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QUALITY CONTROL CONSIDERATIONS FOR FLEXIBLE PAVEMENTS-BEFORE CONSTRUCTION.

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Abstract: *Quality assurance is the planned and systematic actions necessary to provide adequate confidence that the work is satisfying all the quality requirements. Thus, the quality control system includes all those planned actions that are necessary to provide adequate confidence that the products or service will meet the requirements and is essentially a system of planning, organizing. and controlling human skills to assure quality. The quality control involves the acceptance criteria which includes the tests, frequency of testing and tolerance limits, inspections for critical examination of the work by selected tests to determine its conformity to specifications and action taken to ensure quality. In the existing system, the quality control tests are carried out at the three different levels; before, during and after construction. In the present paper some effective ways to ensure quality control before the construction of flexible pavements is studied.*

Keywords: *Flexible Pavements, Quality Control, Base Course, Aggregates.*

1.Introduction

Flexible pavements are those pavements which on the whole have low or negligible flexural strength and are rather flexible in their structural action under the loads. The flexible pavement layers reflect the deformation of the subgrade and the subsequent layers on-to the surface of the layer. Thus if the lower layer of the pavement or soil subgrade is undulated, the flexible pavement surface also gets undulated. A typical flexible pavement consists of four components: (1) soil subgrade (2) sub-base course (3) base course and (4) surface or wearing course.

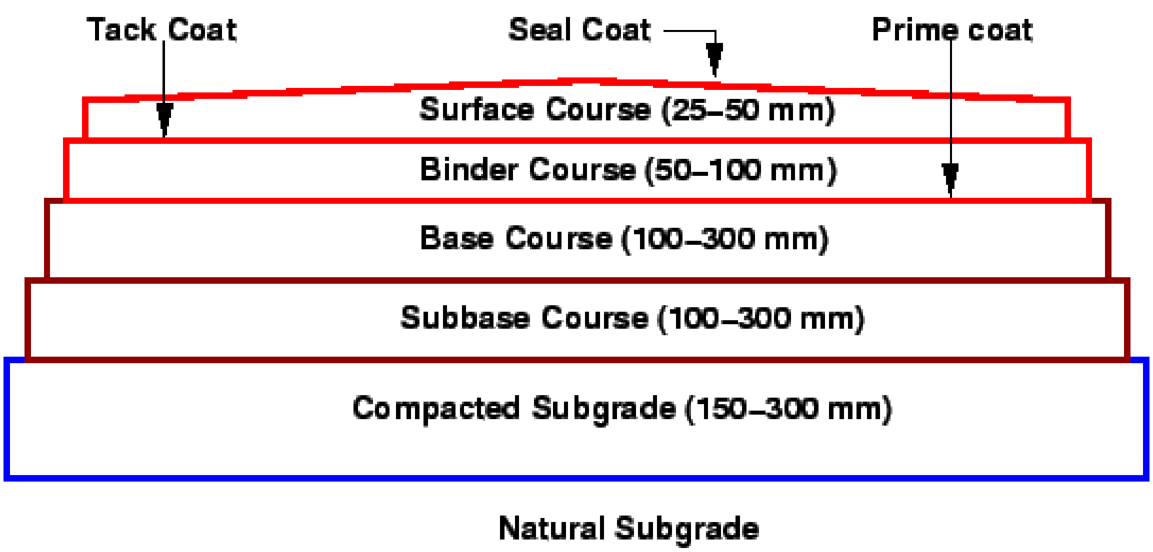

Fig1.Typical cross section of a flexible pavement
Source: Pavement Design by Tom Mathew and Krishna Rao

The flexible pavement layers transmit the vertical or compressive stresses to the lower layers by grain to grain transfer through the points of contact in the granular structure. A well compacted granular structure consisting of strong graded aggregate (interlocked aggregate structure with or without binding materials) can transfer the compressive stresses through a wider area and thus forms a good flexible pavement layer. The load spreading ability of this layer therefore depends on the type of materials and the mix design factors. Examples of flexible pavement layer materials are: Bituminous concrete, Water bound macadam, Wet mix macadam, Hot mix asphalt etc. The vertical compressive stress is maximum on the pavement surface directly under the wheel load and is equal to the contact pressure under the wheel.

Due to the ability to distribute the stresses to a larger area in the shape of a truncated cone, the stresses get decreased at the lower layers. Therefore by taking the full advantage of the stress distribution characteristics of the flexible pavement, the layered system concept was developed. According to this, the flexible pavement may be constructed in a number of layers and the top layer has to be the strongest as the highest compressive stresses are to be sustained by this layer in addition to the wear and tear due to the traffic. The lower layers have to take up only lesser magnitude of stresses and there is no direct wearing action due to traffic loads, therefore inferior materials with lower cost can be used in lower layers. The lowest layer is the prepared surface consisting of the local soil itself, called the subgrade. Each of the flexible pavement layers above the subgrade, viz. sub-base, base course and the surface course may consist of one or more number of layers of the same or slightly different materials and specifications.

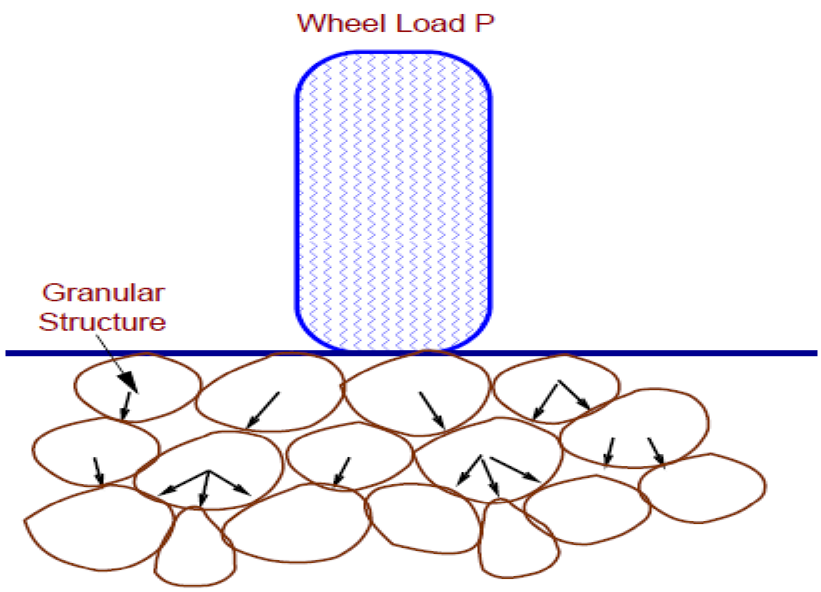

Fig 2.Load transfer in granular structure
Source: Pavement Design by Tom Mathew and Krishna Rao

2. Quality control considerations before construction

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2.1 Preliminary investigations. Characteristics of subgrade soils and peculiar features of the site must be known to predict pavement performance. Investigations should determine the general suitability of the subgrade soils based on classification of the soil, moisture-density relation, degree to which the soil can be compacted, expansion characteristics, susceptibility to pumping, and susceptibility to detrimental frost action. Such factors as groundwater, surface infiltration, soil capillarity, topography, rainfall, and drainage conditions also will affect the future support rendered by the subgrade by increasing its moisture content and thereby reducing its strength. Past performance of existing pavements over a minimum of 5 years on similar local subgrades should be used to confirm the proposed design criteria. Soil conditions should be investigated by a combination of a general survey of subgrade conditions, preliminary subsurface investigations, and soil borings.

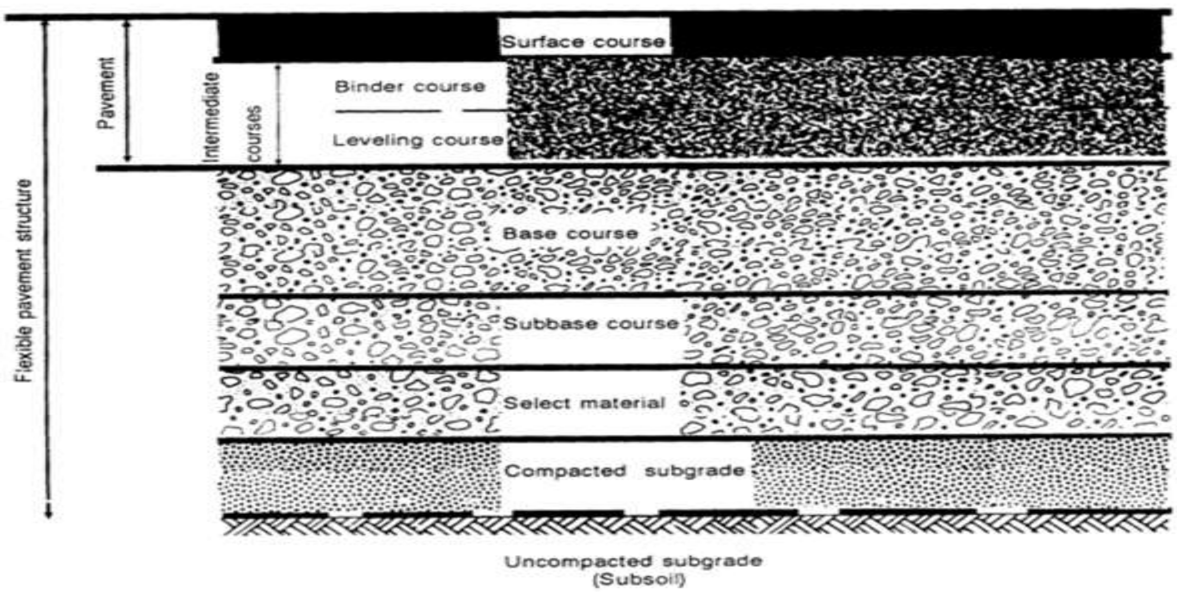
Where material is to be borrowed from adjacent areas, subsurface explorations should
these areas and carried 2 to 4 feet below the anticipated depth of borrow. Samples from the explorations should be classified and tested for moisture content and compactions characteristics.

2.2 Site preparation. The soil subgrade is a layer of natural soil prepared to receive the layers of pavement materials placed over it. The loads on the pavement are ultimately received by the soil subgrade for dispersion to the earth mass. It is essential that at no time the soil subgrade is overstressed .It means that the pressure transmitted on the top of the subgrade is within the allowable limit, not to cause excessive stress condition or to deform the same beyond the elastic limit. Therefore it is desirable that atleast top 50cm layer of the subgrade soil is well compacted under controlled conditions of optimum moisture conditions and maximum dry density. It is necessary to evaluate the strength properties of the soil subgrade. This helps the designer to adopt the suitable values of the strength parameter for design purposes and in case this supporting layer doesn't come up to the expectations, the same is treated or stabilized to suit the requirements.

Site preparation is the first major activity in constructing pavements. This activity includes removing or stripping off the upper soil layers from the natural ground. All organic materials, topsoil, and stones greater than 3 inches in size should be removed. Removal of surface soils containing organic matter is important not only for settlement, but also because these soils are often moisture-sensitive, they lose significant strength when wet and are easily disturbed under construction activities. Most construction projects will also require excavation or removal of in-situ soil to reach a design elevation or grade line.

2.3. Material investigation.

2.3.1. General. It is common practice in pavement design to use locally available or other readily available materials between the subgrade and base course for economy. These layers are designated as select materials or sub bases. Those with design CBR values equal to or less than 20 are designated select materials, and those with CBR values above 20 are designated sub-bases. Minimum thicknesses of pavement and base have been established to eliminate the need for sub-bases with design CBR values above 50.Where the design CBR value of the subgrade without processing is in the range of 20 to 50, select materials and sub-bases may not be needed. However, the subgrade cannot be assigned design CBR values of 20 or higher unless it meets the gradation and plasticity requirements for sub-bases.



Note:-All layers and coats are not present in every flexible pavement structure. Intermediate courses may be placed in one or more lifts. Tack coats may be required between the intermediate courses and under the surface course.A prime coat may be required between the highest aggregate surface and the first layer of asphalt.

Fig3.Typical cross section of a flexible pavement
Source: Introduction to pavement design by Paul Guyer

2.3.2. Select Materials. Select materials will normally be locally available coarse-grained soils (prefix G or S), although fine-grained soils in the ML and CL groups may be used in certain cases. Limerock, coral, shell, ashes, cinders, caliche , disintegrated granite, and other such materials should be considered when they are economical. A maximum aggregate size of 3 inches is suggested to aid in meeting grading requirements.

2.3.3. Sub-base Materials. Sub-base materials may consist of naturally occurring coarse-grained soils or blended and processed soils. Materials such as limerock, coral, shell, ashes, cinders, caliche, and disintegrated granite may be used as sub-bases when they meet the requirements. The existing subgrade may meet the requirements for a sub-base course or it may be possible to treat the existing subgrade to produce a sub-base. However, admixing native or processed materials will be done only when the unmixed subgrade meets the liquid limit and plasticity index requirements for sub-bases. Material stabilized with commercial additives may be economical as a sub-base. Portland cement, lime, flash, or bitumen and combinations thereof are commonly employed for this purpose. Also, it may be possible to decrease the plasticity of some materials by use of lime or Portland cement in sufficient amounts to make them suitable as sub-bases.

2.3.4. Base course Materials. High-quality materials must be used in base courses of flexible pavements. These high-quality materials provide resistance to the high stresses that occur near the pavement surface. Guide specifications for graded crushed aggregate, limerock, and stabilized aggregate may be used without qualification for design of roads, streets, and parking areas. Guide specifications for dry- and water-bound macadam base courses may be used for design of pavements only when the cost of the dry- or water-bound macadam base does not exceed the cost of stabilized-aggregate base course, and the ability of probable bidders to construct pavements with dry- or water-bound macadam base to the required surface smoothness and grade tolerances has been proved by experience in the area.

2.3.5. Binder. The binder shall be an appropriate type of bituminous material complying with the relevant Indian Standard (IS), as defined in the appropriate clauses of the specifications. The choice of binder shall be stipulated in the contract or by the Engineer.

2.3.6. Coarse aggregates. The coarse aggregates shall consist of crushed rock, crushed gravel or other hard material retained on the 2.36mm sieve. They shall be clean, hard, durable, of cubical shape, free from dust and soft of friable matter, organic or other deleterious matter.

Where crushed gravel is proposed for use as aggregate, not less than 90% by weight of the crushed material retained on the 4.75mm sieve shall have at least two fractured faces.

2.3.7. Fine aggregates. Fine aggregates shall consist of crushed or naturally occurring material, or a combination of the two, passing 2.36 mm sieve and retained on the 75 micron sieve. They shall be clean, hard, durable, dry and free from dust and soft of friable matter, organic or other deleterious matter.

2.3.8. Source of material. The source of all materials to be used on the project must be tested to the satisfaction of and be expressly approved by the Engineer. Any change in aggregate source for bituminous mixes, will require a new mix design, and laying trials, where the mix is based on a job mix design. Stockpiles from different sources approved or otherwise, shall be kept separate, such that there is no contamination between one material and another. Each source submitted for approval shall contain sufficient material for at least 5 days work.

Aggregate is produced from materials formed by geologic processes on and within the Earth's crust. Sand and gravel created by the process of erosion may have been deposited thousands of years ago . Sand and gravel deposits are products of erosion of bedrock and the subsequent transport, abrasion, and deposition of the particles. Water and glacial ice are the principle geologic agents that affect the distribution of deposits of sand and gravel. Consequently, gravel is widely distributed and abundant near present and past rivers and streams, in alluvial basins, and in previously glaciated areas .Gravity, commonly with the aid of water, moves soil material down from the mountains or other high areas and it accumulates in stream valleys. Streams pick up the particles and in the process of transporting them, subject the particles to abrasion and rounding. Eventually, stream-transported material is deposited on floodplains. Stream deposits consisting of sand and gravel may be suitable for aggregate, but deposits of silt and clay are not suitable. Bedrock is the source material for crushed stone.

2.4. Material properties.

Subgrade soil is part of the pavement support system. Subgrade performance generally depends on three basic characteristics:

2.4.1. Strength. The subgrade must be able to support loads transmitted from the pavement structure. This load-bearing capacity is often affected by degree of compaction, moisture content, and soil type.A subgrade having a California Bearing Ratio (CBR) of 10 or greater is considered essential and can support heavy loads and repetitious loading without excessive deformation. Subgrade materials are typically characterized by their strength and stiffness. Three basic subgrade stiffness/strength characterizations are commonly used: California Bearing Ratio (CBR), modulus of subgrade reaction (k), and elastic(resilient) modulus. Although there are other factors involved when evaluating subgrade materials (such as swell in the case of certain clays), stiffness is the most common characterization and thus CBR, k-value, and resilient modulus are discussed here.

2.4.1.1. California Bearing Ratio (CBR). The CBR test is a simple strength test that compares the bearing capacity of a material with that of a well-graded crushed stone (thus, ahigh-quality crushed stone material should have a CBR of 100%). It is primarily intended for, but not limited to, evaluating the strength of cohesive materials having maximum particle sizes less than 0.75inches.

The CBR is a comparative measure of the shearing resistance of soil. The test consists of measuring the load required to cause a piston of standard size to penetrate a soil specimen at a specified rate .This load is divided by the load required to force the piston to the same depth in a standard sample of crushed stone .The result, multiplied by 100, is the value of the CBR.

Usually, depths of 0.1 to 0.2 inches are used, but depths of 0.3, 0.4, and 0.5 inches may be used if desired. Penetration loads for the crushed stone have been standardized. This test method is intended to provide the relative bearing value, or CBR, of sub-base and subgrade materials. Procedures are given for laboratory-compacted swelling, non-swelling, and granular materials. These tests are usually performed to obtain information that will be used for design purposes.

The CBR value for a soil will depend upon its density, molding moisture content, and moisture content after soaking. Since the product of laboratory compaction should closely represent the results of field compaction, the first two of these variables must be carefully
controlled during the preparation of laboratory samples for testing. Unless it can be ascertained that the soil being tested will not accumulate moisture and be affected by it in the field after construction, the CBR tests should be performed on soaked samples.

Relative ratings of supporting strengths as a function of CBR values are given in Table 1.

Table 1: Relative CBR values for sub-base and subgrade soils

CBR (%)	Material	Rating
> 80	Sub-base	Excellent
50 to 80	Sub-base	Very Good
30 to 50	Sub-base	Good
20 to 30	Subgrade	Very Good
10 to 20	Subgrade	Fair-good
5 to 10	Subgrade	Poor-fair
<5	Subgrade	Very poor

The higher the CBR value of a particular soil, the more strength it has to support the pavement. This means that a thinner pavement structure could be used on a soil with a higher CBR value than on a soil with a low CBR value. Generally, clays have a CBR value of 6 or less. Silty and sandy soils are next, with CBR values of 6 to 8. The best soils for road-building purposes are the sands and gravels whose CBR values normally exceed 10.

The change in pavement thickness needed to carry a given traffic load is not directly proportional to the change in CBR value of the subgrade soil. For example, a one-unit change in CBR from 5 to 4 requires a greater increase in pavement thickness than does a one-unit change in CBR from 10 to 9.

Table 2: Suitability of soils for subgrade applications

Subgrade soils for design	**Unified soil classification**	**Load support & drainage characteristics**	**Modulus of Subgrade Reaction (k),psi/inch**	**Resilient Modulus (MR),psi**	**CBR Range**
Crushed Stone	GW,GP and GU	Excellent support and drainage characteristics with no frost potential	220 to 250	Greater than 5700	30 to 80
Gravel	GW,GP and GU	Excellent support and drainage characteristics with very slight frost potential	200 to 220	4500 to 5700	30 to 80
Silty gravel	GW-GM, GP-GM, and GM	Good support and fair drainage, characteristics with moderate frost potential	150 to 200	4000 to 5700	20 to 60
Sand	SW, SP, GP-GM, and GM	Good support and excellen drainage characteristics with very slight frost potential	150 to 200	4000 to 5700	10 to 40
Silty sand	SM, non-plastic (NP), and >35% silt (minus #200)	Poor support and poor drainage with very high frost potential	100 to 150	2700 to 4000	5 to 30
Silty sand	SM, Plasticity Index (PI) <10, and <35 % silt	Poor support and fair to poor drainage with moderate to high frost potential	100 to 150	2700 to 4000	5 to 20
Silt	ML, >50% silt, liquid limit <40, and PI <10	Poor support and impervious drainage with very high frost value	50 to 100	1000 to 2700	1 to 15
Clay	CL, liquid limit >40 and PI >10	Very poor support and impervious drainage with high frost potential	50 to 100	1000 to 2700	1 to 15

***Source: Design manual of SUDAS (Statewide Urban Design And Specifications*)**

2.4.2. Moisture content. Moisture tends to affect a number of subgrade properties, including load-bearing capacity, shrinkage, and swelling. Moisture content can be influenced by a number of factors, such as drainage, groundwater table elevation, infiltration, or pavement porosity (which can be affected by cracks in the pavement). Generally, excessively wet subgrades will deform under load.

2.4.3. Shrinkage and/or swelling. Some soils shrink or swell, depending upon their moisture content. Additionally, soils with excessive fines content may be susceptible to frost heave in northern climates. Shrinkage, swelling, and frost heave will tend to deform and crack any pavement type constructed over them. Pavement performance also depends on subgrade uniformity. However, a perfect subgrade is difficult to achieve due to the inherent variability of the soil and influence of water, temperature, and construction activities. Emphasis should be placed on developing a subgrade CBR of at least 10. Research has shown that with a subgrade

strength of less than a CBR of 10, the sub-base material will deflect under traffic loadings in the same manner as the subgrade. That deflection then impacts the pavement, initially for flexible pavements, but ultimately rigid pavements as well.

Conclusion

1. Ensure that road interventions are carried out safely, more efficiently and to high quality standards while causing as little inconvenience as possible.
2. To avoid risk involved in a project such as completion of work on time and any inefficiency that could result in poor quality of products.
3. Contribute to an increase in product quality, improvements in workmanship and efficiency, a decrease in wastage.
4. To avoid the failures in roads such as ruttings, ditches, potholes, corrugations etc. and to prevent accidents and loss of life.

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