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Effect of Local Coarse Aggregate Type on Concrete Mechanical Properties in Bangladesh

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Abstract: ***Different types of natural coarse aggregate are available in the local market of Bangladesh, which are primarily imported from several regions of the neighboring country, India. This paper aims to find the best locally available natural coarse aggregate for concrete preparation in terms of mechanical strength. It also reports on the results of an experiment investigation that looked at the effects of six different types of natural coarse aggregate, namely Burimari, Bhurungamari, Bholaganj, Tamabil, Jaflong and Dinajpur Hili (Indian Black Stone), available in the local market of Bangladesh on the mechanical properties of concrete. Concrete cylindrical specimens of 100mm diameter were prepared by each type of natural coarse aggregate keeping other ingredients constant. Concrete mix ratio and water/cement ratio adopted for the study were 1:1.5:3 and 0.48, respectively. The Compressive strength, splitting tensile strength and modulus of elasticity were investigated at 7, 14 and 28 days of curing age. The obtained results showed Dinajpur Hili (Indian Black Stone) is most suitable for concreting having distinguished variation in compressive strength, splitting tensile strength and modulus of elasticity compared to other types of natural coarse aggregates used in the research.***

Keywords: Concrete, Local Market, Mechanical Properties, Natural Coarse Aggregate.

I. INTRODUCTION

Infrastructure development in Bangladesh is happening at an impressive rate. Mega structures are being constructed and large-scale projects are being implemented to improve the country's socio-economic condition. Concrete is the leading element of this development and most of it is constituted by coarse aggregate. The type and properties of the natural coarse aggregate vary depending on its source and constituents. Aggregates are mined from hard-rock quarries, natural sand-and-gravel pits, dredging submerged deposits like rivers, lakes and seabed or underground sediments. Limited natural resources of the country can't meet the demand for coarse aggregate, and most of the natural coarse aggregate available in the local market is imported from neighboring India. Rocks and minerals mixed to form naturally occurring aggregates. A mineral is a solid material that forms spontaneously and has an organized internal structure and chemical composition. Depending on their origin, rocks are categorized as igneous, sedimentary, or metamorphic. They are made up of a variety of minerals. Quartz, feldspar, mica, and a few other minerals are found in granite, whereas calcite, dolomite, and tiny quantities of quartz, feldspar, and clay are found in most limestone. Stone, gravel, sand, silt, and clay are produced through the weathering and erosion of rocks. The parent rock determines the quality of natural aggregate. Sand and gravel formed from igneous and metamorphic rocks, for example, is more likely to be sound than sand and gravel derived from shale and siltstone-rich rocks. Natural aggregate deposited by glaciers at higher elevations may be superior to low-lying deposits. Sand and gravel that have been smoothed by agitation in water for an extended period are typically regarded as excellent quality.

Concrete is made up of several different materials that combines cement, aggregate and water uniformly. Major portion of weight (70-85%) and volume (60-80%) of concrete originate from aggregate. Aggregate is regarded as inert material, but it is an essential element determining concrete's thermal, elastic, and structural integrity. Concrete's workability, strength, durability, and economy are all influenced by aggregate qualities. As aggregate's thermal, physical and chemical attributes impact the performance of concrete, it is not inert [1]. The coarse aggregate used in concrete mixing significantly affects the compressive strength of fresh and hardened concrete. Because coarse aggregates account for most of the volume in concrete, their overall properties impact the properties of concrete produced with various nominal mixes. The source, size, form, unit weight, texture, and other coarse aggregate characteristics determine their properties. The source from which coarse aggregates was collected significantly impacts their geological, mineralogical, physical, and mechanical properties. The strength, workability, and durability of concrete are all affected by variations in aggregate properties (either mechanical or physical) [2-4]. The overall performance and strength of concrete in both fresh and hardened stages is significantly influenced by the aggregate type by source. [5-7]. Different aggregate types substantially impact concrete compressive strength, with more substantial aggregate types improving total concrete strength [8-16]. Bleeding, segregation, workability, finishing ability, and pumping capacity of fresh concrete and durability, stiffness, strength, creep, shrinkage, density, and permeability of hardened concrete are influenced by aggregate characteristics such as grading, shape, and surface texture [17].

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The attributes of parent rock, such as specific gravity, hardness, chemical and mineralogical composition, strength, physical petrographic classification, chemical stability, and pore structure, have an important influence on fresh and hardened concrete [18]. The impact of coarse aggregate content and particle size distribution on concrete compressive strength demonstrated that coarse aggregate characteristics (grain size distribution, percentage of fine to coarse aggregate, and quantity) are closely associated with compressive strength [19-23].

Soroka, 1993 [24] conducted a test that indicated differences in the compressive strengths of crushed stone and uncrushed stone concrete. The crushed rock has a higher compressive strength than the uncrushed stone. The water/cement ratio, grading, surface texture, shape, strength, and stiffness of the aggregates used contributed to the strong performance. Bloem and Gaynor, 1963 [25] investigated the influence of form, surface roughness, fine coatings, and maximum aggregate size on concrete water requirements and strength. The study found that irregularly shaped smaller-sized aggregates without layers outperformed smooth spherical big-sized aggregates at a similar water/cement ratio. They also suggested that the size difference between aggregates and the specific qualities might contribute to an increase or decrease in concrete strength at a constant cement concentration. Stanton and Bloem, 1960 [26] found that varying water/cement ratios result in varying strength levels for different aggregate maximum sizes. They observed that concrete strength always decreased when the maximum size of aggregate grew.

II. MATERIALS AND METHODS

A. Cement

Portland Composite Cement (PCC) with a 42.5 N strength class was utilized in this study. PCC has a specific gravity of 3.11 and comprises 70-79% clinker, 21-30% slag, fly ash, limestone and 0-5% gypsum. The initial setting time for this cement was 153 minutes and final setting time was 407 minutes. Its early strength after three days was 21.8 MPa.

B. Fine Aggregate

Locally available coarse sand (Sylhet Sand) was used as the fine aggregate in this study. Table 1 shows the physical characteristics of fine aggregate.

Table 1: Physical properties of fine aggregate

Fine Aggregate Type	Fineness Modulus (FM)	Unit Weight (Dry Rodded) (kg/m3)	Absorption Capacity %	Bulk Specific Gravity (OD)
Coarse Sand	2.53	1547	1.34	2.54

C. Coarse Aggregate

Six different types of natural coarse aggregate (Figure 1) available in the local market, namely Tamabil, Dinajpur Hili (Indian Black Stone), Bhurungamari, Bholaganj, Burimari and Jaflong were collected. Various tests were then conducted to assess the physical properties of the natural aggregates, which are shown in Table 2. Particle size distributions (ASTM C136/136M-19) are shown in Figure 2.

Figure 1: Different types of natural coarse aggregates available in the local market: (a) Tamabil, (b) Dinajpur Hili (Black Stone), (c) Bhurungamari, (d) Burimari, (e) Bholaganj, (f) Jaflong.

Table 2: Physical properties of different types of natural coarse aggregate

Type / Source of Natural Stone Aggregate	Fineness Modulus (FM)	Unit Weight (SSD) (kg/m3)	% Void	Apparent Specific Gravity	Bulk Specific Gravity (SSD)	Absorption Capacity (%)
Tamabil	7.74	1498	43	2.65	2.62	0.63
Dinajpur Hili	7.11	1603	42	2.9	2.78	2.21
Bhurungamari	7.26	1511	43	2.68	2.64	1.08
Bholaganj	7.46	1578	41	2.73	2.69	0.97
Burimari	7.94	1523	43	2.71	2.66	0.94
Jaflong	7.69	1597	37	2.63	2.52	2.7

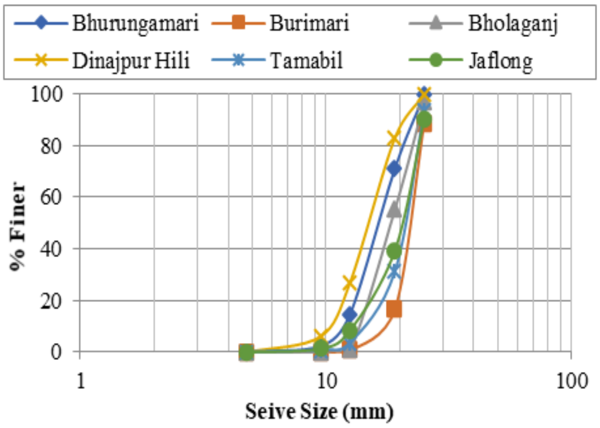

Figure 2: Particle size distributions of six different types of natural coarse aggregate.

D. Concrete Mix Proportion

The concrete mix ratio and water/cement ratio adopted for the study were 1:1.5:3 and 0.48 respectively. The trial mixes were designed to achieve an intended strength of 20 MPa after 28 days and a slump value of 75-100 mm. Six different types of concretes were then prepared by varying the type of coarse aggregate only. A total of 90 concrete cylinders of 100 mm diameter x 200 mm length, 15 cylinders for each kind of natural aggregate, were prepared to evaluate the compressive strength (ASTM C39/39M-09a) at 7, 14, and 28 days, splitting tensile strength of concrete (ASTM C496-96) at 28 days and modulus of elasticity of concrete (ASTM C469-02) at 28 days. The test setups are shown in Figure 3.

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(a) (b) (c)

Figure 3: Test setup for (a) Compressive strength, (b) Splitting Tensile strength and (c) Modulus of Elasticity

III. RESULTS AND DISCUSSION

Figure 4 displays the compressive strength of concrete made of six different natural coarse aggregates at 7, 14, and 28 days. The concrete made of Dinajpur Hili type natural coarse aggregate attained the maximum compressive strength of 23.13 MPa. The Jaflong type natural coarse aggregate concrete gained a minimum compressive strength of 16.62 MPa at 28 days.

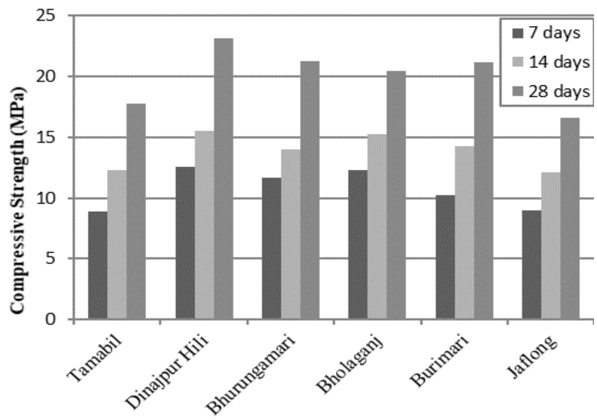

Figure 4: Compressive strength of concrete made of six different types of natural coarse aggregate at 7, 14, and 28 days.

The size of aggregates impacts the compressive strength as Dinajpur Hili has the smallest aggregate size among all and has maximum compressive strength [27-28]. But despite having the largest aggregate size, Burimari doesn't have the minimum compressive strength. So, it can be said that the aggregate size isn't the only factor affecting concrete's compressive strength. The smooth surface texture of Jaflong natural coarse aggregate may cause compressive strength reduction [29-30]. Figure 5 presents the splitting tensile strength of concrete made of six different natural coarse aggregates at 28 days. Splitting tensile strength followed almost the same trend as compressive strength. Here, the maximum splitting tensile strength of 2.77 MPa was observed for concrete made of Dinarpur Hili and the minimum splitting tensile strength of 1.94 MPa was observed for concrete made of Jaflong. The smooth surface texture of the aggregates may lead to poor bonding of the cement mortar and coarse aggregate. This poor bonding at the interfacial transition zone may cause splitting tensile strength reduction for concrete made of Jaflong type coarse aggregate [31].

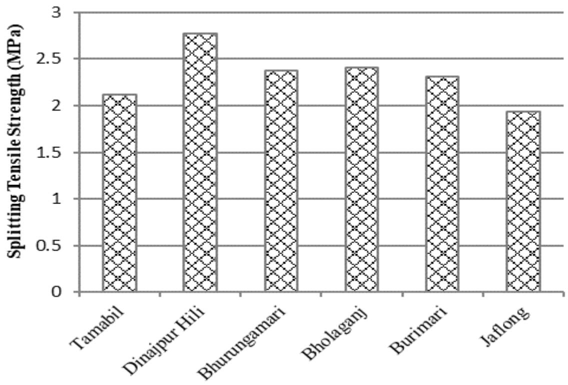

Figure 5: Splitting tensile strength of concrete made of six different types of natural coarse aggregate at 28 days.

Figure 6 presents the results of modulus of the elasticity test and Figure 7 shows the corresponding stress-strain diagram of concrete made of different types of natural coarse aggregates at 28 days. The modulus of elasticity of the concrete followed almost the same trend as compressive and splitting tensile strength except for some exceptions. Here, the maximum modulus of elasticity of 32.85 GPa was observed for concrete made of Bholaganj and minimum modulus of elasticity of 24.86 GPa was observed for concrete made of Burimari type natural coarse aggregate. It is observed from the stress-strain diagram that the type of aggregates has little influence on the elastic behavior of concrete.

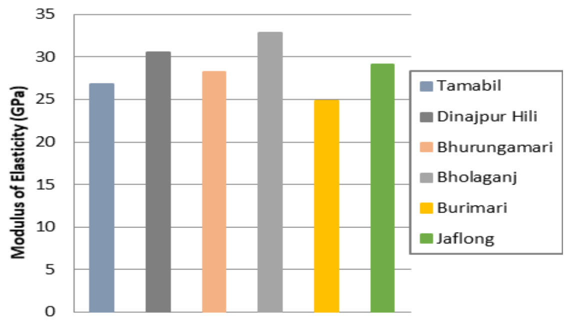

Figure 6: Modulus of elasticity of concrete made of six different types of natural coarse aggregate at 28 days.

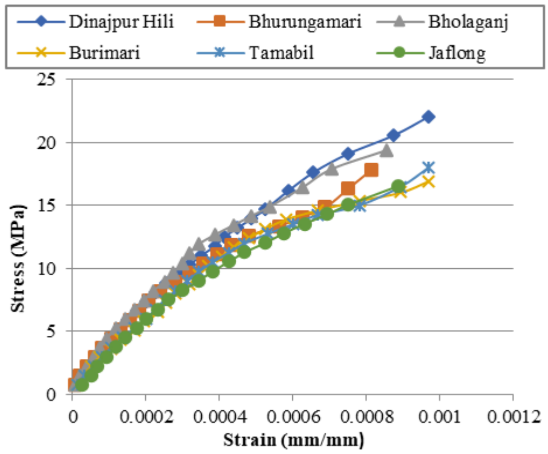

Figure 7: Stress-strain diagram of concrete made of six different types of natural coarse aggregate at 28 days.

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IV. CONCLUSION

The original purpose of this study is to find out the appropriate natural coarse aggregate for construction works in terms of mechanical strength of concrete among the locally available materials. For this purpose, six different types of natural coarse aggregate were collected which are primarily available in the local market of Bangladesh. Concrete cylindrical specimens were prepared by varying the natural coarse aggregate type. The samples were then analyzed in terms of compressive strength, splitting tensile strength and modulus of elasticity. The obtained results show that Dinajpur Hili, also known as Indian Black Stone, showed better performance than other types of aggregate used in the research. Dinajpur Hili has achieved maximum compressive strength and splitting tensile strength though Bholaganj showed maximum modulus of elasticity. Out of six different natural coarse aggregate types, four (Burimari, Bhurungamari, Bholaganj, and Dinajpur Hili) have achieved the target compressive strength of 20 MPa. Among all the types of natural coarse aggregate used, Jaflong showed the minimum compressive strength and splitting tensile strength. However, the modulus of elasticity of Jaflong was slightly higher than some of the other types of aggregates used.

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