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Optimization of Pond Ash for Black Cotton Soil in Design of Flexible Pavement as Per IRC 37 Guidelines

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***Abstract* - Black cotton soil is a problematic soil which covers 20% of the Indian land. Construction of infrastructural projects-in particular roads on such soil offers greater challenge to highway engineers due to its low bearing capacity in presence of water and low resistance to moisture change due to presence of montmorollonat a type of clay mineral. Thus it increases the thickness of the flexible pavement to overcome above problem. In this investigation an attempt is made to reduce the moisture movement capacity of the black cotton soil and clay content by addition of particles which are finer than clay and behaviour as silt type- that is pond ash. From direct shear test under the normal stress of 100 kPa with curing it is found that, black cotton soil stabilized with 30% pond ash (by weight of soil) show higher strength carrying capacity. Flexible pavement is designed after conducting CBR test under soaked conduction as per Indian Road congress-37 guidelines, from the design it is found that addition of optimum pond ash to black cotton soil- pavement thickness reduces by 27% on compared with black cotton soil alone.**

Key Words: Flexible Pavement, Soaked, CBR

I. INTRODUCTION

Black cotton soil causes many problems to structures constructed on that ground in general and light weight structures like road in particular due to presence of problematic mineral called montmorollonatic a type of clay mineral. About 20% of the soil found in India is expansive problematic black cotton soil. Thus black cotton soil is very poor and undependable subgrade materials. The only remedial measure before using such soil for pavement subgrade is to stabilize the soil before its usage to road work. Many stabilization methods were available starting from good old lime stabilization to reinforced earth. However, we are making an attempt to use the waste material from the thermal power plant as ash. But as on dated accountable research work were carried out about utilization of fly ash as stabilizing material to soil, however in thermal power plant another biggest challenge is effective disposal/utilization of pond ash. The research related to pond as is not as high as fly ash. Therefore, it is necessary to invent large scale utilization of pond ash in soil, which can be possible through pavement subgrade construction. So many researchers done notable work on utilization of pond ash to stabilize the soil. According to Girish and Sushma (2015) says that addition of pond ash to black cotton soil maximum dry density increases up to optimum percentage of pond ash beyond that density decreases. They also conclude that at their optimal combination(soil with 20% pond ash (by weight of soil) there will be improvement of California bearing ration by 1.53% on compared to other combination of soil with pond ash. Hima Latheef and Dipin (2016) says that soil treated with pond ash decreases the maximum dry density and unconfined compressive strength increases up to 60% pond ash (by weigh of soil) there after trend reverses. From the above literature it is found that still some more research is required to optimize the soil with pond ash combination for arriving a concrete air mark about the density and strength relationship.

II. MATERIALS AND METHODS

Soil sample used for the present investigation was collected from Raichur at a depth of 1.5 m below the natural ground level through open pit method of direct soil exploration technique and soil passing through 425 micron Indian standard sieve exception for sieve analysis. The basic properties of the soil is shown in Table 1.0

Pond ash is an by-product obtained from the thermal power plant in Raichur Thermal Power Plant Station and the research wing of RTPS strongly appreciated the methodology proposed by us for during research in pond ash area and they are issued a encouragement letter as indicated in Photo.3.0 and the basic properties as indicated in Table 1.0 Particle size distribution of soil and pond ash is shown in Fig.1.

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Table 1.0 Basic Properties of Block Cotton Soil and Pond Ash

SI No	Physical parameters	Values	
		BCS	PA
1	Colour	Black	Gray
2	Natural water content	8.18%	2.12%
3	Specific gravity	2.44	2.12
4	Atterberg Limits Liquid limit Plasticity index	57.8 29.47	NP
5	Compaction characteristics Maximum dry density (KN/m^3) Optimum moisture content (%)	16.7 21.5%	13.26 25.94%
6	Particle size distribution Sand % Silt and clay size fraction	97.9% 2.01%	79% 21%
7	UCS in KN/m^2	129.53	37.77
8	Angle of shearing resistance Ø°	21	32
9	Cohesion (kN/m2)	37.27	5.04
10	CBR (%), soaked sample	2.91	4.71

Note: NP= Non Plastic, PA=Pond Ash BCS=Black Cotton Soil

Table 2.0 Chemical properties of Pond ash

SI No	Chemicals	Composition (%)
1	$Sio_2+Al_2O_3+Fe_2O_3$	91.04
2	Sio_2	67.24
3	Mgo	0.74
4	SO_3	0.19
5	Loss on ignition	3.19
6	Insoluble residue	91.22
7	Cao	3.53

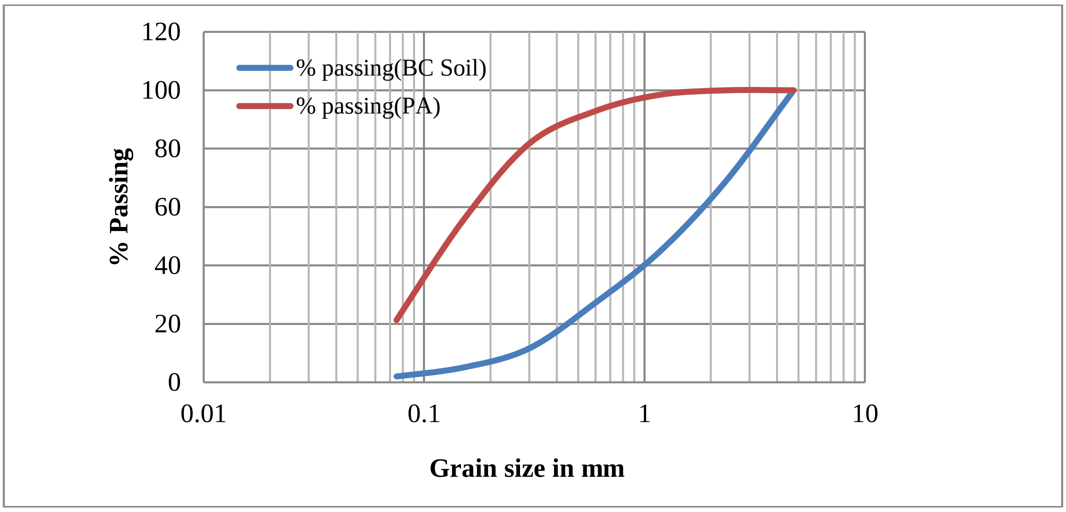

Fig 1.0 Grain size distribution curve for BC soil, pond ash

III. METHODOLOGY

All the tests were conducted as per IS: 2720 Guidelines except for compaction test, which is conducted by using mini compaction test apparatus (Sridharan and Sivapulliah, 2005). Direct shear test is conducted under a constant normal stress of 100 kPa and the black cotton soil is mixed with 10 to 100 % pond ash (by weight of soil) and The CBR tests were conducted according to IS 2720 part-16, 1997. The soil-additives mixture were compacted to optimum moisture content and soaked in water for 4-days under a surcharge weight of 5 kg before testing.

IV. RESULTS AND DISCUSSIONS

From Fig 2.0 it is observed that addition of varying percentage of pond ash to black cotton soil reduces the specific gravity of the matrix. This is because of replacement of higher specific gravity of soil by lower specific gravity of pond ash reduces the matrix specific gravity.

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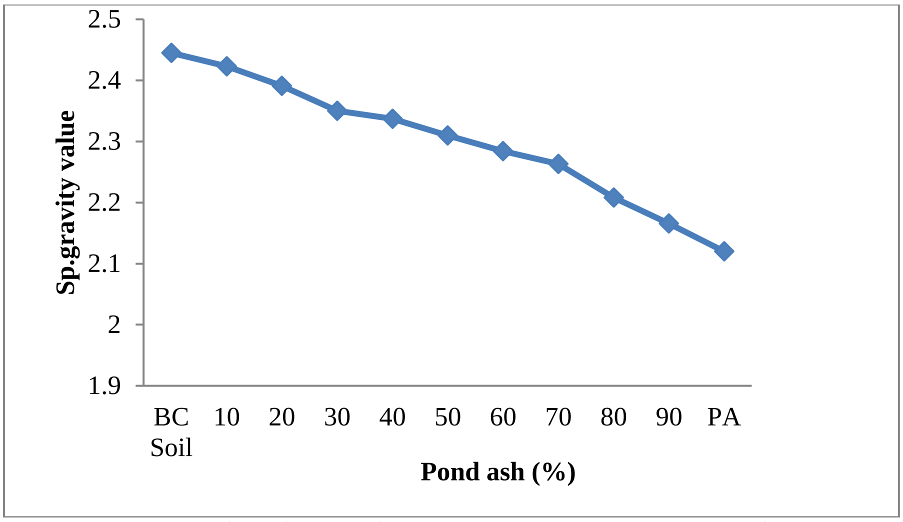

Fig 2.0 Variation of specific gravity for BC soil treated with varying percentage of pond ash

From Fig 3.0 it is observed that black cotton soil stabilized with pond ash in general maximum dry density reduces and optimum moisture content increases exceptional for 10% combination. This may be due to the replacement of higher density soil particles by lower density light weight ash particles.

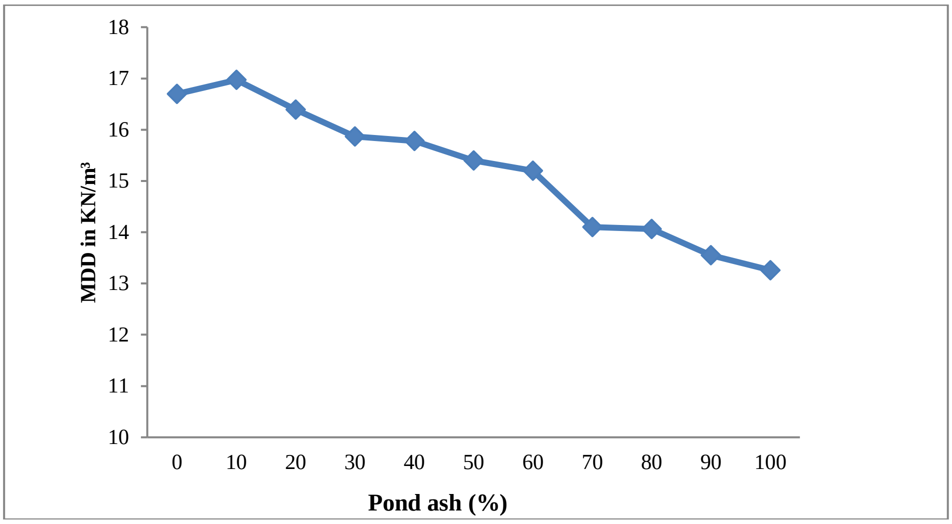

Fig 3.0 Variation of maximum dry density for BC soil treated with varying percentage of pond ash

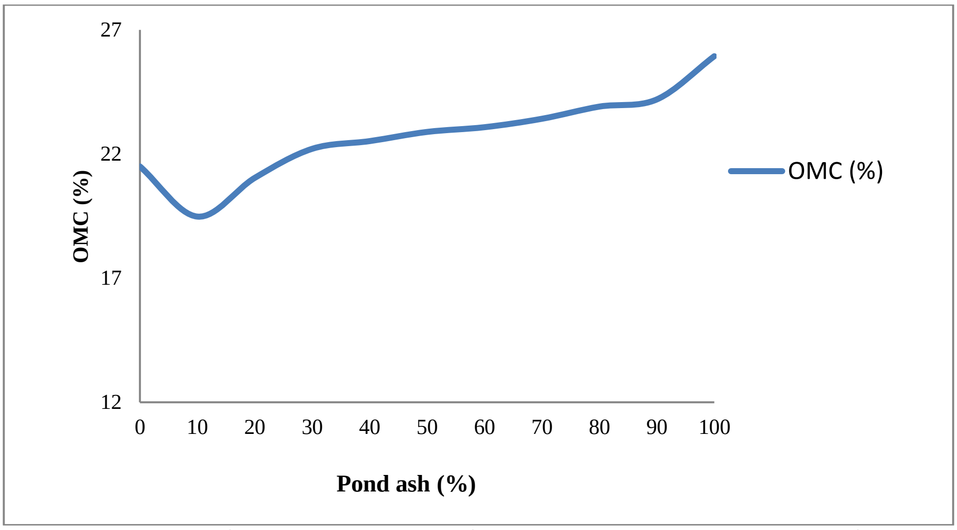

Fig 4.0 Variation of optimum moisture content for BC soil treated with varying percentage of pond ash

International Journal of Engineering Research & Technology (IJERT)
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Vol. 7 Issue 04, April-2018

To assess the shear strength at a constant normal stress rate of 100 kN/m^2 with a constant rate of 1.25 mm/min strain is applied for BC soil alone, BC soil treated with different percentage of pond ash. From Fig.5.0 it is observed that, as the percentage of pond ash in soil increases both for immediate as well as with curing the strength increases. However, it is found that soil stabilized with 30% pond ash (by weight of soil) is found to be optimum. This may be due to formation of cluster up to optimum combination and disintegration of cluster beyond the optimum combination due to more silt particle rather than clay particles.

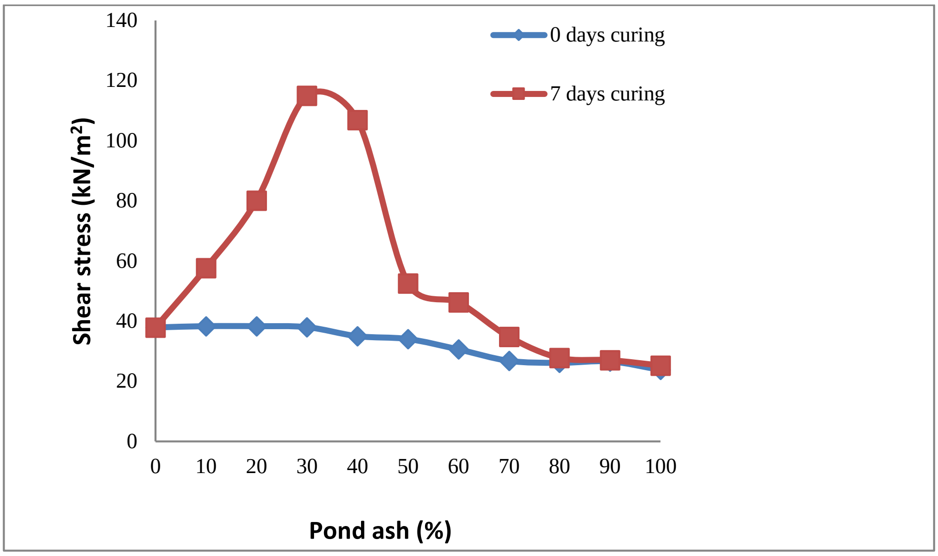

Fig 5.0 Variation of shear stress for BC soil treated with varying percentage of pond ash at a normal stress of 100 kpa

After direct shear test, CBR test were performed on obtained optimum proportions of soil and pond ash matrix (BC Soil+ 30% pond ash). CBR test were most important because as per the IRC-37 the pavement thickness is depends upon CBR value of soil. The CBR values obtained from the matrix of BC Soil, BC Soil and optimum pond ash as shown in below figure 6.0

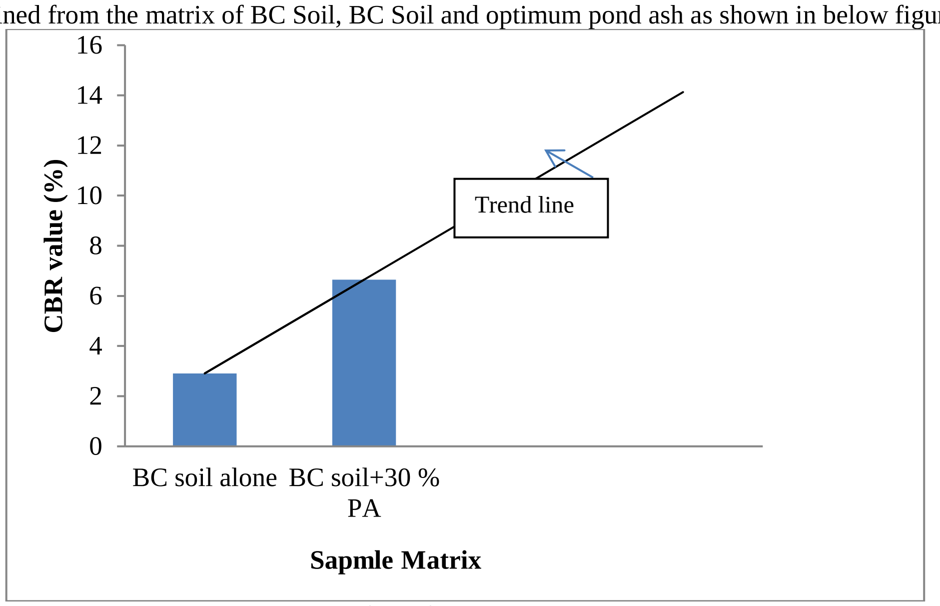

Fig 6.0 Variation of CBR for BC soil with optimum pond ash

Design of flexible pavement as per IRC 37-2001 for black cotton soil stabilized with pond ash

Design is to done based on IRC: 37-2001, the crust thickness is calculated for CBR value of treated and untreated black cotton soil. The obtained CBR value for untreated black cotton soil is 2.91% and for treated block cotton soil with an optimum of 30 % pond ash is 6.65%.

In order to design a flexible pavement IRC: 37-2001 is used in which the evaluated of factors (design traffic, vehicle damage factor, design life, etc) are considered for state highway of 2 lane.

The data for pavement design are assumed for state highway which are given below and from that thickness design of flexible pavement is carried out as per the IRC 37-2001 guidelines. Data considered for design of pavement is given below.

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1. Number of lanes= 2 lane, two way traffic
2. Initial traffic in each direction in the year of completion of construction A=1200 CVPD (assumed)
3. Design life n=15 years
4. The traffic growth rate r = 7.5 %
5. Vehicle damage factor (VDF) = 3.5
6. Distribution factor D = 0.75

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

$$N= \frac{[365\times(1+0.075)^{15}-1]}{0.075} \times 1200 \times 0.75 \times 3.5$$

N= 3.36 msa

Cumulative standard axles N= 3.36 msa is taken into considering according to IRC 37-2001

A. Composition of pavement for untreated soil, having CBR = 2.91% and the corresponding thickness is worked out as per from the plate (IRC 37 pg, No 22) and the corresponding IRC chart is as shown in below fig.
   1. SDBC = 25 mm
   2. DBM = 60 mm
   3. Base = 250 mm
   4. Sub-base = 335 mm

Total pavement thickness = 690 mm

IRC:37-2001

PAVEMENT DESIGN CATALOGUE

PLATE 1 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 1-10 msa

CBR 3%

Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION			
		Bituminous Surfacing		Granular Base (mm)	Granular Sub-base (mm)
		Wearing Course (mm)	Binder Course (mm)		
1	550	20 PC		225	435
2	610	20 PC	50 BM	225	335
3	645	20 PC	60 BM	250	335
5	690	25 SDBC	60 DBM	250	335
10	760	40 BC	90 DBM	250	380

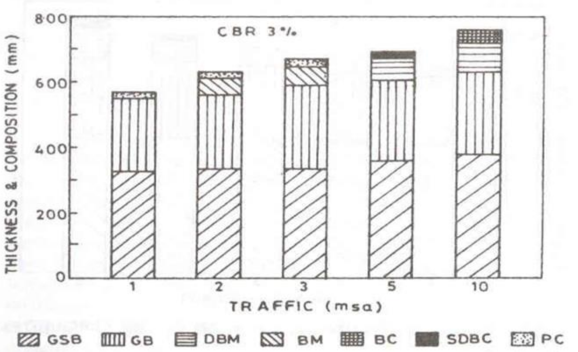

Photo 2.0 Crust thickness chart for the CBR value of 3% and traffic range 1-10 msa (Curtsey by IRC 37-2001)

B. Composition of pavement for soil treated with optimum of 30% pond ash from plate 2 (IRC 37 pg. No 26) and the corresponding chart from IRC 37-2001 is as shown in below fig

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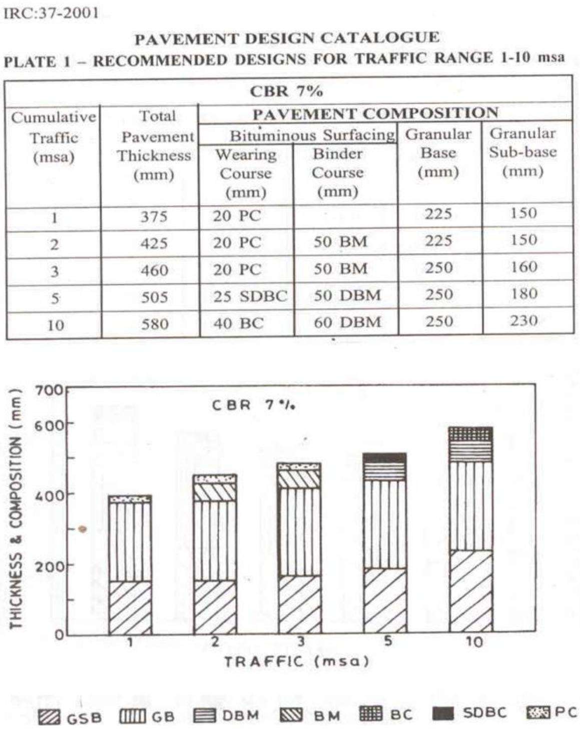
For untreated soil, treated with 30% pond ash, having CBR= 6.65 % corresponding design is worked out as per IRC: 37

1. SDBC= 25 mm
2. DBM= 50 mm
3. Granular Base= 250 mm
4. Granular sub base= 180 mm

Total pavement thickness = 505 mm



IRC:37-2001

PAVEMENT DESIGN CATALOGUE

PLATE 1 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 1-10 msa

CBR 7%					
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION			
		Bituminous Surfacing		Granular Base (mm)	Granular Sub-base (mm)
		Wearing Course (mm)	Binder Course (mm)		
1	375	20 PC		225	150
2	425	20 PC	50 BM	225	150
3	460	20 PC	50 BM	250	160
5	505	25 SDBC	50 DBM	250	180
10	580	40 BC	60 DBM	250	230

Photo 3.0 Crust thickness chart for the CBR value of 7% and traffic range 1-10 msa (Curtsey by IRC 37-2001)

C. Comparison of thickness of natural and treated soil

Table 3.0 Out-lay about pavement thickness between soil stabilized with pond ash on compared with unsterilized soil

Pavement Layer	Untreated BCS	BCS+30%PA
SDBC	25 mm	25 mm
DBM	60 mm	50 mm
Base	250 mm	250 mm
Sub-base	335 mm	180 mm

From the above Table 3.0, it is observed that black cotton soil stabilized with optimum pond ash reduces the thickness of the pavement by 27% on compared with untreated black cotton soil

V. CONCLUSIONS

Based on the above experimental investigation following conclusions were drawn

1. Addition of pond ash to black cotton soil reduces the specific gravity and increases the maximum dry density.
2. Black cotton soil stabilized with 30% pond ash (by weight of soil) improves the strength carrying capacity to a maximum extend and its improvement continues with long term curing effect.
3. Black cotton soil stabilized with optimum pond ash improves the CBR value by 128% on compared with black cotton soil alone
4. Optimum utilization of Pond ash in black cotton soil reduces the flexible payment thickness by 27%.

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VI. ACKNOWLEDGMENTS

We are very much thank full to the RTPS Research wing CASHUTEC for encouraging us to do research work on the current trend of practice and also we are thanks to Govt.SKSJTI Principle ,HOD and PG Highway Technology coordinator for permitting us to do research in the area of soil stabilization using pond ash.

CASHUTEC NIRMITHI KENDRA
(Technology Transfer Centre for Promoting Intensive Use of Industrial Waste (Fly Ash) In Construction Industry and Agriculture)
418/2, Beside RTPS, Hyderabad Main Road, SHAKTINAGAR-584170 Dist: RAICHUR
E-mail:- cashutec@gmail.com Website: www.cashutec.com Phone & Fax 08532-247099
Chairman: DEPUTY COMMISSIONER, RAICHUR   Executive Chairman: CHIEF EXECUTIVE OFFICER, ZILLA PANCHAYATH RAICHUR

Ref: CASHUTEC/R&D/M.Tech/2017-18 / 1805   Date:09.02.2018

To,
Dr.K.V.Manoj Krishna
Asst.Professor
Dept. of Civil Engineering
GSKSJTI
Bangalore-01

Dear Sir,

Sub: Regarding Supply of Pond Ash for M.Tech Project work.
Ref: Your letter Dated: 09.02.2018

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We the under signed here by encouraging and appreciating the research work carrying by Sri. Lakshmisha.A(USN 5WK16CHT05) in M.Tech Highway technology under the Guidance of Dr.K.V Manoj Krishna, Assistant professor, Department of Civil Engineering Government SKSJ Technological Institute, Bangalore-560 001 under the Topic **"Effective utilization of Raichur thermal power pond ash in stabilization of Black cotton soil in presence of coir pith (coco peat)".**

We wish that your valuable outcome from the research work on the above topic- helps us for further utilization of pond ash in infrastructure development especially for ground improvement of soil and thereby it improves the disposal of waste pond ash problem to society in general and thermal power plant in particular.

We here by inform to you that as we are supplying pond ash on free of cost basis for research purpose, so after submission of your thesis to VTU send the copy of the finding to Cashutec, RTPS, Raichur.

Thanking you,

Yours faithfully,
(Ravi Kumar H) 9/2/18
R & D Incharge
CASHUTEC

Photo 3.0 CASHUTEC of RTPS issue encouragement letter for our research work.

VII. REFERENCES

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ABBREVIATION USED
BCS - Black cotton soil
CBR - California Bearing Ratio
MSA - Million Standard Axles
MDD - Maximum Dry Density
OMC - Optimum Moisture Content
PA - Pond Ash