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Behavior of Fly Ash at Different Mix Ratios with Plastic Recycled Polymers

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Abstract—: ***Fly ash is a waste produced from burning of coals in thermal power stations. The staggering increase in the production of fly ash and its disposal in an environment friendly manner is increasingly becoming a matter of global concern. Many efforts have been made to use the fly ash in various Geotechnical applications viz. embankment, roadway, railway, backfill material. In this study, plastic recycled polymers were mixed with fly ash at different mix ratios so as to inspect its influence on the geotechnical properties of fly ash. In this regard, the laboratory study includes Atterberg limits, Compaction characteristics, unconfined compressive strength, Direct shear test, Triaxial shear test and X-ray fluorescence test. Tests were carried out on only fly ash and treated fly ash with plastic recycled polymers. Results indicate increase in maximum dry density and also in shear parameters of the fly ash with inclusion of plastic recycled polymers.***

Keywords— ***Fly ash, Plastic recycled polymers, X-ray fluorescence, and shear parameters***

I. INTRODUCTION

Thinking about the stability of either new slopes formed by earthworks or of naturally occurring slopes is of great and obvious importance in the field of civil and geotechnical engineering. While constructing for example Railways, highways, canal and excavations, analysis of related slopes must be carried out and possibly remedial work done to the slope [15]. Bahareh et al. (2010) carried an experimental work on stabilization and erosion control of slopes using cement kiln dust [2].

Pandian (2004) studied fly ash characterization with reference to geotechnical applications. Coal-based thermal power plants all over the world face serious problems of handling and disposal of the ash produced. The high ash content (30%–50%) of the coal in India makes this problem complex [13].

Safe disposal of the ash without adversely affecting the environment and the large storage area required are major concerns. Hence, attempts are being made to utilize the ash rather than dump it. The coal ash is utilized in bulk only in geotechnical engineering applications such as construction of embankments, fills, landfill liners [3]. Shenbaga et al. (2003) have carried out experimental study to investigate the influence of randomly oriented fiber inclusion in fly ash [14].

Plastic recycling or plastic waste recycling is the process of recovering scrap or waste plastic material into useful products. As for example, the spare soft drink bottles, refrigerator, coolers, air Conditioners, mobiles, spare parts of computers and televisions can be melted down and recycled to another plastic products. Basically all types of plastic can be recycled except those made from recycled plastics, often unrecyclable. Besides, a plastic cannot be recycled in to the exact plastic it was before. Before recycling, the plastics are sorted according to their resin type. Different types of plastics need different types of recycling process; that is why we can see a single digit ranging from 1 to 7 and surrounded by a triangle made of clockwise arrows right at the bottom of the plastic containers. The identification coding system follows Indian Standard IS: 14534-1998 Part III, “The Guidelines for recycling plastic” [12].

II. MATERIAL DESCRIPTION

The plastic recycled polymers as shown in Fig. 1 were collected from R.J. Plastic Enterprises Pvt. Ltd., Mumbai. The dimensions, specific gravity and density of the plastic polymers are mentioned in Table I These are produced from shredding of the polymer wastes like computer accessories, mobile phones, television sets, washing machine, air conditioners, refrigerators, air Cooler, polymers accessories in car, chairs, tables and electronic chips etc.

Fig. 1 Plastic Recycled Polymer

TABLE I

SPECIFICATION OF RECYCLED POLYMERS

Type and Colours	**Diameter (mm)**	**Length (mm)**	**Specific gravity (G)**	**Density (kg/m^3)**
Polymers (Orange and White)	2.98	4.0	2.154	0.62

The fly ash was collected from Tata thermal power plant, Trombay, Mumbai. Table II represents the physical properties of fly ash. The chemical compositions of fly ash were found out by conducting X-ray Fluorescence test and reported in Table III. It can be observed that the fly ash mainly consists of SiO_2 (71%), Al_2O_3 (32%) and Fe_2O_3 (6%). The CaO content (0.626%) is very low and thereby it is classified as Class F fly ash according to ASTM C618-08a (2008)[1].

TABLE II

PHYSICAL PROPERTIES OF FLY ASH

Properties	**Value**
Water Content	22.35%
Specific Gravity	2.154
Liquid limit	23.6%
Plastic limit	NP
Maximum dry density	1220 kg/m^3
Optimum moisture content	18.6%
D_{10}	0.0030 mm
D_{30}	0.01 mm
D_{60}	0.45 mm
C_u	15
C_c	1. 45
Cohesion (c)	23.14kPa
Angle of internal friction (ϕ)	20.4°

TABLE III

CHEMICAL COMPOSITIONS OF FLY ASH

Chemical Composition	**Content %**
CaO	0.626
Fe_2O_3	5.908
K_2O	0.962
MnO	0.034
P_2O_5	0.349
SO_3	0.039
SrO	0.056
TiO_2	1.776
Al_2O_3	32.077
MgO	0.819
SiO_2	71.046
Na_2O	0.136

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III. MATERIALS AND METHODOLOGY

First, the fly ash was oven dried at approximately 40^0C for 24 hours. To prepare the fly ash-plastic recycled polymer mixture, the required amount of fly ash and plastic recycled polymers were measured and mixed together in dry or wet state. The recycled polymers were mixed at different percentages of the dry weight of the fly ash. As the plastic recycled polymers have tendency to lump together, it requires considerable care to get an even distribution of the polymers in the mixture. Then, required amount of water was mixed with the dry mix. Proper care was taken to prepare homogeneous mixture. Plastic recycled polymers could be mixed with fly ash in the moist state as in dry state the fly ash particles tend to fly.

IV. RESULT AND DISCUSSION

The laboratory experimental study was carried out by mixing fly ash with Plastic recycled polymers considering 0%, 25%, 50% and 75% weight of Plastic recycled polymers by weight of fly ash. The blending operation was carried out manually by hand mixing and proper care was taken to obtain homogeneous mixture. The homogeneous mixture so formed was tested for Standard Proctors test to find optimum moisture content and maximum dry density.

A. STANDARD PROCTOR *test*

Standard Proctor compaction tests on Fly ash were conducted using Standard Proctor mould with varying percentage of Plastic recycled polymers and fly ash mixes. IS light compaction tests were carried out on different mix proportions of Plastic recycled polymers and fly ash as per IS: 2720 (Part VII) 1980/87 to study their maximum dry density and optimum moisture content. As per IS: 2720 recommends that a mould of 1000ml capacity having internal diameter of 100mm and an internal effective height of 127.5mm should be used. The rammer has a mass of 2.6 kg with a drop of 310 mm.

Fig.2 shows typical dry density (kg/m^3) versus water content (%) relationship obtained for fly ash. Also it shows that fly ash having maximum dry density is 1220 kg/m^3 and optimum moisture content is 18.6%.

A standard Proctor compaction test was also carried out on different mix proportions of plastic recycled polymer and fly ash (i. e. 0, 25, 50 and 75%). Fig. 3 shows the compaction curves for different mixing proportions.

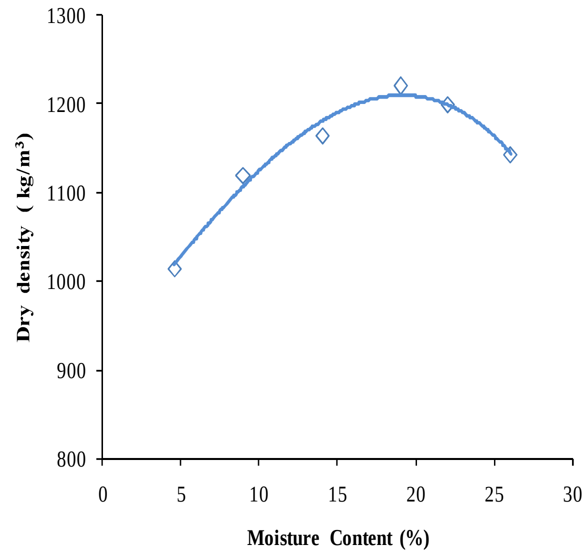

Fig. 2 Standard Proctor test Compaction Curve for Fly Ash

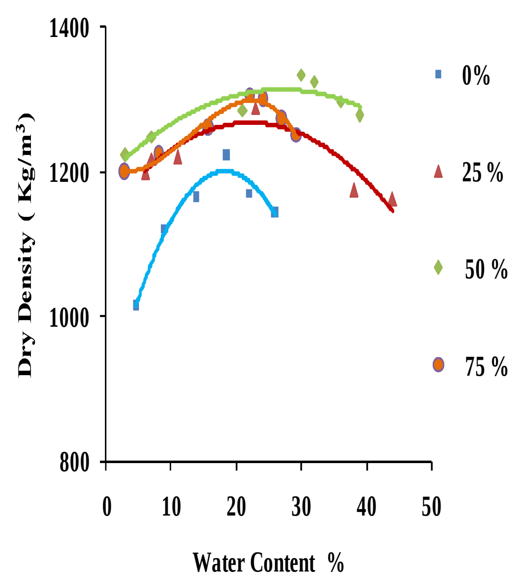

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Fig. 3 Compaction curve for Fly Ash mixed with different Percentage of Recycled Polymer

The maximum dry density (MDD) and optimum moisture content (OMC) values are increased initially up to a mix proportion of 50% and then it decreases for 75%. It may be due to the increase in the plastic recycled polymer which creates voided space owing to its geometry causes decreased MDD and OMC. The optimization values for mixtures of plastic recycled polymers and fly ash are shown in Table. IV

TABLE IV

OPTIMIZATION OF RECYCLED POLYMERS CONTENTS (%) WITH MDD AND OMC

Plastic recycled polymers (%)	**Maximum dry density (MDD) (kg/m^3)**	**Optimum moisture content (OMC) (%)**
0	1220	18.6
25	1280	23.0
50	1330	30.0
75	1300	22.0

B. Shear Strength Characteristics

1. Direct Shear Test

Consolidated drained (CD) direct shear test was carried out on 60 mm X 60 mm x 20 mm specimens as per IS:2720 (Part 13)-1986 [4]. The test was carried out on specimens prepared from fly ash and Plastic recycled polymer mixes compacted on their corresponding optimum moisture content. The normal stress varied in the range of 50kPa, 100kPa and 150 kPa. The specimens were sheared at a constant strain rate of 0.125 mm/min under saturated condition.

Fig. 4 shows the shear stress and horizontal displacement behavior of fly ash tested for different normal stresses. Cohesion (C) and angle of internal friction (ϕ) obtained from CD direct shear test are found to be 23.14 kPa and 20.4° respectively as shown in Table V.

TABLE 5

DIRECT SHEAR TEST RESULTS FOR FLY ASH AND MIXTURE OF FLY ASH WITH PLASTIC RECYCLED POLYMERS IN DIFFERENT PERCENTAGE

Plastic recycled polymer Percentage (%)	**Cohesion (C) (kPa)**	**Angle of Internal Friction(ϕ)in degree**
0	23.14	20.4
25	17.65	27.5
50	12.94	39.5
75	16.47	29.4

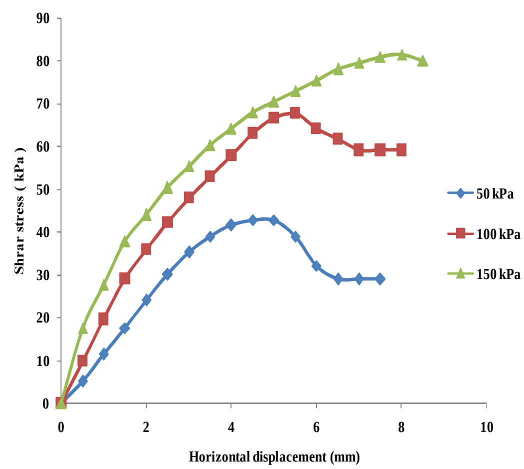

Fig. 4 Shear stress vs. horizontal displacement for Fly Ash

Failure plane in case of fly ash and mixture of fly ash with Plastic recycled polymers 50% as shown in Fig.5 and Fig.6 respectively. When fly ash mixing with Plastic recycled polymers contents in different percentage the optimum value for angle of internal friction (Ø) is obtained at plastic recycled polymers(PRP) content about 50%.

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Fig. 5 Failure of Fly ash

Fig. 6 Failure on Fly ash with 50% PRP

The variation of stress and percentage strain is shown in Fig. 7. For this optimum percentage, angle of internal friction (Ø) and Cohesion (C) are 39.5^0 and 12.94 kPa respectively.

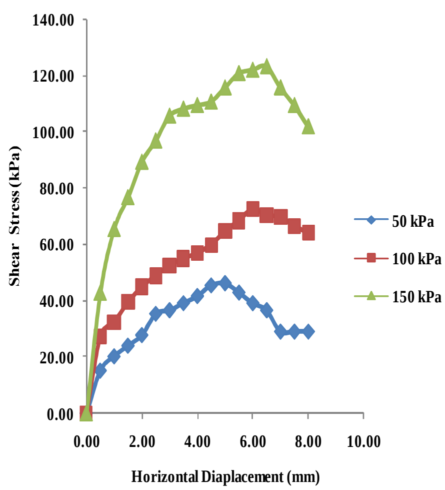

Fig. 7 Shear Stress Vs horizontal displacement for Mixture of Fly ash with Plastic recycled polymers 50 %

2. Unconfined Compression Strength (UCS) Test

In Laboratory Unconfined Compression strength test were carried out on height of the sample 7.62 cm with diameter of the sample is 3.82 cm having an area and volume of specimens are 11.4 cm^2 and 87 cm^3.

A minimum three specimens were prepared for each combination of variables at a deformation speed rate of 0.125 mm/min Specimens as per IS: 2720 (Part 10) 1973 [5]. According to their respective mixture fly ash and plastic recycled polymers maximum dry density (MDD) and optimum moisture content (OMC) for the preparation of samples are used.

The test was carried out on specimens prepared from fly ash and fly with Plastic recycled polymers mixes and compacted at their corresponding optimum moisture content to maximum dry density.

The Plastic recycled polymers inclusion had a significant effect on the stress-strain behavior. The fly ash specimens attained distinct failures but plastic recycled polymers with fly ash specimens exhibit a highly ductile behavior. Fig.8 shows that Unconfined Compression Strength test for the mixture of Fly ash and Fly ash with plastic recycled polymers (50%).

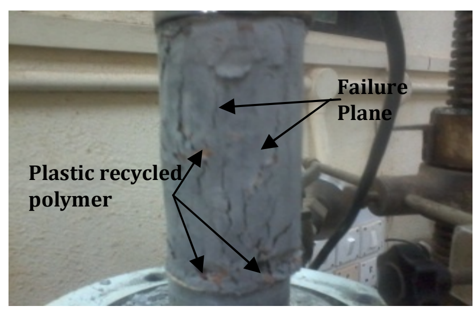

Fig. 8 Unconfined Compression strength Test- Fly Ash + Plastic recycled polymers 50%

Unconfined Compression strength (UCS) test were carried out on fly ash and mixture of fly ash with plastic recycled polymers (PRP) the values of cohesion (C) as shown in Table.VI

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TABLE VI

UNCONFINED COMPRESSION STRENGTH (UCS) TEST

	Fly Ash	Fly Ash + 25% PRP	Fly Ash +50% PRP	Fly Ash +75% PRP	Fly Ash +100% PRP
UCS (q_u) kPa	31.77	44.69	51.84	43.00	30.10
Cohesion (C) kPa	15.88	22.34	25.92	21.50	15.05

The percentage strain with deviators stress variation as shown in Fig.9 and also the optimization of UCS values shows in Table 6 and Fig.10.

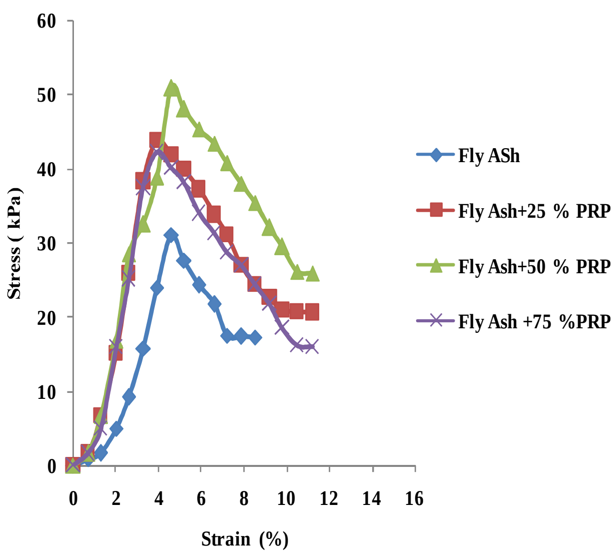

Fig. 9 Percentage Strain Vs Stress for Fly ash and Plastic recycled polymers (PRP)

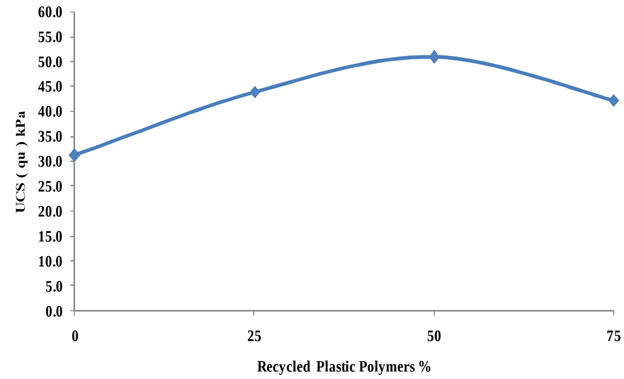

Fig. 10 Variation of UCS Value with Plastic recycled polymer content percentage.

3. Unconsolidated Undrained (UU) test

In Laboratory Unconsolidated Undrained (UU) triaxial shear test were carried out on Height of the sample 7.62 cm with diameter of the sample is 3.82 cm having an area and volume of specimens are 11.4 cm^2 and 87 cm^3. A minimum three specimens were prepared for each combination of variables (50 kPa, 100 kPa, 150 kPa) at a deformation rate of 0.125 mm/min Specimens as per IS: 2720 (Part XI)-1993 [11]. According to their respective mixture of fly ash and plastic recycled polymers maximum dry density (MDD) and optimum moisture content (OMC) for the preparation of samples for both the cases fly ash and mixture of fly ash with plastic recycled polymers are used. The failure patterns in both case of fly ash and Mixture of fly ash with plastic recycled polymers (50%) as shown in Fig.11.

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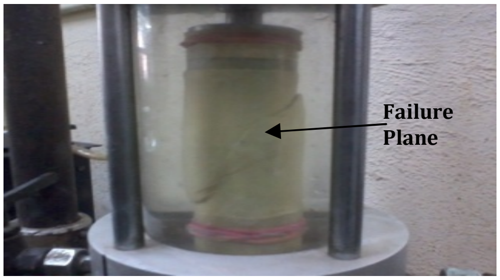

Fig.11 Unconsolidated Undrained (UU) test Samples.

The normal stress varied in the range of 50kPa, 100 kPa, and 150 kPa. Specimens were tested under the saturated condition. This may be a manifestation of the ductile behavior induced by both the confining pressure and the fiber inclusions. For determination of the total stress shear strength parameters C_{uu} and $Ø_{uu}$. The variation of stress versus percentage strain as shown in Fig. 11 and Fig. 13

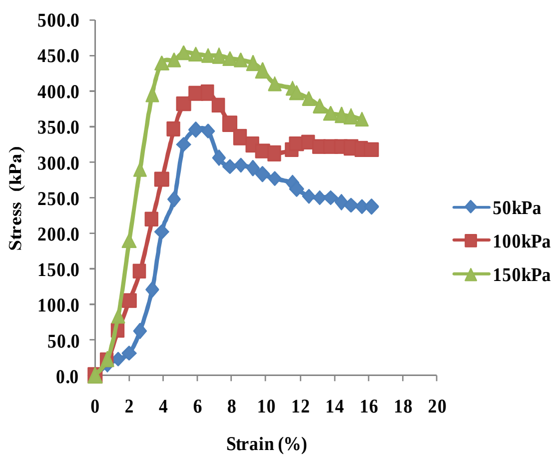

Fig. 12 Stress Strain variation of Unconsolidated Undrained (UU) test on Fly ash

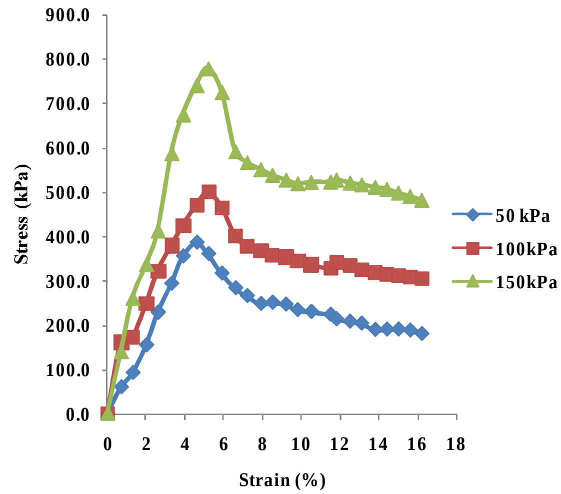

Fig. 13 Stress Strain variation (UU) test on Fly ash with Plastic recycled polymers 50%.

The variation plastic recycled polymers in different percentage gives the variations of cohesion (C) and also angle of internal friction (Ø) as shown in Table VII.

TABLE VII

UNCONSOLIDATED UNDRAINED (UU) TEST

Plastic recycled polymers Percentage (%)	Cohesion (C) kPa	Angle of internal Friction (Ø) Degrees
0	27.00	8.50
25	32.73	13.6
50	19.11	18.3
75	30.81	14.2

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The variation of Angle of Internal Friction (Ø) and Cohesion (C) are respect to plastic recycled polymers content in percentage as shown in Fig.14 respectively.

This is because of partially saturated fly and mixture of fly ash with plastic recycled polymers that's why the angle of internal friction has taken into consideration.

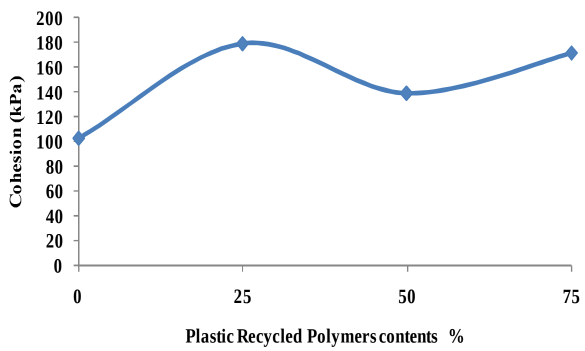

Fig. 14 Plastic recycled polymers (RP) percentage vs. Cohesion (C) kPa

V. CONCLUSIONS

Fly ash is a waste material imposing hazardous effect on environment and human health. Also it cannot be disposed of properly and its disposal is not economically viable but if it is mix with other materials like Plastic recycled polymers then it can be used best for construction of embankments. This feasibility study is aimed at improving the properties of fly ash to suitable for Embankments construction. Based upon the above study following conclusions can be drawn:

1 In Light Compaction test (Standard Proctor) compaction characteristics of the fly ash with Plastic recycled polymers in different mixing proportion shows that due to Plastic recycled polymers inclusions increased the maximum dry density (MDD) beyond 50% mixes after that maximum dry density (MDD) was decreased.

2 In Case of in the unconsolidated undrained tests, the deviator stress attained a peak value at axial strains in the range of 4-6% and thereafter remained almost constant. This may be a manifestation of the ductile behavior induced by both the confining pressure and the Plastic recycled polymers inclusions. In unconfined compression tests, the raw fly ash specimens attained a distinct axial failure stress at a strain. The Plastic recycled polymers inclusions increased the failure deviator stress and the shear strength parameters C uu and Ø uu.

3 The Increased in shear strength parameter was also found in case of direct shear test for Fly ash and Fly ash with Plastic recycled polymers having different mix proportions.

4 On addition of increasing content of Plastic recycled polymers in fly ash maximum dry density (MDD) of mixtures initially increases then it starts decreasing and optimum moisture content (OMC) of fly ash increase on addition of increasing content of plastic recycled polymers in it. The maximum dry density was found to be for at 50 % mixing proportion of Fly and Plastic recycled polymers.

5 From this study will helps to understand the behaviour of different blended ratios with Soil, Fly ash and plastic recycled polymers.

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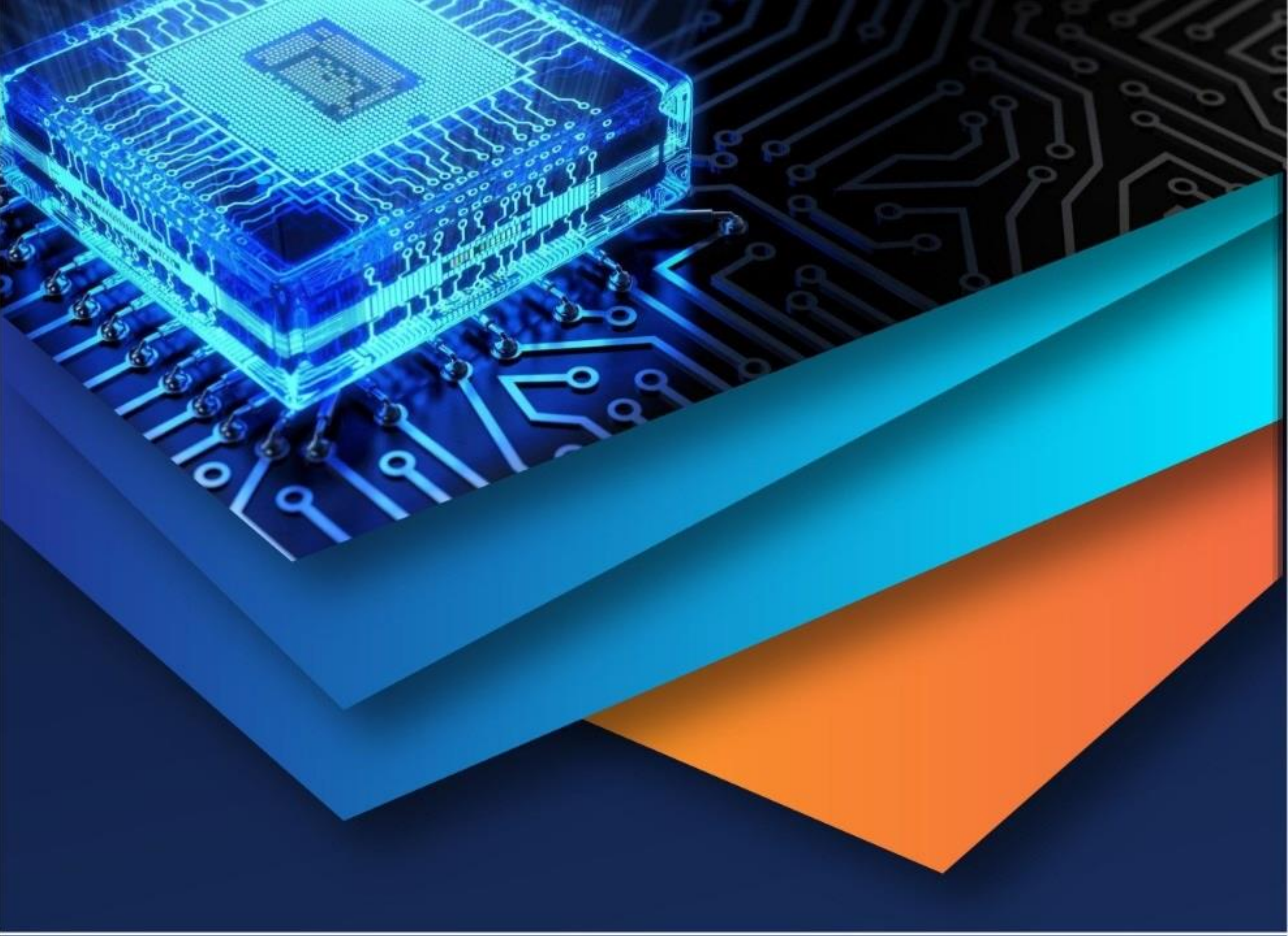

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