Experimental Study On Waste Recycled Product (W.R.P.) And Waste Plastic Strips (W.P.S.) As Pavement Sub-Base Material

Priti Mishra, Jha Ajachi R.B., Mohnish Satrawala, Harsh Amin

Abstract: The need to fulfill the demands of an increasing population has resulted in rapid industrialization. Subsequently the demand for iron and steel has risen ensuing in setting up of more such industries. The paucity of land has made the disposal of solid waste from these industries an issue of concern. The present work suggests a unique approach of recycling and utilizing the solid waste from the steel industries, called Steel Slag (or WRP) as a pavement sub-base and a highway embankment material. A new material comprising of a matrix of WRP and HDPE strips in which the latter has been used as reinforcement has been developed. The investigations have been carried out by mixing different percentages of HDPE strips cut in the aspect ratios of 2,3and 4 in the WRP.A comparative study of inclusions of such reinforcement has then been made experimentally through Direct Shear, Split Tensile ,Unconfined Compression Strength and CBR tests.

Index Terms: Aspect Ratio , CBR , Compressive Strength ,Fibers , High Density Polythene (HDPE), Reinforced earth , Slag ,Waste Plastic Strip (WPS), Waste Recycled product (WRP).

1. Introduction

Steel slag, a by-product of steel making, is produced during the separation of the molten steel from impurities in steel-making furnaces. The slag occurs as a molten liquid melt and is a complex solution of silicates and oxides that solidifies upon cooling. The present work deals with the basic physical properties of WRP (steel waste), and reinforcing these with plastic strips. Although various studies have been carried out for the use of WRP in pavement construction, the combined study of WRP and plastic strips can prove extraordinarily advantageous for the purpose, by providing extra strength to the pavement constructed with a known mixed proportion of WRP and plastic strips. As past study has indicated, construction using WRP provides both initial and long range economic advantages. Its versatility, high yield, bond and light weight all work together to reduce construction costs. For proposing it as a good highway pavement material, CBR tests were performed on the samples. In the present study the reinforcements are of HDPE having a thickness of 0.40 mm and average tensile strength of strip equal to 15-20 MPa.

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CBR method is used to find the relative bearing ratio and expansion characteristics of soil of base ,sub-base and sub-grade for design of roads, pavements and runways. The machine used for carrying out the experiments meets the requirements of BIS-2720 Part XVI. The strips of desired lengths were cut, in different aspect ratios and the required quantity of strips was mixed with WRP. The WPS to be added at different percentage to the WRP and was considered a part of the solid fraction in the void solid matrix of the WRP. The tests were carried out for reinforced as well as unreinforced cases.

1.1 Properties of materials used

1.1.1. Waste Recycled Product (WRP)

Table 1.1 Chemical Composition Range of WRP

Components	Basic Oxygen Furnace (%)	Electric arc furnace (carbon steel)	Electric arc furnace (alloy/ stainless steel)	Ladle
SiO_2	8-20	9-20	24-32	2-35
Al_2O_3	1-6	2-9	3.0-7.5	5-35
FeO	10-35	15-30	1-6	0.1-15
CaO	30-55	35-60	39-45	30-60
MgO	5-15	5-15	8-15	1-10
MnO	2-8	3-8	0.4-2	0-5
TiO_2	0.4-2	N/A	N/A	N/A
S 0	0.05-0.15	0.08-0.2	0.1-0.3	0.1-1
P 0	0.2-2	0.01-0.25	0.01-0.07	0.1-0.4
Cr 0	0.1-0.5	0.1-1	0.1-20	0-0.5

1.1.2. Waste Plastic Strip (WPS)
Fibers are of two types: synthetic fiber and natural fiber. Some commonly used fibers are jute fiber, wool fiber, polypropylene fiber, polyamide fiber etc. Fibers like polypropylene have excellent chemical resistance, low density, high melting point and moderate cost. All these make it an important fiber in construction applications. Fiber structure of Polypropylene is composed of crystalline and non-crystalline regions. The degree of crystallization is between 50-65%, depending on processing conditions. In view of low strength and lack of durability, natural fibers are not in wide use as reinforcements but are preferred due to their biodegradability. In the present study, the reinforcements shall be of High Density Polyethylene (HDPE) having a thickness of 0.4mm and average tensile strength of strip equal to 15.20 MPa.

2. Materials and Methods
The WRP was collected from JUSCO (Jamshedpur Utility and Services Company, Jamshedpur, Jharkhand, India) and the HDPE strips were taken from a rag collector. Influence of inclusion of randomly oriented WPS in a matrix of WRP and WPS were investigated experimentally as follows:

- Determination of specific gravity (IS 2720 Part III) and grain size distribution curve of WRP by sieve analysis (IS Set No.4).
- Determination of Optimum Moisture Content (OMC) and Maximum dry density (MDD) by Standard Proctor Test (SPT) (BIS 1980), Unconfined Compressive strength (IS 2720 Part X), shear strength parameters by Direct Shear test (IS 2720 Part X), tensile strength by Split tensile test and California Bearing Ratio (CBR) Value (BIS 2720 Part XVI).

The experiments were carried out with different aspect ratios of 2, 3 and 4 and strip content of 0%, 0.1%, 0.15%, 0.2%and 0.25%. Separate tests were carried out for determination of physical and engineering properties of WPS, results of which are given below in Table 2.1:

Table 2.1 Physical and Engineering properties of fibers used

PROPERTY	VALUE
Type	Polyethylene
Cut length(mm)	32,24,16
Breadth(mm) constant	8
Cross section	Rectangular
Tensile Elongation (%)	>100
Specific Gravity	1.34-1.4
Tensile strength(N/mm^2)	400-600
Color	White

Separate tests were carried out for reinforced and unreinforced WRP and a detailed comparison was made at each level.

2.1 Directions of placement of WPS
Fibers can be oriented or randomly mixed in soil. In the oriented category, the inclusions are placed within the soil at specific positions and directions whereas in random category, inclusions are mixed with soil and placed within the probable shear zone. The fibers were mixed as per the Randomly Distributed Fibers in Soil (RDFS) technique.

3. Results and Discussions

3.1Grain size Distribution Curve
The grain size distribution curve is shown in Fig.3.1

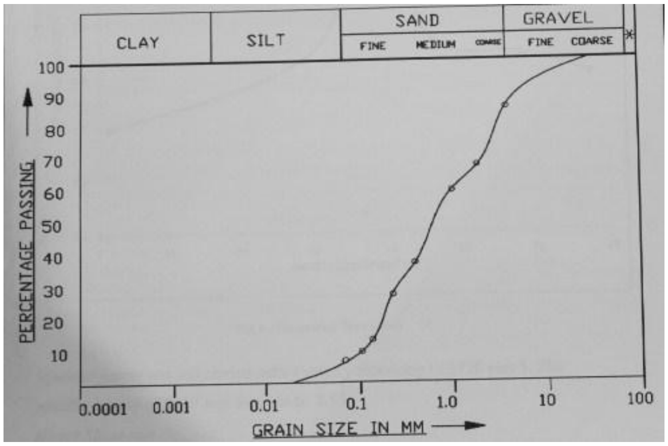


Fig 3.1. Grain size distribution curve of WRP

It can be seen from Figure 3.1 that the following composition exists: Clay-0%, Silt-8%, Sand-80 %(Fine-25%, Medium-30%, Coarse-25%), Gravel-12%.

3.2 Compaction Test and Specific Gravity Test
MDD was found as 2.05 kg/cm2 and OMC was 16.67%. Specific Gravity was found to be 2.55

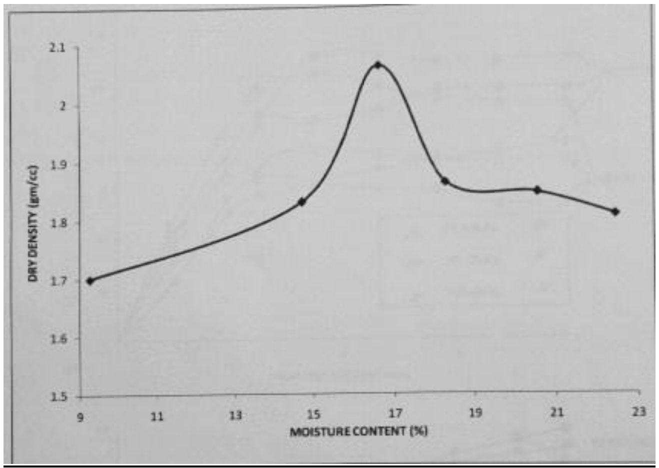
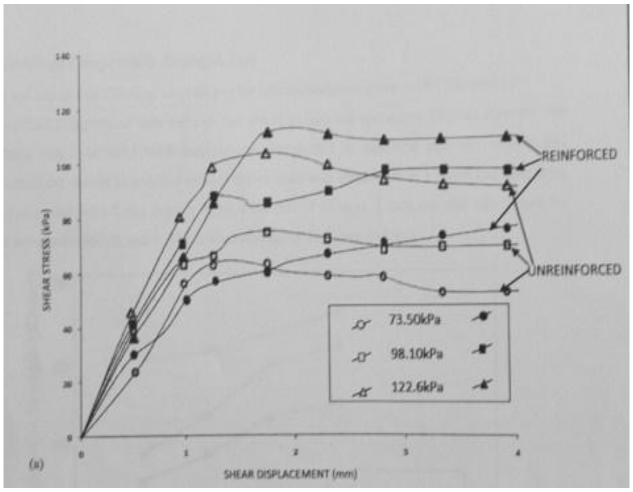
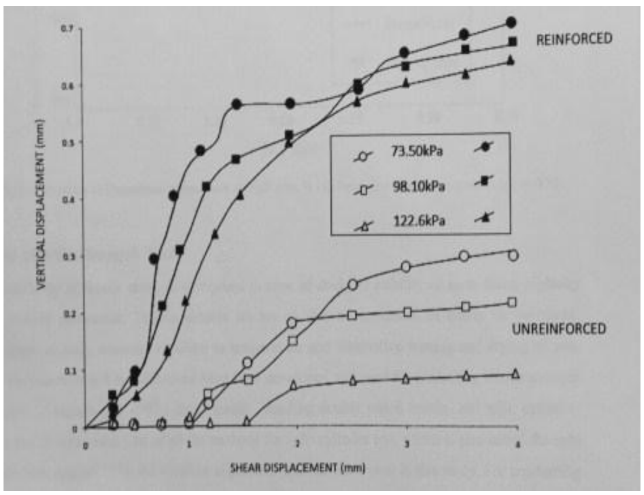


Fig.3.2. Compaction Test Result

3.3 Direct Shear Test
Direct Shear Test was carried out both for reinforced and unreinforced WRP samples. Shear test vs. displacement and vertical displacement vs. shear displacement curves were plotted for both the cases as shown in Figures 3.3. (a) and(b)



(a)



(b)

Fig 3.3 Unreinforced and Reinforced WRP in Direct Shear Test (a) Shear stress - displacement curves (b) Vertical displacement-shear displacement curves

It can be observed from Figures 3.3 (a) and 3.3(b) that the unreinforced WRP specimens reached their failure shear stress at displacements of 1-2mm, while the corresponding displacements in fiber reinforced specimens were generally more than 4mm and even exceeded 10mm at higher normal stresses, proving that the fiber reinforcement imparts more ductility to the unreinforced WRP specimens. The maximum vertical displacement in unreinforced specimen was <0.3 mm and decreased with increase in normal stress. The vertical displacement was generally >0.6mm in fiber reinforced specimens at all stress levels.

3.4 Unconfined Compressive Strength Test

Comparative result is shown in Fig.3.4

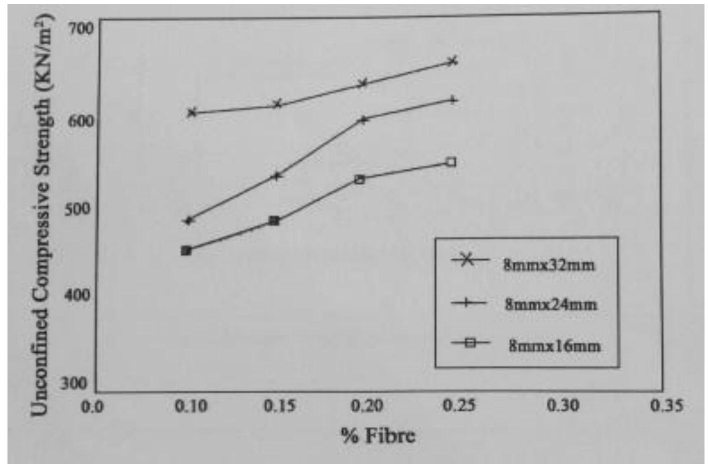


Fig 3.4 Variation of Unconfined Compressive Strength with % reinforcement at different aspect ratios of WPS

3.5 Split Tensile Strength Test

The variation of split tensile strength with percentage of reinforcement and varying aspect ratio is shown in Fig.3.5.

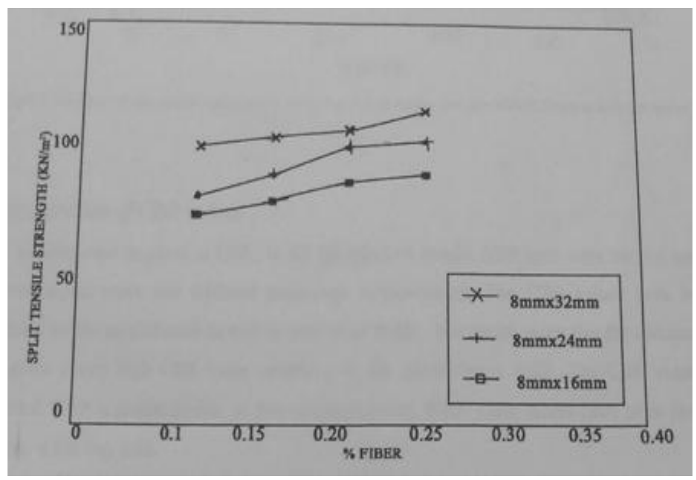


Fig 3.5 Variation of split tensile strength with % reinforcement and variable aspect ratios

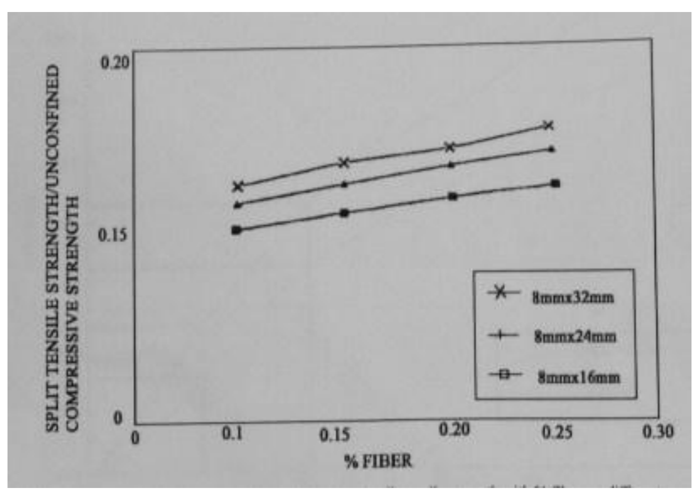


Fig 3.6 Variation of unconfined compressive strength and split tensile strength with % fibers at different aspect ratios

From Figures 3.4 and 3.5 it can be observed that the addition of 0.2% of 8X16 mm fibers or 0.15% of 8X24mm fibers to WRP-fiber mixtures increases unconfined compressive strength (UCS) and split tensile strength (STS) by 74 and 100% respectively, as compared to that of the same mixture without fibers. Also, with the addition of 0.2% of 8X24mm fibers or 0.15% of 8X32mm fibers, the gain in UCS and STS is about 100 to 135%, respectively as compared to that of the same mixture without fibers. Fig 3.6 shows that WRP reinforced with WPS develop substantial unconfined compressive strength and split tensile strength and that these are closely related. It was observed that the ratio of split tensile strength and unconfined compressive strength increased with increase in WPS content, indicating that WPS is more efficient when WRP was subjected to tension rather than to compression.

3.6 California Bearing Ratio (CBR) Test

CBR test is used to evaluate the stability of soil subgrade. CBR values have been calculated using equation (1) CBR(%) = [(load or pressure sustained by specimen at 2.5 or 5 mm penetration)*100]/[load or pressure sustained by standard aggregate at the corresponding penetration level] (1) Standard load values are taken as 1370 and 2055 kg(70 and 105 kg/cm2) respectively at 2.5 and 5 mm penetration.

Table 3.1 Comparative CBR behavior of inclusion of strips in soaked and unsoaked conditions.

STRIP SIZE	% OF STRIPS USED	UNSOAKED		SOAKED	
		CBR 2.5	CBR 5	CBR 2.5	CBR 5
16X8	0.25	0.35	0.426	0.23	0.322
	0.20	0.313	0.421	0.223	0.28
	0.15	0.305	0.416	0.216	0.27
	0.10	0.298	0.406	0.201	0.24
24X8	0.25	1.19	1.86	0.93	1.512
	0.20	1.126	1.78	0.89	1.498
	0.15	1.11	1.76	0.87	1.46
	0.10	0.813	1.53	0.44	1.09
32X8	0.25	1.48	1.98	1.15	1.81
	0.20	1.33	1.97	1.04	1.48
	0.15	1.30	1.86	1.007	1.33
	0.10	1.186	1.84	0.977	1.28

Table 3.1 was incorporated after performing CBR tests on WRP samples containing variable amounts of plastic strips at different aspect ratios. CBR value was 0.25 and 0.38 for 2.5 mm and 5mm penetration respectively for unreinforced WRP. The results of CBR test show that CBR value of reinforced WRP is almost double that of unreinforced WRP.The addition of fiber gives a very high CBR value compared to the unreinforced WRP The basic mechanism of reinforced earth (RE) is derived from interaction between reinforcement and its adjacent soil grains. The soil which is composed of many small discrete particles has relatively low deformation modulus, whereas the reinforcement has a high deformation modulus. As an axial compressive force is applied to the reinforced soil column, entire body tends to deform. Since the RE Body is a mixture of soil and reinforcement, interaction does exist along the contact forces between soil grains and reinforcement. This interaction induces shearing stress along all contact faces where relative movements tend to occur. A change of stress state in soil leads to changes both in strength and deformation properties. On the contact face it tends to move more than reinforcement thus shearing stresses develop and induce restraint on the lateral movement of soil particles. Transmitting this shearing stress induce a positive confining stress state change in the area adjacent to the reinforcement. This causes less bulging of the reinforced soil sample than the plain soil sample at the time of failure. This is due to friction at the interface of the soil and reinforcement.

4. CONCLUSION

The fiber inclusion changes the behavior of WRP from brittle to ductile. The ratio of STS and UCS increases with increase in fiber content, which shows that polythene fibers are more efficient when WRP was subjected to tension rather than to compression. The vertical displacement was significantly higher in the fiber reinforced specimens than the unreinforced specimens.

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