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EFFECT OF FLYASH STABILISATION ON DESIGN OF RIGIDPAVEMENT OF ROADS

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ABSTRACT

The development of efficient transport infrastructure is of utmost importance for the socio-economic growth of any country. In India, a vast and diverse country with a growing population, the importance of well-designed roads cannot be overstated. Among the various types of road pavements, rigid pavements stand out as a reliable solution to provide longevity, durability and better performance on Indian roads. This article examines the importance of robust pavement design and its suitability for improving road quality in India. Rigid pavements, commonly known as concrete pavements, are constructed using reinforced concrete slabs. These slabs are designed to distribute loads imposed by traffic and environmental factors over a large area, resulting in reduced stress on the subgrade. Factors such as traffic volume, load distribution, weather conditions and subgrade characteristics should be carefully considered in the design of rigid pavements. Rigid sidewalks, often identified as concrete pavements, are a fundamental part of transportation infrastructure, playing a vital role in facilitating the movement of people, goods, and services. These sidewalks distinguish themselves by their construction using a series of interconnected reinforced concrete slabs, each designed to withstand the rigors of vehiculartraffic, environmental forces and climatic variations. The underlying principle of their design lies in the artful distribution of the loads imposed by these factors over a wide expanse, thereby reducing the stress on the underlying subgrade – the natural soil foundation upon which the pavement rests. The design process of rigid pavements is a complex and precise endeavor, involving the harmonious integration of many factors to ensure their resilience, longevity and performance under various conditions. One of the primary considerations is the volume and composition of traffic that meets the pavement. Rigid fenders are built to withstand a wide variety of vehicles, from light passenger cars to heavy-duty commercial trucks. Therefore, engineers must thoroughly analyze the prevailing traffic patterns, axle loads, and vehicle configurations in the particular area where the pavement will be laid. Load distribution is an important factor in rigid pavement design. Concrete slabs are strategically placed and reinforced to evenly distribute the weight of vehicles and their loads, avoiding localized stress concentrations. This redistribution of loads is achieved through intricate calculations that determine the appropriate thickness, spacing and reinforcement of concrete slabs. By reducing concentrated stresses on the subgrade, rigid pavements not only extend their own life, but also reduce the risk of subgrade failure, which leads to deformations and ruts over time. Weather conditions have a significant effect on the performance of rigid pavements. India's diverse geography exposes its roads to various climatic challenges, including extreme temperatures, heavy rainfall and seismic activity in some regions. These factors contribute to the expansion and contraction of concrete materials, which, if not taken into account, can lead to cracks and structural deterioration. To combat these effects, engineers design rigid pavements by selecting appropriate concrete mix designs, incorporating expansion joints to accommodate thermal movement, and even consider using fiber-reinforced concrete to increase durability. Subgrade properties are another important factor that cannot be overlooked in rigid pavement design. The properties of the subgrade soil significantly affect the load-bearing capacity of the pavement and its ability to settle or heave due to changes in moisture content. Thorough geotechnical investigations are conducted to assess the properties of the subgrade, including its bearing strength, drainage capabilities, and susceptibility to shrinkage or swelling. This information informs decisions about pavement thickness, sub-base preparation and drainage systems to ensure the long-term stability of the pavement.

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Keywords: Subgrade Soil, Fly Ash, Stabilization, Rigid Pavements And Concrete Pavements.

I. INTRODUCTION

Development of efficient transport infrastructure is of utmost importance for the socio- economic growth of any country. In India, a vast and diverse country with a growing population, the importance of well-designed roads cannot be overstated. Among the various types of road pavements, rigid pavements stand out as a reliable solution to provide longevity, durability and better performance on Indian roads. This article examines the importance of robust pavement design and its suitability for improving road quality in India. Rigid pavements, commonly known as concrete pavements, are constructed using reinforced concrete slabs. These slabs are designed to distribute loads imposed by traffic and environmental factors over a large area, resulting in reduced stress on the subgrade. Factors such as traffic volume, load distribution, weather conditions and subgrade characteristics should be carefully considered in the design of rigid pavements. Rigid sidewalks, often identified as concrete pavements, are a fundamental part of transportation infrastructure, playing a vital role in facilitating the movement of people, goods, and services. These sidewalks distinguish themselves by their construction using a series of interconnected reinforced concrete slabs, each designed to withstand the rigors of vehiculartraffic, environmental forces and climatic variations. The underlying principle of their design lies in the artful distribution of the loads imposed by these factors over a wide expanse, thereby reducing stress on the underlying subgrade – the natural soil foundation on which the pavement rests. The design process of rigid pavements is a complex and precise endeavor, involving the harmonious integration of many factors to ensure their resilience, longevity and performance under varying conditions. One of the primary considerations is the volume and composition of traffic that meets the pavement. Rigid curbs are built to withstand a wide range of vehicles, from light passenger cars to heavy-duty commercial trucks. Therefore, engineers must thoroughly analyse the traffic patterns, axle loads, and vehicle configurations prevalent in the particular area where the pavement will be laid. Load distribution is an important factor in rigid pavement design. Concrete slabs are strategically placed and reinforced to evenly distribute the weight of vehicles and their loads, avoiding localized stress concentrations. This redistribution of loads is achieved through intricate calculations that determine the appropriate thickness, spacing and reinforcement of concrete slabs. By reducing concentrated stresses on the subgrade, rigid pavements not only extend their own life, but also reduce the risk of subgrade failure, which leads to deformations and ruts overtime. The nitrogen adsorption method was introduced to characterize the pore structure of fly ash pavement concrete. Combined with the pore structure parameters, the mechanism of the pore structure on the strength, brittle property, and durability of fly ash pavement concrete wasanalyzed, respectively. The research provided scientific basis for the design method of fly ash pavement concrete mix proportion, which improved the service life of cement pavement concrete.

II. MATERIALS AND METHODS

Designing rigid pavements involves a systematic approach that considers various factors such as traffic loads, weather conditions, subgrade characteristics, and material properties. Many design methods and procedures have been developed to ensure the durability, longevity and structural integrity of rigid pavements. Here are some commonly used design methods for rigid pavements, Classical Mechanistic-Empirical Design, Portland Cement Association (PCA) Method, Westergaard's Theorem, Road Note No. Method 4, IRC (Indian Road Congress) Method, Finite Element Analysis (FEA), Pavement ME Design, Software Based Design Tools, Semi – Rigid Pavements. Factors to be considered in Design of Pavements, Pavement design consists of two parts:

- Mix design of materials to be used in each pavement component layer.
- Thickness design of the pavement and the component layers.

The various factors to be considered for the design of pavements are given below:

1. Design wheel load
2. Subgrade soil
3. Climate factors
4. Pavement component materials
5. Environmental factors

6. Special factors in the design of different types of pavements.

Pavement component materials are important components used to construct durable and functional road surfaces. These ingredients include:

- Aggregate: Crushed stone, gravel, and sand provide most of the pavement's load-bearing capacity and stability.
- Asphalt Binder: Used in flexible pavements, asphalt binder binds the aggregatestogether to form a resilient and flexible surface.
- Concrete: In rigid pavements, concrete is the primary material, providing high strength and durability to withstand high traffic loads.
- Reinforcement: Steel bars or fibres can be added to concrete for improved strengthand crack resistance.
- Subbase/Subgrade Materials: These provide foundational support and stability to thepavement structure.
- Geotextiles/Geogrids: Used for soil stabilization and reinforcement, improving pavement performance.

Environmental factors significantly affect the design, construction and performance of rigid pavements. These factors include:

- Temperature Variations: Extreme temperature fluctuations cause rigid pavements to expand and contract, leading to cracks and deterioration of joints.
- Precipitation and drainage: Adequate drainage is critical to prevent water ingress, which can weaken the pavement structure and lead to erosion, rutting, and freeze-thawdamage.
- Freeze-thaw cycles: In areas with freezing temperatures, water can seep into pavement cracks, freeze and expand, causing distress such as cracking and cracking.
- Subsurface Water: Elevated groundwater levels or poor drainage can adversely affect subgrade stability, leading to settlement and structural problems.
- Chemical exposure: Harsh chemicals such as de-icing salts accelerate the deterioration of concrete pavements, leading to corrosion of reinforcement and surface scaling.
- UV Radiation: Prolonged exposure to sunlight and UV radiation degrades the surface appearance and properties of concrete, reducing its longevity.
- Seismic Action: Pavements in earthquake prone areas should be designed to withstand ground movements without significant damage.
- Environmental Sustainability: Rigid pavement design should consider environmentally friendly practices and the use of recycled materials to reduce the project's environmental footprint.
- Vegetation: Tree roots and vegetation near pavements can put pressure on concrete slabs, leading to uplift, cracking and joint failure.

III. RESULTS AND DISCUSSIONS

Soil samples were collected every 250 meters along the 1 km road length. Tests were conducted as per Bureau of Indian Standards and the results were tabulated.

3.1 Discussion on Muzaffarpur Soil Results

The results of various routine tests and strength characteristics of soil found for the selected road length of one km from Mithanapura Chowk to Bela Industrial estate has been tabulated in table no.1. The percentage clay varies form 3% to 5%; the percentage silt varies from 60% to 72% and the percentage sand varies from 24% to 35%. The liquid limit varies from 34% to 36.5%, the plastic limit varies from 25.1% to 28.5% and the plasticity index varies from 8% to 9.39%. the optimum moisture content (OPC) of the soil collected from the different chainages of the road length have been tabulated in table.1 and varies from 17% to 19.1% while the maximum dry density varies between 1.64 gm/cc to 1.7 gm/cc. the CBR value for the same road length at different chainages ranges between 6.2% to 7.8% for 2.5 mm. penetration and 5.75% to 8.8% for 5mm penetration in unsoaked condition, whereas CBR value ranges from 4.2% to 6.3% for 2.5mm penetration and 4.3% to 6.25% for 5mm penetration in soaked condition (96 hours). The young modules of the soil at the different chainages of the road length have been found out and found to vary from 183 kg/cm^2 to 253 kg/cm^2. Specific gravity of soils at different chainage varies from 2.61 to 2.64. These data indicate that soil of the selected road length inherits reasonable strength and is suitable for the constructing road pavement.

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3.2 Discussion on Results of Soil Fly Ash Mixture in Different Percentage

The fly ash has been mixed with soil sample collected from the different chainages (0m, 250m, 500m, 750m, 1000m) of the road length of 1KM from Mithanapura chowk to BelaIndustrial Estate, in different proportion of 10% and 20% b weight. The route properties and strength characteristics tests have been conducted and results have been presented in table.2. and 3. The result show that the optimum moisture content of soil fly ash mixture generallydecreases while dry density increases in the same condition.by addition of fly ash in different percentages (10% and 20%) with natural soil, the percentage clay and silt size particles mostly decreases and the sand size particle of soil fly ash mixture generally increases. The maximum dry density increases with the increase of fly ash proportion in the soil. Addition of fly ash increases the CBR value both in unsoaked and soaked condition. It is revealed from the table.1, 2 & 3, where the test results of the natural soil and soil fly ash mixtures in different percentages have been tabulated. Rate of gain of strength is quite considerable when fly ash is added to the soil at the rate of 10% by weight. Further addition of fly ash beyond 10% and up to 20% yields a slow rate of gain of strength.

3.3 Discussion on Design of Pavement Thickness

Indian road congress (IRC) method has been used for determining the pavement thickness in the present study. The results obtained by above mentioned method for determining the pavement thickness, in the case of natural soil and soil mixed with different percentages of fly ash have been tabulated in Table.4, 5, 6 & 7. In the case of natural soil, the pavement thickness has been found 17.7 cm, whereas 17.3 cm and 17.5 cm have been found in the cases of soil mixed with 10% to 20% fly ash respectively. A comparative study regarding the percentage saving in pavement thickness has been made and tabulated in table.8. It is revealed from table.8, the percentage saving in pavement thickness have been obtained using IRC method of design of Rigid pavement and found 2.26% in the case of soil stabilized with 20% fly ash has been found to be 1.13% with respect to natural soil. It has been studied from the table – 4.8, the rate of percentage saving in pavement thickness is very rapid (2.26%) when soil mixed with 10% fly ash but rate of percentage saving between 10% to 20%. Mixing of fly ash with natural soil has been found slow as compared to the percentage spacing of thickness when soil mixed with 10% fly ash.

Table.1. Discussion on Muzaffarpur Soil Results

S.NO	SAMPLE NO.	1	2	3	4	5
	chainage in m	0	250	500	750	1000
1	**Specific Gravity**	2.62	2.624	2.61	2.64	2.623
2	**Atterberg's Limits**					
	liquid limit in %	35.15	36.55	34.5	34	35.3
	plastic limit in %	25.76	28.5	25.2	25.1	26.2
	Plasticity index in %	9.39	8	9.3	8.9	9.1
3	**Compaction Test**					
	optimum moisture content in %	18	17	19.1	17.5	18.25
	dry density in gm/cm3	1.68	1.7	1.65	1.68	1.64
4	**Triaxial Test**					
	young's modulus in kg/cm2	183	225	253	229	247
5	**CBR Test**					
	Unsoaked					
	(a) at 2.5mm penetration in %	6.2	6.5	7.8	6.3	7.1
	(b) at 5mm penetration in %	8.27	8.02	8.8	8.75	5.75
	soaked for 96 hours				8	8.75

	(a) at 2.5mm penetration in %	5.4	4.2	5.2	6.3	4.8
	(b) at 5mm penetration in %	6.08	5.2	6.2	6.25	4.3
6	**Particle Size Distribution In %**					
	Clay	4	3	3	4	5
	Silt	72	66	65	61	60
	Sand	24	31	32	35	35

Table.2. Details of soil properties Mithanpura Chowk to Beka Industrial Estate mixed with 10% flyash

S.NO	**SAMPLE NO.**	**1**	**2**	**3**	**4**	**5**
	chainage in m	0	250	500	750	1000
1	**Specific Gravity**	2.63	2.63	2.62	2.65	2.64
2	**Atterberg's Limits**					
	liquid limit in %	25.1	25.7	24.8	24.1	30.2
	plastic limit in %	18.3	20.3	19.1	18.5	21.3
	Plasticity index in %	6.8	5.4	5.7	5.6	8.9
3	**Compaction Test**					
	optimum moisture content in %	15.1	16.5	14.3	15.3	16.3
	dry density in gm/cm3	1.7	1.75	1.69	1.68	1.66
4	**Triaxial Test**					
	young's modulus in kg/cm2	201	235	266	250	260
5	**CBR Test**					
	Unsoaked					
	(a) at 2.5mm penetration in %	8.68	11.5	10.2	10.25	10.2
	(b) at 5mm penetration in %	10.5	9.15	11.3	8.75	8.32
	soaked for 96 hours					
	(a) at 2.5mm penetration in %	9.9	8.3	9.6	10.3	8.7
	(b) at 5mm penetration in %	9.3	7.1	9.6	9.8	7.3
6	**Particle Size Distribution %**					
	Clay	3	2	2	3	4
	Silt	65	61	62	59	55
	Sand	32	37	36	38	41

Table.3. Details of soil properties Mithanpura Chowk to Beka Industrial Estate mixed with 20% flyash

S.NO	**SAMPLE NO.**	**1**	**2**	**3**	**4**	**5**
	chainage in m	0	250	500	750	1000
1	**Specific Gravity**	2.66	2.63	2.65	2.51	2.65
2	**Atterberg's Limits**					
	liquid limit in %	23	22.7	22.1	21.2	27.3
	plastic limit in %	15.7	14.6	13.8	15.2	20.3
	Plasticity index in %	5.3	8.1	8.3	6	7

3	**Compaction Test**					
	optimum moisture content %	13.45	15.25	13.1	14.1	15.3
	dry density in gm/cm3	1.72	1.73	1.7	1.67	1.68
4	**Triaxial Test**					
	young's modulus in kg/cm2	224	260	275	266	268
5	**CBR Test**					
	Unsoaked					
	(a) at 2.5mm penetration in %	9.18	10.8	11.8	14.25	10.7
	(b) at 5mm penetration in %	120	8.2	13.7	12.3	8.4
	soaked for 96 hours					
	(a) at 2.5mm penetration in %	7.3	7.1	12.3	10.3	6.71
	(b) at 5mm penetration in %	9.7	7.1	12.3	10.3	6.71
6	**Particle Size Distribution %**					
	Clay	4	2	2	2	3
	Silt	58	56	55	57	52
	Sand	40	32	43	41	45

Table .4. Combination of Critical Stresses-Trail-I

Stress due to	Corner stress Kg/cm^2	Edge stress Kg/cm^2	Interior stress
Load	40.344	18.84	
Warping	8.82	21.294	24.297
Friction	0.799	0.799	0.799
Critical stress	49.963	40.134	25.096

Here, Critical stress at edge & corner are more than 40 Kg/cm^2, hence design is unsafe Pavement Fails.

Table.5. Combination of Critical Stresses-Trail-II

Stress due to	Corner stress Kg/cm^2	Edge stress Kg/cm^2	Interior stress
Load	36.42	15.61	
Warping	8.51	18.02	20.72
Friction	0.799	0.799	0.799
Critical stress	39.729	34.249	21.519

Here, Critical stress at edge & corner are less than 40 Kg/cm^2, hence design is safe

Table.6. Natural soil mixed with 10% flyash pavement thickness = 17.3 cm

Stress due to	Corner stress Kg/cm^2	Edge stress Kg/cm^2	Interior stress
Load	30.17	15.026	
Warping	8.90	21.36	24.47
Friction	0.799	0.799	0.799
Critical stress	38.869	37.185	25.269

All the critical stresses are less than 40 Kg/cm^2 hence design is safe.

Table.7. Natural soil mixed with 20% flyash pavement thickness = 17.5 cm

Stress due to	Corner stress Kg/cm^2	Edge stress Kg/cm^2	Interior stress
Load	30.29	14.97	
Warping	8.82	21.6	24.42
Friction	0.799	0.799	0.799
Critical stress	39.909	37.369	25.219

Here, All the critical stresses are less than 40 Kg/cm^2 hence design is safe.

Table.8. Percentage saving of cost in terms of pavement thickness

Nature of soil	Pavement thickness in cm	Percentage saving
Nature of soil	17.7	
Soil + 10% fly ash	17.3	2.26
Soil + 20% fly ash	17.5	1.13

IV. CONCLUSION

It was possible to draw the following conclusions for the natural soil of the selected road length of one km from Mithanpura Chowk to Bela Industrial Estate. Soil samples were collected from different chains and mixed with different percentages of flyash. A conclusionis also made for savings in pavement thickness for incorporating different percentages of flyash using the IRC design method of rigid pavement. The soils of Muzaffarpur are generally alluvial. Generally, they consist of sand and silt witha trace of clay. Flyash added to the soil at a ratio of 103 to 20% by weight decreased the clay and silt content, but it increased the sand content of the soil. Mixing flyash with natural soil also increased the maximum dry density. Hence it is concluded that flyash is a good stabilizing material. The soil in Muzaffarpur has low porosity and high CBR value. Flyash produced in thermal power industry contains silica, alumina, ferric oxide, magnesia, free lime and calcium oxide. Possessing this material, inherit pozzolanic and self-hardening property. Soil mixed with different percentages of flyash (10% & 20%) has reasonably high value ofCBR in both soaked and non-soaked condition. Therefore, it is concluded that flyash is a goodsubgrade material for roads. The effect of mixing flyash at different percentages on the design of rigid pavement in terms was found to be 2.26% when soil was mixed with 10% flyash, while it was 1.133 when mixed with 203 flyash. The percentage reduction in pavement thickness was found using the IRC method of rigid pavement design. There is saving in material of pavement, when it will be constructed. Therefore, it is concluded that flyash can be used for cost-effective and economical design and construction.

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