tyre pressure) are claimed for the two intercontinental bombers B-36 and B-52. The introduction of jet aviation in the postwar era is wholly responsible for rapid strides towards increases in weights and tyre pressures. The impact of these developments on the strength of runways is severe. Obviously, an extraordinarily strong runway possessing a high quality riding surface is what is needed now-a-days.

## Recent trends in runway construction

Until the close of World War II, the majority of airfields in different countries had been built with the conventional types of pavements rigid or flexible. The total thickness of construction of these pavements and their strength were adequate for the successful operation of light and medium aircrafts. In order to meet high loading demands imposed by heavier aircrafts, it was thought prudent to strengthen the existing pavement by having another layer constructed at the top of the surfacing. The pavement thus strengthened is termed composite pavement and has been described by Skinner [1]. In U.S.A., the additional layer has been called as overlay pavement. Its design and construction have been discussed elsewhere[2].

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The conversion of orthodox type of pavement into a composite one represents really a short term solution in preference to abandoning the existing pavements.

However, when the construction of a new runway is contemplated, careful consideration has to be given in deciding the type of pavement to be constructed and in arriving at the best and most economic design, keeping in view the type and the magnitude of the traffic. The choice of pavement though depending on soil characteristics, is greatly influenced by the extent of the availability of stone and cement. The design of pavement is governed by the load characteristics of the aircraft and also the soil characteristics which have been exhaustively examined [1,3,4].

The ever increasing weights and tyre pressures of the modern aircraft are becoming problems for the runway engineers. To adequately support and sustain such enormous loads, thickness of pavement has to be considerably enhanced both for rigid and flexible pavements on the basis of their accepted methods of design. Depending upon wheel load, *K* and *C.B.R.* values of the subgrade, total depth of the pavement can be upto two feet for rigid pavement and upto five feet for the flexible type. Moreover, with tyre pressure of 300 psi the tyre virtually becomes a solid and tends to shear the surface of a flexible pavement. This calls for a much stronger and smoother surface that could resist high shear stresses induced on impact of landing. Speaking of single-slab rigid pavement, concrete is not capable of being laid as a single continuous layer beyond a thickness of 12″ for want of an efficient concrete compacting machine. Attempts to lay concrete in two separate layers and effect bonding between the two have resulted in failure[1]. For these reasons as also for other factors the single slab-method of constructing concrete pavement is ruled out. The construction of a fairly thick flexible pavement is both time and material consuming and requires tight control. With increase in depth, the overall cost of construction would be exorbitant. Therefore there is pressing need for economy at all levels of construction, while preserving the efficiency and usefulness of the ultimate product *viz* the pavement. A careful analysis of the present trends leads to the conclusion that the following three types of pavements can successfully meet the requirements of high performance aircraft:—

(1) Double-slab concrete pavement.

(2) Pre-stressed concrete pavement.

(3) Flexible pavement having soil stabilised base.

**Double-slab concrete pavement**

In this method, one slab is placed on another, so that the corner of the top slab rests on the centre of the lower slab. But in practice sympathetic cracks are formed in the upper slab, a difficulty that is usually avoided by staggering the joints in the top slab so that they do not coincide with the joints of the lower slab. Entire load is transferred from the top slab to the bottom slab, so in essence the lower slab bears the burden. Being hidden, the lower slab is less subjected to complicated state of strain with changes in weather. When it is required to construct a rigid pavement to a thickness greater than 12″, the double slab design is both practicable and economical. Double-slab concrete pavements having 20″ depth were constructed at London and Filton airports.

**Pre-stressed concrete payment**

The development of pre-stressed concrete and its use as a constructional material is of recent origin and marks the highest perfection ever achieved. Prestressed concrete pavement is of two types :—

(1) The mobile type in which the pavement has the freedom to expand and contract thus overcoming the subgrade restraint.

(2) The immobile type in which the pavement is fixed and cannot slide over the subgrade.

It is claimed that a mere 6″ thickness of construction develops enormous strength which is far in excess of the present-day needs[5]. Efforts are in hand to further reduce this thickness of construction to just 3″ or 4″ so as to reduce cost. Load tests performed on such a runway in U.S.A. have established that the surface is able to receive a contact pressure of about 30,000 lb. p.s.i. without showing any failure. Trial runways have shown no failure over a period of 10 years thus predicting a very long life for such runways. The initial cost of construction may be little high but as there will be no maintenance expense subsequently, the pre-stressed pavement is eventually bound to be cheaper. Pre-stressed concrete runways have passed the experimental stage and have been laid in France, U.S.A., U.K., Australia and Belgium etc. for regular service.

**Flexible pavements having soil stabilised base**

The construction of both double-slab concrete pavement and pre-stressed concrete pavement takes an unusually long time. In the double-slab concrete pavement the standard value for the flexural strength of concrete is 450 lb. p.s.i. and for concrete to mature to such strength, a period of 6 months has to be allowed before the pavement is ready for use[1]. Besides, the techniques of presenting concrete are quite elaborate. Considering military requirements for the construction of emergency airfields during war, it follows that both these pavements leave much to be desired. Their construction with a view to commercial aviation in highly industrialised countries is justifiable; but for less developed countries like India, such construction even for civil use would put severe strain on their economy.

The history and practice of runway construction in this country reveal that the flexible pavement alone has been favoured since the advent of aviation in India. That this has been so is mostly due to the availability in abundance of the raw material that is required for its constituent layers coupled with the large scale experience of making roads having flexible pavement. A flexible pavement is easier and simpler to construct and its design is based on sure C.B.R. method. However, as stated previously, for the flexible pavement to be effective, its thickness of construction has to be fairly big which means uneconomic and delayed construction. This difficulty can be overcome if by some process the total depth is reduced by a good margin thus affording a reasonable reduction in cost and also if the speed of construction is considerably accelerated. The second factor, too, contributes much to the savings made. Both these views have been notably fulfilled by stabilising the soil *in situ* with cement and utilising the product soil-cement as a constructional material.

## Soil cement

The admixture of Portland cement in small proportions to 14 per cent to soil at or about its optimum moisture content with subsequent compaction of this intimate soil cement mixture results on curing, in a hard stable mass after about 7 days. This ultimate product can usefully serve as a structural material. In fact, the stabilisation of soil with cement dates back to 1930. The stabilised soil has been put to many uses in engineering construction of roads, runways, embankments, cheap houses and as lining material for canals to check seepage etc. A survey of the existing literature on the subject indicates the voluminous work done by numerous workers[6]. Recently, Antia [7] has advocated the use of soil-cement for road construction in India laying stress on the economical aspects of such construction. The scope of this paper is to briefly review the developments in runway construction employing soil-cement and to assess the suitability of Indian soils for such construction. It is also proposed to deal with the subject of soil-cement at some length.

## Mechanism of soil stabilisation

The role of cement is to act as binding material. The interaction between the cement and the soil particles is similar to hardening by hydration in concrete but other chemical reactions may also take place. It is difficult to gain an insight into such reactions. By a study of the effect of chemicals on the setting of soil-cement. Winterkorn[8] has come to the conclusion that the surface chemicals can enhance the hardening and that ionic treatment of such soils can improve the hardening action in soil-cement.

According to Maclean[9], with a purely granular soil or a clean sand addition of portland cement promotes formation of bonds between individual particles. On the other hand, with a clayey soil, the mixing of cement brings about two types of bonds, rigid cement bonds and plastic soil bonds. The latter are attributed to the aggregated clay particles in the soil. Such bonds tend to weaken with ingress of water. Therefore in contact with water, stabilised clayey soil loses much of its strength in contrast to a sandy soil that loses little.

## Soil

The main constituent of soil-cement is soil. The texture of the soil and the type and amount of cement determine to a very large extent the strength and durability of this constructional material.

## Criterion of suitability of a soil for stabilisation

The gradation of the soil suitable for stabilisation varies between wide values. Fig. 1.

In the U.S.A., the second criterion of suitability of any particular soil is its durability which is decided by subjecting standard specimens to alternate cycles of wetting and drying and of freezing and thawing[10]. Webb[11] has reported a crushing test which has gained wide acceptance in U.K. The crushing test is made on a 4-in cube compacted to a bulk density at optimum

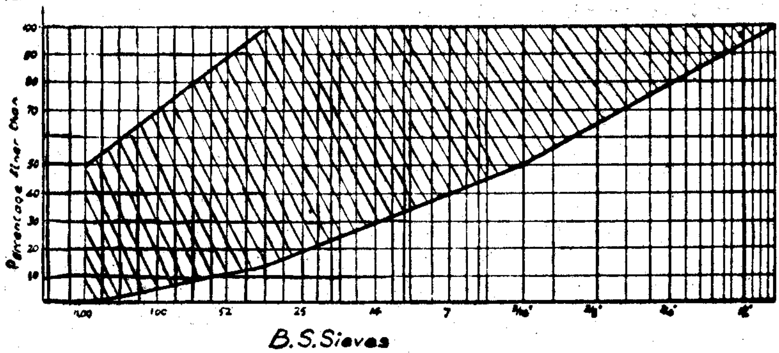


FIG. 1—Gradings for Soil Cement Construction (Highway Research Board U.S.A.)

moisture and cured under moist atmosphere for 7 days. A crushing strength of 250 lbs per sq. in. is a satisfactory index of soil-cement construction. The duration of this test is 7 days whereas the duration of durability test is 31 days. Thus comparatively it is a quicker test.

Table 1 lists the essential characteristics of broad groups of soils that can be successfully treated.

TABLE 1

| Soil Group No | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Type of soil .. .. | Predominantly sandy | Silty | Clayey | Peaty & highly organic or heavy clays |
| Effect of cement treatment | Very marked hardening | Marked hardening | Substantial hardening | Cannot be successfully treated. |
| Liquid Limit .. .. | → < 60 | ← | | |
| Plasticity index | → < 25 | ← | | |
| Clay Content (·005 mm) | → < 35 | ← | | |
| Minimum Compressive Strength .. .. | → < 250 psi | | ← | |
| Maximum allowable volume change. | 2% | 2% | 2% | |
| Normal minimum cement content on dry weight basis. | 6—10% | 8—12% | 10—14 % | |

**Non-suitability of highly clayey soils**

Highly clayey soils are not suitable for cement stabilisation due to the fact that considerably large quantity of cement is required and that cement and clayey soil should be in highly pulverised condition before mixing. The mechanism of soil-cement has already been considered. The cement acts as a binder. The stabilisation of a given soil will be the highest only if each individual particle of the soil is coated with layer of cement. In a highly clayey soil, the component particles though of the same size as those of cement, are actually in an aggregated state. It follows, therefore, that for effective stabilisation, the aggregates in the case of a heavy soil have to be broken down to a fine state. The cement too must be in a fine state. The quantity of cement required to form films round the soil particles will be proportionally greater. In view of the above considerations, the consumption of a large quantity of finely ground cement for stabilisation makes the process uneconomical.

**Recent progress towards stabilisation of heavy soils**

As stated above large proportion of cement required stands in the way of stabilising heavy soils. Another important condition for the successful stabilisation is that the soil should be in a pulverised state which is difficult to attain with heavy textured soils owing to their inherent strong cohesion. In practice, a compromise approach between the two extremes has to be adopted. Economy in cement is brought about by adding a small amount of secondary additive, say 2—4 per cent hydrated lime to a clayey soil. The function of lime is to confer granular structure to the soil. For pulverising the soil, a rotary tiller is employed. This sturdy machine is usually trailed by a tractor. The soil along with the cement is next intimately mixed in a stationery plant employing a pottery-type pugmill with an output of 10—15 tons per hour[12] sometimes, the processes of pulverising and mixing are combined in a single machine known as the Seaman Pulvimixer which works extremely well on fine grained soils.

**Organic matter**

Certain sandy soils containing 1-2 per cent of active type of organic matter have inhibited the setting of soil-cement by more than a week. The active organic compound has been isolated and found to be lignin-enriched humic acid[13]. Addition of 1-2 per cent of calcium chloride or calcium nitrate to the soil has proved beneficial.

**Cement**

*Quantity of cement*

The required quantity of cement for a given soil is dependent on the texture of the soil and to some extent on the amount of organic matter present in it. In general, granular soils require less cement than cohesive soils. Soils with a high organic content require relatively large amount of cement for hardening. Therefore soils having organic matter more than 2 per cent are not preferred.

*Type of cement*

Normally for soil-cement construction the use of ordinary portland cement is recommended, though laboratory trials have been made with other varieties like rapid-hardening, super-rapid-hardening, and high alumina cement but the results obtained are only of academic interest.

*The influence of particle size of cement on stabilisation*

The particle size of a cement materially affects the strength developed. It has been proved that if the cement has been finely ground, it gives higher strengths. Grinding reduces the particle size to state of fine sub-division thereby increasing the surface area. Consequently less quantity of fine cement is required to obtain an equivalent strength that would result when coarse cement is used.

*Properties of soil-cement*

Soil-cement possesses remarkable properties such as high density, high resistance to slaking action of water, high compressive strength and low thermal expansion. It has a small but significant flexural strength which varies between 50 and 100 lb. per sq. in.

**Soil-cement pavement**

Soil-cement pavement may consist of the stabilised soil base covered by an appropriate thickness of either cement concrete or bituminous surface. Minimum thickness of the bituminous surface to be laid is a variant of the wheel and load assembly of the air-craft and its tyre pressure. Table 2 shows minimum thickness as related to these factors[14].

TABLE 2

| Wheel Assembly | Tyre pressure (psi) | Load assembly (kips) | Minimum thickness (inches) |
|---|---|---|---|
| Single | 100 | Up to 30 | 2 |
| | | Above 30 | 3 |
| | | Up to 30 | 3 |
| | | Above 30 | 4 |
| Dual spacing 37·5 in | Based on contact area of 267 sq. in. per tyre | Up to 45 | 2 |
| | | 45—65 | 3 |
| | | Above 60 | 4 |
| Twin tandem spacing 31 in × 60 in | | Up to 125 | 3 |
| | | Above 125 | 4 |

With the introduction of jet aircraft, the existing pavements suffer from the serious effects of heat, blast and fuel spillage[15]. Of the two common types, the flexible pavement is more susceptible to severe damage than is the case with rigid pavement which stands fairly well to the three critical aspects of jet mentioned above. However it is difficult to ignore the pertinent merits of a flexible pavement like ease of repair and a good riding surface etc., and with this in view, researches continue in the direction of evolving a suitable anti-jet binder[16]. These researches have met with partial success and until complete success has been achieved, it will be necessary to have the wearing surface made of cement concrete if the jet aircrafts are to operate. The data presented in Table 2 therefore is applicable to conventional aircrafts having reciprocating type of engines and operating on soil-cement pavement having a bituminous surface.

## Strength requirements and formation of cracks

The unconfined compressive strength of soils treated with 10 per cent of cement may exceed 1000 lb. per sq. in. in case of granular soils at the end of 7 days but may be as low as 200 lb. per sq. in. with clayey soils. Strengths in excess of 500 lb. per sq. in. are not desired since these lead to the formation of big wide cracks that seriously affect the stability of the material formed. The formation of cracks soon after construction is a characteristic feature of soil-cement. The cause of these cracks is the shrinkage that takes place during the hardening of cement which is far in excess of the subsequent expansion of the material on exposure to seasonal fluctuations. So long as the cracks are fine and closely spaced, the sides of these cracks remain interlocked and the stability of the material does not suffer.

## Developments in other countries

The use of stabilised soil for runway construction started with the start of World War II. Catton[17] has given an account of war time soil-cement construction problems connected with the various runways constructed in U.S.A. In Germany, many airfields were laid with cement stabilised soil—a fact which came to light during the Allied occupation. The French were getting engaged in building a large number of aerodromes when their country was suddenly invaded. Laerum[18] has described the use of soil-cement for roads and runways in Norway. Frasch[19] has mentioned similar developments in Finland. Soil-cement progress in Australia has been reviewed by Chaston[20]. Andrews[21] and later on Maclean[9] have extensively dealt with the application of soil-cement to the construction of airfield pavements.

Most of these pavements constructed in various countries upto 1950 had a 6″ thick base and were designed for medium aircraft having wheel loads upto 15,000 lb. The thickness of base has been enhanced to 12″ and 18″ making use of double and triple layered construction, the thickness of each layer being 6″. Good bonding between the layers has been achieved, the base assuming a monolithic structure throughout. Developments along these lines have placed the soil-cement pavement at par with the other conventional pavements, *i.e.*, rigid and flexible, in its ability to support heavy superimposed loads. Lately, the work on three modern airports in England has been described, all embodying stabilised soil pavement and catering to traffic [22, 23, 24] by conventional aircraft. Of these, one is a heavy-duty military airfield designed to serve heavy military aircraft, the second, a municipal airport at Southend and the third at Christchurch to be used for test-flying by de Havilland Aircraft Company. Particulars pertaining to these runways have been summarised by Maclean[25] and are presented in Tables 3 and 4.

TABLE 3

*Strength of soil-cement in relation to applied pressures to airfield pavements*

| Airfield | Design Tyre pressure lb./sq. in. | Soil Type Stabilised | Avg. field strength of soil cement at 7 days (top layer) lb./sq. in. | Percentage cement used | Thickness of bituminous surface in inches |
|---|---|---|---|---|---|
| 1. Heavy duty military Airfield. | 250 | Sandy gravel | 820 | 8 | 4½ |
| 2. Southend | 110 | Clay | 295 | 14 | 2 |
| 3. Christchurch | 160 | Sandy gravel. | 680 | 9 | 3 |

TABLE 4

*Design of soil-cement pavements*

| Airfield | Design Traffic | | C.B.R. % | Design thickness on CBR method in inches | Actual thickness laid in inches |
|---|---|---|---|---|---|
| | Wheel load | Tyre pressure | | | |
| 1. Heavy-duty military airfield | 55,000 | 250 | 8 | 28 | 22½ |
| 2. Southend | 40,000 | 110 | 9 | 20 | 19½ |
| 3. Christchurch | 25,000 | 160 | 9 | 17 | 9 |

Statistics in respect of speed and cost of construction for these runways are reproduced below. These need not apply to conditions in India.

Speed of construction varied from 20 ft/min. in case of sandy soils to 6·9 ft/min. for cohesive soil using the single-pass machine. This rate of construction is quite phenomenal. Thus the time taken to stabilise a modern runway of standard dimensions may be minimum of 4 weeks to maximum of 12 weeks.

**Cost of construction**

Cost of construction at Christchurch was 9s 4d/sq. yd. of runway inclusive of all charges for earth moving, laboratory control and surface dressing. This represenets single-layer construction. For two-layer construction including provision for bituminous surfacing the cost incurred was 16 s/sq. yd. A three layer soil-cement construction should not cost more than £1/sq. yd.

**Reduction in the depth of pavement construction**

The use of cement stabilisation of sandy soils occurring in England has resulted in the reduction of overall pavement depth by a factor 0·7.

**Method and Machine**

When single-layer construction is aimed at, the surface is loosened to a depth of 6″ or so. In case of two or three layered construction, the excavated material is stockpiled and utilised later on. Dry densities and optimum moisture content of the soils are determined and also the *in situ* C.B.R. value of the sub-grade. The amount of cement is determined by trial mixes.

The processes of digging the soil, pulverising, mixing the cement, adding the optimum moisture content and compacting to a high density are carried out mechanically. The stabilisation equipment comprising various units like scarifier, water bowser, towing unit, cement spreader and mixer, compactor and planishing roller etc. are grouped to form a train.

There are three main methods of constructing soil-cement bases namely the Pre-mix, the Mix-in-place and the Travel-mix each employing a different type of plant. A full description of these methods and equipment is given in the literature[26, 27]. For runway construction, the choice rests on the latter two. The Mix-in-place method gives a high rate of out put and is usually capable of laying a 6″ thick layer; whereas the Travel-mix method achieves thorough mixing and can be relied upon for laying base of greater thickness.

The *in situ* stabilisation proceeds under strict laboratory control. Vertical plugs are removed for determining strength and control of density is exercised by frequent tests. The finished base is left to cure under damp condition for a week about. Curing materials employed are moist earth, water proof paper, straw, sand, P.B.S. and asphalt emulsion etc.[28].

**Life of pavement**

It has been claimed that the soil-cement pavement enjoys a long life, ease of repair, and lower cost of maintenance[29]. As a matter of fact, wet temperature climates are ideal for cement stabilisation since cement absorbs water during hydration. Nevertheless many airfields have been laid in dry areas of the United States and elsewhere, and have functioned remarkably well. Soil-cement without a cap, may disintegrate after a lapse of few years when exposed to extremes of wetting and drying or continued hot dry weather. With a suitable thickness of overlay bituminous surfacing, it may endure the extremes of weather for long periods of many years. Prolonged existence in arid zones necessitates preserving the optimum-moisture content of compaction in the pavement since the moisture is likley to drop to a lower level after some time and means must be found to correct it to original value as and when required. As to disintegration, the more easily accessible the interior of the material to weathering agents, the more easily it is destroyed. Increasing density at fixed moisture content decreases the accessibility of the internal surface of soil-cement and therefore higher the density of the product, the safer and stabler it is.

**Soils of India and their suitability**

The following broad groups have been recognised among soils of India [30]—

(1) Red soil including red loams, yellow earths etc.

(2) Laterite and Lateritic soils.

(3) Black soils of varying types including black cotton soil or regur.

(4) Alluvial soils.

(5) Forest and Hill soils.

(6) Desert soils.

(7) Saline soils.

(8) Alkaline soils.

(9) Peaty and marshy soils.

Mehra and Uppal[31] have investigated the suitability of certain alluvial soils occurring in the Punjab. Bose[32] has reported a black cotton soil having 54 per cent clay content that could not be stabilised even with 20 per cent cement. Apart from those attempts, no systematic probe has been made on the rest of the soils with a view to assessing their worth for cement stabilisation. Fortunately, as a result of the intensive researches on the subject, it is now definitely concluded that most of the soils respond to cement treatment.

As has been made clear, the following tests have been evolved to determine the suitability of a given soil for stabilisation with cement:

(1) Grading test based on dry sieve analysis.

(2) Durability test in which soil specimens are subjected to alternate cycles of freezing and thawing, and wetting and drying.

(3) Crushing strength test which determines the strength of soil-cement after 7 days' wetting.

Grading test is simple and rapid but is not conclusive. Durability test has been criticised on account of its long duration. Crushing strength test does not take into account the absence of lateral restraint on the test specimen in unconfined compressive strength apparatus and gives values for strength that are lower than those encountered in the field. The behaviour of a soil in wetting and drying cycles is governed by the affinity of clay for water and the accessibility of its internal surface. Thus it is very useful and important if the response of soil to water is known. This is determined by subjecting the soil to wet sieve analysis by employing Yoder's technique[33]. A combination of grading test based on dry sieve analysis and the test of water stability of soil aggregates based on wet sieve analysis will be helpful in determining the suitability of a given soil for cement stabilisation. Both these tests have been performed in this Laboratory on soils representing broad groups [34]. Results are presented in Fig. 2 and summarised in Table 5.

TABLE 5

| Type of soil | Percentage aggregates finer than 0·076 mm on dry sieve basis corresponding to lower limit of 200 mesh (B.S.S.) on Grading curve, Fig 1 | Percentage water stability of aggregates made up of percentages of water stable aggregates retained on B.S. seives of mesh no 22, 30, 72, 100, 150 and 200 on immersion test (½ hr) |
|---|---|---|
| 1 Red .. .. .. .. | 14·9 | 84·1 |
| 2 Laterite .. .. .. .. | 25·4 | 79·5 |
| 3 Black .. .. .. .. | 9·7 | 40·1 |
| 4 Alluvial .. .. .. .. | 29·7 | 83·6 |
| 5 Forest .. .. .. .. | 30·8 | 87·9 |
| 6 Desert .. .. .. .. | 8·1 | 90·1 |
| 7 Saline .. .. .. .. | 7·3 | 15·8 |
| 8 Alkaline .. .. .. .. | 37·8 | 46·7 |
| 9 Peaty .. .. .. .. | 15·10 | 87·8 |

From a study of the above data, it is clear that all the nine soils appear suitable on the basis of dry sieve analysis since the permissible range of percentage aggregates finer than 200 B.S. mesh lies between 0 and 50. But judging from the point of view of water stability of the soil aggregates, Black, Alkaline and Saline soils are unsuitable. Thus of the two tests the latter is really critical. It is tentatively suggested that a percentage water stability of 80 may be accepted as an index of suitability of soils for cement stabilisation. Though peaty soil has stood the water stability test pretty well, its stabilisation with cement is not recommended since it contains high proportions of organic matter. Excepting peaty and highly organic soils, most Indian soils are known to contain only a small percentage of 0·5 and 2·0 per cent of organic matter and will present no appreciable difficulty in so far their stabilisation with cement is concerned. Provided the meteorological and topographical factors are favourable in the siting and planning of airfields, soils of India falling under broad groups—Red, Laterite, Alluvial and Forest could be recommended. The area containing saline, alkaline and peaty soils is comparatively small. Regardnig black soils, though encouraging reports about the successful stabilisation are coming in, a somewhat cautious approach is necessary. There is considerable scope for

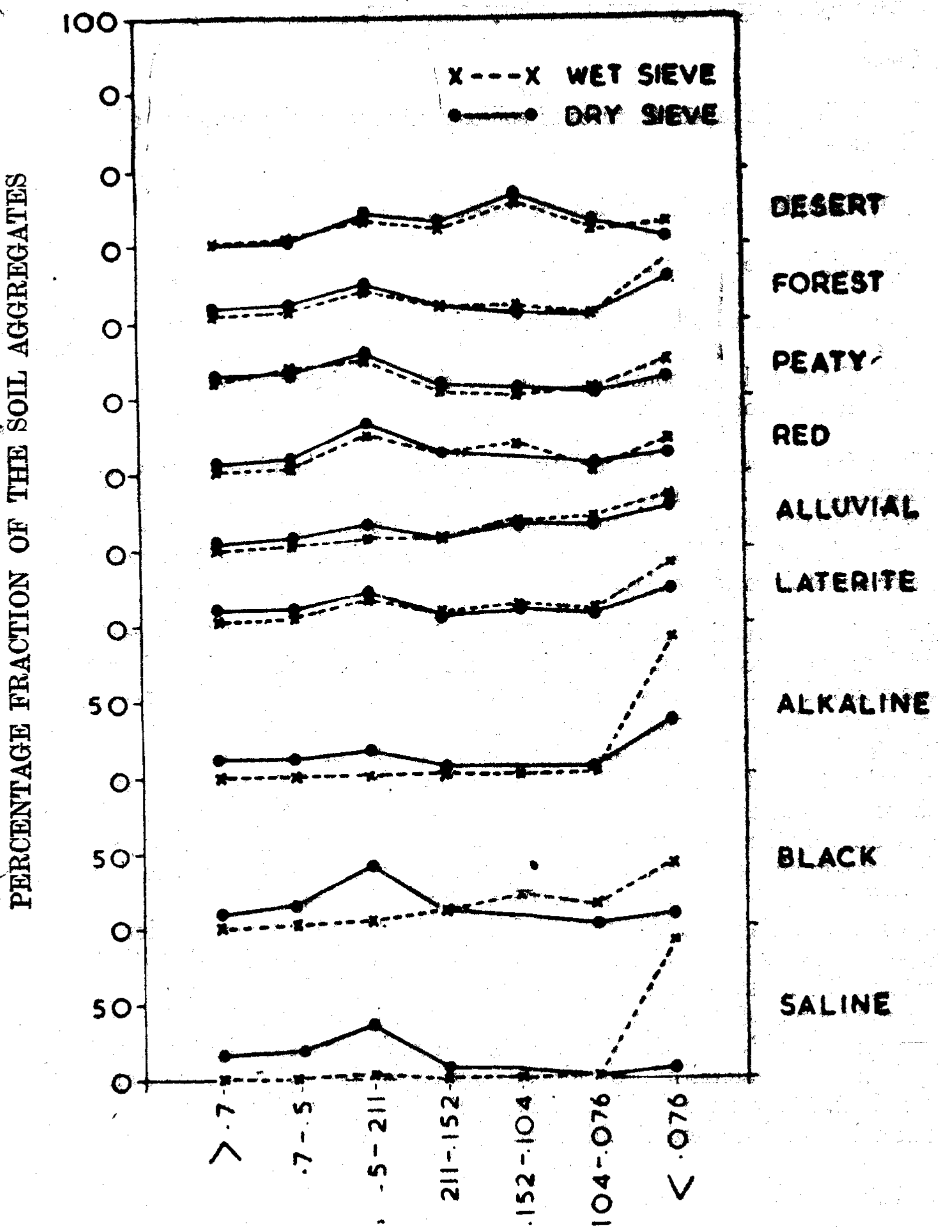


FIG. 2—Relative water stabilities of the aggregates in the typical Indian soils

original research aimed at achieving sizable reduction in the quantity of cement to be used by trying indigenous secondary additives.

## Conclusion

Concluding, the salient features of soil-cement construction are summed up as follows:—

(1) Complete mechanisation of process.

(2) High speed of construction.

(3) Low cost of construction and maintenance.

(4) Use of soil as a constructional material in conjunction with a small amount of cement.

These features enhance the utility of soil-cement for military purposes. For temporary military airfields soil-cement base can successfully serve the purpose as deterioration of structure is acceptable in an emergency whereas for permanent military airfields, the pavement may have either a cement concrete surface or a metal track overlay.

As to the construction of civil aerodromes, it is suggested that large scale field trials may be undertaken culminating in the laying of test strips in different climatic zones of India and testing their performance by load tests. In the arid, semi-arid and sub-humid zones, less cement should be needed as a rise in temperature leads to an increase in strength[35]. Work of Indian workers[31] indicates that for light textured soils, the 7 day strength with 3-5 per cent cement on volumetric basis is more than adequate. Moreover in constructing a multi-layered base, only the top layer is required to be extra-strong, the bottom layers need not possess high strength. As a consequence, there can be further reduction in the quantity of cement to be used. These helpful factors should go a long way in assuring the success of test strips followed by the actual construction of soil-cement runways for regular service. But it should be borne in mind that the success of in situ stabilisation of soil with cement largely depends on employing the right type of machine since throughout it is a mechanised process. Uniform spreading of cement, control of optimum moisture and a tight check of density have to be maintained. All this can only be obtained with adequate and efficient plant. If there are deficiencies in plant, the results may truly betray the economies of soil-cement stabilisation.

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