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Alkali Silica Reactivity Potential of Laki Limestone as Coarse Aggregate by Using Petrographic Examination

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INFORMATION

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ABSTRACT

Present study is aimed at assessment of Alkali Silica Reactivity potential of Laki limestone as coarse aggregate from Nooriabad area, district Jamshoro, Pakistan. Eleven coarse aggregate samples were collected for petrographic examination using optical microscope. It is observed that the aggregate comprises of hard, compact, massive, crystalline and fossiliferous limestone. As per Dunham classification of limestone, Laki limestone can be classified in decreasing order as Mudstone>Pack stone>Wackestone. Microfractures are obvious in some of the collected samples indicating the imprint of compressional tectonic forces. Large number of samples showing Mudstone suggest calm quite environment of deposition where clastic influx is less likely to be deposited. Hence, limestone is devoid of any reactive silica and free from chert, chalcedony and other harmful constituents like clays or organic matter. It is concluded that Laki limestone is suitable for use as road aggregate and concrete mix design.

1. Introduction

Durability of concrete is dependent upon mineralogical and textural properties of the rock from which aggregate has been produced (Gondal et al., 2008). Petrography describes the relative amount and properties of aggregate constituents as well as physical and chemical characteristics. Aggregate constituents can react with alkali hydroxide in concrete which can cause significant expansion leading to concrete deterioration (Yu et al., 2019; Chaudhry and Zaka, 1998; Hobbs, 1988). Alkali Silica Reactivity (ASR) is caused due to the presence of reactive forms of silica in aggregate (Smith and Collis, 2001; Hobbs, 1978; Gillot and Swenson, 1969).

It is necessary to understand the ASR mechanism for the identification and reduction of ASR potential of aggregate. Reactive silica in aggregate and alkalis in the cement can react to form a gel and if the gel absorbs moisture from cement paste, it expands (Farny and Kosmakta, 1997; Okada, 1989; Hobbs,1988). Pressure is developed, due to this expansion, which leads to start cracking of aggregate and cement paste in concrete (Kurugol and Gulec, 2012; Hobbs, 1978; Swamy, 1992). Amount of gel depends upon the type and amount of silica present in aggregate as well as type of alkali hydro oxide in cement (West, 1996). This gel can be present in cracks, voids and also on aggregate surroundings. Deterioration in concrete due to ASR is very slow (Yu et al., 2019) but it is one of the most important reasons of stress development in concrete (Kurugol and Gulec, 2012; Stanton, 1942).

Petrography is used to identify presence of chemically unstable material like reactive silica, chert, chalcedony and other reactive mineral constituents (Nixon and Sims, 2006). It is one of the most effective methods for the identification of alkali silica reactive material in aggregate (Tramblay et al., 2008). Chemically unstable minerals such as soluble sulfates and unstable sulfides may form sulfuric acid or create distress in concrete exposed to high temperatures during service (Watters, 1969).

Moreover, this examination identifies the portion of coarse aggregate that is composed of weathered or altered particles and the severity of alteration. If concrete containing reactive aggregate is exposed to freezing and thawing in a critically saturated condition, it will be damaged by freezing and thawing. This will ultimately destroy the concrete because such aggregates cannot be protected by adequately air entrained mortar (Lopez et al., 2006). Finely porous aggregates near the concrete surface are also likely to form pop outs, which blemishes on pavements and walls (ASTM C295/C295M-19, 2019). Petrographic examination is also used to determine the shape of aggregate (cubic, spherical, ellipsoidal, pyramidal, tabular, flat, and elongated). Flat and elongated aggregate particles decrease the concrete strength by increasing mixing water requirement (Smith and Collis, 2001; Jamkar and Rao, 2004).

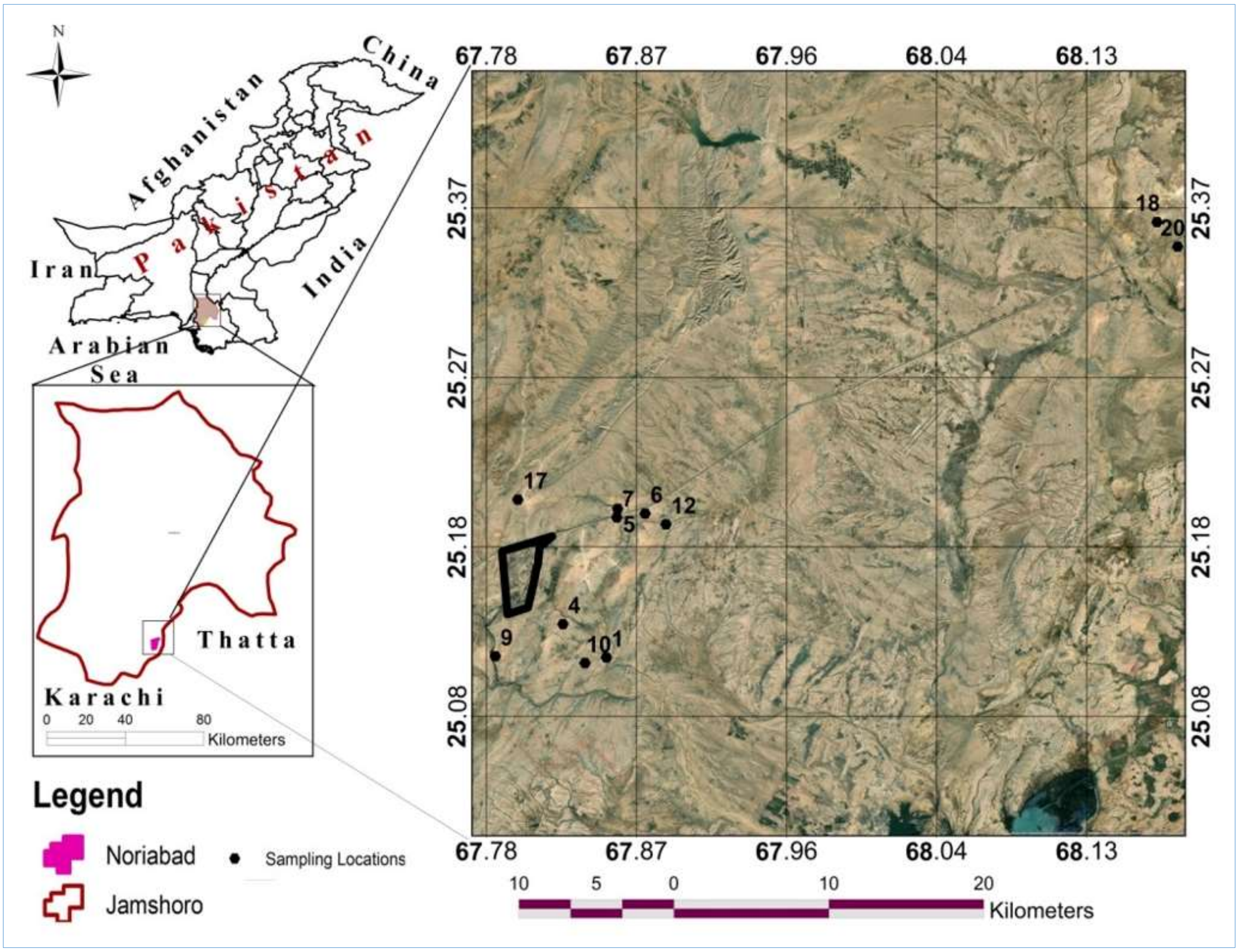

Fig. 1. Sample's location map

Generally, limestone and dolomite are considered as good source of crushed stone among all sedimentary rocks. However, some limestone and dolomite may be soft, absorptive and friable, resulting in low quality aggregates (Kosmakta et al., 2003). Chert, chalcedony, jasper, flint and all other cryptocrystalline silica as well as holohyaline material can lead to severe chemical reaction when used in cement concrete (Cody et al., 1994; Gress, 1997; Mindess and Young, 1981; Wenk, 1998). Limestone and dolomite may be highly reactive due to their high surface energy and weak internal structure.

The Nooriabad is an industrial zone which was established to bridge two major cities of Sind province (Karachi and Hyderabad) for socio-economic development. Nooriabad area has been serving as a hub of aggregate supply to Karachi city and adjoining areas. Geologically, Laki limestone of Eocene age is exposed in study area which is being quarried from outcrops for aggregate production. Many crush and asphalt plants are operating in this area. Besides M-9 motorway project, these crush plants are the main suppliers of two mega projects that are Bahria Town and DHA City, Karachi, Pakistan.

It is essential to determine the relative amounts and properties of the limestone constituents because it affects the performance of the material in its particular use. Despite of intense use as aggregate, Laki limestone has not been evaluated so far for its suitability as coarse aggregate. Therefore, present study is aimed at assessment of Laki limestone ASR potential as coarse aggregate by petrographic technique.

2. Study Area

Nooriabad is located in vicinity of Eastern Kirthar Basin (Fig. 1). Laki Formation of Eocene age is exposed in Nooriabad area. Laki Formation includes Sohnari, Laki and Tiyon members. This Laki series was subdivided into basal Laki laterite (8 m), Meting limestone (45 m), Meting shale (30 m) and Laki Limestone (70-200 m).

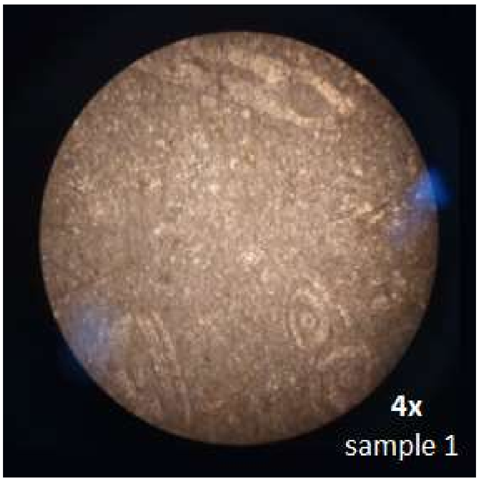

Fig. 2. Microfossils

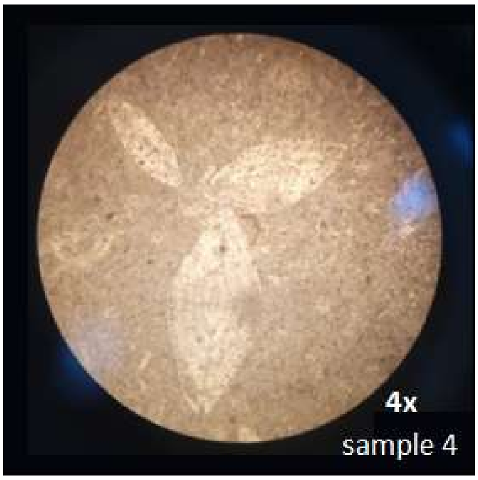

Fig. 3. Microfossils and organic matter

Akhter et al. (2012) used the term Laki Formation for all members of Laki Group due to scale problems. Laki Formation mainly comprises of limestone with subordinate shale and marl. Laki Formation has lower disconformable contact with Sohnari member and upper transitional contact with Nari Formation. Laki Formation contains micro fossils of foraminifers including Assilina granulose, A. pustulosa, Lockhartiahunti, var pustulosa, etc. and some mega fossils like gastropods, bivalves and echinoids (Walcott, 1905; Nuttall, 1925; HSC, 1961). Presence of these fossils indicates that age of Laki Formation is Early Eocene and extends up to middle Eocene.

The rocks in the study area are highly deformed due to the occurrence of major folded (anticline and syncline) structures. Structurally, Nooriabad is located in the synclinal valley part of area. It causes arrival of runoff from adjacent hills towards the base area. Locally, this area has two major faults i.e., Surjan and Jhimpir Faults which are present around study area.

According to Kazmi and Jan (1997) farther to the south and west of Lakhra, the north-south Surjan fault cuts across the Quaternary deposits. West of Jhimpir, the southern end of this fault is intersected by the north-west trading Jhimpir Faults. The intersection of two faults is characterized by at least four tele-seismic events of shallow focal depth and magnitude between 3-6 (Kazmi and Jan, 1997).

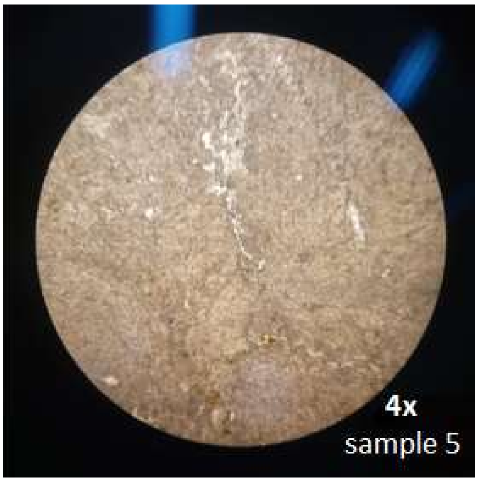

Fig. 4. Stylolitic sutures and microfractures filled with sparite

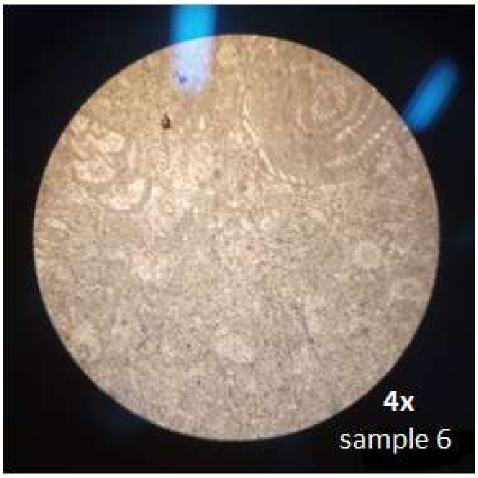

Fig. 5. Microfossils and fractures

3. Material and Methods

Petrography of Laki limestone was carried out as per ASTM C295/C295M-19, 2019. Optika microscope (B-165POL) was used for thin section study. Thin sections of Laki limestone samples were prepared for petrographic examination by cutting aggregate of 37 mm into rectangular chips of 3-4 cm by 2 cm size chips with electric sawing unit. One of the two surfaces of the sample chip was smoothened out and polished prior to mounting on glass slide.

The polished sample chips were mounted on glass slide using Canada balsam and left for twenty-four hours for proper mounting. The mounted chips were later grinded and polished to a thickness close to 0.03 mm with 1000 grade corundum powder. During polishing, the chips were examined several times under polarized microscope in order to obtain the desirable thickness for petrography. Polished thin section was examined under optical microscope in plane polarized and cross polarized mode at a magnification of 4x, while examination of discrete grain features was carried out at 10x.

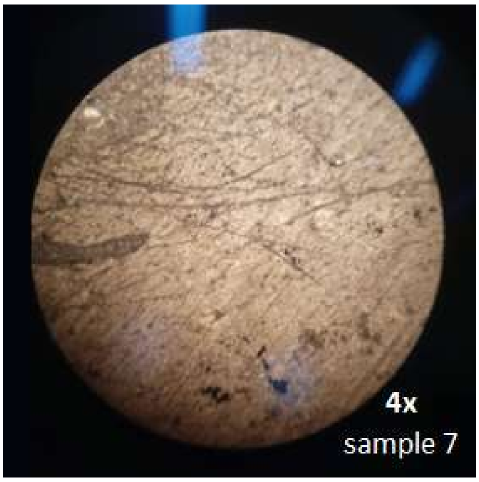

Fig. 6. Microfractures and organic matter

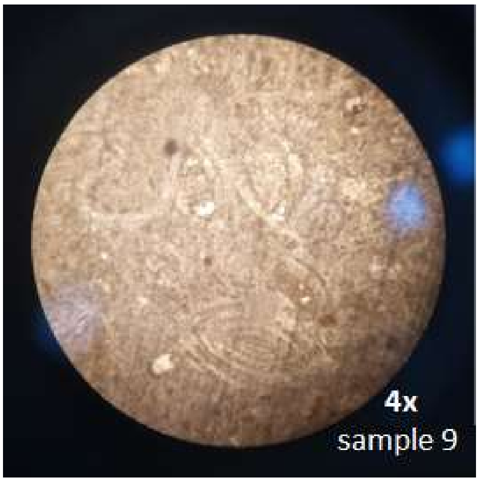

Fig. 7. Various microfossils

4. Results and Discussion

Aggregate samples (n=11) of Laki limestone were used for petrographic examination. These samples were collected from various crush plants located in the study area. Mineral composition of aggregate is found to be calcite hence, chemical composition of parent rock is calcium carbonate (Figs. 2-11).

Microfossils (Foraminifera) are reported to occur in all samples which are clearly visible under optical microscope. Since, fossils are biochemically precipitated calcite material which contains crystallized and homogeneous structures. Hence, it is more stable and non- reactive material toward cement or asphalt. Based on grain to matrix ratio, most of the samples are classified as micrite (Mudstone, less than 10% grain) while two are termed as Pack stone (grain supported) and one sample (Fig. 7) is Wackstone (Dunham, 1962). It is obvious from the study that micro fractures also occur in about half of the samples which is the indicator of compressional forces.

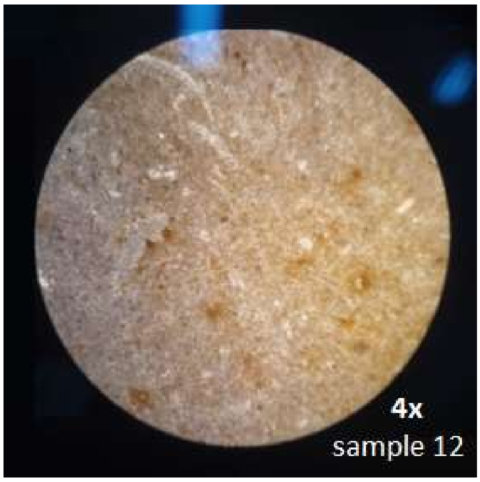

Fig. 8. Microfractures

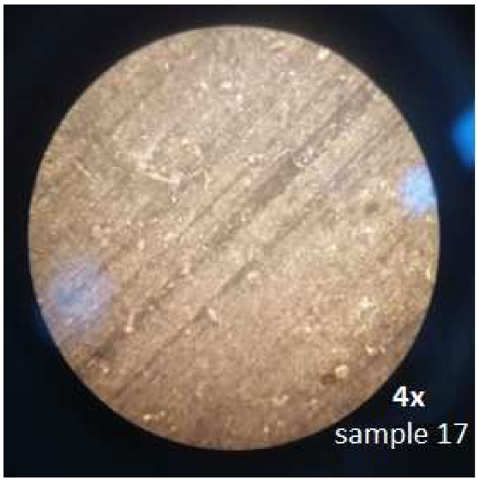

Fig. 9. Microfractures

In sample 5 (Fig. 4), the microfractures are filled with recrystallized lime mud known as sparite. Micrite is amorphous material while sparite is crystalline which is relatively more stable and non-reactive as compared to micrite. Presence of stylolitic suture also confirms the response of compressional tectonic forces which has improved the mechanical and chemical quality of Laki limestone. Organic matter is also reported in some of the samples which is shown in thin section as the presence of dark brown or black streaks visible in both plane polarized light and cross nicol mode. The one set calcitic cleavage is also visible in thin sections of the samples 18 and 20 (Figs. 10 and 11).

Samples represented fractured, non-fractured, micritic, sparitic and stylolite occurrence. All samples have angular to sub angular grains with fractured surfaces and less than 10% flat and elongated particles. All of the samples are free from clay, chert and any other reactive siliceous material harmful for concrete.

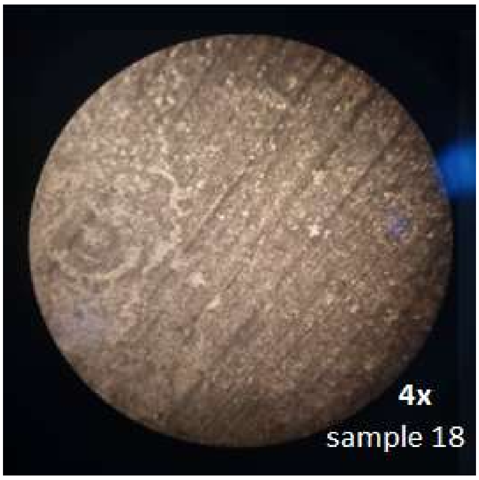

Fig. 10. Microfossils and 1 set calcitic cleavage

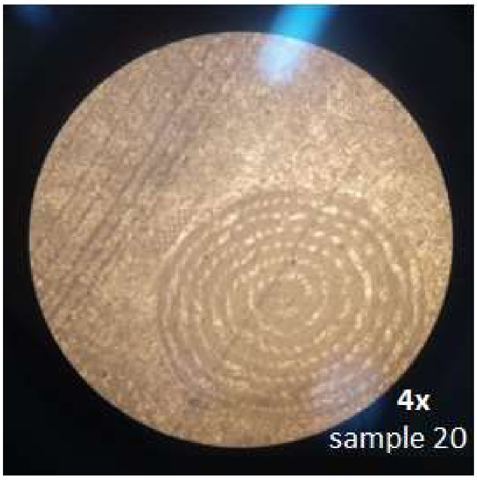

Fig. 11. Relatively large microfossils with 1 set cleavage

5. Conclusion

It is concluded from present study that Laki limestone is fossiliferous limestone. It is free from chert, chalcedony and other reactive siliceous material or harmful constituent including clay. Hence, Laki limestone is suitable for use as road aggregate and concrete mix design.

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