SPATIAL VARIATION OF PHYSICAL AND MICRO-STRUCTURAL CHARACTERISTICS OF COARSE AGGREGATES IN BANGLADESH

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ABSTRACT

Concrete has been extensively used as construction material all over the world due to its versatile characteristics. The properties of concrete may vary widely because of seasonal and spatial variations in properties of locally available coarse aggregates. As the geological and geo-morphological processes of rock are different, the aggregates formed at various places are also different. The specific objectives of this study has been to observe spatial variations on physical and and micro-structural characteristics of coarse aggregates collected from different sources in Bangladesh. Coarse aggregates have been collected from different sources of Jaflong, Dinajpur, Volagonj, Patgram, Mymensingh. According to ASTM specifications sieve analysis, specific gravity, moisture contant, absorption capacity, unit weight, aggregate crushing value (ACV) and los angles abrasion test (LAAT) for coarse aggregate have been performed in the laboratory. Non-destructive tests are performed for micro-structural characteristics of coarse aggregate. In this study, X-Ray Diffraction (XRD) technique has been used to predict quantitative phase analysis and percent of each compound present in the sample of different coarse aggregate. XRD results show the presence of Quartz (SiO_2), Calcite ($CaCO_3$), Magnetite (Fe3O4), Kyanite (Al_2SiO_5), Gismondine ($CaAl_2Si_2O_8{\cdot}4H_2O$) for the different samples. The spatial variations in the mechanical and micro-structural properties of coarse aggregates have been observed during this study for all the tests. Quartz (SiO2) is identified as a major constituent of the powdered sample from the XRD test. All the test result values of coarse aggregates have been compared with standard values of ACI, BS, AASHTO, IS and PWD.

Keywords: *Coarse aggregate, physical properties, micro-structural characteristics, X-Ray Diffraction test, Bangladesh*

1. INTRODUCTION

Many desirable properties of concrete such as high compressive strength, excellent durability and fire resistance contributed toward its wide range of applicability. The most advantageous and unique feature of concrete is that it can be produced using locally available ingredients. Due to the variations in properties of locally available coarse aggregates, the properties of concrete may vary widely. Coarse aggregates generally exhibit two types of properties; namely physical properties and micro-structural properties. These properties of aggregates vary a lot according to aggregates sources. The geological and geomorphological processes of all rocks are not same from which the aggregates are processed. Moreover temperature, humidity and rainfall vary in different seasons. For this reason, remarkable variations on the properties of aggregate are observed according to various sources. At present, high strength concrete is being used in many construction projects of Bangladesh. High strength of concrete mainly depends on coarse aggregate properties, quality of cement, proper mix design and curing. Coarse aggregates at different places in Bangladesh are different in size, shape, formation and gradation. Therefore, it is very difficult to determine a general concrete conception on aggregate in Bangladesh (Rahman, Noor & Das, 2014).

Where concrete of high strength and good durability is required, aggregate grading curve is very essential which has much greater effect on workability of concrete (Settee, 2000). The compressive strength of concrete depends on the water to cement ratio, degree of compaction, ratio of cement to aggregate, bond between mortar and aggregate, and grading, shape, strength and size of the aggregate (Rocco and Elides, 2009; Elides and Rocco, 2008). With an increase of the size of the aggregate from 40 to 80 mm for concretes with a water/cement ratio from 0.40 to 0.68, the compressive strength increases insignificantly (up to 9%) and the splitting strength, conversely, decreases up to 10% (Ibragimov, 1989). Concrete can be visualized as a multi-phase composite material made up of three phases; namely the mortar, mortar/aggregate interface, and the coarse aggregate phase. The coarse aggregate in normal concrete are mainly from rock fragments characterised by high strength.

Therefore, the aggregate interface is not a limiting factor governing the strength requirement (Beshr, Almusallam, and Maslehuddin 2003). The specific objectives of this study has been to observe spatial variations on physical and micro-structural characteristics of coarse aggregates collected from different sources in Bangladesh. Coarse aggregates have been collected from different sources.

Aggregate is a common and widely used construction material and it undergoes chemical changes with time when exposed to various environments. The extent of the damage depends on concrete quality and is rarely damaged in the life time of a structure but chemical changes in aggressive environmental conditions may cause a considerable damage to it. X-ray powder diffraction (XRD), is an instrumental technique that is used to identify minerals, as well as other crystalline materials. X-Ray Diffraction (XRD) technique has been used for quantitative phase analysis and percent of each compound present in the sample (Jenkins, 1974).

2. MATERIALS AND METHODOLOGY

Bangladesh is a developing country. Development program of a country like Bangladesh has a great emphasis on infrastructure. Construction sector is one of the prominent sectors to contribute in gross domestic product (GDP) in Bangladesh. Aggregate is mostly used as construction material in almost every construction work in Bangladesh. Aggregates are collected from different sources. Coarse aggregates also have been collected from different places in Bangladesh like Jaflong, Dinajpur, Mymensingh, Patgram, Volagonj. The aggregates were tested for absorption capacity, specific gravity, unit weight, and abrasion. The specific gravity and absorption capacity are determined as per ASTM C128, unit weight as per ASTM C29, and abrasion value as per ASTM C131.

Five types of Coarse aggregate were used for comparison of compressive strength. Coarse aggregates were mixed as 5% from 25 mm to 20 mm, 57.5% from 20 mm to 10 mm, and 37.5% from 10 mm to 5 mm as per ASTM C33-93. The aggregates were tested for absorption capacity, specific gravity, unit weight, and abrasion. Sylhet sand was use as fine aggregate. Cylinders of diameter 150 mm and 300 mm height were prepared using the standard moulds. The concrete adopted with mix ratio 1:2:4 and water cement ratio of 0.68. The samples are casted using the five different fine aggregate. Total mixing time of concrete was controlled at 5.5 minutes. After mixing concrete, the workability of concrete was measured by slump cone test. Cylinders are demoulded after 24 hours from casting and kept in a water tank continuously. The compressive strength of concrete was measured at 28 days by using Universal Testing Machine (UTM). The strain of concrete specimens was measured by a strain measurement setup with two dial gauges. The gauge length was 100 mm.

X-ray diffraction (XRD) is one of the most important non-destructive tools to analyze all kinds of matter ranging from fluids, to powders and crystals. This technique uses X-ray diffraction on powder or microcrystalline samples, where ideally every possible crystalline orientation is represented equally. When X-ray radiation is directed on a sample, the X-rays are scattered ("diffracted") by electrons present in the material. If the atoms in the material are arranged in a regular structure, i.e. if the material is crystalline, this scattering results in maxima and minima in the diffracted intensity. The signal maxima follow Bragg's law $n\lambda = 2d\sin\theta$. Here n is an integer, λ is the X-ray wavelength, d is the distance between crystal lattice planes and θ is the diffraction angle (Ref. Fig. 1). During an X-ray diffraction (XRD) measurement the angles of incidence and detection are scanned. Bragg's law is satisfied when the path length difference of the X-rays (indicated in green) is equal to $n\lambda$. The diffraction angle θ is half the angle between the incident and diffracted X-rays (Bragg and Bragg, 1913).

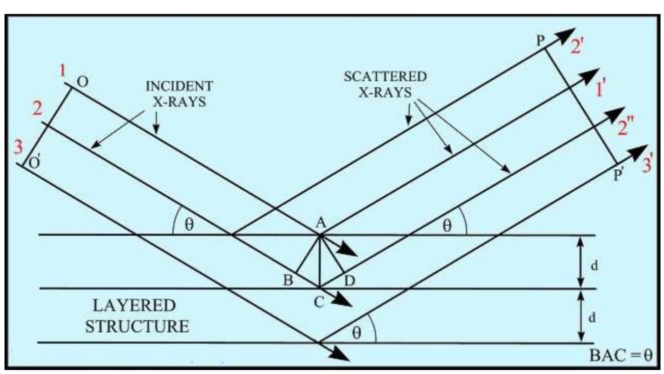

Figure 1: Schematic representation of diffraction of X-rays in a crystalline material

Powdered sample were used for XRD analysis. In powder or polycrystalline diffraction, it is important to have a sample with a smooth plane surface. Coarse aggregate samples were collected from existing source and grounded the sample down to particles of about 0.002 mm to 0.005 mm cross section. The ideal sample is homogeneous and the crystallites are randomly distributed.

3. RESULTS AND DISCUSSION

The test results of coarse aggregates have been shown in Figure 2 and Figure 3. Patgram has the maximum FM value of 7.6 in comparison with other sources. Samples of Jaflong have the maximum specific gravity (OD and SSD) values of 2.73 and 2.76 respectively, and the minimum absorption capacity of 0.91% in comparison with other sources. This is because of the samples of Jaflong are uniformly sized and almost in regular shape. Also, samples of Jaflong have the higher unit weight (loose and compacted) of 1465 and 1682 kg/m^3 respectively than other sources whereas other source samples have almost similar values of unit weight. Samples of Jaflong have the lowest ACV (16.7) and the sample of Dinajpur have the lowest LAAV (15.6) values compared to other sources.

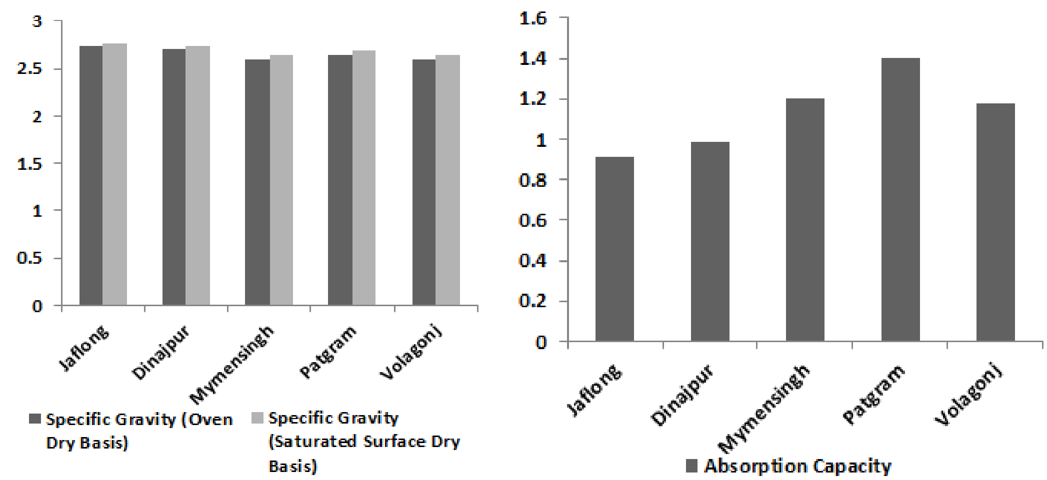

Figure 2: (i) Speific Gravity and (ii) absorption capacity of Coarse aggregates

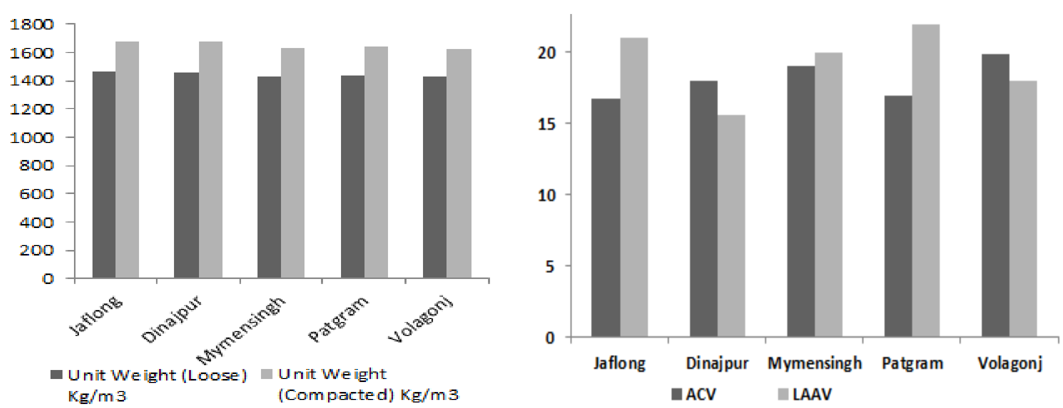

Figure 3: (i) Unit weight (ii) ACV and LAAV of Coarse aggregates

In general, properties of coarse aggregates compared well with the values of standard specifications like specific gravity values of ACI (2.3 to 2.9) and PWD (2.2 to 2.6); absorption capacity values of ACI (0.5 to 4%) and PWD (1 to 6%); unit weight values of ACI (1280 to 2250 kg/m3) and PWD (1400 to 2250 kg/m3); ACV values of AASHTO, BS and IS (less than 30%) and LAAV values of AASHTO, BS and IS (less than 40%). However, sample of Jaflong in Sylhet is most satisfied with the values of standard specifications.

Table 1: Compressive strength of Concrete made with different types of Fine aggregate in Bangladesh

Source of fine Aggregate	Mix proportion ratio	Water/Cement ratio	Compresive Strength (Psi)	Average (Psi)
Jaflong Stone	1:2:4	0.68	3080 3130 3060	3090
Dinajpur Stone	1:2:4	0.68	3080 3070 3000	3050
Mymensingh Stone	1:2:4	0.68	2890 2872 2860	2874
Patgram sand	1:2:4	0.68	2800 2780 2805	2795
Volagonj sand	1:2:4	0.68	2980 3030 2990	3000

XRD is normally used for identifying single-phase materials – minerals, chemical compounds, ceramics or other engineered materials, measuring the average spacing between layers or rows of atoms, determining the orientation of a single crystal or grain, finding the crystal structure of an unknown material, measuring the size, shape and internal stress of small crystalline regions. Table 2 represents the weight (%) of phase of concrete samples under X-Ray Diffraction analysis. Figure 4 to Figure 8 shows XRD diffractogrames for different fine aggregates.

Table 2: Results of powdered Fine aggregate samples

Sample	Phase Present with Formula	% of Weight of phase
Jaflong Stone	Quartz(SiO_2) Calcite($CaCO_3$) Gismondine($CaAl_2Si_2O_8.4H_2O$) Mullite($Al_6Si_2O_{13}$)	72.75 7.3 15.44 4.5
Dinajpur Sand	Quartz(SiO_2) Calcite($CaCO_3$) Gismondine($CaAl_2Si_2O_8.4H_2O$) Mullite($Al_6Si_2O_{13}$)	60.04 10.93 17.87 8.2
Mymensingh Stone	Quartz(SiO_2) Gismondine($CaAl_2Si_2O_8.4H_2O$) Mullite($Al_6Si_2O_{13}$)	54.38 19.65 25.97
Patgram	Quartz(SiO_2) Gismondine($CaAl_2Si_2O_8.4H_2O$)	80 20
Volagonj Stone	Quartz(SiO_2) Gismondine($CaAl_2Si_2O_8.4H_2O$)	84.40 15.55

From Table 2, it was observed that the samples indicate higher percentage of quartz (SiO_2) and Gismondine ($CaAl_2Si_2O_8.4H_2O$). Quartz is nearly always inert when used as aggregate (not fine powder as cement replacement material) in concrete. It means that it will not react at normal conditions, possesses less reactivity, more controllable situation in concrete. But under adverse environmental condition alkali-silica reaction can occur in concrete. In concrete, there would be reaction between quartz and the alkaline compounds of the concrete, typically $Ca(OH)_2$, if the proportion of amorphous or cryptocrystalline (very fine crystalline) quartz increases. And quartz (SiO_2) is a glassy or crystalline form of silicon dioxide. Thus alkali-silica reaction occurs and causing serious expansion and cracking in concrete. Carbonation occurs in concrete because the calcium bearing phases present are attacked by carbon dioxide of the air is converted to calcium carbonate. It is a disadvantage in reinforced concrete, as pH of carbonated concrete drops to about 7. When the pH level is less than 11, and the rods are exposed to aggression by the oxygen and humidity which are present in the atmosphere. Under these conditions, corrosion process of the reinforcement rods initiates, which increases their volume and thus concrete cracks.

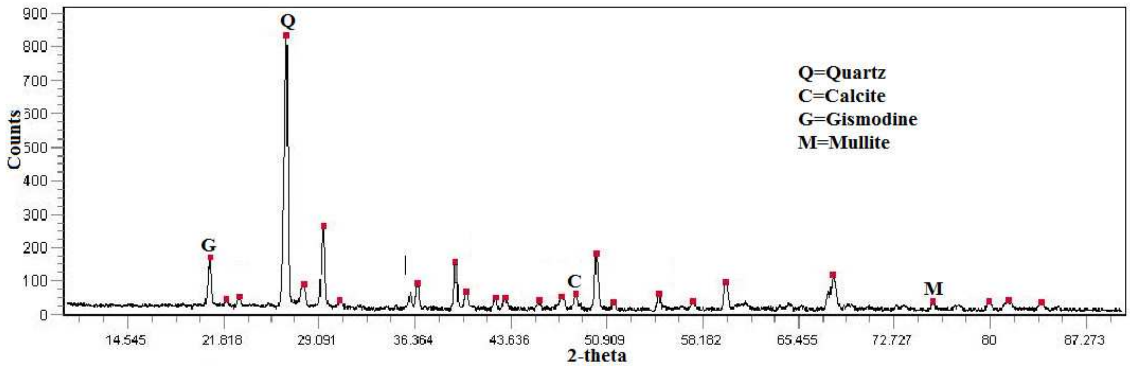

Figure 4: XRD diffractograms for Jaflong Stone

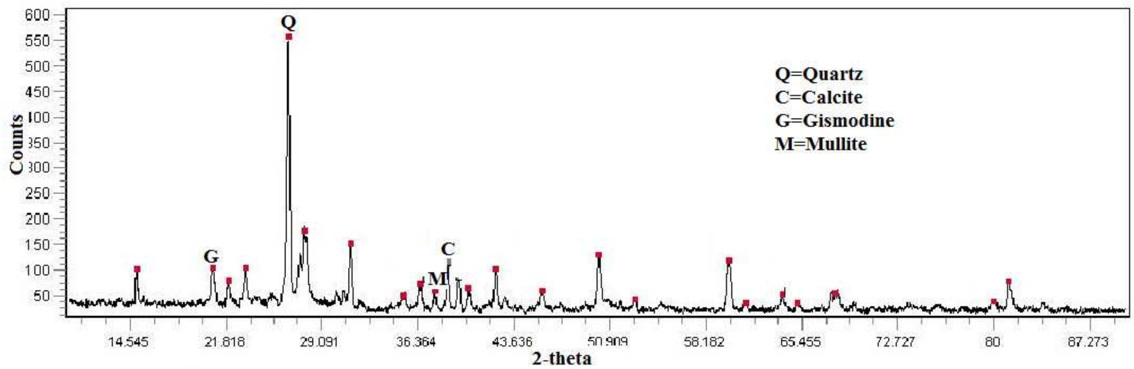

Figure 5: XRD diffractograms for Dinajpur Stone

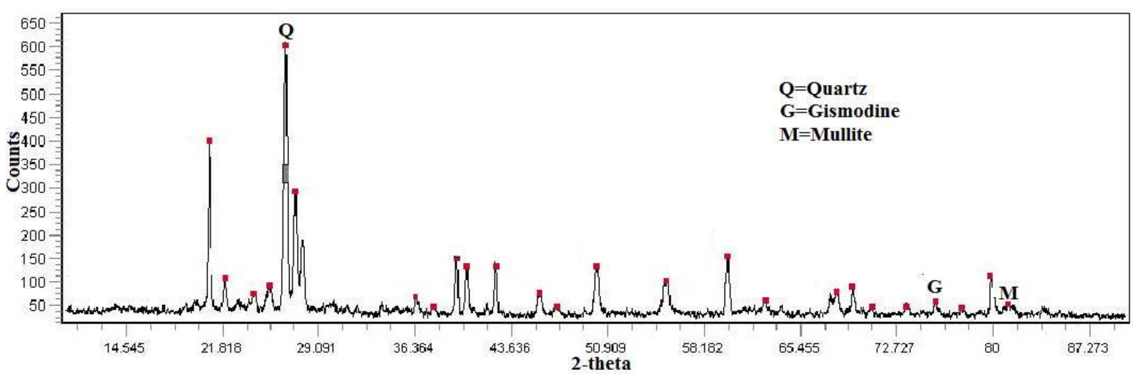

Figure 6: XRD diffractograms for Mymensingh Stone

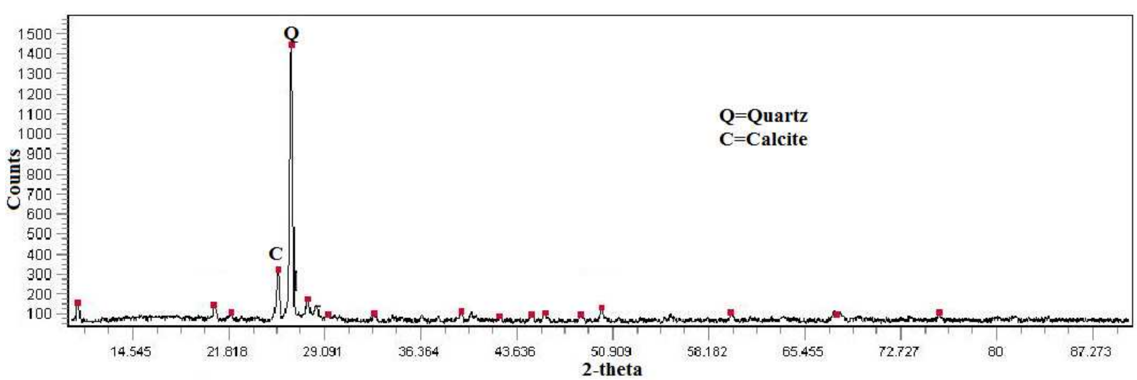

Figure 7: XRD diffractograms for Patgram Stone

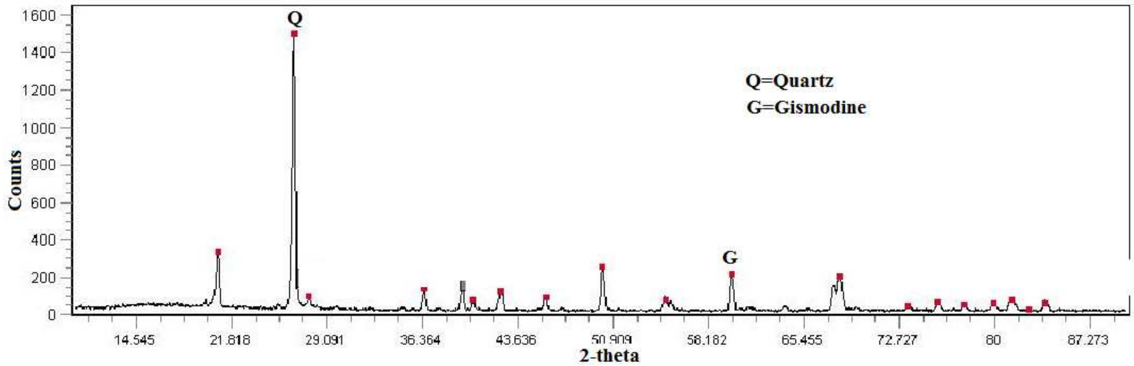

Figure 8: XRD diffractograms for Volagonj Stone

Figure 4 to Figure 8 shows XRD diffractograms of the samples from 1 to 4 for peak list of the samples. X-Ray diffraction analysis indicates predominance of quartz (SiO2) and calcite (CaCO3) peaks.

4. CONCLUSIONS

This research work represents in depth analysis of aggregate properties from different sources in Bangladesh. The spatial variations in the properties of coarse and fine aggregates have been observed during this study for all the tests. All test results of coarse aggregates also have been compared with standard values of ACI, BS, AASHTO, IS and PWD. Coarse aggregates of Jaflong in Sylhet are most satisfied with standard values of ACI, BS, AASHTO, IS and PWD among all the sources. In addition, the concrete made with Jaflong stone show the maximum compressive strength of 3090 Psi for same mix ratio and water-cement ratio than others. On the basis of this study, the government and construction companies in Bangladesh can get a clear idea of aggregates from different sources to ensure the quality and strength of concrete. Aggregate can be subjected to different degradation mechanisms. Quartz (SiO2) is identified as a major constituent of the powdered and it is subjected to alkali-silica reaction causing serious expansion and cracking in concrete.

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