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No. RW/NH-34041/35/88-DOII *Dated the 28th October, 1988*

To

1. Director General (Works), CPWD.
2. Director General Border Road Development Board.
3. All Chief Engineers of States & Union Territories dealing with roads

Subject : Road Subgrade — Guidelines on

It is universally recognised amongst highway engineers that the road subgrade is an extremely important component of the road pavement and efficient performance of the road pavement depends to a very large extent on the functioning of the subgrade. In view of its importance and special function, the road subgrade has been treated as distinct from rest of the earth work for road embankment in the Second Revision of Ministry's Specifications for Road and Bridge Works (1988). The specifications for the subgrade (Section 305) inter-alia provide for the following :—

a) The material should be free from logs, stumps, roots, rubbish or any other ingredient likely to deteriorate or affect the stability of embankment/subgrade.

b) Material from swamps and marshes or bogs, peat, log, stumps or perishable material, material susceptible to spontaneous combustions, material in frozen condition and clay of liquid limit exceeding 80 and plasticity index exceeding 55 are considered unsuitable for subgrade.

c) The maximum laboratory dry density when tested as per IS 2720 part VII (Determination of water content dry density relation using light compaction) of subgrade material (Standard Proctor density) shall be not less than 1.65 gm/cc.

d) Highly expensive clay exhibiting marked swell and shrinkage properties shall not be used in subgrade.

e) Field dry density as percentage of maximum laboratory dry density as per IS : 2720 part VII (Standard Proctor density) should be not less than 100% for the subgrade and moisture content at the time of compaction should be within 1% above to 2% below OMC (Optimum Moisture Content).

f) CBR of constructed subgrade shall not be less than CBR value adopted in pavement design. In case of lower values pavement design will be revised based on actual value obtained.

g) The surface of the subgrade at all times during construction shall be maintained at such a cross fall (not flatter than that required for effective drainage of an earthen surface) as will shed water and prevent ponding.

2. Subsequent to the publication of the above specifications the requirements for the subgrade for heavily trafficked roads, 15 msa (million standard axles) or more over the designed period of 10 years or more, have been further examined in the Ministry and it has been decided that for new pavement constructions (including widening/realignment) following shall be followed in addition :

2.1 Strength of subgrade for a heavily trafficked road (as defined above) shall be minimum of 5% CBR, preferably this value should be 7% or above, as far as possible.

2.2 Where it is envisaged to use vibratory rollers or other compaction equipment capable of achieving higher degree of compaction, field dry density of subgrade as percentage of maximum laboratory dry density as per IS : 2720 Pt viii (modified proctor density) shall be prescribed and it should not be less than 95%. In such cases the field dry density of earth work in embankment below the subgrade should also be prescried to be not less than 90% maximum dry density as per IS : 2720 Pt viii. (Determination of water content dry density relation using heavy compaction).

2.3 In case of vibratory rollers or other compaction equipment capable of higher degree of compaction, the loose thickness of each layer of soil for the subgrade and embankment could be upto 400 mm or 250 mm compacted, subject to the trial demonstration about efficacy of the equipment to be used to the satisfaction of Engineer that the density as per 2.2 above will be achieved for the material in use.

2.4 Where relative compaction is more than 95% with respect to modified proctor density as per 2.2. above CBR test may be conducted on samples remoulded at 95% modified proctor density at OMC and soaked for 4 days prior to testing unless otherwise indicated as per para 3.3.4.3 of IRC 37-1984.

2.5 Where the road shoulders are earthen to the full depth of the road pavement, the entire pavement section functions as housed in a box/trench and it leads to the entrapment of the water in the pavement layer and/or saturation of the subgrade soil. In order to obviate ill effects of such a situation drainage measures as stipulated in Clause 5 of IRC : 37-1984 shall invariably be taken suiting to particular situation.

3. General guidelines for selection of soil for embankment are given in Table 3 of IRC : 36-1970. Further it may be added that the soils of CH, OL, OI, OH classification, i.e. organic soils and peat shall not be used in subgrade. Often soils of CH, ML, MI & CI classification as per IS : 1498-1970 may show CBR less than 5%. These soils and other soils having CBR less than 5% shall not be used in subgrade unless treated by some method such as soil stabilisation to improve the soil properties and its unproved strength is 5% or more in terms of CBR value.

4. Keeping in view the importance of subgrade, guidelines on subgrade are enclosed herewith for general guidance. It is expected that observance of the instructions/guidelines will lead to better performance of road pavements and consequential reduction in Total Transportation Cost.

5. Suitable provisions shall be made in the Contract documents and specifications to incorporate the requirements spelt out above.

5. The contents may kindly be brought to the notice of all concerned working with you for adoption. The Ministry would welcome feed-back on implementation of these guidelines.

Enclosure to Ministry's letter No. RW/NH-34041/35/88-DOII dated 28th October 1988. and Circular No. 304.7/406.

GUIDELINES ON ROAD SUBGRADE

1. Introduction

1.1 The importance of road subgrade in the efficient and economic performance of a highway can never be over-emphasised. The road subgrade has been varioulsy defined as the 'natural foundation' or 'fill material' which directly receives the load from the pavement or 'the in-situ soil' on which the highway pavement is constructed. It will be noted that although at times it has been termed as 'soil surface' and 'foundation' it can neither be treated only as a part of the embankment nor fully as a part of the pavement. The subgrade requires individual identity, special attention and separate treatment.

1.2 In recent years this aspect has engaged the attention of the highway engineers in most countries. PIARC — the Permanent International Association of Road Congresses has also taken note of the situation and has observed that now an increasing attention is being paid to the road subgrade although this layer is not envisaged similarly by all countries'. Also, considering that pavement performance is dependent on the inservice functioning of subgrade, added importance is being attached to the provision of a dependable subgrade rather than providing a thicker pavement subbase and/or base-over a weak subgrade with addition of overlays at times at subsequent stages.

1.3 In view of the importance and the special function of the subgrade as the part of embankment acting as foundation layer for the road pavement, it is necessary that the zone immediately and directly affected by the load of traffic is demarcated, and a strategy is developed for improvement in its strength and performance and a rigorous quality control is exercised during the construction of this layer.

2. Extent of Subgrade

2.1 At present there is no uniformity of opinion regarding the depth or extent upto which the embankment can be considered as effective 'subgrade'. The second revision of the 'Book of Specifications for Road and Bridge Works (1988) of the Roads Wing indicates 500 mm as the depth of subgrade below the pavement. Considering the general effect of load on the subgrade many authorities have felt the need for extending the thickness of the subgrade layer to a larger depth say about 1 metre to 1.2 metre or the depth upto which vibrations due to dynamic loads both during construction operations of various pavement layers and during in-service life of the road pavement have appreciable effect.

2.2 This Ministry has undertaken a research scheme (R-5-'Studies on moisture content for the evaluation of subgrade strength for pavement design under different conditions') the field work for which in a number of States has been completed recently. Although the data collected are still under analysis findings for the observations made in the State of Tamil Nadu point out, among other things, the following :—

(i) The evapotransportation is high on the top 0.6m of the subgrade/embankment.

(ii) When watertable is far below and shoulders are of earth moisture content of subgrade is influenced by rainfall upto a depth of 0.9 m to 1.2 m in case of clayey sand and sandy clay subgrade. During rains moisture content below subgrade at the centre of pavement increases upto a depth of 1.2 m. Below this depth moisture content is in decreasing order.

(iii) If the subgrade is sandy then depth of subgrade has no effect in the changes of moisture i.e. the moisture content of the sandy sub-grade remains constant irrespective of rainfall.

2.3 Considering that the effects of load and rainfall are most pronounced in the top 300 mm to 500 mm, it has been suggested by many authorities to divide the subgrade into two parts i.e. the 'upper subgrade' and the 'Lower subgrade'. The Upper Subgrade thickness is confined to the top 300 mm/500 mm and the rest of the depth underneath (up to 1 to 1.2 m) may be termed as 'Lower Subgrade'.

The two portions may also be assigned different degree of compaction, density and strength requirement criteria.

2.4 It may, however, be mentioned in this connection that the concept of a thicker subgrade or division of subgrade in two parts are not directly applied to Indian practices at the present moment and the thickness of subgrade in clause 305.1.2 of the specifications will only hold good. However, the principle is applied in identical manner in construction of Subgrade and embankment below the subgrade.

3. **Material for Subgrade**

3.1 In general, the material for subgrade is the local soil in its full depth. But with the introduction of the concept of subgrade of a predetermined strength, the material can be artificially improved, strengthened in its properties or the subgrade can be built up with different materials altogether, if necessary. It will perhaps be ideal if the ordinary local soil, if otherwise considered permissible for use in embankment and subgrade as per provisions of specification,is used just below the subgrade in the embankment (or in the so called lower subgrade) and superior materials, either local or obtained on lead by selection, is saved for being used in subgrade.

3.2 Certain physical requirements of the material for the subgrade have already been indicated in clause 305.2.1 of Ministry's 'Book of Specifications for Road and Bridge Works (Second Revision). The same are repeated below for recapitulation.

(i) The materials used in embankment and subgrade shall be earth, moorum, gravel, a mixture of these or any other material approved by the Engineer. Such materials shall be free of logs, stumps, roots, rubbish or any other ingredient likely to deteriorate or affect the stability of the embankment subgrade.

(ii) The following types of materials may also be considered unsuitable :

a. Material from swamps, marshes or bogs,

b. Peat, log, stump or perishable material.

c. Materials susceptible to spontaneous combustion.

d. Materials in a frozen condition.

e. Clay of liquid limit exceeding 80 and.plasticity index exceeding 55.

All materials unsuitable for use in embankment are also unsuitable for use in the subgrade.

(iii) The work shall be so planned and executed that the best available materials are saved for the subgrade and the embankment portion just below the subgrade.

(iv) The size of the coarse material in the mixture of earth shall not exceed 60 mm when being placed in the subgrade.

(v) The density requirement of material being placed in the subgrade, earth shoulders and verge shall not be less than 1.65gm/cc in maximum laboratory dry density as per IS : 2730 (Part-VII).

(vi) Highly expensive clays, exhibitiny marked swell and shrinkage properties shall not be used in the subgrade.

4. **Layer Thickness for Construction**

As per the existing provisions in the Ministry's Specifications for Road and Bridge works (Second Revision) layers of material for construction are to be laid in loose thickness not exceed 250 mm. In general, the same will hold good for most works using, conventional compactions.equipment. However, where vibratory rollers or other equipment capable of exerting high compaction efforts are used, depending on the material to be compacted, larger loose thickness of layers may be allowed by the Engineer. The Ministry has already taken up a scheme for formulating thickness specification for some common types of materials under compaction by vibratory rollers and it is expected that the recommendations regarding the above will be available soon.

Till such time that the results of the above are out, the Engineer may, however, at his discretion allow, laying and compaction of material upto a maximum loose thickness of 400 mm for compaction or 250 mm compacted thickness under vibratory roller of adequate weight (not less than 10 tonnes) when he is thoroughly convinced as per actual field demonstration trials that the type of soil in use can be properly and economically compacted upto the required density by the equipment in use.

5. **Compaction and Strength**

5.1 It is commonly known that, in general, the strength of a material in embankment and subgrade increases with increase in density and compaction. Findings of an earlier study carried out by CRRI are :

(i) The higher the initial density of the subgrade material the higher is its CBR value.

(ii) The higher the intial density, the lesser is the fall in CBR as a result of increased intake of moisture by the subgrade. (except in certain expensive clays)

(iii) The typical effect of increase of stress on an alluvial soil in the subgrade is causing compaction or settlement within itself and consequent deformation on the surface.

(iv) At suitable moisture the same loads can increase the density of a soil considerably and the effect is further enhanced at higher loads. With a change in weather conditions, the moisture in the subgrade keeps changing and it is possible for loads to catch the subgrade soil at moisture most suitable for providing maximum possible compaction and consequent deformation.

(v) In a large majority of the cases, the settlement of the road starts from the subgrade because of its low degree of compaction in relation to loads imposed on it.

(vi) In cases where the subgrade gets saturated due to water logging, settlement under load and bulging on the sides is possible causing a partial failure of the subgrade due to plastic deformation. The complete failure is accelerated in most cases by ingress of moisture from the top.

(vii) There is a case for compaction of the subgrade so as to substitute a part of the thickness of the pavement with processed soil.

5.2 The Ministry's 'Specifications' states that only the compaction equipment approved by the Engineer shall be employed to compact the different material types encountered during compaction. Smooth-wheeled, vibratory, pneumatic, sheep's foot roller etc. of suitable size and capacity as approved by the Engineer shall be used for the different types and grades of materials required to be compacted either individually or in suitable combinations. If directed by the Engineer, the Contactor shall demonstrate the efficacy of the equipment the intends to use by carrying out compaction trials.

5.3 Each layer of the material shall be thoroughly compacted to the densities specified in Table 300-2 of the Specifications. Subsequent layers shall be placed only after the finished layer has been tested according to clause 902 and accepted by the Engineer. A record of the same shall be maintained by the Contractor. When density measurements reveal any soft areas in the embankment/ subgrade, earthen shoulder (verge), further compaction shall be carried out as directed by the Engineer. If inspite of that, the specified compaction is not achieved, the material in the soft areas shall be removed and replaced by approved material, compacted to the density requirement and satisfaction of the Engineer.

5.4 It will be noted that although all types of compaction equipments including vibratory roller are covered in the list of equipment mentioned in the specifications the compaction requirement in subgrade as per Table 300-2 is restricted only to 100% of Proctor's Density (IS : 2720-Part VII). This is, of course, because of the obvious reasons of non-availability of suitable compaction equipment in common constructions works. This, it is apprehended may lead to wastage of compactive effort on many occasions where better equipment for compaction are available. Also, there are a number of heavily trafficked corridors in the country where a higher degree of compaction in the subgrade at the initial stages i.e. construction may be actually needed because of existing high axle-loads and a high repetition of load otherwise the subgrade will get further compacted during its inservice life which will be detrimental to the road pavement. Keeping in view the above it is being suggested that in selected cases of new construction of important road links, specially where heavy vibratory rollers are envisaged for use, field dry density of subgrade may be specified as 95% of modified proctor Density (as per IS-2720 Pt-VIII). In such cases the field dry density of earthwork below the subgrade of 500 mm (lower subgrade) shall not be less than 90% maximum dry density as per IS: 2720-Pt-VIII. (i.e. modified proctor density).

5.5 Further, it will also be noted that the Specification does not at present specify any definite minimum value for subgrade strength. Clause 305.9 only provides that it shall be ensured that prior to actual execution the borrow area material to be used in the subgrade satisfies the requirement of designCBR and the subgrade shall be compacted and finished to the design strength consistent with other physical requirements.

It will be seen that with increase in strength of subgrade soil, the requirement of thickness for flexible pavement considerably reduces for a given value of repetition of standard axles. Also providing a thicker subbase over a weak subgrade and improvement of subgrade strength (by any method) may not exactly mean the same thing either in cost or in effect. Since the level of the subgrade top remains in most cases fixes from the consideration of prescribed clearance over HFL etc., saving in final height of road and consequent material required for construction (for the total embankment, cross-drainage work, slope-protection etc.) can be made only by reducing requirement of pavement thickness.

In view of the above it is felt that serious thought need be given to improve the CBR in the subgrade material. It is suggested that preferably, compatible with demands of economy, all attempts should be made to achieve a minimum CBR of 5% in the subgrade (in the top 500 mm below pavement). In the area below it for another 500 mm (which may conform to the lower subgrade) material with at least a CBR of 2% should be sought to be provided. Although the above is not at present mandatory as per specifications, a good beginning can be made in selected schemes of new constructions of important roads.

6. Methods for Strengthening and Improving Subgrade

6.1 The need for a strong and dependable foundation material for the pavement structure can be met in various ways. A suitable locally available subgrade material can be searched for or use can be made of a selected soil of desired strength, if available within economic leads. In case the local soil is not suitable to be used in the subgrade and it is also not possible to import suitable soil economically, one of the following methods may be adopted to improve its strength :

(i) Mechanical stabilisation with sand, murum and other coarse grained material.

(ii) Line/cement stabilisation.

(iii) Bitumen stabilisation.

(iv) Chemical stabilisation.

(v) Reinforcement of soil with various materials.

6.2 The treatment has preferably to be a permanent one improving with time and under traffic. Possibility of speedy and easy execution will be added advantage.

Mechanical stabilisation and stabilisation with addition of lime, cement, bitumen or chemical additives are well-known techniques in highway engineering and available guidelines/procedures for the same may be made use of. Use of new chemical stabilising agents are also reported which, it is claimed, lead to 'petrification' or 'irreversible agglomeration' of fines to increase the strength of the material. Use of chemical agents for stabilisation, however, is not common in this country at present.

In the recent years use has also been made of geosynthetics (geotextiles/geogrids) at the interface of subbase and subgrade or within the subgrale to indirectly improve its strength. Geosynthetics are generally used in case of weak subgrade with CBR of 3% or less and it is claimed by the manufacturers that improvement in subgrade strength achieved is of the order of 3% to 4% of CBR. Apart from reinforcing the geosynthetics may perform drainage and separation functions also when used on the subgrade top.

7. **Other Factors Influencing the Performance of Subgrade**

7.1 There are several other factors which have marked effect on the strength and performance of the subgrade. Skill of construction, height of water-table, perviousness of the wearing surface, cross-fall in the subgrade and quality control on work during construction are some of these points.

7.2 Saturation of subgrade soil brought about by capillary moisture with rise in water-table due to subsequent changes in surrounding ground and drainage conditions will naturally affect subgrade strength.

7.3 Ineffective drainage at the interface of subgrade and the bottom of the pavement may result in saturation of both the subgrade and the pavement over it. The need to provide adequate drainage to the subgrade and earthwork to maintain them properly to avoid pavement failures is widely recognised. Adoption of drainage systems using granular filter material in conjunction with geotextiles is common in many developed countries.

Plastic sheeting and other impervious membranes are also used to prevent wetting of the subgrade during rains.

7.4 The longitudinal gradient of the road affects the subgrade drainage. It is a common knowledge that a road having pronounced longitudinal gradient has better drainage potential than the one with a level or near-level longitudinal profile.

7.5 Crossfall requirement for efficient drainage of subgrade deserves serious consideration. In this regard the TRRL laboratory Report-1132. (The structures design of bituminous roads) stipulates that under average construction conditions of variable weather if delay is unavoidable, it is particularly important that the site be well-drained with soil laid to a good fall.

However, in actual practice in India the cross-fall provided in the subgrade is same as that in the wearing surface for ease of construction of pavement layers. Generally the wearing surface is bituminous in flexible pavements. The cross-fall requirement for efficient drainage of a bituminous surface is much less than that for an earthen surface. It will be noted that cross-fall provision in subgrade (an earthen surface) of the same order as that for a bituminous surface is not at all conducive to quick and proper drainage of the water accumulation at the interface of the subgrade and the bottom of the pavement structure. Besides, the construction schedule is normally such that the subgrade and the pavement are not constructed in one go. Many a time the road is constructed only upto the formation level and the pavement structure is provided at as much later date under a separate package. In addition shoulders are generally earthen and granular subbase is generally constructed to the carriageway width only. All these together lead to situation rendering drainage of the subgrade sluggish. Apart from having adverse effect on the subgrade, the prolonged saturation of the granular subbase/base adversely affects stability leading to pavement failure.

In the light of the above, it is felt necessary that the cross-fall in the subgrade be provided to match the requirement of draining the material used in the subgrade.