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A Laboratory Study on Compaction Behavior of Plastic Soils Mixed with Recycled Aggregates

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Abstract: The use of recycled aggregate in geotechnical engineering to enhance soil properties has received considerable attention in recent times. The use of recycled aggregate from demolition waste in conjunction with fine-grained soil is one of the most promising ways to recycle this waste material. The study has covered five different fine-grained base soil samples with a wide range of plasticity and addition rates of up to 50% of graded recycled aggregates (passing through a #4 ASTM sieve). Different geotechnical tests were carried out to evaluate the engineering properties of fine-grained soil samples mixed with different percentages (30% and 50%) of recycled aggregates. The optimum water content of the improved soils tends to decrease for soils with the addition of different percentages of recycled aggregate, and the change in the optimum water content (ΔOWC) is related to the addition rate. The maximum dry density increased for soils with the addition of recycled aggregate, and the change in the maximum dry density, ΔMDD, is also related to the addition rate. The improvement effect on soil is related to the liquid limit of soil as a high liquid limit reduces the improvement effect due to recycled aggregate addition. An increase in dry density with reduced water content of a soil can generally be equated to an increase in strength, lower permeability, and better volume stability.

Keywords: *Recycled Aggregate; Fine-Grained Soil; Optimum Water Content; and Maximum Dry Density*.

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I. INTRODUCTION

Mineral waste from construction and demolition projects is produced in large quantities worldwide. In 2014, 869 Mt of construction and demolition waste was generated in the European Union (Eurostat, 2017). Modern societies aim for a more sustainable use of resources, thus resulting in a large scientific interest in the generation, reduction, reuse, recycling and management of construction and demolition [1]wastes (Yuan & Shen, 2011). Expanding the public's knowledge in these fields is imperative if these materials are to be broadly accepted as alternatives to natural resources in construction practice (Correia, 2015). In recent years, numerous studies have attempted to establish a clear picture of their engineering properties to evaluate their suitability as construction materials for geotechnical applications, such as unbound base and sub-base layers or subgrade materials (Dettenborn et al., 2015). A few researchers have sought to describe the difference between the behavior of such mineral wastes and that of natural aggregates (Melbouci, 2009). Recycled aggregate is defined as aggregate resulting from the processing of inorganic or mineral material previously used in construction (BSI, 2013). Recycled aggregates (RAs) from construction and demolition waste (CDW) have been used since World War II. In several countries, mostly in Europe, high recycling ratios have been achieved, such as in the Netherlands, Denmark and Germany, among others. This has been potentiated by those countries' relatively reduced reserve of natural resources and subsequent transformation to construction aggregates or by the promotion of very stringent environmental policies. These factors have allowed the use of RA, albeit with considerable limitations, in real construction applications, mainly in-road pavement layers, embankments, and earth-filling operations. One early study reported on the improvement of a fine-grained soil using fine-crushed concrete. They dry mixed 32 mass % of a plastic clay with 68 mass % of crushed concrete aggregates (< 0·425 mm) and attributed the improvement in the plasticity of the soil to the change in the grain size distribution and the presence of

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calcium hydroxide (Hansen, 1986). The alternation of the plasticity of fine-grained soils due to the presence of calcium ions in the pore water is principally known from soil improvement measures with lime as an additive (Dash & Hussain, 2012). It can be expected that over time, the properties of such mixtures may also be influenced by the self-cementing properties of the fine recycled concrete aggregates (Poon & Chan, 2006). A recent study shows that dry-mixing a high plasticity soil with crushed recycled aggregates (<4.25 mm) from a cement-sand layer in various mixing ratios exhibits maximum dry density and optimum moisture content to decrease with increasing addition rate of recycled aggregate (Sharma & Hymavathi, 2016). This paper represents a laboratory study on the effect of recycled aggregates on the physical properties of different fine-grained soils. The soil samples were classified using the USCS method and mixed with different percentages (30% and 50%) of crushed and 4.75 mm downgraded recycled aggregates containing broken mortar and concrete obtained from a demolition site. Atterberg limits test, grain size analysis (both sieve and hydrometer analysis) had been carried out to classify soil samples. Compaction proctor tests for base soil were conducted to find out the optimum water content and corresponding maximum dry density of soil. Also, the compaction proctor tests were performed for soils mixed with different percentages of graded recycled aggregate to ascertain the variation in optimum moisture content and maximum dry density from the value obtained for the base soil.

II. METHODOLOGY

➢ *Location of the Study*

Recycled aggregates derived from demolition waste and different base soil samples were used in this investigation. The present investigation was carried out on five different soil samples that were collected from the KUET campus at Khulna, Bangladesh. The recycled aggregates used were processed from broken concrete blocks, which are also collected from the KUET campus, Khulna, Bangladesh.

➢ *Testing Methods*

Laboratory testing on base soil included grain size analysis (sieve analysis and hydrometer analysis), Atterberg limits (liquid limit and plastic limit), and standard proctor test. Standard compaction tests were conducted on specimens prepared with the addition of 30% & 50% of 4.75 mm downgraded recycled aggregate, respectively.

➢ *Properties of Base Soils and Recycled Aggregates*

The properties of base soil and recycled aggregate were evaluated according to ASTM standards. The soil samples were classified according to the Unified Soil Classification System (USCS). The Unified Soil Classification System is adopted by ASTM D-2487-98 and IS: 1498-1970 for the classification and identification of soils for general engineering purposes. Tables 1,2 and 3 represent the particle size, Atterberg limit, and compaction properties of samples, respectively.

Table 1: Base Soil Grain Size Distribution Properties

Soil	D_{10} (mm)	D_{30} (mm)	D_{60} (mm)	Cu	Cc
Sample 1	0.010	0.031	0.055	5.4	1.7
Sample 2	0.003	0.024	0.069	23.7	3.0
Sample 3	0.006	0.030	0.060	10.5	2.6
Sample 4	0.002	0.016	0.050	24.5	2.6
Sample 5	0.004	0.037	0.056	13.3	5.8

Table 2: Base Soil Atterberg Limit Properties and Classification using USCS method

Soil	Liquid Limit (LL) %	Plastic Limit (PL) %	Plasticity Index (PI)	Flow Index	Group Symbol acc. To USCS	Soil Designation acc. To USCS
Sample 1	36.9	15	21.9	-47.0	CL	Lean Clay with Sand
Sample 2	51.3	32	19.3	-33.4	MH	Sandy Elastic Silt
Sample 3	32.3	19	13.3	-118.1	CL	Lean Clay with Sand
Sample 4	42.3	21	21.3	-52.5	CL	Lean Clay with Sand
Sample 5	40.8	19	21.8	-20.3	CL	Lean Clay with Sand

Table 3: Compaction Parameters of Base Soils and Soils with Recycled Aggregates

Soil	MDD (gm/cc)	ΔMDD (gm/cc)	OMC (%)	ΔOMC (%)
Sample 1	1.61	-	15	-
Sample 1+ 30% RA	1.67	+0.06	13	-2
Sample 1+ 50% RA	1.66	+0.05	12	-3
Sample 2	1.63	-	16	-
Sample 2+ 30% RA	1.66	+0.03	12	-4
Sample 2+ 50% RA	1.64	+0.01	10	-6
Sample 3	1.60	-	15.5	-
Sample 3+ 30% RA	1.71	+0.11	12	-3.5
Sample 3+ 50% RA	1.70	+0.10	12	-3.5

Sample 4	1.74	-	10	-
Sample 4+ 30% RA	1.75	+0.01	12	+2
Sample 4+ 50% RA	1.75	+0.01	12	+2
Sample 5	1.67	-	12	-
Sample 5+ 30% RA	1.70	+0.03	13	+1
Sample 4+ 50% RA	1.68	+0.01	16	+4

➢ *Improvement Effect*

• *Improvement Effect on OMC*

The improvement effect (ΔCI) was measured to identify the extent to which the compactability of a soil can be improved by a given soil improvement measure (shift in the optimum initial water content in terms of consistency). Each base soil was characterized by its liquid limit (LL), and the values for the ΔCI are calculated.

ΔCI= CI **-** (OMC of improved soil / PI of base soil) ------(1)

CI= OMC of base soil / PI of base soil ----------------------(2)

• *Improvement Effect on MDD*

ΔCI = (MDD of improved soil / PI of base soil)-CI -------(3)

CI= MDD of base soil / PI of base soil ----------------------(4)

➢ *Methodological Approach*

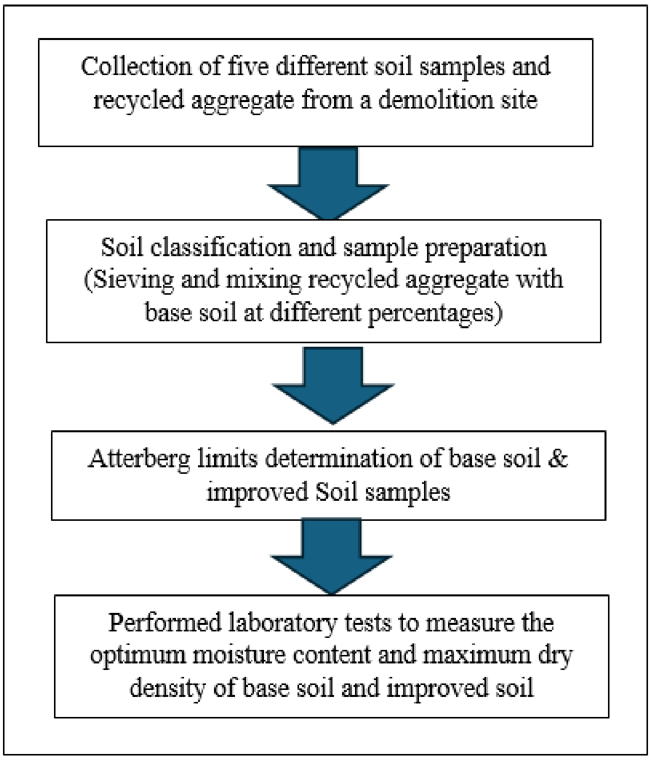

Fig 1 Methodological Approach

III. RESULTS AND DISCUSSIONS

➢ *Variation in OMC of Base Soils for Recycled Aggregate Addition*

Fig. 2 shows the Variation in OMC of base soils for recycled aggregate addition at different rates. two primary observations can be made on OMC from the plotted data: (a) the OMC of the improved soils tends to decrease for soils of initially high OWC and vice versa, and (b) the change in the optimum water content (ΔOWC) is related to the addition rate of recycled aggregates.

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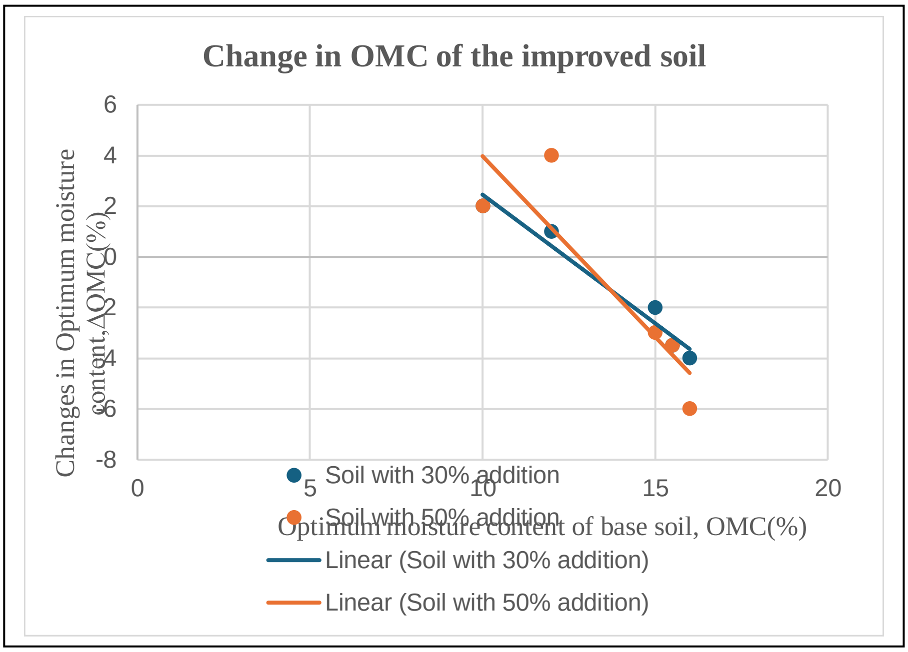

Fig 2: Variation in OMC of Base Soils for Recycled Aggregate Addition

➢ *Variation in MDD of Base Soils for Recycled Aggregate Addition*

Fig. 3 shows the Variation in MDD of base soils for recycled aggregate addition at different rates. The MDD increases for soils for both 30% and 50% additions of recycled aggregate, and the ΔMDD is related to the addition rate of recycled aggregate.

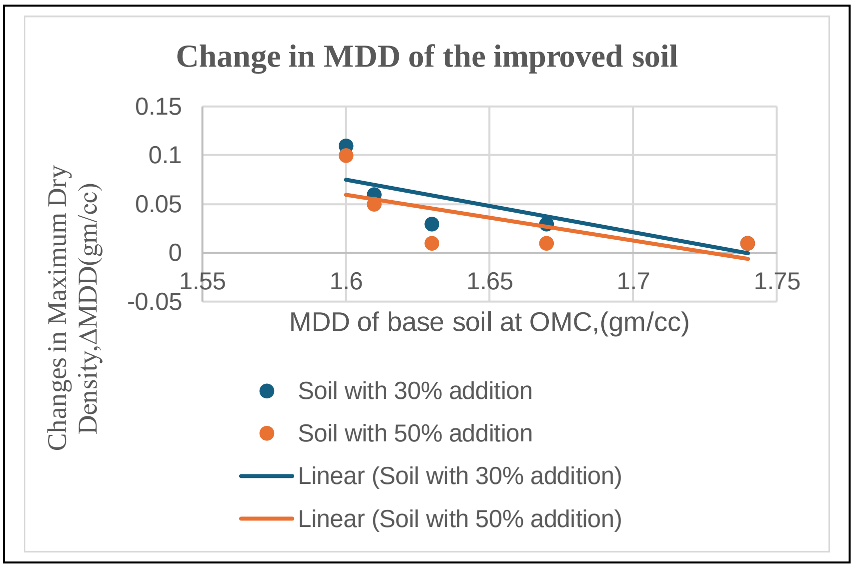

Fig 3: Variation in MDD of Base Soils for Recycled Aggregate Addition

➢ *Improvement Effect on OMC of Base Soils Due to Recycled Aggregate Addition*

Table 4: Improvement effect on OMC for different additions of recycled aggregate

Soil	LL (%)	Improvement Effect, ΔCI (OMC) for 30% addition of RA	Improvement Effect, ΔCI (OMC) for 50% addition of RA
Sample 1	36.9	+0.09	+0.14
Sample 2	51.3	+0.21	+0.31
Sample 3	32.3	+0.26	+0.26
Sample 4	42.3	-0.09	-0.09
Sample 5	40.8	-0.05	-0.18

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From *Fig. 4*, primary observations can be made on the degree of improvement from the plotted data. It can be easily said that the improvement effect on OMC of base soil due to the addition of recycled aggregates is decreasing with increased liquid limit of soil, and after a particular critical point, the improvement effect starts to increase again along with the liquid limit of base soil. The improvement effect is also dependent on the addition rate of recycled aggregate.

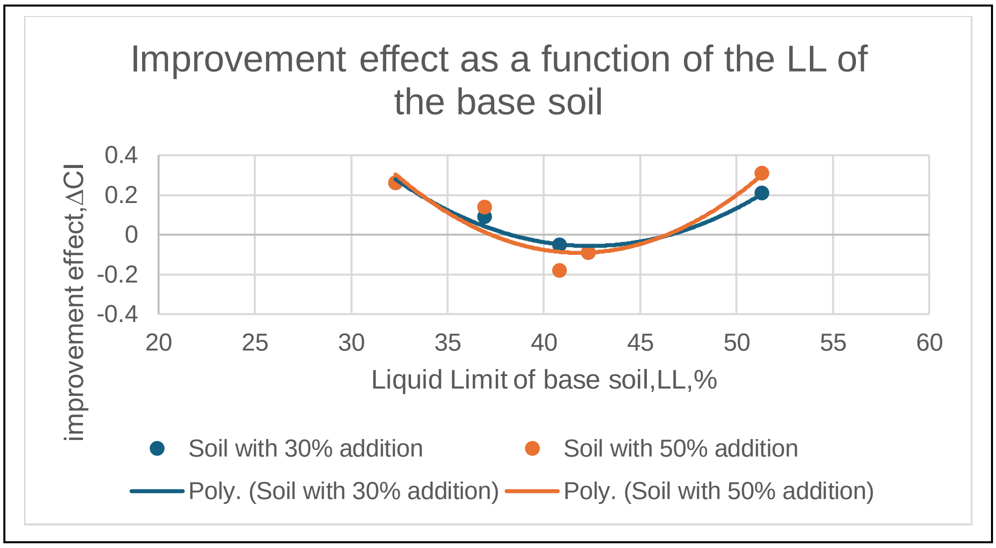

Fig. 4: Improvement effect on OMC for different additions of recycled aggregate

➢ *Improvement Effect on MDD of Base Soils Due to Recycled Aggregate Addition*

Table 5: Improvement Effect on MDD for Different Additions of Recycled Aggregate

Soil	LL (%)	Improvement Effect, ΔCI (MDD) for 30% addition of RA	Improvement Effect, ΔCI (MDD) for 50% addition of RA
Sample 1	36.9	+0.0027	+0.0023
Sample 2	51.3	+0.0016	+0.0005
Sample 3	32.3	+0.0083	+0.0075
Sample 4	42.3	+0.0005	+0.0005
Sample 5	40.8	+0.0014	+0.0005

From *Fig. 5*, primary observations can be made on the degree of improvement from the plotted data. It can be easily said that the improvement effect on MDD of base soil due to the addition of recycled aggregates is decreasing with increased liquid limit of soil, and after a particular critical point, the improvement effect starts to increase again along with the liquid limit of base soil. The improvement effect is also dependent on the addition rate of recycled aggregate.

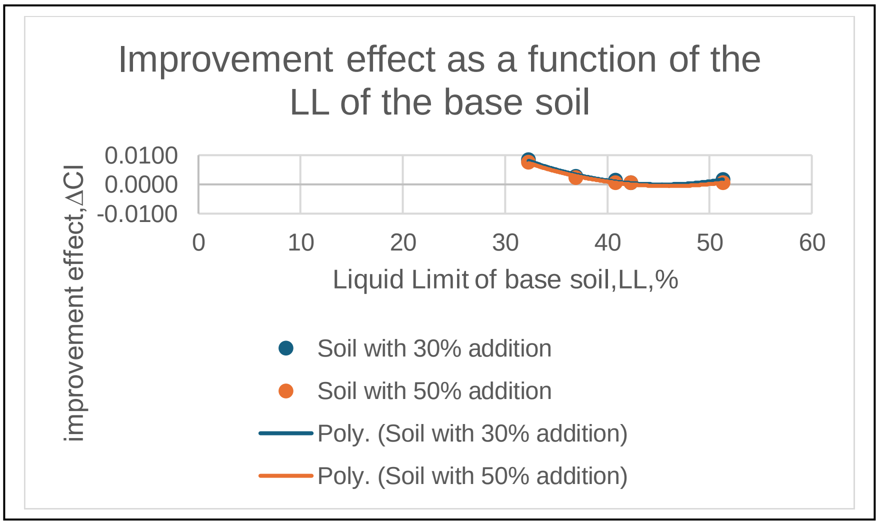

Fig. 5: Improvement Effect on MDD for Different Additions of Recycled Aggregate

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IV. CONCLUSIONS

Based on the experiment carried out on different base soils and recycled aggregate mixtures, the following observations and conclusions are drawn: Optimum moisture content and maximum dry density are two of the most important properties of soil, which are determined by the compaction test, the most reliable method. The improvement of fine-grained soil by recycled aggregate is a function of the Liquid limit of the soil. The improvement of both optimum moisture content and maximum dry density depends on the addition rate of recycled aggregate. Improvement is mainly focusing on increasing the maximum dry density of the base soil and reducing the corresponding optimum moisture content of the soil with recycled aggregate addition.. Maximum Dry Density with minimum moisture content means: Minimum voids, Minimum permeability, less frost, Minimum erosion, Maximum Bearing Capacity due to increasing strength of soil, and Minimum shrinkage.

REFERENCES

[1]. BSI. (2013). Aggregates for concrete : British Standards. *British Standards Institution. European Committee for Standardization.*, 56.

[2]. Correia, A. (2015). *Geotechnical Engineering for Sustainable Transportation Infrastructure*. https://doi.org/10.1680/ecsmge.60678.vol1.003

[3]. Dash, S. K., & Hussain, M. (2012). Lime Stabilization of Soils: Reappraisal. *Journal of Materials in Civil Engineering*, *24*(6), 707–714. https://doi.org/10.1061/(ASCE)MT.1943-5533.0000431

[4]. Dettenborn, T., Forsman, J., Rämö, P., Pieksemä, J., Suominen, M., & Korkiala-Tanttu, L. (2015). *Utilisation of crushed concrete aggregate in urban earth construction: streets and pipe trenches* (pp. 919–924). ICE Publishing.

[5]. Eurostat. (2017). Regional Yearbook. *Publications Office of the European Union*.

[6]. Hansen, T. C. (1986). Recycled aggregates and recycled aggregate concrete second state-of-the-art report developments 1945-1985. *Materials and Structures*, *19*(3), 201–246. https://doi.org/10.1007/BF02472036/METRICS

[7]. Melbouci, B. (2009). Compaction and shearing behaviour study of recycled aggregates. *Construction and Building Materials*, *23*(8), 2723–2730. https://doi.org/10.1016/J.CONBUILDMAT.2009.03.004

[8]. Poon, C. S., & Chan, D. (2006). Feasible use of recycled concrete aggregates and crushed clay brick as unbound road sub-base. *Construction and Building Materials*, *20*(8), 578–585. https://doi.org/10.1016/J.CONBUILDMAT.2005.01.045

[9]. Sharma, R. K., & Hymavathi, J. (2016). Effect of fly ash, construction demolition waste and lime on geotechnical characteristics of a clayey soil: a comparative study. *Environmental Earth Sciences*, *75*(5), 1–11. https://doi.org/10.1007/S12665-015-4796-6

[10]. Yuan, H., & Shen, L. (2011). Trend of the research on construction and demolition waste management. *Waste Management*, *31*(4), 670–679. https://doi.org/10.1016/J.WASMAN.2010.10.030