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Interpretation of Rice Husk Ash on Geotechnical Properties of Cohesive Soil

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Abstract

This paper demonstrates the effects of rice husk ash (RHA) on the geotechnical properties of soil in stabilized forms specifically strength, workability, compaction and compressibility characteristics. Therefore, laboratory tests such as compaction, Atterberg limits, free swell index, unconfined compressive strength, direct shear and consolidation tests for different percentages of RHA content and original soil samples were performed. These test results show that the soil can be made lighter which leads to decrease in dry density and increase in moisture content and reduced free swelling and compressibility due to the addition of RHA with the soil. Besides that the unconfined compressive strength and shear strength of soil can be optimized with the addition of 10

Index terms— RHA, Index Properties, strength properties, swelling and consolidations.

1 INTRODUCTION

enerally, partially saturated clayey soils having high plasticity are very sensitive to variations in water content and show excessive volume changes. Such soils, when they increase in volume because of an increase in their water contents, are classified as expansive soils. This highly plastic soil may create cracks and damage on the pavements, railways, highway embankments, roadways, building foundations, channel and reservoir linings, irrigation systems, water lines, sewer lines etc (Gromko, 1974, Mowafy, 1985and Kehew, 1995). Thereafter, highly plastic soil exhibits undesirable engineering properties under load. They have low shear strengths and tendency to lose shear strength further upon wetting or other physical disturbances (Mitchell, 1986). Therefore, this plastic soil are very prone to shear failure due to the constant load over time and considered poor material for foundations (Liu, et. al., 2008).

Khulna is the southwest part of Bangladesh having high clayey and silt content of very soft to soft consistency up to 20 ft. from the ground surface level on the basis of several soil report collected from CRTS of Khulna University of Engineering & Technology.

High water content, high compressibility and low workability of these soils often caused difficulties in the civil engineering construction projects. The soil which is used for the construction pavement or sub-base should have some specification of geotechnical properties for obtaining required strength against tensile stresses and strains variety. In this study, RHA was used for the improvement of workability, compressibility and compaction characteristics as well as the physical properties of highly plastic clayey soil. In the earlier, cement and lime are the two main materials used for stabilizing soils which is now costly in price due to the sharp increase in the cost of energy since 1970s (Neville, 2000). RHA is the most cost-effective locally available materials act as a binding agent like cement which increases some geotechnical properties as well as stabilization of soil as an alternative option of cement and lime.

Rice husk is an agricultural waste obtained from rice milling. About 108 tons of rice husks are generated annually in the world (Alhassan, 2008). In Bangladesh, about 39.3 million ton of rice is produced annually (Mustafi, 2005) which generate about 9.83 million ton of RH after milling of the paddy is used as animal food as well as fuel in rural area. RHA which is generated from the burning of Rice husk is considered as waste material and usually dumped backside of the kitchen of the village people in Bangladesh. Rice husk ash has high quantity of silica with small quantities of oxide ??Agarwal, 1989, Kumar, 1993) having high specific surface that is very suitable for activating the reaction of soil and act as a binding material like cement. Thus RHA can be used as a cost-effective additive particularly in regions having high production capacity like Bangladesh. The silica content in RHA depends on the burning temperature. The technique which is used for burning RH to produce amorphous silica is suitable for pozzolana cement production, have been developed (Kumar, 1993 ?? Ahmed, et al.1993).

A mini incinerator has been designed by Ahmed, et al.(1993) in BCSIR laboratory, Dhaka to produce RHA and a comparative study has been carried out in relation to compressive strength and setting time of the pozzolana cement prepared by using this ash and boiler ash.

2 II.

3 MATERIALS AND METHODS

4 a) Specification of Soil

Nearly greyish silty clayey soil was used in this study, collected from Khanjahan Ali Hall at Khulna University of Engineering & Technology(KUET) in Khulna, Bangladesh. The collected soils was hard and it was pulverized manually by hammer. Then the soils were screened through the sieve of 4.75 mm apearture before preparing the specimensfor testing. According to the AASHTO classifiation systems, the soil is classified as A-7-6 and acoording to the Unified soil classification sytems, soil is CL(Clay with low plasticity). The particle size distribution of the original soil is shown in the Figure 1. RHA was prepared by simply burning rice husk, collected from the locally available mill. In this arrangement, rice husk were kept into a Steel box of 1.5m x 1.5m in dimensions. Five thermocouples with a connecting data logger were used for measuring the burning temperature. Briquettes were used as fuel to start and maintain fire. The produced RHA contains about 93% silica which is a key factor for improving the properties of soil.

5 c) Preparation of testing samples

The collected soils and ash contents were oven-dried at 105 0 C overnight to remove moisture and repress microbial activity.Then the oven dried samples were mixed throughly by hand in a large tray in a dry state as per shown in Table 1. To determine the workability, compressibility, strength and compaction characteristics of treated and original soil samples several tests were performed in the laboratory.

Before conducting the compaction test, the non-treated and RHA treated soils (5, 7.5, 10% and 12.5% RHA content) were mixed with water for about ten minutes by hand. After that, the mixtures were put into polyethylene bags and mixing was continued by shaking, overturning and pressing the bag to squeeze out the air from the soil voids. In the similar way, different amount of water contents were added to the different soil samples and mixing were done as described before to obtain the optimum moisture content and maximum dry density. A series of standard proctor tests on non-treated and RHA treated soils were conducted according to ASTM D 698.

Specific gravity of original and ash treated soil samples were determined according to ASTM D854. Consistency of the original and treated soil samples were determined by Atterberg limit test (ASTM D-4318).The effect of shrinkage of fine grained soils are of considerable significance to cause serious damage to small building and highway pavements. Free swell index of soil samples were determined as per as IS: 2720(Part-40). Ten grams of soil samples were put into two 100ml glass cylinders and the remaining volumes of the cylinders were filled with distilled water and kerosene respectively. After keeping it overnight the volume of soil in each cylinder was measured and from this volume free swell index of soil was determined from the equation shown in below.

Free swell index (%) = ker 100 ker

6 Volume of in distilled water Volume of in distilled osene x Volume of in distilled osene

7 ?

All the test specimens for strength and consolidation tests were prepared by compacting the soils mixed with RHA (0, 5, 7.5, 10% and 12.5%) in the standard compaction molds at the corresponding optimum moisture content which has been determined already. The specimens were demolded after completion of compaction and samples of different size

8 RESULTS AND DISCUSSIONS a) Compaction characteristics

The variation of optimum moisture content and maximum dry density of RHA treated and untreated soil is shown in figure 2. This figure represents the maximum dry density of soil decreases gradually with an increase of RHA content. This is due to comparatively low specific gravity value (2.25) of RHA than that of replaced soil (2.65) and the initial simultaneous flocculation and agglomeration of clay particles caused by cation exchange may be the another cause. On the other hand, the optimum moisture content of soil increases with an increase RHA, because RHA are finer than the soil. The more fines the more surface area, so more water is required to provide well lubrication. The RHA content also decrease the quantity of free silt and clay fraction, forming coarser materials, which occupy larger spaces for retaining water. The increse of water content was also attributed by the pozzalanic reaction of RHA with the soil. The specific gravity of composite soil is decreasing due to the addition of RHA as shown in Figure 3 because of the low specific gravity of participating RHA as compared with soil. Soil index properties are used extensively by engineers to discriminate between the different kinds of soil within a broad category.The index properties of soil is obtained from Atterberg limit test results and free sweel index test. The Atterberg limits are a basic measure of the nature of a fine-grained soil. The test result of atterberg limt is shown in Table 2. Figure 4 shows that liquid limit of soil increses graduallywith the increses of RHA content. This improvement attributed that more water is required for the RHA treated soil to make it fluid because of the pozalonic characteristics of RHA. Similar trend was obtained for plastic limit that the value of plastic limit increases with the increases of RHA due to the pozalonic charactericts of RHA as shown in Figure **??**. This increase of plastic limit implies that RHA treated soil required more water to change it plastic state to semisolid state. This may also improve the shear strength characteristics of soil. The shrinkage limit (SL) is the water content where further loss of moisture will not result in any more volume reduction. The variation of shrinkage limit and shrinkage ration is shown in Figure 6. Figure 6 illustrate that as the addition of RHA the value of shrinkage limit increases. It is clear from that result that the RHA treated soil absorb more water to change it semisolid state to solid state. This figure also illustrate the variation of shrinkage ratio with the RHA content. The value of shrinkage ratio decreases with the increases of RHA . From the test result of Atterberg limit, changing of soil grain size due to the addition of RHA can be illustrated by plasticity chart. The effect of RHA on the particle size of soil is shown in Figure 7. This figure illustrate that initially the soil was clay with medium plasticity. Due to the addition of RHA, the soil class shifts to silt (due to the increase in particle sizes for the aaglomeration of caly particles with RHA) and high plasticity zone. For 12.5% of RHA, it changes to silt with high plasticity. The variation of free swell index with increasing RHA content is shown in Figure 8. The free swell index gradually decreased from 20% to 17.5% for up to 10% RHA content. After the addition of 2.5% more RHA content with the soil, it felt down pointedly from 17.5% to 2012 ebruary 10%. So it is clear from the above discussion that swelling of soil as well as the possibility of crack formation on foundation can be minimized with the addition of RHA. The test result of unconfined compressive strength is shown in Figure 9. This figure illustrates the stress-strain behavior of original and RHA treated soil under vertical load. Initially the stress is gradually increases with the increase of strain. After attaining the peak stress, it decreases with the increase of strain for all the combination of RHA and soil. Approximately all the specimen shows shear failure after observing the failure plane of specimens. The variation of unconfined compressive strength for soil at different percentages of RHA is shown in Figure 10. There is a rapid increase of unconfined compressive strength from 0.06 MPa to 0.172 MPa with the addition of only 5% RHA. The optimum value of unconfined compressive strength 0.255 MPa were obtained for 10% of RHA content. After that, the value of unconfined compressive strength decreased from 0.255 MPa to 0.211 MPa for 12.5% of RHA content. So it can be accomplished that the maximum unconfined compressive strength were obtained at 10% of RHA and after that the value of unconfined compressive strength decreased with the addition of RHA. The following mechanism also explains that there is an positive impact of RHA on uncofined confined compressive strength.The reason for this improvement is due to the pozzolanic reactions of RHA with soil. This results in agglomeration in large size particles and causes the increase in compressive strength In this study one dimensional consolidation test were performed to determine the consolidation characteristics of original and RHA treated soil and the corresponding consolidation curves are shown in Figure 13. The variation of compression index and initial void ratio with RHA content are shown in Figure 14. Firstly, this plot shows that the compression index (Cc) is decreasing gradually from 0.368 to 0.328 with increasing RHA for up to 7.5%. The value of Cc decreased well under from 0.328 to 0.248 for the addition of 10% RHA with the soil and after that it is slightly increased from 0.248 to 0.258 for 12.5% RHA content. This decrease in compression index implies that there could be a result of increased formation of pozzolanic products within the pore spaces of soil from physicochemical changes (Osinubi et al. 2006) which leads to a reduction in compression index. When the rice husk ash content exceeds the quantity required for the soil-ash reaction, they will be filled between the voids of the soil. A more compact state of the soil is probably attained. On the other hand the value of initial void ratio (e o) increased gradually from 1.305 to 1.378 with increasing RHA for up to 7.5%. Then the value of e o decreased well under from 1.378 to 1.315 for the addition of 10% RHA and after that, it decreased slightly from 1.315 to 1.314 for 12.5% RHA content.

9 CONCLUSIONS

In this study the effect of RHA on the geotechnical properties of cohesive soil are investigated and it can be concluded that there is an improvement of all the geotechnical properties of RHA treated soil. It was observed that the maximum dry density of soil decreased with the addition of RHA because of the lower specific gravity of RHA. The value of optimum 2012 ebruary of the pozzalonic action of RHA and soil, which needs more water. Moreover, the value of liquid limit and plastic limit also increased with the increasing percentage of RHA whereas the value of plasticity index shows different characteristics. Increasing the amount of RHA cause a decrease in shrinkage limit as well increase in shrinkage ratio which improves the shear strength characteristics of soil. The pozzalonic behavior of RHA makes the RHA treated soil coarser than original soil samples due to the agglomerations of RHA and soil particles. This improvement changes the naming of soil from clay to silt. The free swell index test result shows a negative relationship with RHA as it decreased with the increase of RHA content which reduced the possibility of crack formation on the surface of foundation. The optimum unconfined compressive strength was obtained for 10% of RHA content. The best shear strength envelope of soil was obtained for 10% of RHA. The cohesion of soil shows an increasing order for first 5 % of RHA and after that this value decreases with the addition of RHA whereas the angle of internal friction shows a positive relationship with RHA content. From the consolidation test result, it can be concluded that the values of compression index decreased with the increases of RHA and the initial void ration shows positive relation with RHA. [1] [2]

1

Figure 1: Fig 1 :

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[2] (E) © 2012 Global Journals Inc. (US) Interpretation of Rice Husk Ash on Geotechnical Properties of Cohesive Soil

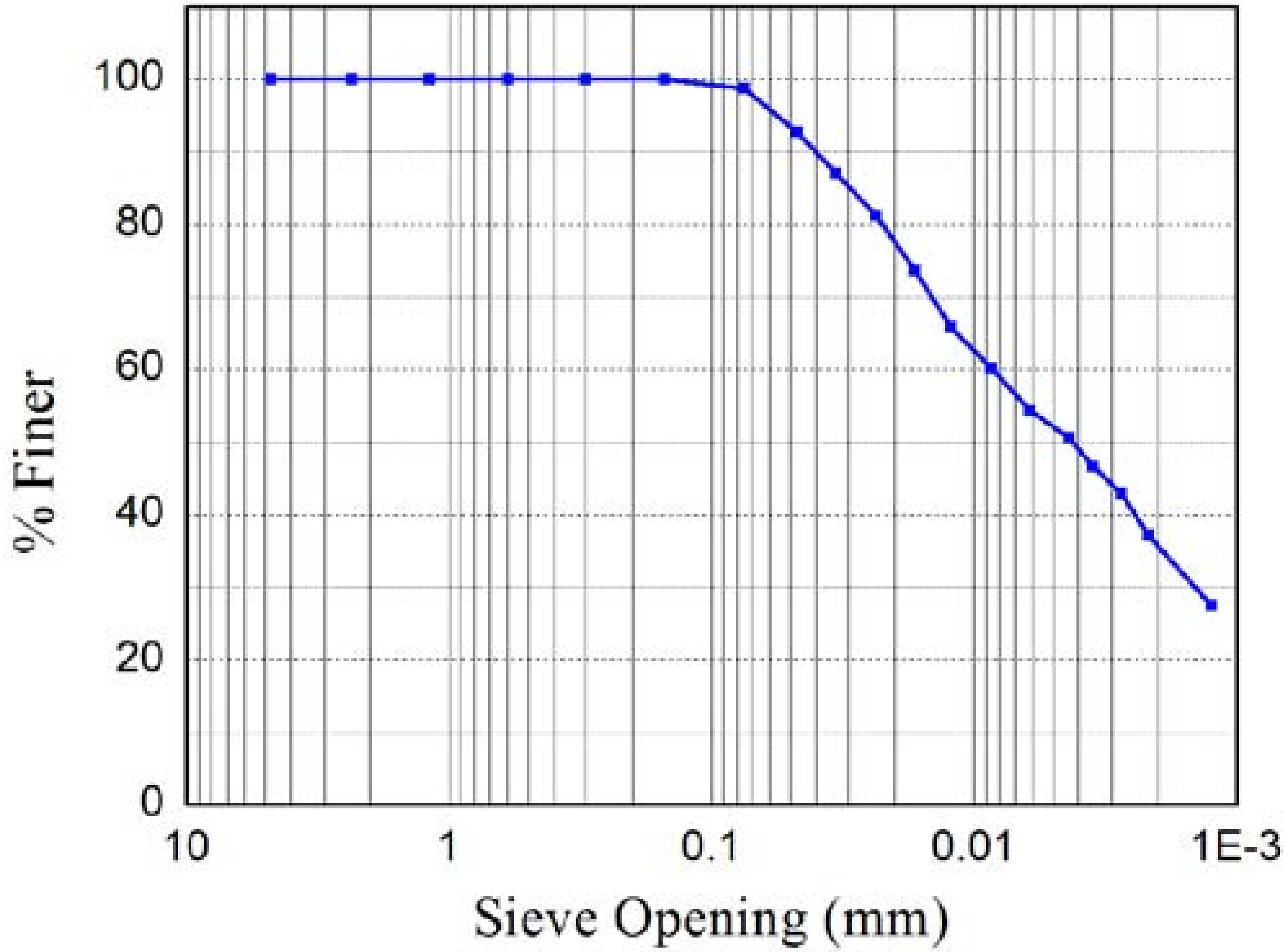

Figure 2:

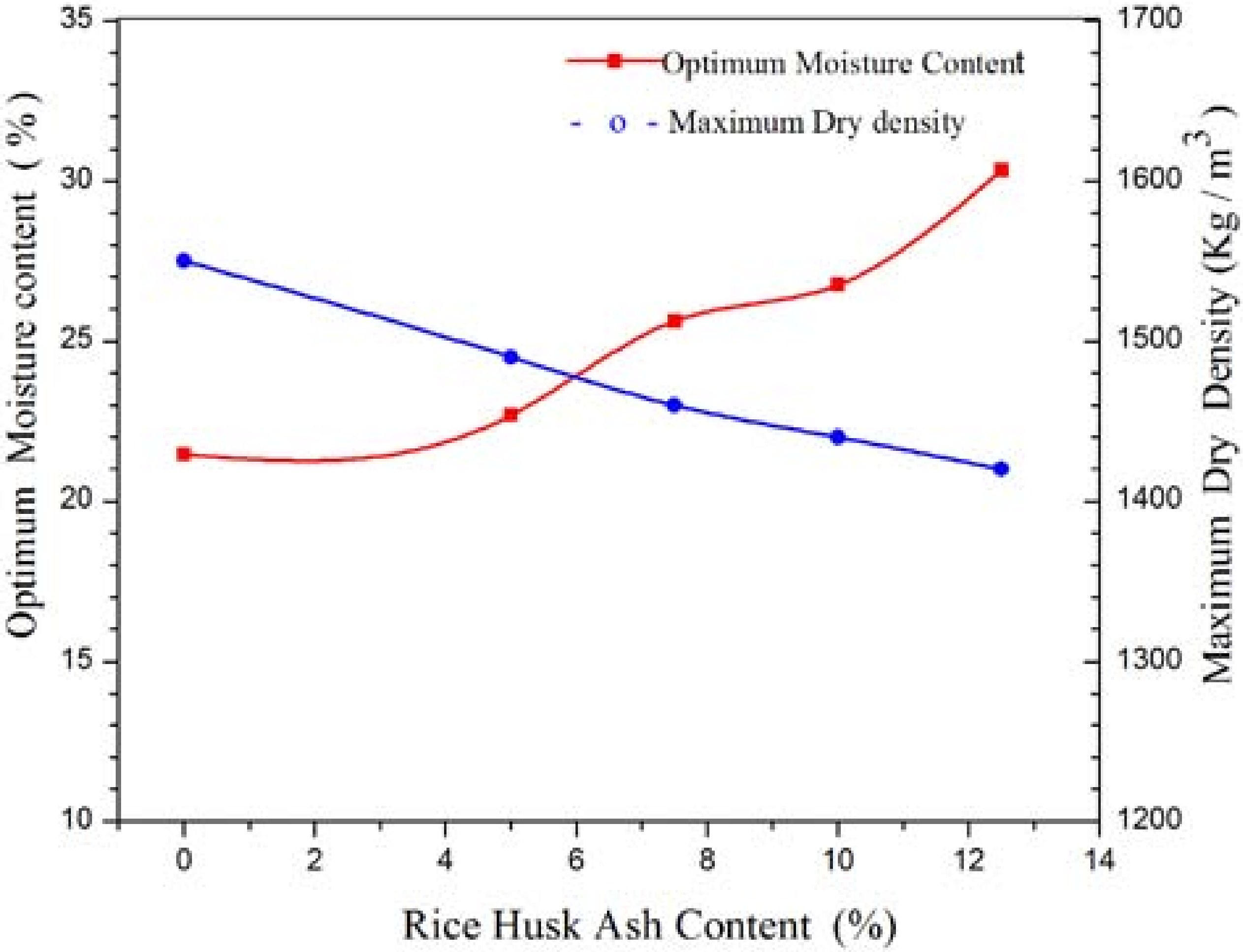

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Figure 3: Fig 2 :

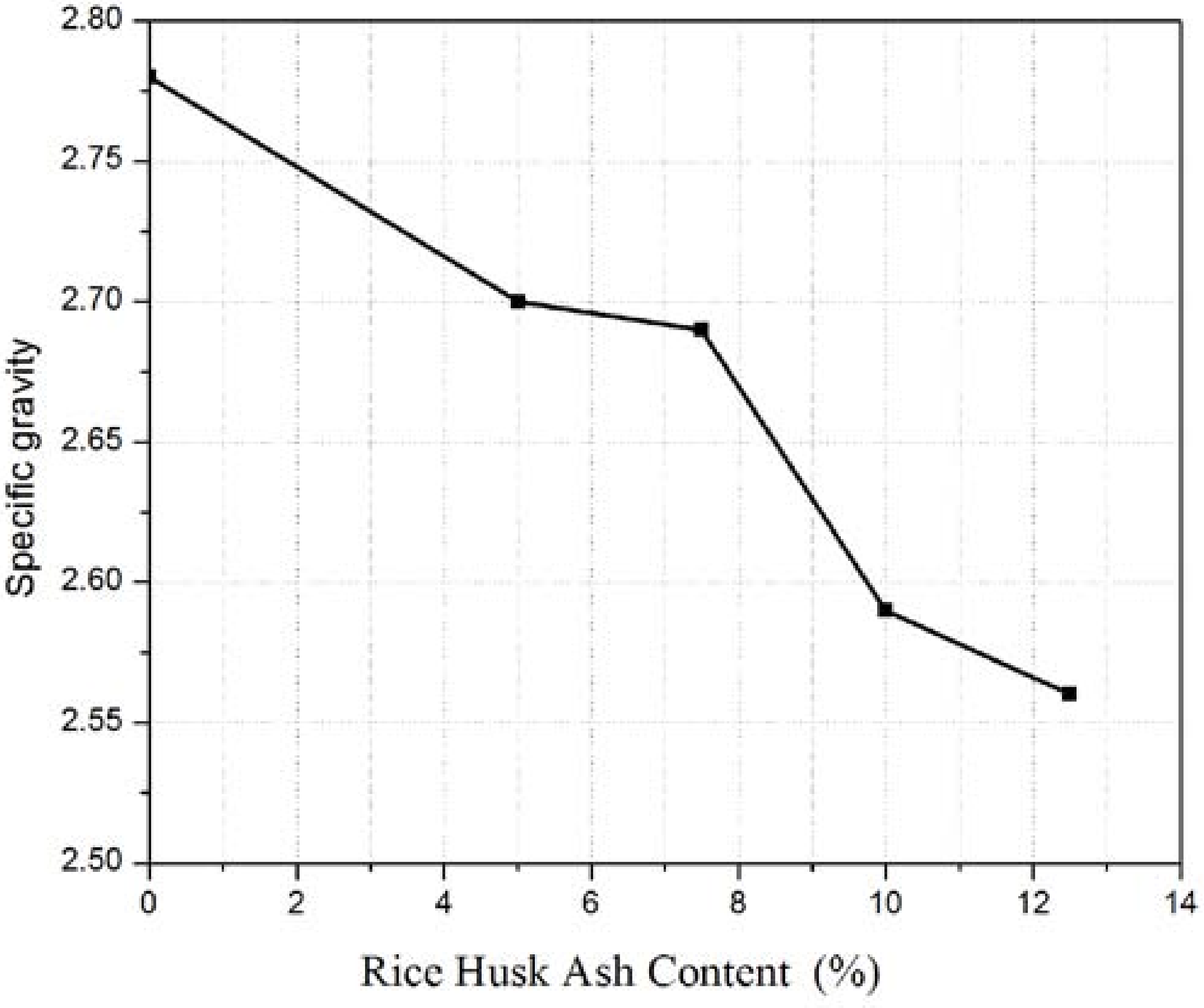

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Figure 4: Fig 3 :

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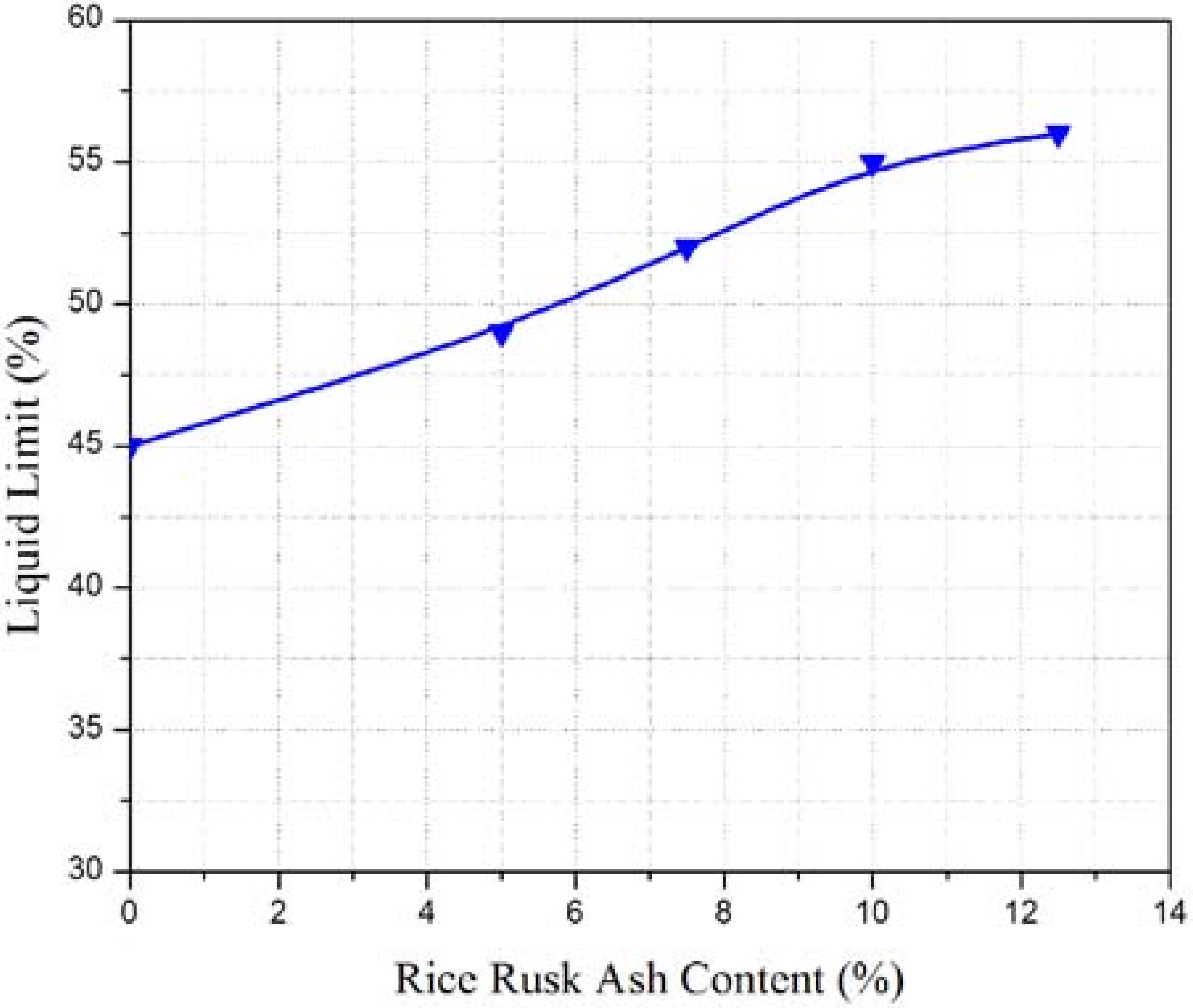

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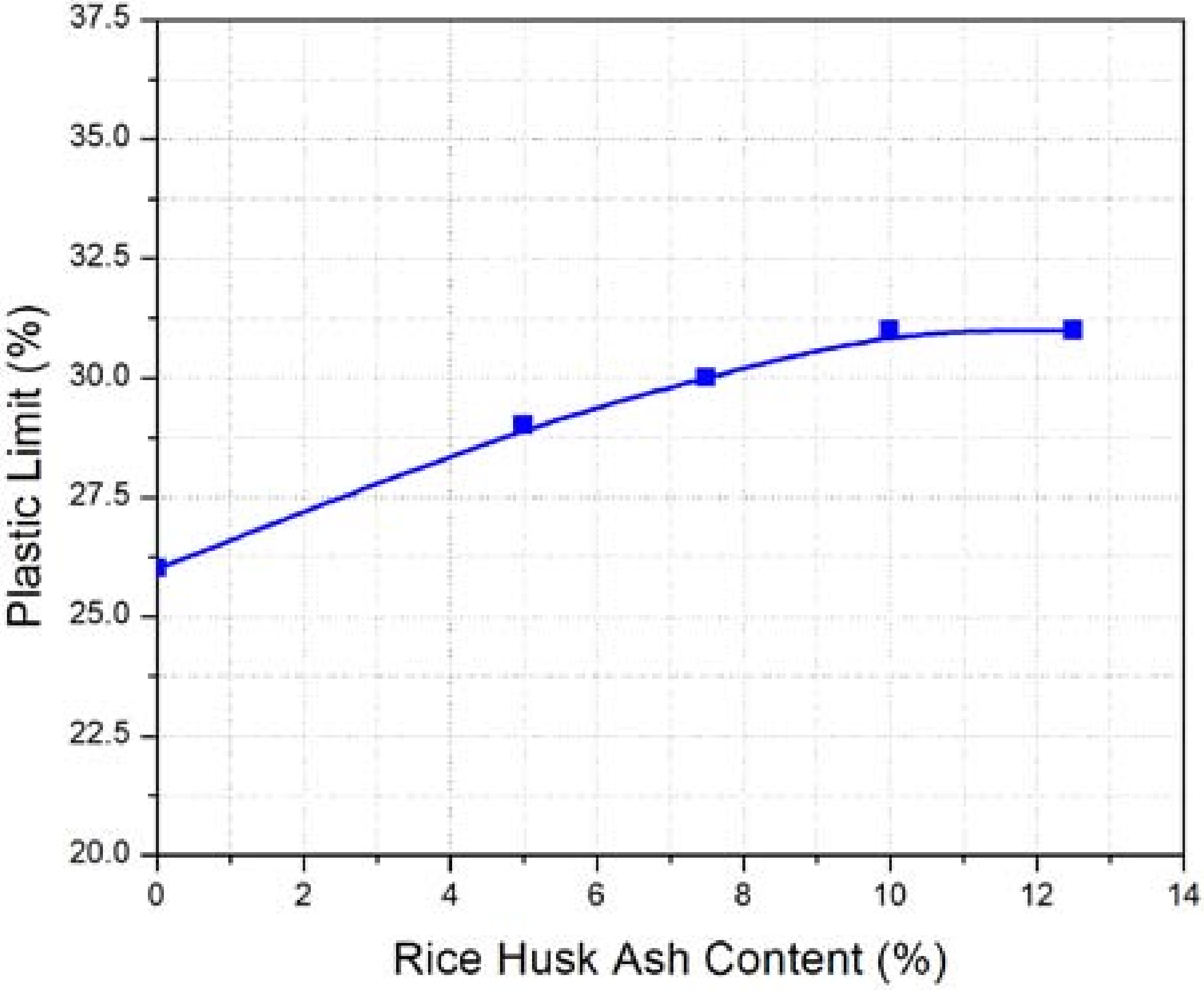

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Figure 6: Fig 6 :

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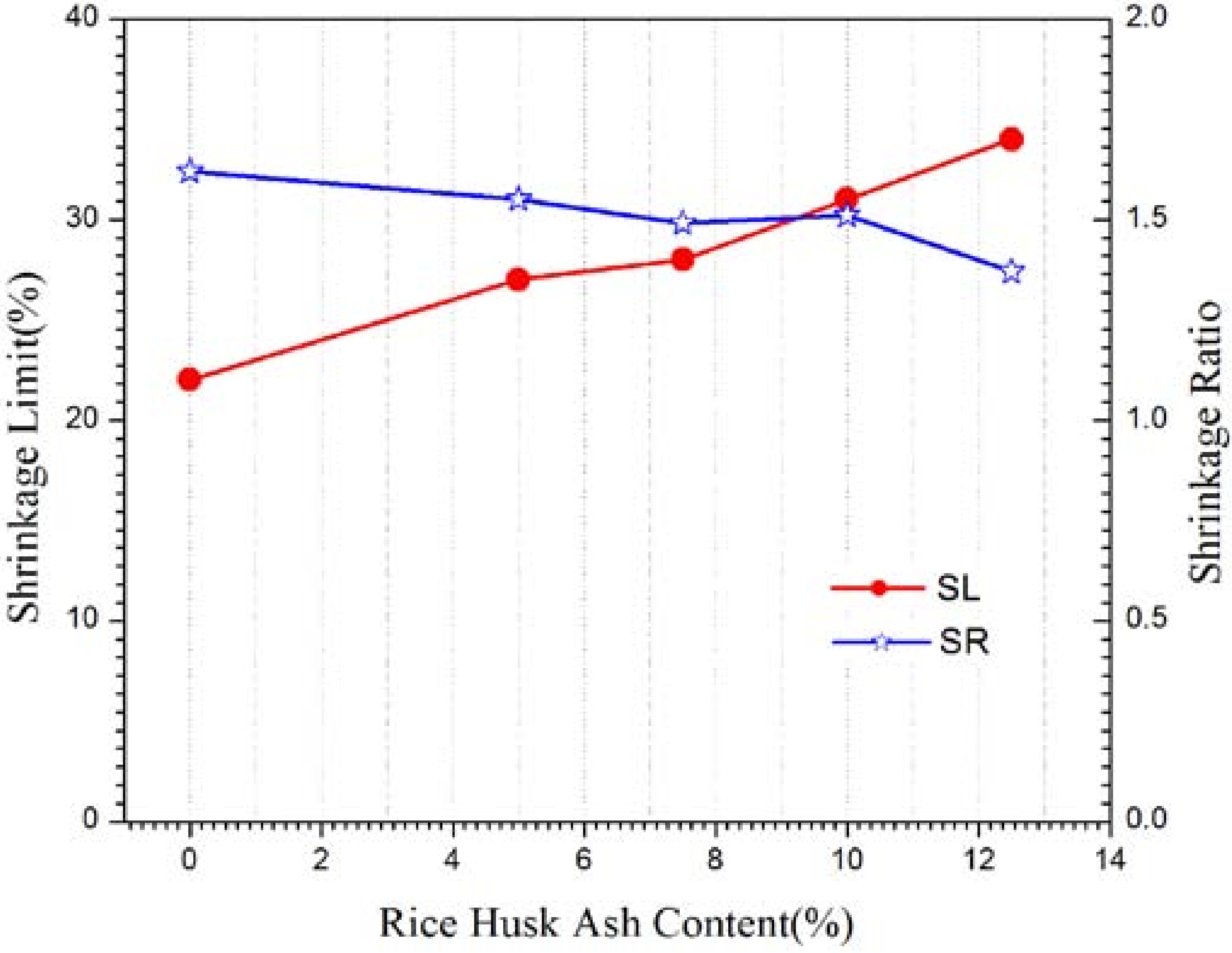

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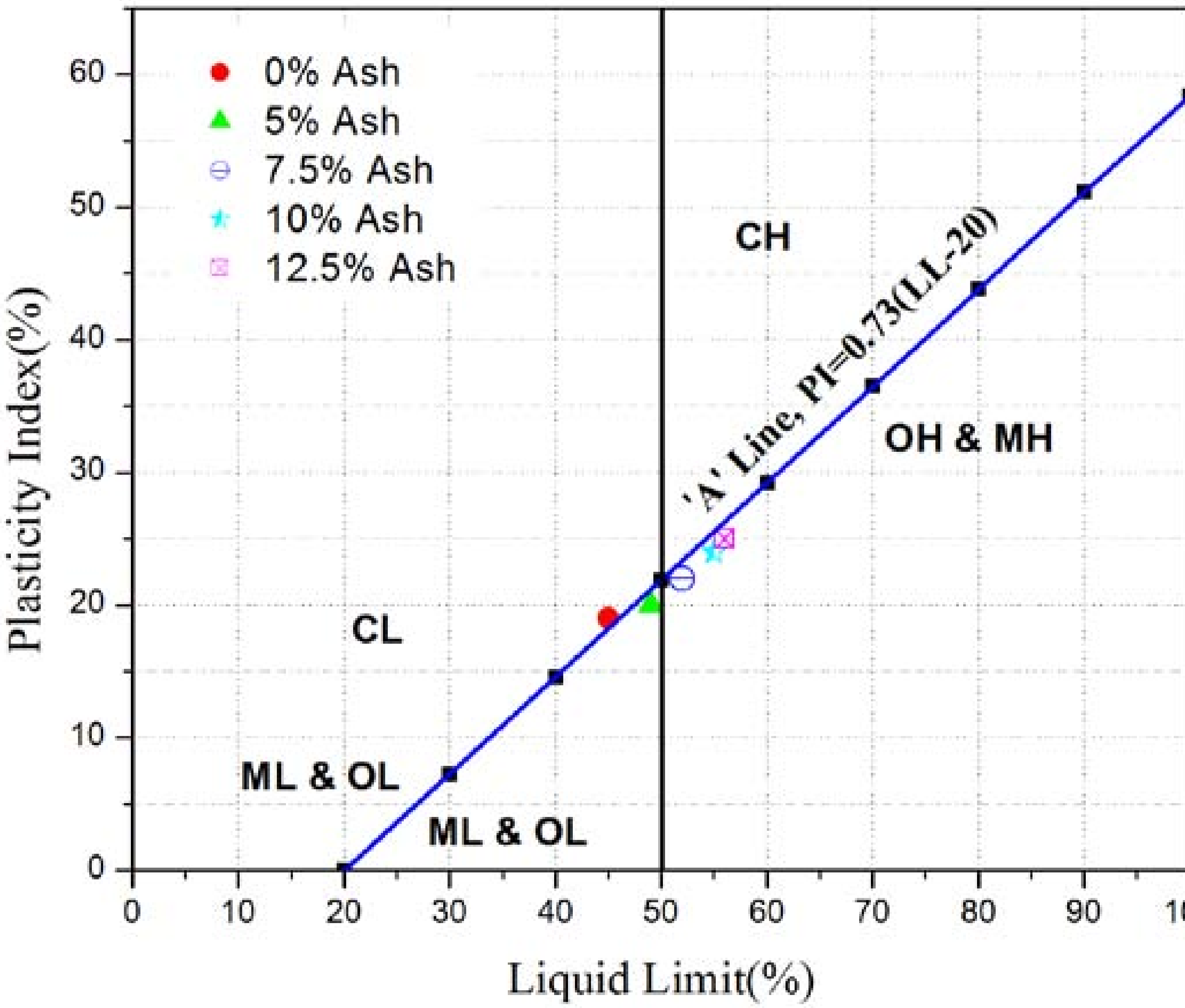

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Figure 8: Fig 8 :

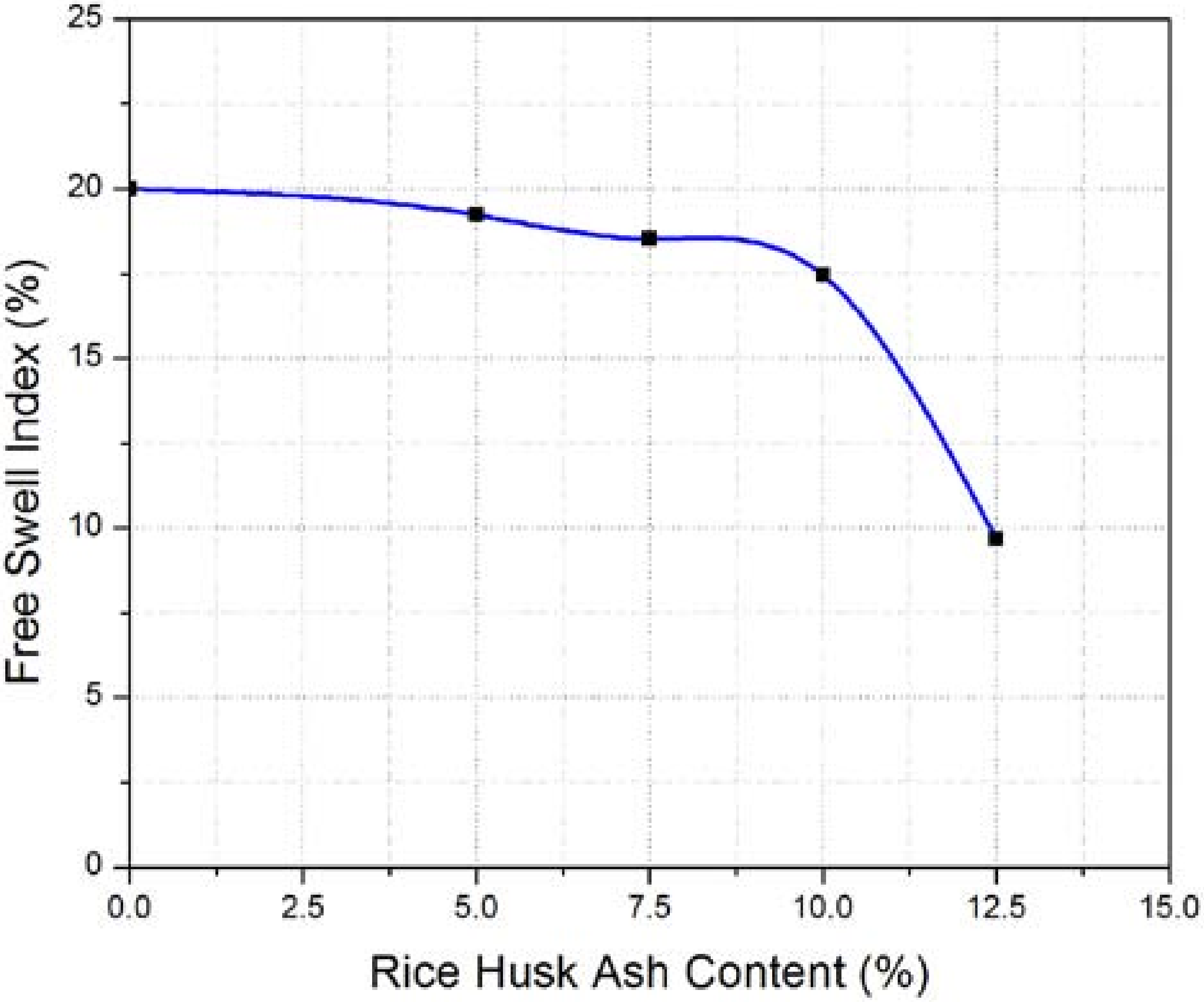

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Figure 9: Fig 9 :

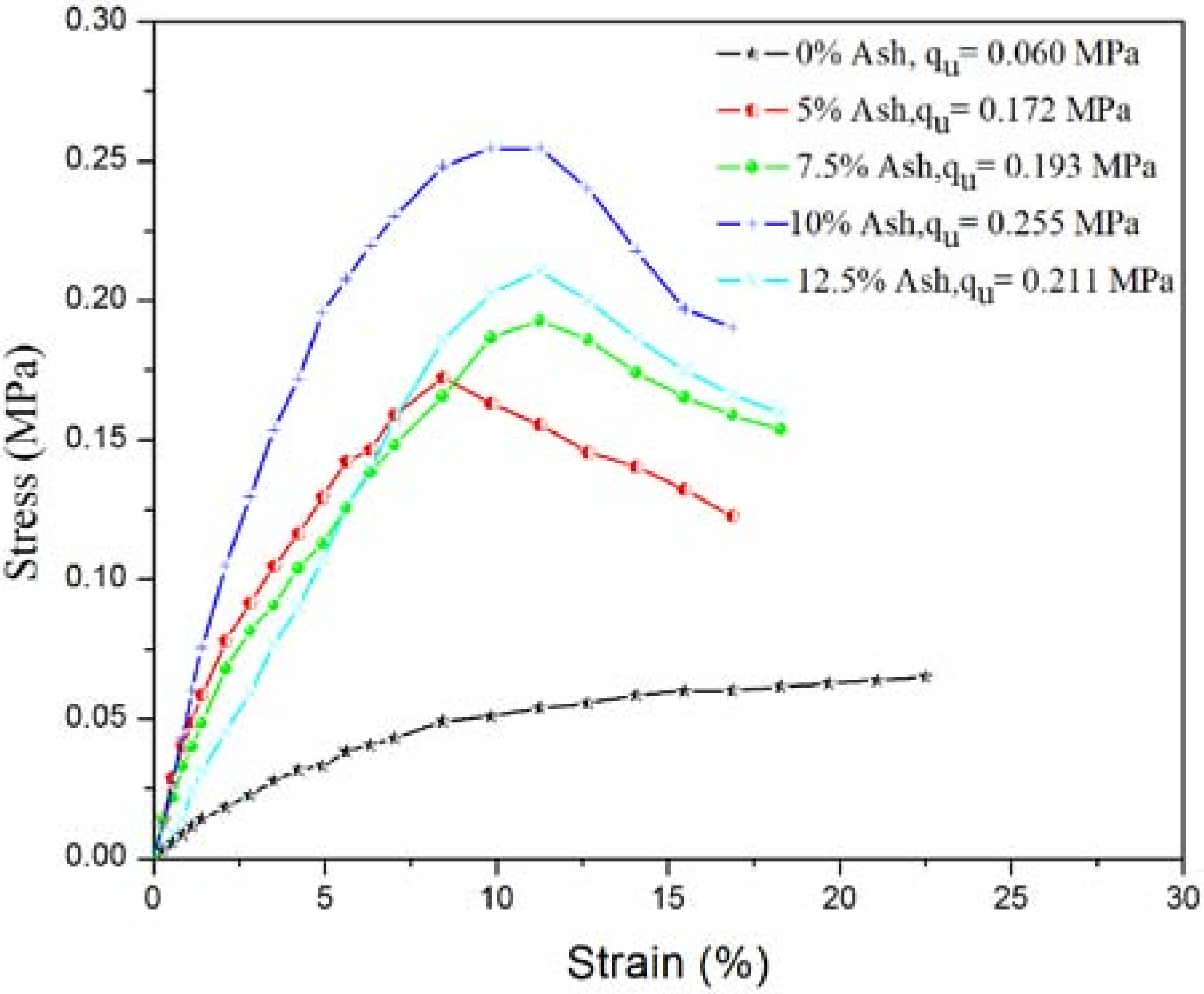

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Figure 10: Fig 10 :

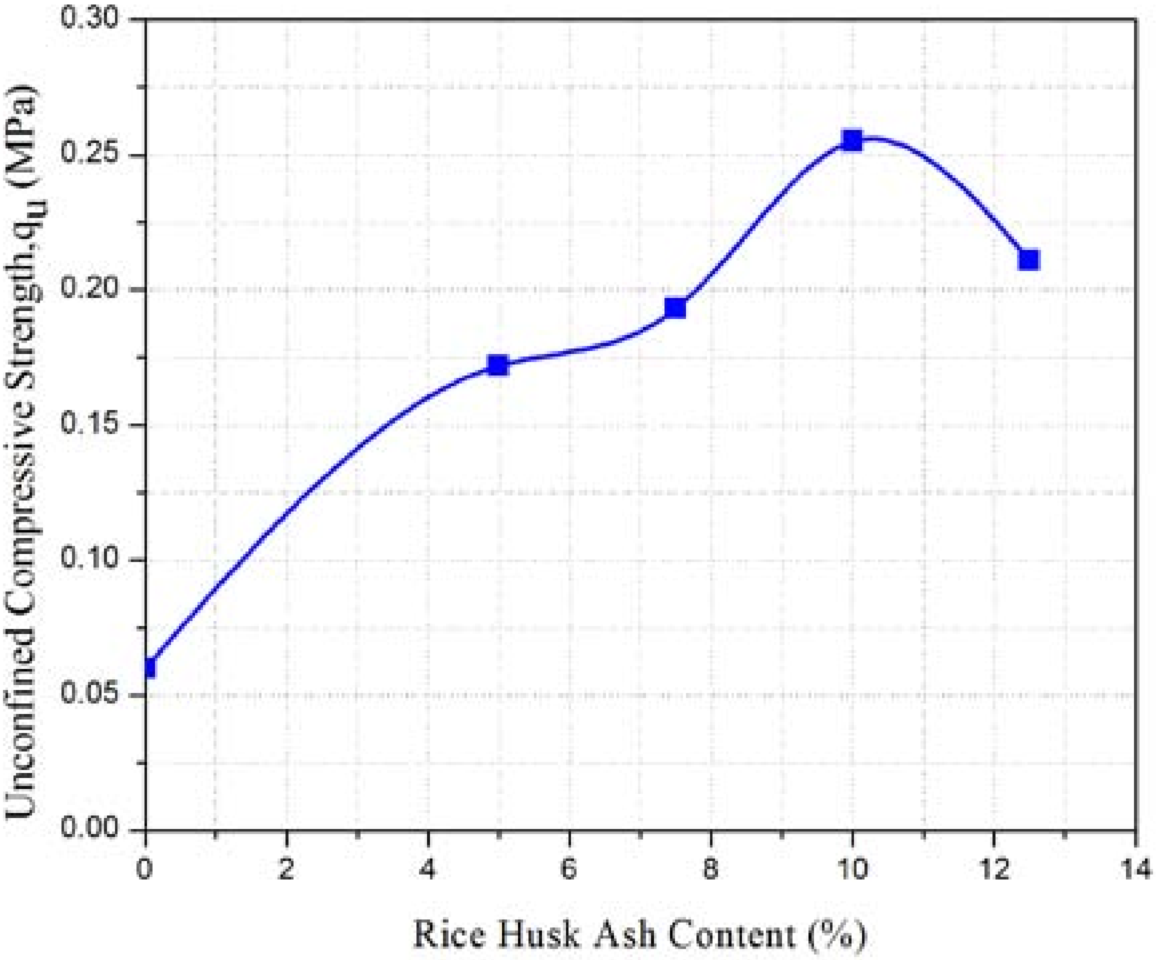

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Figure 11: Fig 11 :

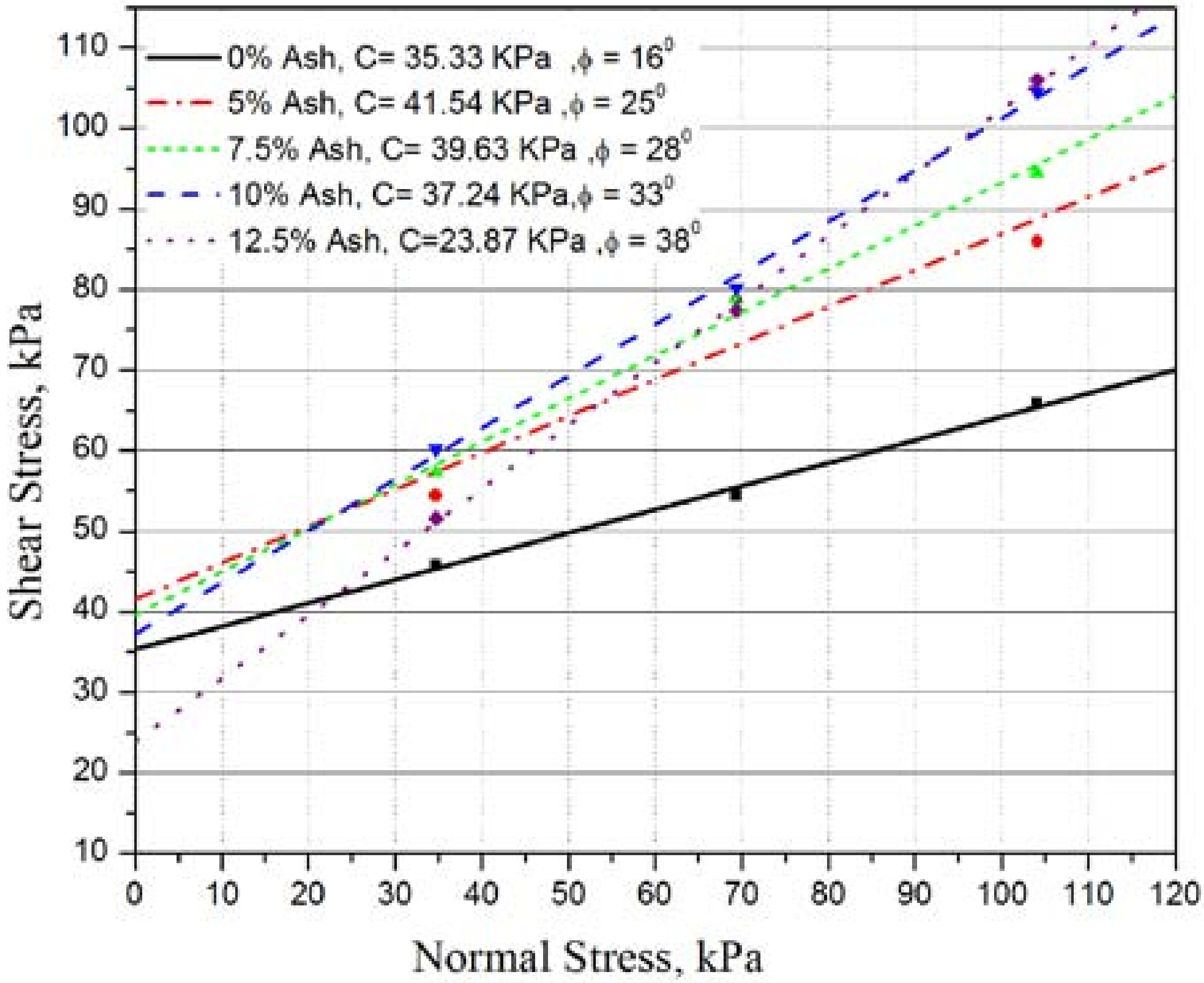

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Figure 12: Fig 12 :

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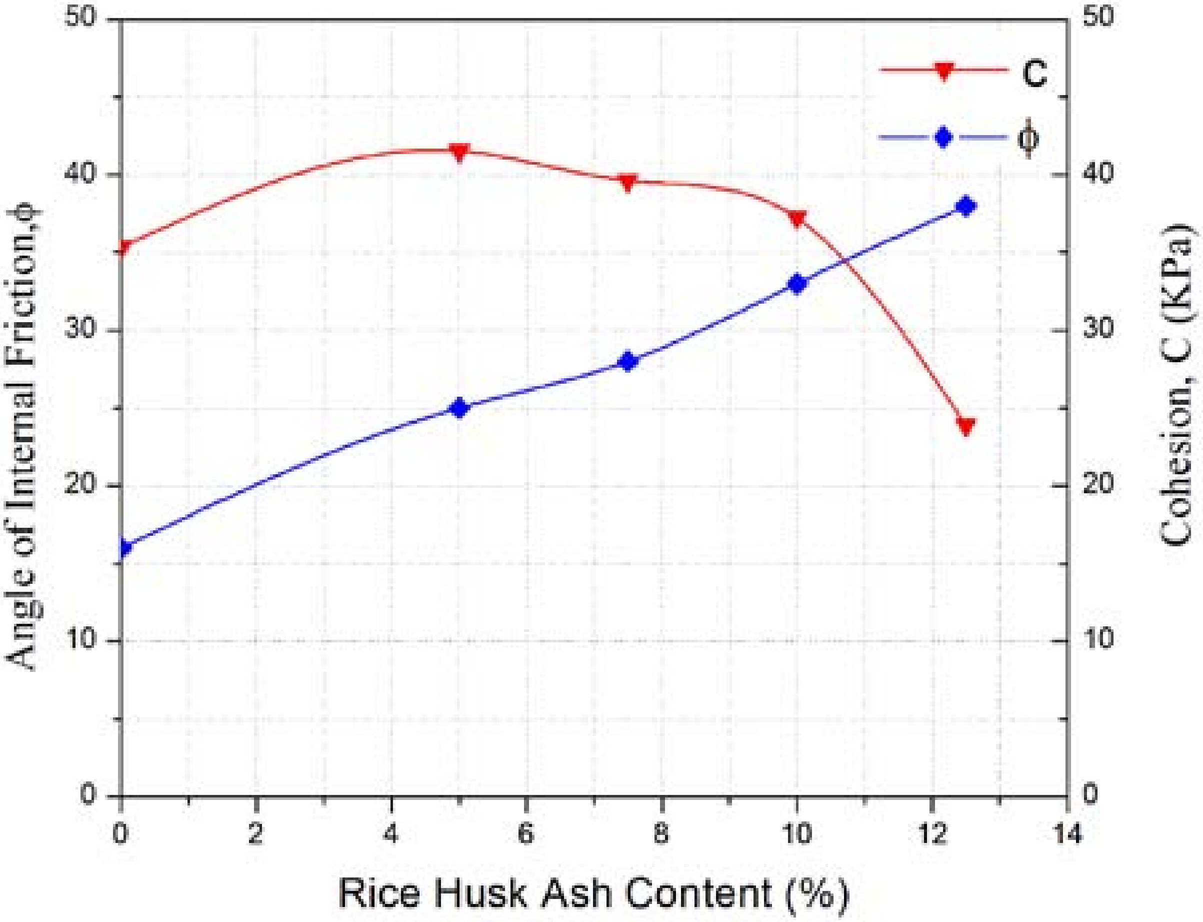

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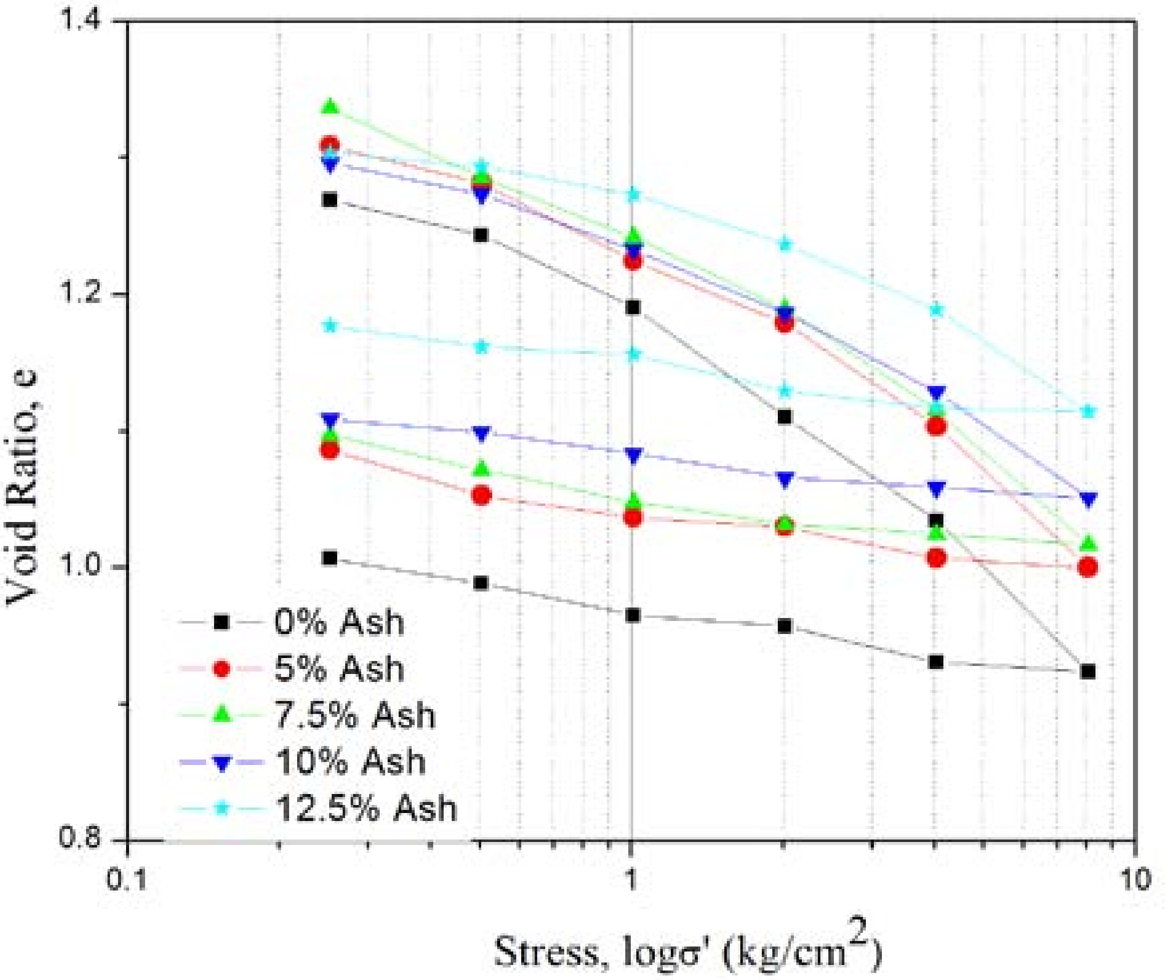

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Figure 14: Figure 14 :

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Samples ID	Samples Description RHA Soil (gm)	(gm) content	% Ash
Original soil	4000	–	0
R1	4000	200	5
R2	4000	300	7.5
R3	4000	400	10
R4	4000	500	12.5
d) Testing procedure			

Figure 15: Table 1 :

2

0	46	22	24	22	1.62
5	50	27	23	27	1.55
7.5	52	31	21	28	1.49
10	55	34	21	31	1.51
12.5	56	36	20	34	1.37

[Note: RHA(%) LL(%) PL(%) PI(%) SL(%) SR]

Figure 16: Table 2 :

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