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Research paper

Cost benefit analysis of flexible and rigid pavements of rural roads using rice husk ash and stone dust as additives

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Abstract

In today scenario of Infrastructure development, Road network development plays an important role. Lack of stable ground for the construction of roads is very common especially when subgrade is made of expansive soil subjected to alternate swelling and shrinkage. Making of a suitable ground is a real challenging issue for Geotechnical Engineers. To overcome the difficulties experienced with problematic soil on one side and to make a path for safe disposal of waste materials on the other side, an at-tempt is needed to explore the possibilities of utilizing waste materials to improve the engineering behaviour of problematic soil.
Disposal of waste materials on the landfill can be minimized if the waste which possess desirable properties can be utilized for various geotechnical application viz. reclamation of land and embankment construction etc. Rice husk ash and stone dust are such waste materials when blended with soil along with cement and lime separately can be of great advantage in reducing swell and shrinkage of expansive soils and make the ground more stable in consideration of rural road subgrades with problematic soils.
This project works with the basic aim of laboratory mixing of rice husk ash and stone dust with lime and cement separately and variation of Atterberg limits, CBR were studied. Then by means of IRC SP 72-2015 and IRC SP62:2014 flexible and cement concrete pavement designs were made for improved CBR by using rice husk ash and stone dust as additives independently to cement and lime stabilized the soil. This project also aims at providing a cost-effective solution for rural subgrade by means of cost-benefit analysis of various mixes viz. soil – lime- rice husk ash, soil - lime - stone dust mixes, soil-cement-rice husk ash and soil-cement-stone dust mixes.

***Keywords**: Rural Roads; Rice Husk Ash, Stone Dust, Flexible Pavement Design; Cement Concrete Pavement Design; Cost Benefit Analysis.*

1. Introduction

In general, Expansive soils possess greater strength in dry state, while it decreases on water absorption. This kind of soil when exists as a foundation of a pavement exerts considerable amount of pressure during selling finally leading to greater damages.
Expansive soil contain clay minerals (Montmorillonite) which attracts and absorb water, these soils when exposed to water, the water molecules enter into the gap of expansive soils and there would be greater changes in volume, again this volume change is linked to and is dependent on initial dry density and water content and amount of clay fraction and type of clay minerals available.
India is recognized worldwide as major rice producing country, while milling 22 % is received as rice husk apart from 78 % as rice. This husk is being used as cooking fuel till now in many rural habitations of which 25 % is converted in to ash and is dumped open. When observed it was found that RHA contains around 80-90% of amorphous silica which when used as a stabilizing agent along with lime and cement independently can significantly improve properties of underlying soil.
Stone dust a waste by product of stone milling industries have been creating a lot of havoc, since it is disposed of open in atmosphere. A recent survey confirmed that out of the total quarries available in India only 30 % are authorized, while the remaining 70 % are unauthorized. Every year it has been recorded that around million tons of stone dust has been produced, whether disposed of open or led to a land fill site. When stone dust was checked from geotechnical point of view it has been noticed that stone dust along with cement and lime separately can greatly enhance the properties of underlying black cotton soil.
In the present study stone dust and rice husk ash are taken as additives and blended with optimum cement and lime separately in various percentages ranging from o to 12 % in increments of 2% by weight of soil. UCS and CBR tests were conducted on various mixes. Along with that variation of Attterberg limits were studied. Then flexible pavement and cement concrete pavement were designed for various mixes according to IRC SP 72-2015 and IRC SP62:2014. Finally cost benefit analysis was performed to analyze and suggest a cost effective suggestion for rural road both for cement and flexible pavement.

2. Literature review

In general, expansive soils are problematic nature due to its inherent swelling and shrinkage property posing damaging effects on the structure constructed. We need to improve the overall of performance of the soils by some means.

Different wastes produced from different sources pose a lot of problem. While in the other hand, in recent years, the application of various waste materials has been considered with many underdeveloped and developing countries of their road network. When these materials are used in road network development based on sound technical, economic and ecological criteria's can be better effective. Even the lack of traditional road materials and the high economics involved, protection of the environment made it imperative need for investigation of usage of these materials carefully.

Rice husk is an agricultural by product while stone dust is an industrial by product. Both these waste materials heave been found to enhance the properties of soil subgrade especially expansive soils containing montrimillonite when blended with lime and cement separately due to their pozzolonic properties and high percentage of amorphous silica.

Many researchers have done studies on utilization of rice husk ash and stone dust in geotechnical applications. Below paragraph states various study made by various researches on rice husk ash and stone dust as admixtures.

Onyelowe Ken C et al. reported various applications of quarry dust on soil stabilization and Modification. Naranagowda et al. (2016) studied the effect of quarry dust and lime mixture on expansive soil in terms of specific gravity, compaction CBR and UCS for varying proportions of lime and stone dust. Their findings observed that MDD increased and specific gravity decrease and stated that the decrease in specific gravity is due to the reduced plasticity characteristics of the soil. Aditya Chansoria et al. studied the effect of quarry dust on CBR and compaction properties of expansive soil. They observed that OMC of expansive soil decrease with increase in the percentage of rice husk ash and MDD decrease with increase in the percentage of stone dust. H.Venkateswarlu et al. studied the effect of quarry dust on index and Engineering properties of expansive soil and concluded that liquid and Plastic Limit decreased with the addition of quarry dust, while CBR and dry density increases with the addition of quarry dust while cohesion decreased with the addition of quarry dust. A.A. Amadi et al. investigated the effect of 10% quarry fines and varying percentages of cement kiln dust on expansive soils. They also investigated the effect of various curing periods on these mixtures. They found that the Liquid Limit decreased from 85% to 72.5% when 10% quarry dust and cement kiln fines were attributed this to the effect of reduction in the diffused double layer thickness and effect of dilution of clay content of the mix. They also observed a decrement in Plastic Limit and Plasticity Index. Amadi also observed that maximum dry density and CBR increased due to the formation of time-dependent pozzolanic reactions that produced cementation products that the dry unit weight of the soil increased and the slow rate of increase in strength between 7th day and 14th day followed by steeper increase that extended till 28th day was due to the seeming delay of strength in initial days and that of 28 days was due to the formation of CSH, CAH and CASH gels. Arun Patidar et al. investigated the effect of using HDPE waste fibres, Stone dust and lime on the index and engineering properties expansive soil by mixing each ingredient separately. It was found that the Liquid Limit, Plastic Limit, Plasticity Index decreases, while CBR, UCS and permeability increased with increase in the percentage of stone dust. P.Indiramma et al. studied the effect of the addition of stone dust on compaction strength and cohesion characteristics of expansive soil. Their findings have shown that Liquid Limit decreased, while Plastic Limit decreased from 20% to 16% and Plasticity Index decreased from 24% to 18%, MDD and UCS increased with increase in stone dust from 0 to 25%. Suresh.K et al. studied the effect of stone dust and polypropylene fibres on compaction characteristics, UCS and CBR. It has been found that MDD, UCS and CBR increased with increase in the percentage of stone dust and fibres. Pradeep Muley et al. studied the effect of mixing quarry dust with moorum on index properties, compaction characteristics and CBR parameters blended with various percentages of stone dust observed that Liquid Limit, plasticity limit, OMC were decreasing while MDD and CBR were increasing as stone dust fills the voids of the coarse-grained particles of morrum. Shyam Prakash koganti et al. (2016) studied the effect of mixing quarry dust on expansive soils and morrum on compaction and CBR characteristics of expansive soil varying stone dust from 0 to 20% in increments of 5%. They found a marked reduction in Liquid Limit and Plastic Limit of expansive soil and morrum and revealed that decrease was due to a reduction of flow and plastic characteristics of expansive soil. MDD and CBR increase as stone dust percentages rise to 20% and was maximum at 20%. Sabat et al. (2009) studied the effect of mixing quarry dust and lime for usage of the mix as subgrade for low volume traffic. Their findings revealed that there was considerable improvement in CBR and UCS of the expansive soil as on mixture of quarry dust increases in the mixture. Sabat (2012) in a study on the effect of lime and quarry dust on Atterberg's limit, Compaction, Shear Strength Parameters and Durability, it has been observed that UCS, CBR and other properties were improved and strength of expansive soil lime-quarry dust mixes was more for 28 days compared to 7 days of curing. He also observed that limestone dust mixes sustained with a minimum reduction of UCS after subjecting to 12 wet-dry cycles. He also commented that an increase in shear strength was due to the combined effect of aggregation and cementation and the strength increase with the increase in curing period is due to long term pozzolanic reaction of the stone dust with lime. Sabat (2012) developed statistical models with high accuracy to predict Swelling Pressure due to the addition of lime and stone dust. It has been observed that there is a marked reduction in swell pressure for 28 days in comparison with 7 days as predicted from various models developed by Sabat. Sabat et al. (2013) investigated the effect of fly ash-quarry dust mixes with fly ash quarry dust as 1:2 on engineering properties of expansive soil. Their findings revealed the optimum proportion of fly ash-quarry dust mix was found to be 45%.

Adrian. Eberemu O. et al. (2011) studied the effect of rice husk ash on consolidation properties of compacted lateritic soil in terms of Index properties, compaction characteristics, consolidation characteristics, Pre-consolidation Pressure, Compression Index and swell index. They observed that Index tests showed improved index properties with an increase in the liquid limit (LL), an increase in plastic limits (PL). From the results of Compaction, it was found that there was a decrease in maximum dry density (MDD) and increase in optimum moisture content (OMC) for up to 16% RHA content. Even the pre-consolidation pressure has also been increased. While there was a decrease in Swell Index till 16% RHA content. The Coefficient of Volume Compressibility (MV) decreases with increasing RHA content for up to 4% treatment on specimen sample. Rama Devi. B et al. (May 2016) studied the Impact of RHA on Expansive soils in Road Construction and concluded that rice husk ash can be a better material in stabilization of subgrade, fill material or liner material in geotechnical applications. He concluded that when RHA content was between 30-40% RHA to the soil, the soil has a CBR ranging from 8-10% with increase in percentage of RHA. They also concluded that there was an increase in shear and permeability values. Gandhi Khushbu S. et al. studied the Stabilization of Expansive Soil of Surat Region using Rice Husk Ash & Marble Dust in terms of index properties, swelling index and CBR. By his study he revealed that marble dust and rice husk ash were proven effective for stabilizing expansive soil. Hence it's proved to be economical and easy solution to stabilize the expansive soils and preventing the damage caused to different structural elements and buildings. And as these materials are locally and cheaply available they become first and foremost choice of stabilization when economics is considered. Y. Mohammed Fattah et.al (2013) has studied about the improvements of clayey soil characteristics using rice husk ash and said that RHA is a pozzolanic material that was usually used in soil stabilization though it was moderately available and said that about 17% - 25% of rice husk's weight is produced as ash of its total weight. And he conducted tests on three different mix proportions on clayey soil that was mixed with rice husk ash materials included in it. They also concluded that the liquid limit of the three soils considered for the study has been decreased by 18% and plasticity index has been decreased in ranges of 32% to 80 %, when the percentage of RHA added was around 9%. They also conclude that addition of rice husk to soils showed a reduction in MDD with increase in the rice husk content. The optimum moisture content generally increased with increase in the RHA content. They also concluded that there was an enormous increase in UCS when the increase of RHA was in between 6 to 8%. Jijo James et al. (2016) has studied the industrial wastes as auxiliary additives to cement/lime stabilization and described about the utilization of RHA in combination of lime and cement and also the work related to utilization of RHA in soil stabilization and also said that the addition of lime to soil initiates several reactions like short term and long term. Short term reactions of Lime treatment of soil being immediate ion exchange where the divalent calcium ions are ionized from lime replace univalent cations (M+) on the clay surface and ions in high concentration will replace the ions in lower concentration. Dr. D. Koteswara Rao et al. (2012) studied on the effect of rice husk ash and lime on the properties of the marine clay and said that the marine soil is having higher proportions of organic matter, which acts as a cementing agent and also accumulation of waste materials is now becoming a major concern to the environmentalists. He also said that shrink and swell movements are occurred due to the changes in soil structure and also damaging of foundations and structures are also due to the marine clay, which allows water to rapidly drain. Musa Alhassan (October 2008) has studied about the permeability of laterite soil that was treated with lime and rice husk ash and said about the effects of the ash on the soil lime mixtures that were investigated with respect to unconfined compressive strength, he stated that the minimum values of RHA percent beyond the point may raise the permeability content and this can be used to increase UCS value and reduce the permeability of laterite soil. And MDD may decrease with increase in lime content due to the flocculation and agglomeration of clay particles which are caused by the cation exchange reactions. Agus Setyo Muntohar et al. has studied about the silica waste utilization in ground improvement and the study of expansive soil treated with Lime Rice Husk Ash (LRHA), and said that lime and RHA was mixed to stabilize expansive soils. The results of the experiments done shows that there is decrease in swell of expansive soils due to rice husk ash and also improved strength and bearing capacity. They also stated that lime modifies and immediately improves workability, plasticity, compactability of soils and effectively shrinks the construction. Lime treated soil and cementation is the governing factor causing the formation of clods and these clods reduce the permeability of sample. Yulvi Zaika et al. has studied about the improving of expansive soil by using combination of Rice Husk Ash and Fly Ash and given that the increase of volume due to swelling depends on hydrated ions, water content and types of clay, and swelling can be controlled by exchanging cation neutralizer. Here swelling value is reduced due to the long curing time and then CBR value is increased rapidly and then swelling is reduced and then it gives less damage of road due to the changes in water content. Leonardo Behak (2006) has studied about the soil stabilization with Rice Husk Ash and commented that the carbon content of RHA alters the stabilization process due to the reactions and then produces low increase of its strength, the grain size distribution of soil, RHA, lime materials mix are reduced due to the decrease in dry unit weight (DUW). The optimum moisture content (OMC) is high due to the addition of RHA and lime. Hari Kumar. M et al. (2016) has done the experimental investigation of using Rice husk ash and Lime for Soil stabilization and said that dry unit weight is decreased gradually due to the increase in Rice husk content, OMC is also increased due to RHA content. He observed that addition of Fly Ash and RHA decreases the specific gravity of the soil. This decrease in specific gravity is due to the lower value of specific gravity of Fly Ash and RHA are 2.09 and 2.04 respectively. Iloeje Amechi Francis et al. (2013) has studied about the optimization of Rice Husk Ash-Clay soil stabilization and given that the CBR value of the sample was raised from 5% to 29% at optimum stabilization of 17.5%and he concluded that in any type of soil the addition of stabilizing agent results in the increase in OMC and CBR content. Akshaya Kumar Sabat (January 2013) has studied about the engineering properties of an Expansive Soil Stabilized with Rice Husk Ash and Lime Sludge and stated that the test results in the loss of UCS values of stabilized soil at the curing period of 7 and 28 days. He also said that the CBR, cohesion and angle of internal friction increases with increase in curing period and at last it is found that cost is saved in the construction of pavement. Laxmikant Yadu et al. (October 2011) has studied about the comparison of Fly Ash and Rice Husk Ash Stabilized Black Cotton Soil and said that RHA was more effective in reducing Plasticity index and then Fly Ash, and also stated that addition of Fly Ash and RHA reduces the specific gravity of soil. OMC and MDD values are also decreased due to the increase in percentage of RHA. Decrease in MDD is due to the replacement of soil by Fly Ash and RHA. R.Oviya et al. (May 2016) has done the experimental study on stabilizing the soil using rice husk ash with lime as admixture and quoted that RHA mixed soil is compacted then maximum dry density decreases with increases in moisture content in RHA. Subramanyam M.S. et al. (December 1981) has studied about the use of Rice Husk Ash for soil stabilization and stated that the plasticity index was lowered for soil with admixture for a curing period and it is due to the pozzalonic reactivity of siliceous material from RHA and clayey soil, and then concluded that RHA with a low percentage of ignition loss may be used for soil stabilization. From the RHA soil system is less than required soil system. M.Heeralal et al. has studied about the Laboratory investigation on rut depth potential of flexible pavement laid over morrum and laterite soil subgrade and also stated that subgrade is stabilized with Rice Husk Ash and Cement at a percentage with increase in the pavement thickness is effective compared to laterite subgrade and he concluded that reduction in rut depth in laterite soil subgrade is due to the stabilization of cement with Rice Husk Ash then it increases pavement thickness. Musa Alhassan et al. (2007) has studied about the Effect of rice husk ash on cement stabilized laterite and expressed that MDD and OMC was increased with increase in cement content, increase in OMC is due to the addition of Cement and RHA which is used to decrease the quantity of free silt and clay fraction. UCS improvement is also due to the increase in RHA content from the pozollanic reaction between lime from the hydration reaction of cement and RHA to form secondary cementitious material. Agus Setyo Muntohar has stated about the influence of molding water content and lime content on the strength of stabilized soil with Lime and Rice Husk Ash and stated that UCS values are decreased by adding and reducing the water content, and he concluded that UCS of stabilized soil is affected by the density or unit weight of compacted soil and molded-moisture content, and also increase in lime content results in high strength, The unconfined compressive strength of the stabilized soil increases significantly in range to its unstabilized condition. Chun-Yang Yin et al. (October 2006) has expressed about the Stabilization/Soilidification of Lead contaminated soil using Cement and Rice Husk Ash and said that metal phases precipitating on the surface of CSH. The residual portlandite was identified for all the treated contaminated soils, and concluded that the usage of OPC with RHA as an overall binder system in the regulatory compliance of the test parameters. V K. Sowmya et al. (2013) has studied about the effect of Rice Husk Ash on strength and durability of lime stabilized Black Cotton Soil and given that liquid limit and plastic limit of lime stabilized black cotton soil is increases due to gradual increase in RHA content whereas the MDD is decreased. The decrease in MDD is due to the replacement of soil with RHA. He observed that UCS is increased in curing stage at a specified lime contents due to the pozzolanic reactions between Lime and RHA in the formation of more cementitious compounds. Arshad Husain et.al (2014) has studied about the swelling properties of improved expansive soil by Rice Husk Ash (RHA) and Silica Fume (SF) and observed that by increasing Silica Fume and RHA content in soil, optimum moisture content values increased and maximum dry unit weight values are decreased and also the effect of Silica Fume is more than RHA. The maximum effect is when RHA and Silica Fume are used as additives. M. Prakash et.al (2013) has studied about the effect of Rice Husk Ash and Fly Ash on Engineering Properties of Expansive Soil and stated that low cohesion makes RHA a poor cushioning and constructional material but after stabilizing with Fly Ash and curing for 28 days, RHA requires better cushioning properties and then it is used as constructional material between sub grade and foundation.

3. Methodology of study

The soil collected from the site was pulverized with wooden mallet to break lumps and then air-dried. Subsequently it was sieved through 4.75 mm IS sieve and then dried in an oven at 105^{0}C for 24 hours. Tests were conducted to determine physical and Engineering properties of expansive soil like grain size distribution, Atterberg limits, specific gravity, differential free swell index, IS light compaction test, UCS, CBR test. And IS light Compaction test and specific gravity and grain size analysis on stone dust and rice husk ash. Lime and cement was taken in increments of 2% separately which were sieved so that it is free from lumps and were mixed into the soil separately in increments of 2% to ensure uniform coverage.

Due care was taken to ensure a uniform soil-lime mixture and soil-cement-mixture. Now desired quantity of soil-lime mix & soil-cement-mix were taken into the mould and compacted to required thickness at its OMC. Unconfined compressive strength test and pH studies were conducted on soil mixed with varying lime content from 2-12% of lime & varying cement content from 2-12%with increments of 2% separately. Optimum lime and cement were considered as that percentage where UCS was maximum and pH was around 12.4. The required quantity of optimum lime and optimum cement are taken separately and RHA and stone dust were added separately in increments of 2% thus forming four kinds of mixes viz., Soil- Optimum Lime-Rice Husk Ash Mix, Soil- Optimum Lime-Stone Dust Mix, Soil- Optimum Cement-Rice Husk Ash Mix and Soil- Optimum Cement-Stone Dust Mix under different proportions.

Table 1: Various Mixes Considered for Study

1	soil-lime-rice husk ash mixes	3	soil-cement-rice husk ash mixes
1a	soil-8%lime-2%rice husk ash	3a	soil-8%cement-2%rice husk ash
1b	soil-8%lime-4%rice husk ash	3b	soil-8%cement-4%rice husk ash
1c	soil-8%lime-6%rice husk ash	3c	soil-8%cement-6%rice husk ash
1d	soil-8%lime-8%rice husk ash	3d	soil-8%cement-8%rice husk ash
1e	soil-8%lime-10%rice husk ash	3e	soil-8%cement-10%rice husk ash
1f	soil-8%lime-12%rice husk ash	3f	soil-8%cement-12%rice husk ash
2	soil-lime-Stone dust mixes	4	soil-cement-stone dust mixes
2a	soil-8%lime-2%stone dust	4a	soil-8%cement-2%stone dust
2b	soil-8%lime-4%stone dust	4b	soil-8%cement-4%stone dust
2c	soil-8%lime-6%stone dust	4c	soil-8%cement-6%stone dust
2d	soil-8%lime-8%stone dust	4d	soil-8%cement-8%stone dust
2e	soil-8%lime-10%stone dust	4e	soil-8%cement-10%stone dust
2f	soil-8%lime-12%stone dust	4f	soil-8%cement-12%stone dust

All the samples stated in Table 1 were cured for a period of 28 days in desiccator under water in controlled conditions.

Unconfined compressive strength test and CBR tests were conducted on the above stated 24 mixes, UCS samples are made in to powder and sample passing through 425 microns are studied for variation in liquid limit plastic limit, plasticity index, shrinkage limit, pH, Differential free swell Index according to IS standard procedures. Based on CBR and Atterberg limits and traffic estimated for a period of study of 5 consecutive years both harvesting and non-harvesting seasons designs are made by using rural roads codes for flexible (IRC: SP-72 – 2015) and cement concrete pavement (IRC-62-2014) for above stated mixes. Cost benefit analysis was made for cement concrete and flexible pavements to propose a low cost solution for problematic subgrade on rural roads.

4. Results and discussions

4.1. Physical and engineering properties of expansive soil

The physical properties of expansive soil like specific gravity, plastic limit, soaked CBR etc., are listed in the following Table 2.

Table 2: Physical and Engineering Properties of Expansive Soil

S. No	Property	Value
1	Specific gravity	2.5
2	Particle size distribution	
	a) Sand (%)	24
	b) Silt (%)	3.2
	c) Clay (%)	72.8
3	Liquid limit (%)	86.27
4	Plastic limit (%)	36
5	Plasticity Index (%)	50.27
6	IS Classification of soil	CH
7	Maximum Dry Density (kN/ m^3)	14.4
8	Optimum Moisture Content	23
9	Soaked CBR value (%)	0.85
10	Differential free swell index (%)	140

Table 3: Physical Properties of Stone Dust

S. No	Property	Value
1	Specific gravity	2.77
2	Maximum Dry Density (kN/ m^3)	20.1
3	Optimum Moisture Content (%)	9.4
4	Particle size distribution	
	Gravel size	3%,
	Sand size	81%
	Silt size	16%
5	IS Classification	SM

Table 4: Chemical Composition of Stone Dust

S. No	Constituents	Percentage (%)
1	Silica – SiO_2	95
2	Alumina – Al_2O_3	1.59
3	Carbon	1.45
4	Calcium Oxide – CaO	1.2
5	Magnesium Oxide – MgO	0.4
6	Potassium Oxide – KaO	0.2
7	Ferric Oxide -Fe_2O_3	0.16

Table 5: Physical Properties of Rice Husk Ash

S. No	Property	Value
1	Specific gravity	1.95
2	Maximum Dry Density (kN/ m^3)	7.3
3	Optimum Moisture Content (%)	70

Table 6: Chemical Composition of RHA

S. No	Constituents	Percentage (%)
1	Silica – SiO_2	97
2	Alumina – $Al2O_3$	1.08
3	Carbon	1.03
4	Calcium Oxide – CaO	0.53
5	Magnesium Oxide – MgO	0.17
6	Potassium Oxide – KaO	0.1
7	Ferric Oxide -Fe_2O_3	0.09

From soil properties of soil and a liquid limit of 86.27 % and differential free swell index of 140% making it highly expansive. It was also observed that the soil contained 72% of clay portion, classified as CH and soaked CBR is as low as 0.85.

The high swell index can be inferred making the soil highly problematic also the value of soaked CBR suggest that any type of pavement either flexible or cement concrete pavement can’t be constructed on this soil.

In order to construct the pavement, the alternatives available are either complete replacement of soil or treatment of underlying soil in order that the same soil can be used as subgrade. From the above tables of chemical analysis of Rice husk ash and stone dust it was noticed that Rice husk ash is slightly rich in Silica compared to stone dust, while stone dust possesses calcium oxide percentage slightly more than Rice husk ash. Hence it can be inferred that stone dust has slighter cementitious properties while rice husk ash is highly siliceous.

4.2. Values of MDD, OMC, CBR, PI for various mixes

The results of compaction, CBR and Atterberg limits of different mixes are given below

Table 7: MDD, OMC, CBR, PI for Soil-Lime-RHA mixes

MIX	MDD (gm/cc)	PI	CBR (%)	OMC (%)
soil-8%lime-2%RHA	1.41	39	6.4	28
soil-8%lime-4%RHA	1.41	28	10.8	30
soil-8%lime-6%RHA	1.41	19	15.7	30
soil-8%lime-8%RHA	1.40	7	18.7	30
soil-8%lime-10%RHA	1.36	N.P	22.7	30.2
soil-8%lime-12%RHA	1.35	N.P	17.7	28

Table 8: MDD, OMC, CBR, PI for Soil-Lime-SD mixes

MIX	MDD (gm/cc)	PI	CBR (%)	OMC (%)
Soil+8%Lime+2%SD	1.445	33	4.5	30
Soil+8%Lime+4%SD	1.45	27	7.43	27
Soil+8%Lime+6%SD	1.452	24	13.9	25
Soil+8%Lime+8%SD	1.460	15	15.6	25
Soil+8%Lime+10%SD	1.471	N.P	21.4	24
Soil+8%Lime+12%SD	1.443	N.P	19	26

Table 9: MDD, OMC, CBR, PI for Soil-Cement-RHA mixes

MIX	MDD (gm/cc)	PI	CBR (%)	OMC (%)
Soil+8%Cement+2%RHA	1.41	33	4.5	26
Soil+8%Cement+4%RHA	1.40	22	7.7	26.2
Soil+8%Cement+6%RHA	1.40	11.5	13.4	27
Soil+8%Cement+8%RHA	1.36	6	21.1	28
Soil+8%Cement+10%RHA	1.34	N.P	18.8	25
Soil+8%Cement+12%RHA	1.38	N.P	17.1	24

Table 10: MDD, OMC, CBR, PI for Soil-Cement-SD mixes

MIX	MDD (gm/cc)	PI	CBR (%)	OMC (%)
Soil+8%Cement+2%SD	1.46	27	6.7	26
Soil+8%Cement+4%SD	1.47	22	9.9	25.8
Soil+8%Cement+6%SD	1.48	12	15.9	25
Soil+8%Cement+8%SD	1.48	6	17.3	22.6
Soil+8%Cement+10%SD	1.5	4	21	20
Soil+8%Cement+12%SD	1.47	4	17.3	22

It can be observed seen from above results

In case of soil-lime-RHA and Soil-Cement-RHA mixes it can be seen that the dry density decreases with increase of rice husk ash. This may be due to lower specific gravity of rice husk ash when compared to particles of soil. The decrease in dry density is also due to the quick reaction of cement with the soil which alters the Base Exchange aggregation and flocculation, causing an increase in void ratio and subsequent decrease in the density of the overall mixture.

It was observed that in case of soil-lime-SD and Soil-Cement-SD mixes it can be seen that the dry density increases with increase of Stone dust. This may be due to higher specific gravity of stone dust particles.

In case of soil-lime-RHA and Soil-Cement-RHA mixes it can be seen that the OMC increases with increase of rice husk ash. This may be due to more affinity of gravity of rice husk ash particles towards water requiring more water for the base pozzolanic reaction to occur.

It was observed that in case of soil-lime-SD and Soil-Cement-SD mixes it can be seen that the OMC Decreases with increase of Stone dust. This may be due to less affinity of stone dust towards water while compared to soil which in turn requires less water to reach its confined plastic stage while compaction and making of a dense structure.

CBR enhancement in all the mixes above mentioned may be probably due to acceleration of pozzolanic reactions due to their high reactive capacity and pozzolanic properties of stone dust and lime. And also the addition of stone dust and rice husk ash to lime stabilized soil increases the availability of slice and alumina in the reactions leading to the formation of CSH and CAH minerals. The CSH minerals may be, Calcium chondrite, Killalaite, Suolunite, Poldervaartite and Wallsonite. The high pH environment during lime stabilization results in the destruction of the crystal structure of silica and alumina to dissolution resulting in the formation of more strengthened bonds.

After an optimum slight decrease in CBR value in soil-lime-rice husk ash and soil-cement-rice husk ash mix may be attributed to the fact that the excess rice husk ash remains unused and prevent the aggregate particles from contact and tends to float in a matrix of unused rice husk ash resulting in less stability.

It was observed that as the percentage of Rice husk ash and Quarry dust increases in the above mentioned mixes, the reduction in Plastic may be attributed to reduction in Diffused Double Layer thickness and Clay percentage are responsible for decrease in Liquid Limit with increase the percentage of admixtures of soil admixtures and also due to filling of voids of flocculated soil thereby reducing water holding capacity

4.3. Design of flexible pavement according to IRC: SP-72 – 2015

Twenty-four-hour traffic counts over a period of three days on a single lane rural road during the peak harvesting season yielded the following results of the Average Daily Traffic.

Table 11: Different Vehicular Traffic Data

Type of vehicle	Number of vehicles
Animal drawn cart	38
Bicycles	503
Full sized truck	18
Agriculture tractor/trailers and jugads	73
Cars and jeeps	35
Motor cycles	234

There are two harvesting seasons in the area each having duration of about 2 ½ months, the above traffic count data was collected 2 years before opening the road to traffic

The depth of ground water table was found to be 10m below ground level. The average annual rain fall in the region is 750mm. various percentages of lime and cement mixed with stone dust and the resulting CBR, Plasticity index (PI) and OMC values are given below

Design Calculations:

1) Computation of Design Traffic Parameter:

From fig: 1 of IRC SP-72-2015(pg no: 10)

n=1; t=75 days

(Because the peak harvesting season traffic is double the traffic during the non-harvesting season)

Average Daily Traffic during the non-harvesting season=901/2

T=450.5

Average Annual Daily Traffic (AADT) = T+ (1.2nTt/365)

= 450.5+ ((1.2 X 1 X 450.5 X 75)/365) =561.58

A growth rate of 6%is assumed

AADT=P X $(1+r)^n$

=561.58 X $(1+0.06)^2$

=631
For the given proportions, HCV&MCV out of AADT of 631 worked out as
Heavy Commercial Vehicles (HCV) = 13
Medium Heavy Commercial Vehicles (MCV) =51
Therefore, Commercial Vehicles per Day (CPVD) to be considered for design purpose=13+51 =64
It is assumed that laden and unladen vehicles are equal in number
Taking Vehicle Damage Factor (VDF) from IRC: SP-72-2015 (para3.4.4) (pg. no: 12)
The Equivalent Standard Axle Load ESAL
= ((13/2) x 2.86) + ((51/2) x 0.34) + ((13/2) x 0.31) + ((51/2) x 0.02)
T_o =29.785
Cumulative ESAL applications over 10 years @6% growth rate
$N=T_o \times 365 \times (((1+0.01r)^n-1)/0.01r) \times L$
$=29.785 \times 365 \times (((1+0.06)^{10}-1)/0.06) \times 1$
=143295.6

2) Evaluation of Sub Grade Strength:

Since the GWT is too deep to influence the sub grade moisture, the design moisture may be close to the optimum moisture content. Reference to the nomograph in FIG.2 of IRC: SP72-2015(pg. no: 18), for insitu dry of 1.445gm/cc, GWT depth of 10m PI of 33 and average annual rainfall of 75cm, the Equilibrium Moisture Content works out to be 15% the optimum moisture content of 30% being higher, the CBR value of 4.5 may be taken for sub grade strength.

3) Pavement Thickness and Composition for Cumulative ESAL application over the design life (N) = 143295.6

From the figure 4 of IRC SP-72:2015, N is between 1, 00,000 and 2, 00,000 i.e. T4. Thickness composition of various mixes is stated below

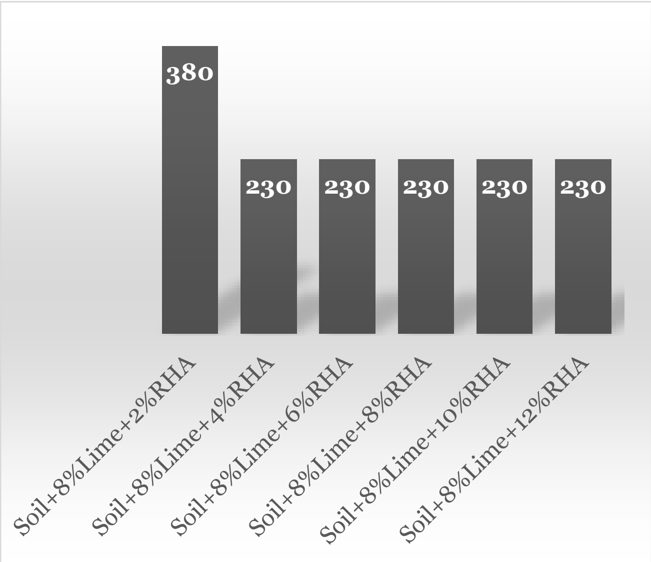

Fig. 1: Graph Showing Pavement Composition - Soil-Lime-Rice Husk Ash Mixes

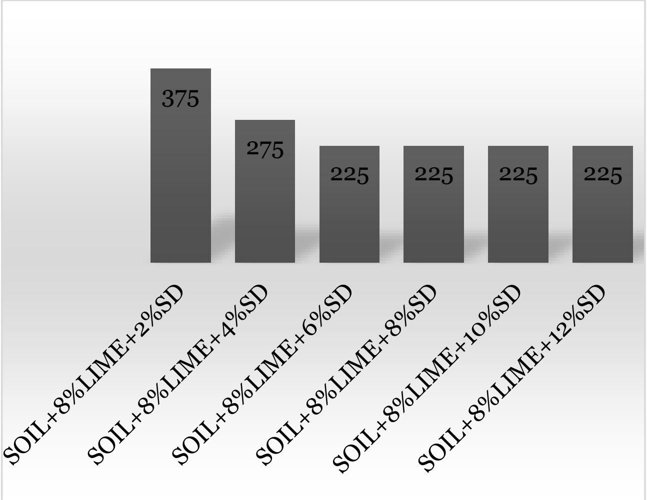

Fig. 2: Graph Showing Pavement Composition - Soil-Lime-Stone Dust Mixes.

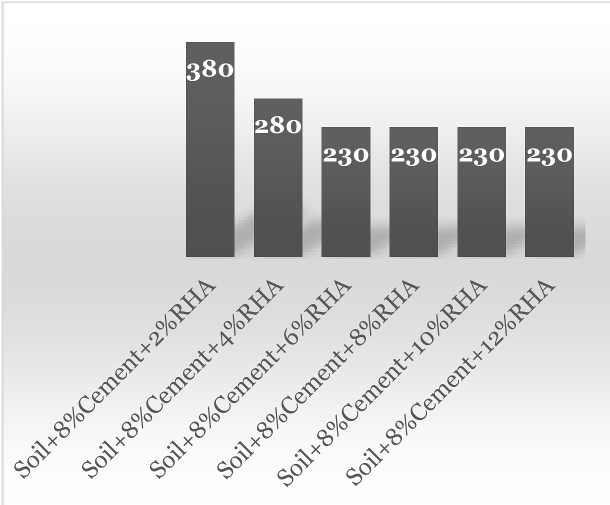

Fig. 3: Graph Showing Pavement Composition Soil-Cement- RHA Mixes.

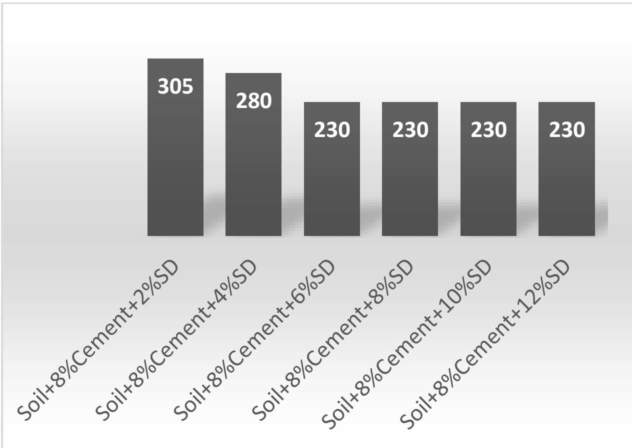

Fig. 4: Graph Showing Pavement Composition - Soil-Lime-Rice Husk Ash Mixes.

4.4. Design of cement concrete pavement according to IRC: SP-72 – 2015

Since the traffic is 64CVPD the traffic will be shifted to Case 2 of excel sheet analysis and our zone will be zone III.
Based on CBR K values are calculated and assuming joint spacing to be 2.5m

From Table 7-10 the design has been made using Excel sheet of IRC-SP-62-2014, it was observed that the thickness of the pavement remains the same for CBR> 4.5 Since K of design is influenced by CBR. But K values have negligible influence on thickness of cement concrete pavement.

Case 1: design traffic is <50cvpd Case 2 : traffic is in between 50 to 150 cvpd Case 3 traffic is >150 cvpd

Enter the Data	
Case 1 /2/3	2
Temperature Zone (1 to 6)	1
Modulus of the subgrade reaction, k Mpa/m	**37**
Elastic modulus of concrete E, Mpa	30000
Poisson Ratio of the concrete, μ	0.15
Temperature differntial, ΔT oC	12.8
Modulus of rupture of concrete, fcr	4.22

Tyre (**1**- single/**2** - dual)	1
Spacing of wheels Sd (mm)	310
wheel load, P kN	50
Tyre pressure, q MPa	0.8
Radius of contact, a (mm)	141.0474
Trial thickness, h m	**0.175**
No. of commercial vehicels per day	300

Transverse joint spacing,m	2.5
Ratio of L/l	3.204469132
Co-efficient of thermal expansion	0.00001
Correction factor C	0.259366231
Design life of pavement, yrs	20
Rate of increase of traffic	0.06
Truck with 50kN Wheel load,%	10

RESULTS FOR WHEEL LOAD AND TEMPARATURE	
Case 2	
temparature stress at edge, Mpa	0.00966792
Wheel load Stresses at edge, Mpa	4.008685322
Total stresses, σ, Mpa	4.018353242
Design is	Safe

Fig. 5: Thickness Determination of Cement Concrete Pavement Mixes Having CBR 4.5 (Soil+8%Lime+2%SD, Soil+8%Cement+2%RHA).

Case 1: design traffic is <50cvpd Case 2 : traffic is in between 50 to 150 cvpd Case 3 traffic is >150 cvpd

Enter the Data	
Case 1 /2/3	2
Temperature Zone (1 to 6)	1
Modulus of the subgrade reaction, k Mpa/m	**38**
Elastic modulus of concrete E, Mpa	30000
Poisson Ratio of the concrete, μ	0.15
Temperature differntial, ΔT oC	12.7
Modulus of rupture of concrete, fcr	4.22

Tyre (**1**- single/**2** - dual)	1
Spacing of wheels Sd (mm)	310
wheel load, P kN	50
Tyre pressure, q MPa	0.8
Radius of contact, a (mm)	141.0474
Trial thickness, h m	**0.17**
No. of commercial vehicels per day	300

Transverse joint spacing,m	2.5
Ratio of L/l	3.296806108
Co-efficient of thermal expansion	0.00001
Correction factor C	0.279731833
Design life of pavement, yrs	20
Rate of increase of traffic	0.06
Truck with 50kN Wheel load,%	10

RESULTS FOR WHEEL LOAD AND TEMPARATURE	
Case 2	
temparature stress at edge, Mpa	0.035698107
Wheel load Stresses at edge, Mpa	4.184218631
Total stresses, σ, Mpa	4.219916738
Design is	Safe

Fig. 6: Thickness Determination of Cement Concrete Pavement Mixes Having CBR > 4.5.

4.5. Cost analysis for design of flexible pavement by replacing the surface soil

i) Quantity of soil required for replacing the existing soil =3.75 x 0.3 x 1,000 = 1,125m^3
Density of soil used for replacing = 2.5 gm/cc and CBR 6
Amount of soil required in terms of tones = 1,125 X 2.5 X 103 =28, 12,500 kgs =2,812.5 tones
Cost of replacing soil including transportation = 320/ ton
Cost for total soil = 2,812.5 X 320 = RS 9, 00,000/-

ii) Quantity of modified soil =1000 X 3.75 X 0.3 = 1,125m3
Supplying and filling in with good earth for construction of sub grade and earthen shoulder in regular layers including watering consolidation by power roller etc. complete =221/m^3 (MORTH spec. 301)
Total cost=1,125 X 221 = RS 2, 48,625/-

iii) Construction of granular sub-base by providing close graded material (Grading I), mixing by mix in place method with rotavator at OMC and compacting with vibratory roller to achieve the desired density=Rs. 2,219/m3 (MORTH spec 401)
Quantity of sub-base material=1,000 X 3.75 X 0.125=468.75m^3
Total cost=468.75 X 2,219= RS 10, 40,157/-

iv) Providing, laying, spreading and compacting graded stone aggregate to wet mix macadam specification including premixing the material with water at OMC in mechanical mix plant carriage of mixed material by tipper to site laying in uniform layers with paver in base course on well prepared surface and compacting with vibratory roller to achieve the desired density. =2,298/m3 (MORTH spec 406)
Quantity of base material =1,000 X 3.75 X 0.075 =281.25m^3
Total cost=281.25 X 2,298= RS 6, 46,313/-

v) Preparation of water bound macadam providing, laying, spreading and compacting graded stone aggregate laying in uniform layers with paver in base course on well prepared surface and compacting with vibratory roller to achieve the desired density. = 3,500/m3
Quantity of base material = 1,000 X 3.75 X 0.075 = 281.25m^3
Total cost = 281.25 X 3500 = RS 9, 84,375/-
Overall cost for construction of flexible pavement = RS 38, 19,470/-

4.6. Cost analysis for design of flexible pavement for various mixes

Table 12: Cost Analysis of Soil-Lime-RHA Mixes

SL. no	Description of the item	Name of the mix					
		Soil + 8%Lime + 2%RHA	Soil +8%Lime + 4% RHA	Soil + 8%Lime + 6%RHA	Soil + 8%Lime + 8%RHA	Soil + 8%Lime + 10%RHA	Soil + 8%Lime + 12%RHA
1	Cost of lime required for soil stabilization						
	number of bags =	4,500	4,500	4,500	4,500	4,500	4,500
	cost of lime bag	220	220	220	220	220	220
	Total Cost of lime	9,90,000/-	9,90,000/-	9,90,000/-	9,90,000/-	9,90,000/-	9,90,000/-
2.	Cost of supplying and filling in with good earth work for construction of subgrade and earthen shoulder in regular layers including watering consolidation by power roller per m^3						
	quantity of modified soil (m^3) =	1000x3.75x0.2 = 750	1000x 3.75x0.1 =375	1000x 3.75x0.1 =375	1000x 3.75x0.1 = 375	1000x 3.75x0.1 =375	1000x 3.75x0.1 =375
	Cost per m^3	221	221	221	221	221	221
	Total Cost	1,65,750	82,875/-	82,875/-	82,875/-	82,875/-	82,875/-
3.	construction of granular sub-base by providing close graded material (grading I) mixing by mix in place method with rotavator at OMC and compacting with vibrator roller to achieve the desired density						
	quantity of sub-base material (m^3) =	1000x3.75x0.125 = 468.75					
	Cost per m^3	2219					
	Total Cost	1040156.25/-					
4.	providing , laying ,spreading and compacting graded stone aggregate to wet mix macadam specification including premixing the material with water at OMC in mechanical mix plant carriage of mixed material by tripper to site laying in uniform layers with paver in base course on well prepared surface and compacting with vibratory roller to achieve the desired density						
	quantity of base material (m^3) =	.075*1000*3.75 =281.25	.150*1000*3.75 =281.25	.150*1000*3.75 =562.5	.150*1000*3.75 =562.5	.150*1000*3.75 =562.5	.150*1000*3.75 =562.5
	Cost per m^3	2298	2298	2298	2298	2298	2298
	Total Cost	6,46,312.50/-	12,92,625/-	12,92,625/-	12,92,625/-	12,92,625/-	12,92,625/-
5.	preparation of water bound macadam providing , laying ,spreading and compacting graded stone aggregate laying uniform layers with paver In base course on well prepared surface and compacting with vibratory roller to achieve the density						
	quantity of base material (	.075*1000*3.75 =281.25	.075*1000*3.75 =281.25	.075*1000*3.75 =281.25	.075*1000*3.75 =281.25	.075*1000*3.75 =281.25	.075*1000*3.75 =281.25

	m³) =						
	Cost per m³	3500	3500	3500	3500	3500	3500
	Total Cost	9,84,375/-	9,84,375/-	9,84,375/-	9,84,375/-	9,84,375/-	9,84,375/-
overall cost of flexible pavement for laying 1 Km length (RS) =							
Total Cost		38,26,593.75	33,49,875	33,49,875	33,49,875	33,49,875	33,49,875

Table 13: Cost Analysis of Soil-Lime-Stone Dust Mixes

SL. no	Description of the item	Name of the mix					
		Soil + 8%Lime + 2%SD	Soil +8%Lime + 4% SD	Soil + 8%Lime + 6%SD	Soil + 8%Lime + 8%SD	Soil + 8%Lime + 10%SD	Soil + 8%Lime + 12%SD
	Cost of lime required for soil stabilization						
	number of bags =	4,500	4,500	4,500	4,500	4,500	4,500
1	cost of lime bag = RS =	220	220	220	220	220	220
	Total Cost of lime	9,90,000/-	9,90,000/-	9,90,000/-	9,90,000/-	9,90,000/-	9,90,000/-
	Cost of supplying and filling in with good earth work for construction of subgrade and earthen shoulder in regular layers including watering consolidation by power roller per m^3						
2.	quantity of modified soil (m³) =	1000x3.75x0.1 = 375	1000x3.75x0.1 =375	1000x3.75x0.1 =375	1000x3.75x0.1 = 375	1000x3.75x0.1 =375	1000x3.75x0.1 =375
	Cost per m³	221	221	221	221	221	221
	Total Cost	1,65,750	82,875/-	82,875/-	82,875/-	82,875/-	82,875/-
	construction of granular sub-base by providing close graded material (grading I) mixing by mix in place method with rotavator at OMC and compacting with vibrator roller to achieve the desired density						
3.	quantity of sub-base material (m³) =	1000x3.75x0.125 = 468.75	1000x3.75x0.125 =468.75				
	Cost per m³	2219	2219				
	Total Cost	1040156.25/-	10,40,156.25/-				
	providing , laying ,spreading and compacting graded stone aggregate to wet mix macadam specification including premixing the material with water at OMC in mechanical mix plant carriage of mixed material by tripper to site laying in uniform layers with paver in base course on well prepared surface and compacting with vibratory roller to achieve the desired density						
4.	quantity of base material (m³) =	.075*1000*3.75 =281.25	.075*1000*3.75 =281.25	.150*1000*3.75 =562.5	.150*1000*3.75 =562.5	.150*1000*3.75 =562.5	.150*1000*3.75 =562.5
	Cost per m³	2298	2298	2298	2298	2298	2298
	Tot	6,46,312.50/-	6,46,312.5/-	12,92,625/-	12,92,625/-	12,92,625/-	12,92,625/-

5.	al Cost						
	preparation of water bound macadam providing , laying ,spreading and compacting graded stone aggregate laying uniform layers with paver In base course on well prepared surface and compacting with vibratory roller to achieve the density						
	quantity of base material (m^3) =	.075*1000*3.75 =281.25	.075*1000*3.75 =281.25	.075*1000*3.75 =281.25	.075*1000*3.75 =281.25	.075*1000*3.75 =281.25	.075*1000*3.75 =281.25
	Cost per m^3	3500	3500	3500	3500	3500	3500
	Total Cost	9,84,375/-	9,84,375/-	9,84,375/-	9,84,375/-	9,84,375/-	9,84,375/-
overall cost of flexible pavement for laying 1 Km length (RS) =							
Total Cost		38,26,593.75	37,437,18.75	33,49,875	33,49,875	33,49,875	33,49,875

Table 14: Cost Analysis of Soil-Cement-RHA Mixes

SL. no	Description of the item	Name of the mix					
		Soil+ 8%Cement+ 2%RHA	Soil+ 8%Cement+ 4%RHA	Soil+ 8%Cement+ 6%RHA	Soil+ 8%Cement+ 8%RHA	Soil+ 8%Cement+ 10%RHA	Soil +8%Cement + 12%RHA
1	cost of cement required for soil stabilization						
	number of bags =	4,500	4,500	4,500	4,500	4,500	4,500
	cost of lime bag = RS =	280	280	280	280	280	280
	Total Cost of Cement	12,60,000/-	12,60,000/-	12,60,000/-	12,60,000/-	12,60,000/-	12,60,000/-
2.	Cost of supplying and filling in with good earth work for construction of subgrade and earthen shoulder in regular layers including watering consolidation by power roller per m^3						
	quantity of modified soil (m^3) =	1000x 0.2*3.75 =750	1000x 0.1*3.75 =375	1000x 0.1*3.75 =375	1000x 0.1*3.75 =375	1000x 0.1*3.75 =375	1000x 0.1*3.75 =3.75
	Cost per m^3	221	221	221	221	221	221
	Total Cost	1,65,750	82,875/-	82,875/-	82,875/-	82,875/-	82,875/-
3.	construction of granular sub-base by providing close graded material (grading I) mixing by mix in place method with rotator at OMC and compacting with vibrator roller to achieve the desired density						
	quantity of sub-base material (m^3) =	1000x3.75x0.125 = 468.75	1000x3.75x0.125 = 468.75				
	Cost per m^3	2219	2219				
	Total Cost	10,40,156/-	10,40,156/-				
4.	providing , laying ,spreading and compacting graded stone aggregate to wet mix macadam specification including premixing the material with water at OMC in mechanical mix plant carriage of mixed material by tripper to site laying in uniform layers with paver in base course on well prepared surface and compacting with vibratory roller to achieve the desired density						

	quantity of base material (m^3) =	281.25	281.25	.150*1000*3.75 =562.5	.150*1000*3.75 =562.5	.150*1000*3.75 =562.5	.150*1000*3.75 =562.5
	Cost per m^3	2298	2298	2298	2298	2298	2298
	Total Cost	6,46,312.50/-	6,46,312.5/-	12,92,625/-	12,92,625/-	12,92,625/-	12,92,625/-
	preparation of water bound macadam providing , laying ,spreading and compacting graded stone aggregate laying uniform layers with paver In base course on well prepared surface and compacting with vibratory roller to achieve the density						
5.	quantity of base material (m^3) =	3500	3500	3500	3500	3500	3500
	Cost per m^3	281.25	281.25	281.25	281.25	281.25	281.25
	Total Cost	9,84,375/-	9,84,375/-	9,84,375/-	9,84,375/-	9,84,375/-	9,84,375/-
overall cost of flexible pavement for laying 1 Km length (RS) =							
Total Cost		42,21,750/-	40,13,719/-	36,19,875/-	36,19,875/-	36,19,875/-	36,19,875/-

Table 15: Cost Analysis of Soil-Cement-Stone Dust Mixes

SL. no	Description of the item	Name of the mix					
		Soil+ 8%Cement+ 2%SD	Soil+ 8%Cement+ 4%SD	Soil+ 8%Cement+ 6%SD	Soil+ 8%Cement+ 8%SD	Soil+ 8%Cement+ 10%SD	Soil +8%Cement + 12%SD
	cost of cement required for soil stabilization						
1	number of bags =	4,500	4,500	4,500	4,500	4,500	4,500
	cost of lime bag = RS =	280	280	280	280	280	280
	Total Cost of Cement	12,60,000/-	12,60,000/-	12,60,000/-	12,60,000/-	12,60,000/-	12,60,000/-
	Cost of supplying and filling in with good earth work for construction of subgrade and earthen shoulder in regular layers including watering consolidation by power roller per m^3						
2.	quantity of modified soil (m^3) =	1000x 0.1*3.75 =375	1000x 0.1*3.75 =375	1000x 0.1*3.75 =375	1000x 0.1*3.75 =375	1000x 0.1*3.75 =375	1000x 0.1*3.75 =3.75
	Cost per m^3	221	221	221	221	221	221
	Total Cost	82,875/-	82,875/-	82,875/-	82,875/-	82,875/-	82,875/-
	construction of granular sub-base by providing close graded material (grading I) mixing by mix in place method with rotator at OMC and compacting with vibrator roller to achieve the desired density						
3.	quantity of su	1000x3.75x0.15 562.5	1000x3.75x0.125 = 468.75				

	b-base material (m³) =						
	Cost per m³	2219	2219				
	Total Cost	12,48,187.50/-	10,40,156/-				
	providing , laying ,spreading and compacting graded stone aggregate to wet mix macadam specification including pre-mixing the material with water at OMC in mechanical mix plant carriage of mixed material by tripper to site laying in uniform layers with paver in base course on well prepared surface and compacting with vibratory roller to achieve the desired density						
4.	quantity of base material (m³) =	281.25	281.25	.150*1000*3.75 =562.5	.150*1000*3.75 =562.5	.150*1000*3.75 =562.5	.150*1000*3.75 =562.5
	Cost per m³	2298	2298	2298	2298	2298	2298
	Total Cost	6,46,312.50/-	6,46,312.5/-	12,92,625/-	12,92,625/-	12,92,625/-	12,92,625/-
	preparation of water bound macadam providing , laying ,spreading and compacting graded stone aggregate laying uniform layers with paver In base course on well prepared surface and compacting with vibratory roller to achieve the density						
5.	quantity of base material (m³) =	3500	3500	3500	3500	3500	3500
	Cost per m³	281.25	281.25	281.25	281.25	281.25	281.25
	Total Cost	9,84,375/-	9,84,375/-	9,84,375/-	9,84,375/-	9,84,375/-	9,84,375/-
	overall cost of flexible pavement for laying 1 Km length (RS) =						
	Total Cost	42,21,750/-	40,13,719/-	36,19,875	36,19,875	36,19,875	36,19,875

It can be seen that from cost analysis of soil-lime-RHA mixes the cost savings resulted in soil lime RHA mixes in design of flexible pavement is Rs.4,76,718.75/- as on RHA increases from 2 to 4% thereafter there is no cost savings and the cost of pavement remains the same. But CBR of the mix are constantly improving making the physical ground to be more stable.

It can be seen that from cost analysis of soil-lime-SD mixes the total soil cost savings resulted in soil - lime - SD mixes in design of flexible pavement is Rs.82, 875/- as on SD increases from 2 to 4% and Rs.4,76,718.75/- as on SD increases from 2 to 6% construction cost is same starting with addition of SD 6% till 12 %.

It can be seen that from cost analysis of Soil-Cement-RHA mixes the cost savings resulted in soil Cement RHA mixes in design of flexible pavement is Rs.2,08,031/- as on RHA increases from 2 to 4% Rs.4,76,718.75/- as on RHA increases from 2 to 6% thereafter there is no cost savings and the cost of pavement remains the same

It can be seen that from cost analysis of Soil-Cement-SD mixes the cost savings resulted in soil Cement SD mixes in design of flexible pavement is Rs.2,08,031/- as on SD increases from 2 to 4% Rs.4,76,718.75/- as on SD increases from 2 to 6% thereafter there is no cost savings and the cost of pavement remains the same.

It can be seen that in the initial stages the cost of construction is same with replacement of entire soil in the subgrade as on the percentage of rice husk ash and soil increase there are cost savings that can be seen from analysis. Even the cost savings are, meagre these savings count to a major amount in case of regular maintenance of rural roads.

4.7. Cost analysis for design of cement concrete pavement for various mixes

Case1: Cost of pavement without any treatment.

1) Quantity of soil required for replacing the existing soil =3.75 x 0.3 x 1,000 = 1,125m³

Density of soil used for replacing = 2.5 gm/cc and CBR 6

Amount of soil required in terms of tones = 1,125 X 2.5 X 10^3 =28, 12,500 kgs =2,812.5 tones

Cost of replacing soil including transportation = 320/ ton

Cost for total soil = 2,812.5 X 320 = RS 9, 00,000/-

2) Provide a granular sub base of 125 mm

Construction of granular sub-base by providing close graded material (Grading I), mixing by mix in place method with rotavator at OMC and compacting with vibratory roller to achieve the desired density=Rs. 2,219/m³ (MORTH spec 401)

Quantity of sub-base material=1,000 X 3.75 X 0.125=468.75m³

Total cost=468.75 X 2,219= RS 10, 40,157/-

3) Total cost of laying cement concrete pavement

Quantity=1000*3.75*.180=675m³

Cost of laying concrete slab @3300 per cum =675*3300=Rs 22, 27,500/-

4) Total Cost of the C.C Pavement= Rs. 41, 67,657

Case2: Cost of cement concrete pavement mixes having CBR 4.5 (Soil+8%Lime+2%SD)

1) Cost of lime required for soil stabilization

Number of bags = 4,500

Cost of lime bag = Rs. 220

Total Cost of lime =Rs.9, 90,000/-

2) Provide a granular sub base of 100 mm

Construction of granular sub-base by providing close graded material (Grading I), mixing by mix in place method with rotavator at OMC and compacting with vibratory roller to achieve the desired density=Rs. 2,219/m^3 (MORTH spec 401)

Quantity of sub-base material=1,000 X 3.75 X 0.100=375m^3

Total cost=375 X 2,219= RS 8, 32,125/-

3) Total cost of laying cement concrete pavement

Quantity=1000*3.75*.175=656.25m^3

Cost of laying concrete slab @3300 per cum =656.25*3300=Rs 21, 65,625/-

4) Total Cost of the C.C Pavement= Rs. 39, 87,750

Case3: Cost of cement concrete pavement mixes having CBR > 4.5 and mixed with optimum lime

1) Cost of lime required for soil stabilization

Number of bags = 4,500

Cost of lime bag = Rs. 220

Total Cost of lime = Rs.9, 90,000/-

2) Provide a granular sub base of 100 mm

Construction of granular sub-base by providing close graded material (Grading I), mixing by mix in place method with rotavator at OMC and compacting with vibratory roller to achieve the desired density=Rs. 2,219/m^3 (MORTH spec 401)

Quantity of sub-base material=1,000 X 3.75 X 0.100=375m^3

Total cost=375 X 2,219= RS 8, 32,125/-

3) Total cost of laying cement concrete pavement

Quantity=1000*3.75*.170=637.50m^3

Cost of laying concrete slab @3300 per cum =637.50*3300=Rs 21, 03,750/-

4) Total Cost of the C.C Pavement= Rs. 39, 25,875

Case4: Cost of cement concrete pavement mixes having CBR 4.5 (Soil+8%Cement+2%RHA)

1) Cost of Cement required for soil stabilization

Number of bags = 4,500

Cost of lime bag = Rs. 280

Total Cost of lime =Rs. 12, 60,000/

2) Provide a granular sub base of 100 mm

Construction of granular sub-base by providing close graded material (Grading I), mixing by mix in place method with rotavator at OMC and compacting with vibratory roller to achieve the desired density=Rs. 2,219/m^3 (MORTH spec 401)

Quantity of sub-base material=1,000 X 3.75 X 0.100=375m^3

Total cost=375 X 2,219= RS 8, 32,125/-

3) Total cost of laying cement concrete pavement

Quantity=1000*3.75*.175=656.25m^3

Cost of laying concrete slab @3300 per cum =656.25*3300=Rs 21, 65,625/-

4) Total Cost of the C.C Pavement= Rs. 42, 57,750

Case5: Cost of cement concrete pavement mixes having CBR > 4.5 and mixed with optimum Cement

1) Cost of Cement required for soil stabilization

Number of bags = 4,500

Cost of lime bag = Rs. 280

Total Cost of lime = Rs. 12, 60,000/

2) Provide a granular sub base of 100 mm

Construction of granular sub-base by providing close graded material (Grading I), mixing by mix in place method with rotavator at OMC and compacting with vibratory roller to achieve the desired density=Rs. 2,219/m^3 (MORTH spec 401)

Quantity of sub-base material=1,000 X 3.75 X 0.100=375m^3

Total cost=375 X 2,219= RS 8, 32,125/-

3) Total cost of laying cement concrete pavement

Quantity=1000*3.75*.170=637.50m^3

Cost of laying concrete slab @3300 per cum =637.50*3300=Rs 21, 03,750/-

4) Total Cost of the C.C Pavement= Rs 41, 95,875.

While design of cement concrete pavement only K value in Excel sheet is influenced by CBR.K value change has only minor effect on CBR changes. Hence the total design of cement concrete mixes for different mixes is divided in to two categories viz, design for K value less than 4.5 and K value greater than 4.5.

The cost savings obtained for thickness variation in cement concrete pavement for all the mixes is minor and is equal to 61,875. In Case of Cement concrete pavement, the mix the lime mixes with RHA and SD (CBR>4.5) result in cost savings of 2, 41,782. This amount may be smaller in value, but plays a major role in initial maintenance of cement concrete pavement built in rural arena.

In Case of Cement concrete pavement, the mix the Cement mixes with RHA and SD (CBR>4.5) result in more cost accounting to 28,218. Which can be considered to be smaller amount when compared with long term maintenance and year wise repair cost of cement concrete built up with soil transported and dumped in from other place, since the soil such used does not take in to account the swelling nature of virgin soil available underneath compacted soil taken from other places.

5. Conclusions

The Decrement in plasticity characteristic of the soil in all the four mixes for different proportions as on the percentage of RHA and stone dust increases when added independently is due to the reduction in thickness of double diffused layer filling of voids of flocculated soil by rice husk ash and stone dust independently in soil-lime-RHA, Soil-lime-SD, Soil-Cement-RHA, Soil-Cement-SD mixes.

The increase in dry density in soil-lime- stone dust, soil-cement-stone dust mixes implies that this is a phenomenon occurred due to the high specific gravity of stone dust compared with soil.

The Decrease in dry density in soil-lime- Rice husk ash mixes, Soil-Cement-Rice husk ash mixes implies that this is a phenomenon occurred due to the very light weight of RHA particles that result in low specific gravity of RHA compared with soil.

The initial increase in CBR in all the four mixes for different percentages can be attributed to the formation of cementitious products like CSH gels and CAH gels as a result of agglomeration, cation exchange that resulted in flocculated structure of soil particles.

In case of flexible pavement, the mixes soil-lime-RHA and soil-lime-stone dust mixes with cost Rs. 33, 49, 87/- is the best cost effective solution. Of these mixes also the soil-lime-RHA mixes proves to be more beneficial from the point of savings in cost involved.

Improvement of soil characteristics with lime and RHA proves to be a cost effective solution for the low volume roads of both flexible and cement concrete roads of rural areas both from construction and initial maintenance point of view.

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