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# Use of Cemented Materials for Pavements on the Basis of Experimental Study

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**ABSTRACT**

**Since Vedic period, mankind has used the natural earth surface for transportation mode. The soil surface roads have been well settled by human and animal traffic and the tracks were developed as a natural result of the movement of traffic. These road surfaces were very large width and covered with stones and gravel, and thus made suitable to tackle the traffic harmless. However, these road surfaces were ruined in to masses of mud by the spring and rain, where as in the summer season the bull carts created clouds of dust. Several precautions were made to take care of these problems. The results of these techniques subsequently results in various pavement design concepts and guidelines.**

## 1. INTRODUCTION

Many of the pavement design guidelines are based on the assumption that aggregates are important materials of pavement structure. However, availability of good quality aggregates may be a lack in some locations. To transport good quality aggregates to large distance may not be economically feasible. Due to the excessive investment and maintenance cost, new methods of design had to be created and new building materials are introduced. Some scientist tried with soil, which is available everywhere. The engineering properties of soil were increase using certain treatment. At the same time various waste products are created by several industrial plants. These waste products could be used in the road construction projects after following certain treatment procedure. By treating natural soil or fly-ash, or by addition of certain materials to it, new road construction materials can be developed. Thus we can use of stabilized soil/waste product as a base/sub-base ingredient of pavement leads not only economic solution, but also offers a potential use of the industrial/domestic waste materials. Thus cemented bases and sub-bases can be designed to economize the feature where, locally available inferior quality materials are stabilized using cemented material.

Many of soils are differentiated by high swelling on wetting and excessive shrinkage on drying. When swelling is restricted, it results in commencement of swell pressure. On account of these peculiar properties, this soil cause serious problems in the construction of roads. Even at places where condition for development of swell pressure do not exist, the road still fails because of poor supporting power of the sub grade in wet condition. Therefore we need a technique for an effective and economic stabilization of such type of soil.

Stabilization of low quality aggregate or soil can be done by many treatments it may be mechanical, chemical, electrical or thermal means. Chemical stabilization involves addition of some admixture like cement, lime, fly-ash, bitumen, chemical compounds etc. In this research work, it is proposed to investigate the best combination of soil-cement-water and fly-ash-lime-water-sodium chloride-fiber-bitumen for the purpose of deciding its performance as pavement base or sub-base material. Fly-ash was stabilized by adding water, lime, sodium chloride, fibers, and bitumen. Combination of soil-cement in the presence of water was considered as another material for pavement base or sub-base.

## 2. SCOPE

The scope of this research is to study the use of cemented materials as a pavement base or sub-base material and suggest guidelines for its use. Following cemented materials are considered in the present study.

- Fly-ash-Lime-Water-NaCl-Fibre-Emulsion

- Soil-water-cement

## 3. BACKGROUND AND LITERATURE REVIEW

Many engineering properties of fly-ash and soils were beneficially modified by cemented materials like lime or cement treatment. Although lime was primarily utilized to treat fine grained soils, it also can be used to modify the characteristics of fine fraction of more granular soils. Cement is suitable for practically various types of soils. Cemented materials have been used in pavement construction as modified sub-grade, sub-base materials, and base materials. In this chapter major research work related to stabilization of cemented material and use of cemented material as an pavement base and sub-base is created.

## 4. NEED OF STABILIZATION

The aggregates are very important matrials of pavement structure. Good quality aggregates may be not always be available nearby the construction site. Transporting the aggregates from large distance may not be economically feasible. Under such conditions, locally available inferior quality material like soil or industrial waste material like fly-ash may be proposed to be used in pavement as base/sub-base material. These materials are of inferior quality, and hence may not satisfy the requirement as pavement material. Therefore engineering properties of these materials are increase by means of a process, known as stabilization. This is not only economic solution, but also offers a potential use of the industrial and domestic waste materials. Advantages of stabilization are summarized in the following.

**1.** Improved stiffness and tensile strength of the material.
**2.** Reduction in pavement thickness.
**3.** Improved durability and resistance to the effect of water.
**4.** Reduction is swelling potential

Mechanism of stabilization can be divided into two categories, mechanical and chemical stabilization. Mechanical stabilization includes compaction, blending of aggregates to improve gradation, and addition of asphalt. When Asphalt is use as a stabilizer, does not generally react chemically with the materials being stabilized, but coats the particles and imparts adhesion and helps waterproofing. Chemical stabilization includes addition of materials such as lime, cement or fly-ash in combination or alone. These materials either react chemically with materials being stabilized (for example, lime reacts with clays) or react on their own to form cementing compounds (for example, Portland cement).

## 5. BASIC MATRIALS FOR CEMENTED BASE OR SUB-BASE IN PAVEMENT

Fly-ash, Portland cement and lime are mostly used cementing materials for construction of cemented base with soil, sand and aggregates for pavements of roads and runways. Low grade or marginal aggregates with suitable mix proportioning of coarse and fine fractions, lime-clay, lime-laterite-soil, lime-fly-ash, lime-granulated blast-furnace-slag-soil mixture, etc. can be used as a cemented base or sub-base. Various types of materials are considered by several researchers to study the suitability of those materials as pavement base or sub-base layer. Natural soil, fly-ash, sand, stone dust, river bed materials, reclaimed asphalt pavement, low quality aggregates etc. are considered as matrials of pavements with cemented base/sub-base. Cemented materials may be classified in three forms:

1. Traditional stabilizers: hydrated lime, Portland cement, and fly-ash

2. By-product stabilizers: cement kiln dust, lime kiln dust and other forms of byproduct lime and

3. Non-traditional stabilizers: sulfonated oils, potassium compounds, ammonium chloride, enzymes, polymers

## 6. MIX DESIGN

Mix design is the process of choosing the optimum stabilized content of various materials of the pavement. The general principle of mix design is that the mixture should provide satisfactory performance when constructed in the desired position in the pavement structure of sub-grade. Design proportions of the materials are generally based on an analysis of the effect of various proportions on selected engineering properties of the mix. Numerous research publications and technical guides are available to aid the engineer in the selection criteria to find out the amount of each ingredient. A wide variety of test methods has been proposed such as- Cali-fornia procedure, Eades and Grim procedure, Illinois procedure, Louisina procedure, Oklahoma procedure, South dekota procedure, Texas procedure, Thompson procedure, Virginia procedure etc. Engineering properties which are considered, depending on the objective are- Attenberg limits California Bearing Ratio (CBR), swell potential, unconfined compression strength (UCS) of cured or uncured mixtures, Freeze-thaw and wet-dry test etc. The mix design procedure includes the testing for strength and for durability. Most researchers reported that a minimum of 3 percenatge lime is necessary to produce adequate reaction in the field. The National Lime Association recommends 3, 5 and 7 percentage lime in the trial mixes.

## 7. PAVEMENT DESIGN

Mechanistic-empirical pavement design procedure has become popular in many countries includ-ing USA, Australia, South Africa and other countries in Europe. Though the design parameters viz., traffic and environment may vary from country to country, the basic principles of analytical design are universal in nature. Indian Road Congress suggests some guidelines which deal with some practical issues related to the use of cemented materials in pavement structure, and are not applicable for structural design of bituminous pavement with cemented base or sub-base. Das and Pandey proposed methodology for mechanistic design of pavement with cemented base which is similar to that proposed by Austroads, South African Code, and other researchers. Singh and Baffour proposed the design methodology for lime stabilized laterite roads, in which he assumed two approaches as cracked and no cracking approach. Cracked approach makes use of an assumption that the pavement possesses slab-type behavior. In this approach, selection of the base thickness is made on the basis of flexural stress of the stabilized layer, the tensile strains in both the asphalt and the stabilized layer and the vertical compressive strain at the top of sub grade. The second approach (no cracking) makes the assumption that the lime stabilized layer will crack shortly after construction, hence it can be assumed as well-compacted granular material. Due to cracking the modulus of stabilized layer will reduces. Otte et. al. proposed the mechanistic structural design procedure for pavements with cement and lime treated lay-ers, in which he considered the traffic associated cracking as limiting distress condition. The gradual cracks in cemented material results in reduction in the effective elastic modulus value. AASHTO guidelines also suggests that an additional distress that needs to be considered in cemented pavements is fatigue fracture in the underlying chemically stabilized base layers. Un-der repeated applications of loading, microcracks form in these layers leading to a stiffness or modulus reduction and ultimately to fatigue fracture. This process will have a impact on the distress progression in the overlying layers, which will reduce the support provided to the up-per pavement layers. AASHTO also suggests the performance criteria for fatigue cracking in chemically stabilized which is defined in terms of a damage index. Typical design damage index values for fatigue cracking in chemically stabilized layers are on the order of 25 %.

1. The first phase is the period soon after construction, when the elastic modulus of cemented layer is high. Hence original elastic modulus (E) value is taken as initial E value of the cemented material. The cracks get propagated due to the shrinkage, thermal effects and construction traffc. Thus the effective elastic modulus drops from E1 to E2 soon after the pavement is opened to traffic. As phase I is too short, it is not considered within the design period

2. For phase II, tensile strain is computed at the bottom of the cemented base with elastic modulus as E2. The fatigue equation of the material can be used to calculate the fatigue life of the cemented base. Since modulus of the bituminous layer is lower than cemented layer, flexural fatigue of bituminous surfacing will not govern the pavement performance as long as cemented layer is intact.

3. When the life of cemented material is consumed completely, it becomes fully cracked and no longer behaves like a layered elastic material, rather it can be considered as a granular layer with an elastic modulus of E3, for the phase III. The elastic modulus will reduce due to cracking and several guidelines suggest various percentage reductions. For example, South African guidelines suggests 90 % reduction in elastic modulus. The fatigue life for the third phase is estimated from the maximum tensile strain at the bottom of bituminous layers.

4. The layer thickness of bituminous layer and cemented layers are adjusted such a way that the sum of these two fatigue lives becomes the design life.

## SUMMARY

The summary of the present study is presented below.

1. Various matrials materials and various mix design procedures for cemented/stabilized layer in the pavement structure has been reviewed.
2. Two types of mixes are considered in the present study viz,
    a. FLWSRE mix (fly-ash + lime + water + sodium chloride + fiber + bitumen) and
    b. SCW mix (soil + cement + water).
3. The optimal proportion of the matrials of the mix is obtained by performing UCS test.
4. CBR test is performed to check the suitability of the mix as a pavement material, and result of soaked and unsoaked CBR test indicates that the proposed proportion of the matrials can be used as pavement base and sub-base layer.
5. The elastic modulus and fatigue life of the SCW mix is evaluated by performing fatigue test on the SCW mix. Fatigue curve is developed for SCW mix and attempt has been made to explain cemented pavement design procedure with an example.

## CONCLUSION

The optimal proportion of the matrials of FLWSRE mix is obtained as, 33 % water, 11 % lime, 0.30 % 12 mm fibers, 1 % sodium chloride, and 1.3 % bitumen which gives maximum UCS of the order of 390 kPa.

The optimum proportions of matrials of SCW mix is obtained as 6 % cement content and 14 % water content which gives the maximum UCS of order of 1.388 MPa.

The unsoaked and soaked CBR of FLWSRE mix is obtained 23.26 % and 18.96 % respec-tively.

The unsoaked and soaked CBR of SCW mix is obtained 86.16 % and 73.31 % respectively.

From UCS, CBR and fatigue test results on SCW mix, following relationship can be developed for elastic modulus. $E = 0.928 \times CBR$ and $E = 57.64 \times UCS$

From fatigue tests on SCW mix, elastic modulus of mix is obtained. From fatigue life Vs strain plot, design of bituminous pavement with cemented base is performed and compared with conventional design of bituminous pavement with granular base. It has been observed that the life of former is more than that of later configuration. Hence bituminous pavement with cemented base is economical than bituminous pavement with granular base.

## FUTURE SCOPE

This section gives some of the works that can be taken as further study-

1. Various combinations of the materials, like recycled aggregates, poor quality aggregates etc. can be tried and the mix which gives maximum fatigue life can be obtained.
2. Most economical combination of the layer thickness and material properties can be ob-tained by performing economical analysis.
3. Durability test can be performed to ensure about the performance of stabilized layer.
4. Rutting equation can be developed for bituminous pavement with cemented base.

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