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PLASTIC ROADS

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Abstract:

A Plastic material is an wide range of synthetic or semi-synthetic organic amorphous solids used in the manufacture of Industrial products. Plastics are typically polymers of high molecular mass and may contain other substances to improve performance and reduce costs. Plastic waste is a material, a major component of solid waste which is broadly available and disposed of irregular or proper treatment. There has an large growth in municipal plastic waste disposal mainly in urban areas which reveals the overall view of the landscape. Plastic was found to be an probable binder for bitumen compositions used in flexible pavements. This effective method helps the pavements to resist higher temperature by reducing the formation of cracks and reducing moisture infiltration which otherwise leads to development of damaging of roads . These pavements have intimates improved crushing and abrasion values and reduced water seepage. Plastic roads would be a new and adoptable technique for India's hot and humid climate, where temperatures frequently cross 50°C and create havoc, increasing most of the roads with big potholes.

Key Words: Plastic roads ,plastic waste, flexible pavement, bitumen, polypropylene ecofriendly.

I. INTRODUCTION

A material that contains one or more organic polymers of large molecular weight, solid in its finished state and at some state while manufacturing or processing into finished articles, can be shaped by its flow, is called as 'Plastic'. Plastics are durable and degrade very slowly; the chemical bonds that make plastic so durable make it equally resistant to natural processes of degradation. Plastics can be divided in to two major categories: thermoses and thermoplastics. A thermoset solidifies or "sets" irreversibly when heated. They are useful for their durability and strength, and are therefore used primarily in automobiles and construction applications. These plastic types are known as phenolic, melamine, unsaturated polyester, epoxy resin, silicone, and polyurethane. Thermoplastics can easily be shaped and moulded into products such as milk jugs, floor coverings, credit cards, and carpet fibres. Use of plastic along with the bitumen in construction of roads not only increases its life and smoothness but also makes it economically sound and environment friendly. Plastic waste is used as modifier of bitumen to improve some of bitumen properties. Roads that are constructed using plastic waste are known as Plastic Roads and are found to perform better compared to those constructed with convention bitumen.

II.PRILIMINARY INVESTIGATION

1. Surveying Methods
2. Geotechnical Methods

SURVEYING METHODS:

The purpose of surveying is to determine the dimensions and contours of any part of the earth's surface, i.e., to prepare a plan or map, establish boundaries of the land, measure area and volume, and select a suitable site for an engineering project. When the topography of the terrain is depicted on map with contours and spot levels, etc., it is called *a Topographic map*.

Levelling:

Levelling is an art of determining the relative heights or elevations of points or objects on earth surface. It deals with measurements in vertical plane. It forms basics for planning, designing, estimating and executing various civil engineering structures. Determination of differences of elevations is therefore very important for many purposes such as topographic mapping, setting up grade stakes for sewer lines, ensuring a proper drainage system so that the flow takes place in the proper direction.

Levelling Instruments:

- Dumpy Level
- Auto Level

Levelling Methods:

- Rise and Fall Method

Rise and Fall Method: The rise and fall is determined by calculating the difference between the staff readings. The RL of each point is obtained

by adding rise to, or by subtracting the fall from the reduced level of the respected point.

- Arithmatic Check : $\sum B.S - \sum F.S. = \sum rise - \sum fall = last\ R.L. - first\ R.L.$

GEO TECHNICAL METHODS:

California Bearing Ratio Method (CBR Method)

The California Bearing Ratio (C.B.R.) test was developed by California Division of Highway as a method of classifying and evaluating soil sub grade and base course materials for flexible pavements. The test is empirical and the results cannot be related accurately with any fundamental property of the material.
The CBR test is a penetration test meant for the evaluation of sub grade strength of roads and pavements. The results obtained by these test are used with empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement. The test is conducted by causing a cylindrical plunger of some diameter to penetrate a pavement component material at 1.25mm/minute. The loads, for 2.5mm and 5mm are recorded. This load is expressed as a percentage of standard load value at a respective deformation level to obtain C.B.R. value.

III. MATERIALS

- Coarse aggregate
- Fine aggregate
- Bitumen
- Plastic waste

Coarse aggregate:

The particles that are predominantly retained on the 4.75mm sieve and will pass through 3-inch screen, are called **Coarse aggregate.** Gravel, cobble and boulders come under this category. In general, 40mm size aggregate used for normal strengths and 20mm size is used for high strength.

Coarse aggregate	Size
Fine gravel	4mm – 8mm
Medium gravel	8mm – 16mm
Coarse gravel	16mm – 64mm
Cobbles	64mm – 256mm
Boulders	>256mm

Fine aggregate:

The aggregates passing through the 4.75mm sieve and predominantly retained on the 75µm sieve are called **Fine aggregate.** Natural sand is generally used as fine aggregate, silt and clay are come under this category. The purpose of fine aggregate is to fill the voids in the coarse aggregate and to act as workability agent. The size range of various fine aggregate are given below

Fine aggregate	Size
Fine Sand	2.0mm – 0.5mm
Medium Sand	0.5mm – 0.25mm
Coarse Sand	0.25mm – 0.06mm
Cobbles	0.06mm – 0.002mm
Boulders	<0.002mm

Bitumen:

Bituminous a black viscous mixture of hydrocarbons obtained naturally or as a residue from petroleum distillation. Tar is produced form coal as a by product of coke or coal gas. Both bitumen and tar have similar appearance as both are black in colour, but they have different binding characteristics. Tar is no longer used for paving applications because of its undesirable characteristics including high temperature susceptibility and harmful effects of fume during heating.

Types of Bitumen Binders:

- Paving grade bitumen
- Modified grade bitumen
- Cut-back bitumen
- Bitumen emulsion

Plastic :

Plastic is a material consisting of any wide range of synthetic or semi-synthetic organic compounds. They are typically organic polymers of high molecular mass and often contain other substance. They are usually synthetic ,most commonly derived from petrochemicals. Due to their low cost, ease of manufacture, versatility and imperviousness to water plastics are used in multiple products of different scales.

Types of plastics used:

- Poly-amides or nylons
- Poly carbonates
- Polyesters
- Polyethylene
- Polypropylene
- Polyethylene terephthalate (PET)

IV. TESTS ON MATERIALS

Tests on Coarse aggregate:

- Crushing value test
- Abrasion test
- Impact test

- Shape test
- Specific gravity test

Crushing value test:

Aggregate Crushing value is measure of the strength of the aggregate. The strength of concrete largely depends upon the strength of aggregate. The aggregate should therefore have minimum crushing value. The aggregate crushing value provides a relative measure of the resistance of an aggregate to crushing under gradually applied crushing load. If aggregate crushing value is less than 10, it signifies an exceptionally strong aggregate. While aggregate crushing value above 35 would normally be considered as weak aggregates.

Abrasion Test:

Abrasion test on aggregate indicates the hardness of aggregate. It shows the ability of aggregate to resist the wear and tear. It is carried out to test the hardness property of aggregates and to decide whether they are suitable for different pavement construction works. A maximum value of **40 percent** is allowed for **WBM base course** in Indian conditions. For **bituminous concrete**, a maximum value of **35 percent** is specified.

Impact test:

Impact test on aggregate indicates the toughness of aggregate. It show the ability of aggregate to resist the sudden shock or impact. Aggregates may be subjected to the sudden shock or impact during and after construction. Because due to such kind of load, aggregate breaks down into smaller pieces.
Aggregates to be used **for wearing course**, the impact value **shouldn't exceed 30 percent**. For **bituminous macadam** the **maximum** permissible value is **35 percent**. For **Water bound macadam** base courses the maximum permissible value defined by IRC is **40 percent.**

Shape test:

Aggregates are available in various size and shape, i.e. rounded, cubical, angular flaky or elongated. It is proved that the flaky and elongated particles have less strength, less bond, as less interlocking and durability compared with cubical, angular or rounded particles of the same size. .
Flakiness index test and elongation index test are used to determine the shape of the aggregate. It is defined in percentage by weight of aggregate particles to the mean dimension of thickness and length of it. It should range in **15 to 30%** according to the use.

Specific gravity:

Specific Gravity of aggregate is defined as the ratio of the weight of aggregate to the Weight of equal volume of water. It shows the strength of aggregate. Aggregates having low specific gravity are generally weaker than those with having high specific gravity. The specific gravity of aggregates generally used in construction ranges from about 2.5 to 3.0.

Tests on Fine aggregate:

- Bulking of sand
- Fineness modulus
- Specific gravity

Bulking of sand:

When sand is damp, the water coating on the surface of each sand particle causes separation of particles from one another due to surface tension. This causes sand to bulk. Bulked sand occupies more volume and hence if volumetric measuring is done while proportioning it, bulking correction is necessary.

Moisture contents %age by wt.	Bulking % by volume
2	15
3	20
4	25
5	30

FINENESS MODULUS:

Fineness modulus is generally used to get an idea of how coarse or fine the aggregate is. More fineness modulus value indicates that the aggregate is coarser and small value of fineness modulus indicates that the aggregate is finer.

Type of Sand	Fineness Modulus Value
Very fine sand	Below 2.2
Fine sand	2.2 to 2.6
Medium sand	2.6 to 2.9
Coarse sand	2.9 to 3.2
Very coarse sand	Above 3.2

V FLEXIBLE PAVEMENT

A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of riding quality, a skid resistance and low noise pollution.

Typical layers of a flexible pavement:

Surface course(25-50mm):
Surface course is the layer directly in contact with traffic loads and generally contains superior quality materials.

Binder course(50-100mm):
This layer provides the bulk of the asphalt structure. It's chief purpose is to distribute load to the base course The binder course generally consists of aggregates having less asphalt and doesn't require quality as high as the surface course.

Base course(100-300mm):
The base course is the layer of material immediately beneath the surface of binder course and it provides additional load distribution and contributes to the sub-surface drainage It may be composed of crushed stone, crushed slag, and other untreated or stabilized materials.

Sub-Base course(100-300mm):
The sub-base course is the layer of materials provided beneath the base course.It is usually provided on sub-grade of good quality. Material used may be either unbound granular or cement-bound .

Sub-grade(150-300mm):
Sub-grade is a layer of natural soil prepared to receive the stresses from the layers above. It is essential that at no time soil sub-grade is overstressed. It should be compacted by rollers to the desirable density, near the optimum moisture content. CBR should not less than 25.

VI. PAVEMENT DESIGN

Design procedure:

Based on the performance of existing designs and using analytical approach, simple design charts and a catalogue of pavement designs are added in the code. The pavement designs are given for subgrade CBR values ranging from 2% to 10% and design traffic ranging from 1 msa to 150 msa for an average annual pavement temperature of 35 C. Using the following simple input parameters, appropriate designs could be chosen for the given traffic and soil strength:

- Design traffic in terms of cumulative number of standard axles
- CBR value of subgrade.

Design traffic:

The method considers traffic in terms of the cumulative number of standard axles (8160 kg) to be carried by the pavement during the design life. This requires the following information

1. Initial traffic in terms of CVPD
2. Traffic growth rate during the design life
3. Design life in number of years
4. Vehicle damage factor (VDF)
5. Distribution of commercial traffic over the carriage way.

Computation of Design traffic:

The design traffic is considered in terms of the cumulative number of standard axles in the lane carrying maximum traffic during the design life of the road. This can be computed using the following equation:

$$N = \frac{365 \times [(1+r)^n - 1]}{r} \times A \times D \times F$$

N = The cumulative number of standard axles to be catered for in design in terms of msa.

A = Initial traffic in the year of completion of construction in terms of the number of the commercial vehicles per day.

D = Lane distribution factor

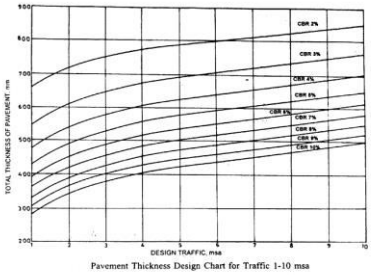
F = Vehicle damage factor

n = Design life in years

r = Annual growth rate of commercial vehicles (r = -0.0075 if growth rate is 7.5 % per annum)

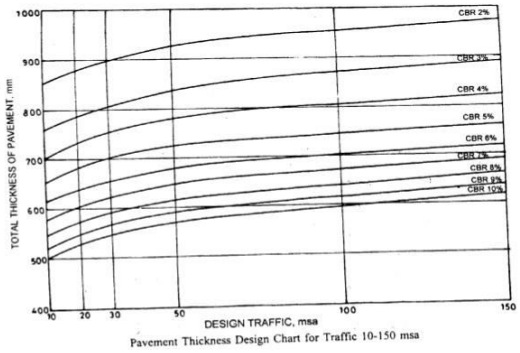
Pavement thickness design charts:

For the design of pavements to carry traffic in the range of 1 to 10 msa, use chart 1 and for traffic in the range 10 to 150 msa, use chart 2 of IRC:37 2001. The design curves relate pavement thickness to the cumulative number of standard axles to be carried over the design life for different sub-grade CBR values ranging from 2 % to 10 %. The design charts will give the total thickness of the pavement for the above inputs. The total thickness consists of granular sub-base, granular base and bituminous surfacing.



Flexible pavement design chart (IRC) (for CSA< 10 msa)

Pavement thickness Design chart for Traffic 1-10msa



Pavement Thickness Design Chart for Traffic 10-150 msa

Flexible pavement design chart (IRC)

Pavement Thickness Design chart for Traffic 10-150msa.

Pavement composition:

Sub-base:

Sub-base materials comprise natural sand, gravel, laterite, brick metal, crushed stone.The sub-base material should have a minimum CBR of 20 % and 30 % for traffic upto 2 msa espectively. Sub-base usually have the thickness should not be less than 150 mm for design traffic less than 10 msa and 200 mm for design traffic of 10 msa and above.

Base:

The materials should be of good quality with minimum thickness of 225 mm for traffic up to 2 msa an 150 mm for traffic exceeding 2 msa. Where WBM construction should be adopted in the base course for roads carrying traffic more than 10 msa, the thickness of WBM shall be increased from 250mm to 300mm.

Bituminous surfacing:

The surfacing consists of a wearing course or a binder course plus wearing course. The most commonly used wearing courses are surface dressing, open graded premix carpet, mix seal surfacing, semi-dense bituminous concrete and bituminous concrete. For binder course, MOST specifies, it is desirable to use bituminous macadam (BM) for traffic upto o 5 msa and dense bituminous macadam (DBM) for traffic more than 5 msa.

Numerical example:

Design the pavement for construction of a new bypass with the following data:

1. **Two lane carriage way**
2. **Initial traffic in the year of completion of construction = 400 CVPD (sum of both directions)**
3. **Traffic growth rate = 7.5 %**
4. **Design life = 15 years**
5. **Vehicle damage factor based on axle load survey = 2.5 standard axle per commercial vehicle**
6. **Design CBR of subgrade soil = 4%.**

Solution :

1. Distribution factor = 0.75

$$N = \frac{365 \times [(1+0.075)^{15} - 1)]}{0.075} \times 400$$

$$= 7200000$$

2. $$= 7.2\ msa$$

3.

4. Total pavement thickness for CBR 4% and traffic 7.2 msa from IRC:37 2001 chart1 = 660 mm
5. Pavement composition can be obtained by interpolation from Pavement Design Catalogue (IRC:37 2001).
    1. Bituminous surfacing = 25 mm SDBC + 70 mm DBM
    2. Road-base = 250 mm WBM
    3. sub-base = 315 mm granular material of CBR not less than 30 %

VI. CONSTRUCTION PROCEDURE

Preparation of Sub-grade Layer:

The sub-grade surface will be compacted levelled and be cut to make camber as in plan. If the material of the soil did not have a good quality, it will be changed with suitable material. Base formation covers with 50-75mm sand layer or quarry dust and will be compacted with 8-10 tone compactors. This job must be done to prevent the clay from absorbing into the stone layer of sub-base and reduce the shear strength of the pavement.

Construction and compacting the Sub-Base:

After the sub-base has been prepared with list materials, it will be placed and constructed into two layers if the thickness is more then150mm. Every layer will be compacted according to the plan. Sub-base layer must be compacted carefully with compactor machine. Compactors with rubber roller can compact 120mm layer in 12 times. Compacting should start from the side of the road hen slowly towards the middle of the road in horizontal way. In super elevated bends compaction machine will start at the lowest part and slowly towards the higher level.

Construction of Road Base:

Before road base is constructed, sub-grade surface and sub-base must be formed perfectly and compacted enough. The lowest layer and sub-base must be prepared

at least distance of 200m from the base construction. This material is place and compacted to on the surface of the road. The road base must be constructed in two layers of same thickness. Each layer should not exceed 150mm

Construction of Surface Coarse:

The road surface is constructed with bitumen along with plastic waste materials such as asphalt. It should be free from dust and waterproof. To construct surface layer, the base course must be prepared.

PLASTIC AS ADDITIVE FOR BITUMINOUS MATERIALS:

Plastic used in road construction is not new. It is already in use as PVC or HDPE pipe mat crossings built by cabling together PVC (polyvinyl chloride) or HDPE (high-density poly-ethylene) pipes to form plastic mats. The plastic roads include transition mats to ease the passage of tyres up to and down from the crossing. Both options help protect roads from rutting by distributing the load across the surface. But the use of plastic-waste has been a concern for scientists and engineers for a quite long time. Recent studies in this direction have shown some hope in terms of using plastic-waste in road construction i.e., Plastic roads.

PROCESSING DETAILS:-

I. Collection of waste plastic

II. Cleaning and shredding of waste plastic.

III. Mixing of shredded waste plastic, aggregate and bitumen in central mixing plant.

1. **COLLECTION OF WASTE PLASTIC:-**

Waste plastic is collected from roads, garbage trucks, dumpsites or compost plants, or from school collection programs, or by purchase from rag-pickers or waste-buyers at Rs 5-6 per kg Rag-pickers

2. **CLEANING AND SHREDDING OF WASTE PLASTIC:-**

Waste plastic litter in the form of thin-film carry-bags, use-and-throw cups, PET bottles, etc. these are sorted, de-dusted, washed if necessary.

3. **MIXING OF SHREDDED WASTE PLASTIC, AGGREGATE AND BITUMIN IN CENTRAL MIXING PLANT:-**

The aggregate mix is heated to 165°c (as per the HRS specification) in central mixing plant. Similarly the bitumen is to be heated up to a maximum of 160ºc. The 8% of waste plastic to the weight of bitumen are added in the conveyor belt or special mechanical device is developed which will spray the plastics inside the chamber to coat the plastics effectively. Central mixing plant helps to have better control of temperature and better mixing of this material thus helping to have a uniform coating and heated bitumen is also sprayed.

Construction Process:

Comparison Between normal roads and plastic roads:

The durability of the roads laid out with shredded plastic waste is much more compared with roads with asphalt with the ordinary mix. Roads laid with plastic waste mix are found to be better than the conventional ones. The binding property of plastic makes the road last longer besides giving added strength to withstand more loads. While a normal 'highway quality' road lasts four to five years it is claimed that plastic-bitumen roads can last up to 10 years. Rainwater will not seep through because of the plastic in the tar. So, this technology will result in lesser road repairs. And as each km of road with an average width requires over two tones of polyblend, using plastic will help

reduce non-biodegradable waste. The cost of plastic road construction may be slightly higher compared to the conventional method.

S.No.	Properties	Plastic Road	Ordinary Road
1.	MARSHALL STABILITY VALUE	MORE	LESS
2.	BINDING PROPERTY	BETTER	GOOD
3.	SOFTENING POINT	LESS	MORE
4.	PENETRATION VALUE	MORE	LESS
5.	TENSILE STRENGTH	HIGH	LESS
6.	RUTTING	LESS	MORE
7.	STRIPPING(POT HOLES)	NO	MORE
8.	SEEPAGE OF WATER	NO	YES
9	DURABILITY OF THE ROADS	BETTER	GOOD
10.	COST OF PAVEMENT	LESS	NORMAL
11.	MAINTENANCE COST	ALMOST NIL	MORE
12.	ENVIRONMENT FRIENDLY	YES	NO

VII. CONCLUSION

Plastic coating on aggregates is used for the better performance of roads. This helps to have a better binding of bitumen with plastic wasted coated aggregate due to increased bonding and increased area of contact between polymers and bitumen. The polymer coating also reduces the voids. This prevents the moisture absorption and oxidation of bitumen by entrapped air. This has resulted in reducing rutting, ravelling and there is no pothole formation. The roads can withstand heavy traffic and show better durability. Following are some points which are drawn from the study:

1. Aggregate Impact value of control specimen was 5.43%. It reduced to 4.91% for PP8 and 4.26% for PP10. Reduction in value was 10% for PP8 and 22% for PP10. This shows that the toughness of the aggregate was increased to face the impacts.
2. Crushing Value was reduced from 19.2% to 13.33% and 9.82% for PP8 and PP10 respectively. Value reduced by 30% for PP8 and 48% for PP10. Low aggregate crushing value indicates strong aggregates, as the crushed fraction is low.
3. Specific Gravity of the aggregate increases from 2.45 for control specimen to 2.7 for PP8 and 2.85 for PP10 due to plastic coating
4. Stripping Value was reduced from 8% for control specimen to nil for PP8 and PP10. This shows that coated aggregate are more suitable for bituminous construction than plain aggregates.
5. Water Absorption is also reduced to nil for PP8 and PP10 from 1.7% for control specimen.

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