IRC : 88-1984

RECOMMENDED PRACTICE
FOR
LIME FLYASH STABILISED SOIL
BASE/SUB-BASE
IN
PAVEMENT CONSTRUCTION

THE INDIAN ROADS CONGRESS
1984

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RECOMMENDED PRACTICE FOR LIME FLYASH STABILISED SOIL BASE/SUB-BASE IN PAVEMENT CONSTRUCTION

1. INTRODUCTION

1.1. This recommended practice describes a method of stabilisation of soils by utilising flyash with lime to provide a base/sub-base course in the design of road pavement. Flyash is a waste product available from coal or lignite burning thermal plants. Flyash can be advantageously used not only in the pavement construction work, but also provides an economic and useful avenue for disposal of flyash, which is now recognised as a national environmental problem.

1.2. Draft of this Recommended Practice was initially prepared by T.K. Natarajan and approved by the Soil Engineering Committee (personnel given below) in their meeting held at *Ootty* on the *19th September, 1981*.

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1.3. The draft was processed and approved by the Specifications and Standards Committee at their meeting held at New Delhi on the 24th May, 1983 subject to certain modifications, which on the authority of the Committee, were carried out by a Working Group consisting of T.K. Natarajan, N. Sivaguru, Dr. B.R. Malhotra, S. Natarajan, K. Arunachalam and P. Bhaskaran assisted by P.R. Rao.

2. SCOPE

2.1. Lime-flyash mixtures can be used for a wide range of pavement systems such as sub-bases and bases for flexible pavements and bases for rigid pavements. This Recommended Practice is intended to provide guidelines for stabilising local soils with lime and flyash for use as a sub-base in pavement construction. It is pre-supposed that the work will be carried out in accordance with appropriate construction specifications and good site supervision will be exercised as regards the quality of constituent materials and process of construction.

3. THICKNESS DESIGN OF LIME FLYASH SOIL SUB-BASE/BASE LAYER

The thickness of lime-flyash-soil layer for use as sub-base or base course in pavement construction should be designed in accordance with IRC : 37-1984 entitled 'Guidelines for the design of flexible pavements'. However, the minimum thickness of lime-flyash-soil layer should be 15 cm. The sub-base layer constructed by using lime-flyash as the stabilising admixture, though semi-rigid in character and behaviour, shall be deemed to be a flexible layer for purpose of applying CBR method of design of thickness.

4. MATERIALS

4.1. Soil

Granular soils free from high concentrations of organic matter or deleterious salts and sands with fine silts produce better mixes than fine grained soils with high clay content which would require a high percentage of lime for stabilisation. Clayey silts and low-plasticity clays having PI between 5 and 20 and liquid limit

less than 25 are, however, quite suitable. For satisfactory stabilisation with lime, it is necessary for a soil to possess a certain minimum proportion of clay fraction, since strength of the stabilised material is derived from the reaction that takes place between lime and clay particles. The minimum proportion of particles smaller than 425 micron size, should be between 15 and 25 per cent by dry weight of the soil lime flyash mixture. Selection of materials and their gradation, as far as possible, should be such as would be conducive to compaction to a high density in the field.

4.2. Lime

The lime to be used for lime-flyash-soil stabilisation, should be commercial dry lime slaked at site or pre-slaked and delivered to the place of work in a suitable and approved packing. Generally the lime used should have a purity (CaO content) of not less than 50 per cent when tested in accordance with IS:1514. Only hydrated high-calcium and monohydrated dolomitic limes are used in Lime Flyash Soil Stabilisation. High-calcium-content varieties of lime give higher strengths especially at low concentrations of lime. Quick lime is not recommended to be used. In exceptional circumstances, if lime with 50 per cent purity is not conveniently available, the difference may be accounted for by providing proportionately higher quantity of lime. Since lime deteriorates with storage, the per cent purity must be checked at site before use and the quantity to be added is regulated accordingly. Lime when stored, should be kept in a covered place to prevent its carbonation.

4.3. Flyash

Flyash to be used should conform to IS : 3812-1981. If it had been stock-piled for some period before use and had got partially or wholly set, it should be pulverised and dry sieved before mixing so as to conform to the following gradation :

Sieve size (mm)	*Per cent passing*
12.5	100
9.5	95 (minimum)
2.0	75 (minimum)

Flyashes are pozzolanas with little cementitious value but in the presence of moisture, react chemically with calcium hydro-oxides at ordinary temperature to form compounds with cementitious properties. It should be ensured before use that the flyash is reactive to lime. It should possess lime reactivity of not less than 35 kg/cm^2. In addition to the primary reaction between lime and flyash, the lime may also react chemically with the 'fines' in the material resulting in base-exchange, flocculation and aggregation of particles. The magnitude of this reaction, apart from the degree of fineness of the clay-component of the material, depends upon its mineralogical characteristics (viz. predominant clay mineral present and its relative abundance). Flyash should be fine enough to have a specific surface area of 3200 cm^2/gm or 320 m^2/kg.

Flyash when stored, should be kept in a covered place safe from moisture.

4.4. Water

Water used for both mixing and curing should be clean and free from injurious salts and other deleterious matter. Potable water is generally considered satisfactory.

5. PROPERTIES OF COMPACTED AND CURED SOIL-LIME-FLYASH MIXTURE

Following are some of the significant properties of the compacted and cured lime flyash-soil mixes which serve as general guidelines in the design of Lime Flyash Soil stabilised pavement layers :

5.1. In the case of clayey soils, addition of lime-flyash may result in a decrease of maximum density and optimum moisture. For silty soils, optimum mositure may increase slightly.

5.2. If the soil is well-graded and it is thoroughly mixed with water, lime and flyash with adequate compaction, it helps in attaining a higher compacted density and higher strength.

Strength achieved at 90 per cent Heavy Compaction density, for example, may be only 60 per cent of that achieved at 100 per cent Heavy Compaction density in some cases.

5.3. Development of strength of lime-flyash-soil mix depends on curing period, moisture and temperature. It is rather slow and takes several years to reach the peak value. The higher the curing temperature the greater is the strength development. Strength development is substantially retarded at low temperatures say less them 4°C. For the pozzolanic reactions to continue, the compaction moisture content (roughly equal to optimum) must be maintatined in the lime flyash-soil mixture during the curing period. In normal practice, a curing period of 28 days under moist conditions should be allowed to the mix to gain a high percentage of ultimate strength.

5.4. The average compressive strength of compacted clay, well compacted sand-clay, well-compacted gravel-sand-clay would normally vary from 1 to 7 kg/cm^2. By using lime-flyash-soil admixture, the strength has been found to range as under :

Clay (admixed with lime flyash and with 28 days of curing period)		14 to 34 kg/cm^2
Silt	-do-	21 to 48 kg/cm^2
Sand	-do-	21 to 48 kg/cm^2
Gravel	-do-	21 to 90 kg/cm^2

Soils stabilised with lime-flyash can give laboratory soaked CBR values ranging between 40 and 90. The available data suggest a roughly linear increase in CBR values of soil lime flyash mixtures when the proportion of (lime+flyash) is between 10 per cent and 30 per cent of the dry weight of the total soil. The range of increase in strength in terms of CBR values is however different for different soil types.

6. FACTORS GOVERNING STRENGTH OF COMPACTED LIME FLYASH-SOIL MIXES

Apart from the physical and chemical properties of the constituent materials, the proportions of these materials in the mix, the

extent and duration of mixing the curing moisture temperature and duration the extent of compaction imparted significantly govern the strength of the compacted mix.

7. MIX DESIGN AND PROPORTIONING

7.1. The mix with optimum proportion of (lime+flyash) to soil and also ratio by weight of lime to flyash should first be decided in the laboratory by trial and error. The same should be adopted in the field. The mix proportion should be designated as :

(a) The ratio of lime to flyash, and
(b) The proportions of lime; flyash and soil in the total mixture expressed in parts by dry weight.

Thus if the ratio : L : FA is 1 : 4 : the designation by parts may be

Lime	:	3 parts
Flyash	:	12 parts
Soil	:	85 parts
Total (cm dry wt. basis)	= 100	

7.2. Experience suggests that lime-flyash ratios of 1:3 to 1:4 give optimum strength for various soil types suitable for lime-flyash soil stabilisation. Further increase in lime content does not indicate a proportionate increase in strength. Lime plus flyash content ranging between 10 and 30 per cent by weight of the total dry mixture has been found to be suitable. Lime flyash requirements, in fact, depend upon the percentage of fines in the total mix. Fine cohesive silts require a higher percentage of (lime+flyash) compared to well-graded soils. Strength development calls for sufficient matrix material (fines) to fill the voids in coarse materials.

7.3. The exact proportions of the ingredients viz. lime, flyash and soil, to be adopted at a particular location should be based on the laboratory mix design depending upon the strength requirement. The minimum unconfined compressive strength and CBR values after 28 days curing and 4 days soaking should be 7.5 kg/cm^2 and 25 per cent respectively. In terms of seven days curing and four days soaking, the minimum unconfined compre-

ssive strength and CBR values should be 3 kg/cm^2 and 10 per cent respectively. The curing may be done at a temperature ranging from 30°C to 38°C.

7.4. Trial mixes using (lime-flyash) ratios of 1:2, 1:3, 1:4, are initially prepared. The following overall proportions may accordingly be used for preparing the mixtures for laboratory tests :

Ratio	*Overall proportions by parts* (*L*: *FA*: *Soil*)
1 : 2	2.5 : 5 : 92.5
1 : 3	2.5 : 7.5 : 90
	4 : 12 : 84
	5 : 15 : 80
1 : 4	2 : 8 : 90
	3 : 12 : 85
	4 : 16: 80

Additional trials may be made if required. Amounts of lime quantity smaller than two per cent are generally not amenable to proper mixing and hence not recommended.

7.5. Each of the mixes suggested above shall be subjected to laboratory compaction tests in accordance with the procedure laid down in IS: 2720 (Part VIII) using Heavy Compaction effort. The values of the maximum Dry Density and Optimum Moisture Content (OMC) shall be scaled out from the plot in each case.

7.6. Either the unconfined compression or the CBR test may be employed for the determination of strength of the compacted soil lime flyash mix depending on the design requirement. In the case of the former test, specimens of the mix compacted at OMC and with the same amount of compaction effort shall be prepared, cured for 28 days at a temperature ranging from 30°C to 38°C and maintaining constant moulding moisture, and finally tested for unconfined compressive strength as per IS: 2720 (Part X). The specimen size may be 50 mm dia x 100 mm height in the case of fine-grained and sandy materials or 100 mm diameter × 200 mm height

for larger particle size mixtures (prepared after rejecting the particles larger than 20 mm in size). Alternatively, the CBR test shall be carried out in the same way by curing samples for 7 days or 28 days, with 4 days soaking as the case may be in accordance with the provisions of IS:2720 (Part XVI-1965). The results of tests shall then be plotted using the compressive strength or CBR and the lime flyash soil ratios as the two axes. The ratio corresponding to the Minimum Strength Requirement as specified in para 7.3. will be adopted and the one which suggests minimum quantity of lime or the one which, according to detailed cost analysis, works out to be the most economical shall finally be selected. Specimen samples using the same proportions, prepared in the same manner will be tested for compressive strength or CBR for verification and confirmation. The maximum dry density (corresponding to heavy compaction effect) at which the soil- lime-flyash mixture is finally prepared to be remoulded shall be called 'Control Density'.

8. CONSTRUCTION OPERATIONS

8.1. Preparation of Subgrade

The subgrade or sub-base over which the lime-flyash-soil layer is to be laid should be checked for line grade and cross-section. All irregularities beyond the permitted tolerance should be rectified. The road bed shall be prepared by removing all vegetation and other extraneous matter, lightly sprinkled with water if necessary and rolled with 8-10 tonne smooth wheeled roller. Soft and yielding spots and ruts, if present, should be corrected and rolled until firm.

8.2. Weather Limitations

Lime-flyash-soil stabilization should not be done when the air temperature in the shade is less than 10°C.

8.3. Degree of Pulverisation

For lime-flyash stabilization, the soil before addition of stabilizer, shall be pulverised to the extent that it passes the require-

ments set out in table given below when tested in accordance with the prescribed method:

Sieve designation of (IS : 460)	Per cent by weight passing the sieve	
	Black cotton soil	Other soils
25 mm	100	100
4.75 mm	50	60

8.4. Batching and Mixing

After determining the proportions of lime, flyash and soil, batching of materials should be done by weight before the same are mixed together. Volume batching may be permitted only when it is unavoidable. The materials before being mixed together shall be thoroughly pulverised. Pulverisation may be done either by making use of mechanical plants or manually by means of rotary tillers, disc harrows, crow bars, pick axes, bullock drawn ploughs, etc. For mixing one of the two methods can be followed. Either the soil, lime and flyash can be mixed together and spread on the subgrade or lime and flyash are stacked on the pulverised soil already spread on the subgrade at suitable distances and then spread and mixed with the soil.

8.5. Tolerance

Limits of tolerance, for various materials in percentage by weight are as follows:

Lime	±	0.3
Fly Ash	±	1.5
Soil/Aggregate	±	2.0

8.6. Plant for Construction

Mix in place method is found to be convenient for achieving consistency than manual mixing. Manual mixing shall be permitted only when the width of laying is not adequate for mechanical operations.

Plants used for mix in place construction shall be capable of pulverising the soil to specified degree and achieving the desired degree of mixing and uniformity of the stabilised material.

For mix in place method of construction before deploying the plant, the soil after it is made free of undesirable and deleterious matter shall be spread uniformly on the prepared road bed in a quantity sufficient to achieve the desired compacted thickness of the stabilised layer. When single pass equipment is to be employed, the soil shall be rolled lightly.

The plant used shall either be of single-pass or multiple-pass type. The mixers shall be equipped with an appropriate device for controlling the depth of processing and the mixing blades shall be maintained or reset periodically so that the correct depth of mixing is obtained at all times.

With single-pass equipment the forward speed of the machine shall be so selected in relation to the rotor speed that the required degree of mixing, pulverization and depth of processing is obtained.

In multi-pass processing, the soil on the prepared road bed shall be pulverized to the required depth with successive passes of the plant and the moisture content adjusted to be within prescribed limits. The stabilizing material shall then be spread uniformly and mixing continued initially dry mixing till it becomes homogenous and then followed by wet mixing with the addition of water in requisite quantity, with successive passes until the required depth and uniformity of processing has been obtained.

The mixing plant shall be so set that it cuts slightly into the edge of the adjoining lane processed previously so as to ensure that all the material forming a layer has been properly processed for the full width.

8.7. Construction with Manual Means

Where manual mixing is permitted, the soil from borrow areas shall first be freed of all vegetation and other deleterious

matter and placed on the prepared road bed. The soil shall then be pulverised by means of crow-bars, pick axes or other approved means. Water in requisite quantities may be sprinkled on the soil for aiding pulverisation. On the pulverised soil, stabilising material(s) in requisite quantities shall be spread uniformly and mixed dry thoroughly by working with spades or other similar implements till the whole mass is mixed uniform and homogenous. After adjusting the moisture content to be within the limits, the mixed material shall be levelled upto the required thickness so that it is ready to be rolled.

8.8. For all the three mehthods the maximum thickness of individual compacted layer shall not exceed 100 mm. The materials and their proportion shall be arranged, keeping this requirement in view. As the minimum thickness of lime flyash soil layer has been prescribed as 150 mm, the same shall be laid in two layers. Before laying the second layer the compacted first layer shall be roughened to ensure proper bond between the layers.

8.9. **Moisture Content for Compaction**

The moisture content at compaction shall not be less than the optimum moisture content corresponding to IS: 2720 (Part VII) nor more than 2 per cent above it.

8.10. **Rolling**

Immediately after spreading, grading and levelling of the mixed material, compaction shall be carried out with 8 to 10 tonne smooth wheel rollers or other approved plant, preceded by a few passes of lighter rollers if necessary. Rolling shall commence at edges and progress towards the centre, except at superelevated portions where it shall commence at the inner edge and progress towards outer. During rolling the surface shall be frequently checked for grade and camber and any irregularities corrected by loosening the material and removing or adding fresh material. Compaction shall continue until the density achieved is at least 100 per cent of the maximum dry density for the material determined in accordance with IS: 2720 (Part VII).

Care shall be taken to see that the compaction of lime stabilised material is completed within four hours of its mixing or such shorter period as may be found necessary in dry weather.

During rolling, it shall be ensured that compaction plant does not bear directly on hardened or partially hardened treated material previously laid other than what may be necessary for achieving the specified compaction at the joint.

The final surface shall be well closed, free from movement under compaction plant, compaction planes, ridges, cracks or loose material. All loose or segregated or otherwise defective areas shall be made good to the full thickness of the layer and recompacted.

8.11. Construction Joint

No joints except construction joints shall be provided. At the end of the day's work, a straight tapering transverse construction joint for full width of the course shall be made by chamfering the edge of the already laid mix at an angle of about 30°. Before resuming work at any construction joint left at the end of previous work, the material at the joint shall be scarified and moistened, blended with new mixture and compacted to form a continuous section without a joint.

8.12. Rectification of Surface Irregularities

The finished surface should be checked for line, level, grade and surface finish. Provisions, in Chapter 7 of IRC : SP : 11-1977 "Handbook of quality control for construction of road and runways (first revision)" should be followed for this purpose. Any area involving any type of undulation or waviness should be removed and relaid to the specification and the surface should be levelled.

8.13. Curing and Sealing

Curing period, temperature and moisture maintained during the process of curing period are important factors in the deve-

lopment of strength. Field curing takes place over a range of optimum temperature though the range prescribed for laboratory testing is from 30°C to 38°C. Both extension of curing period and increasing the curing temperature result in increased pozzolanic reaction. The best method of controlling the curing moisture content is to cover the lime-flyash-soil layer as soon as possible after compaction with a bituminous coating as a protection to prevent drying. The bituminous material to be used for the purpose may be a cut-back (MC-30) applied at 50°C to 60°C or an emulsion applied at 25°C to 55°C at the rate of 8.3 kg per 10 sq m. Additional layers such as base course are constructed, soon thereafter. When a bituminous cut-back is applied at a higher temperature, it may cause loss of moisture in the soil-lime mix. So it is desirable if a slight sprinkling of water is made before applying the cut-back.

Curing of the compacted layer can also be done, by spreading moist straw or sand and sprinkling water on the compacted surface. In that case, a minimum curing period of 28 days is recommended before placing the next layer. This may be done by sprinkling water 5 to 6 times a day ensuring that moisture is maintained close to OMC. Until curing is completed, no traffic shall be allowed on the stabilised layer. Even no construction equipment of such weight which can cause marring or rutting of the surface shall be allowed to ply on the layer. Only light, essential construction equipment may be allowed to ply till the curing is completed.

8.14. Arrangements of Traffic

During the period of construction flow of traffic shall be maintained as per clause 105 of Ministry of Shipping & Transport Specification for Road and Bridge Works.

9. QUALITY CONTROL

For the satisfactory performance of the lime-flyash-soil stabilised road, a strict quality control is very essential. For each consignment of lime and flyash, tests should be done to check the

purity. In the case of lime, Cao content should be determined and it should not be less than 60 per cent. In the same way, flyash should have required fineness i.e. specific surface area should be 3200 cm^2/gm or 320 cm^2/kg. With a view to ensuring adequate strength of the sub-base or base course, density measurements should be made at regular intervals. The compacted layer should be cured for the stipulated period. The quality control tests with minimum desirable frequency should be as given in *Appendix*.

Appendix

QUALITY CONTROL TESTS AND THEIR MINIMUM DESIRABLE FREQUENCY SHOULD BE AS GIVEN BELOW

(i) Quality of Lime Purity of Lime : IS : 1514	:	One initially for approval of source of supply. Later one test for each consignment subject to a minimum of one test per five tonnes of lime.
(ii) Quality of Flyash IS : 3812-1982	:	One initially for approval of source of supply. Later one test for each consignment of the material.
(iii) Lime/flyash content	:	Regularly through procedural checks.
(iv) Degree of pulverisation	:	Periodically as considered necessary.
(v) CBR test on a set of three specimen	:	As required.
(vi) Moisture content prior to compaction	:	One test per 250 m^2
(vii) Density of compacted layer	:	One test per 500 m^2
(viii) Deleterious constituents	:	As required
(ix) Control of grade. camber, thickness and surface finish	:	IRC : SP-11-1977-Regularly