Int. J. Econ. Environ. Geol. Vol. 11 (1) 89-94, 2020

Journal home page: www.econ-environ-geol.org

Open Access

ISSN: 2223-957X

Aggregate Suitability of the Late Permian Wargal Limestone at Kafar Kot Chashma Area, Khisor Range, Pakistan

Rizwan Ullah[1,2], Shuja Ullah[1*], Nazir ur Rehman[1,3], Fayyaz Ali[4], Muhammad Asim[1], Muhammad Tahir[1], Subhan Ullah[1,5], Shafi Muhammad[6]

[1]National Centre of Excellence in Geology, [4]Department of Geology, University of Peshawar, Pakistan
[2]Zeeruk International Private Limited, Islamabad, Pakistan
[3]Department of Geology, Khushal Khan Khattak University Karak, Pakistan
[4]Department of Geology, University of Peshawar, Peshawar
[5]Centre for Earth and Space Sciences, University of Swat, Pakistan
[6]School of Earth Science and Resources, China University of Geosciences Beijing, China

***Email:** shujageo@gmail.com

Received: *06 August, 2019* ***Accepted: 06*** *March, 2020*

Abstract: This study was carried out for the investigation of the Late Permian Wargal limestone at Kafar Kot Chashma area, Khisor Range to determine its suitability as an aggregate that is used in road construction and civil structures with the help of geological engineering testing. The results of geological engineering testing of Wargal limestone samples show the tolerable values of all standard engineering parameters including the Loss Angles Abrasion value (23.37%), Aggregate impact (16.8%), Crushing value 13.1%, Unit weight 1.67, Soundness (1.007%), Specific gravity (2.70), Water Absorption (0.48%), Flakiness Index (6.5%), Elongation value (7.1%), Coating of bitumen (> 95%), stripping of bitumen (<5%), California Bearing Ratio (CBR) value (93.6%), Maximum Dry Density 2.307g/c and Optimum Moisture Content (5.79%). As per different International and National Standards like AASHTO, ASTM, BS and NHA, the mentioned results of various engineering tests were within the tolerable limits. The petrography of the selected samples of the Late Permian Wargal limestone revealed very minor value of quartz (0.5%), hematite/limonite (0.6%) and clay content 1.0% showing the insignificant threat of ASR. The values of dolomite are limited to (1%) which shows that there is no ACR reaction with ordinary Portland cement. The results of geological and engineering parameters of the study area strongly suggest its suitability as a potential aggregate (i.e. for the base course, subbase course, cement concrete and asphalt) in the road construction.

Keywords: Aggregate, Wargal Limestone, Khisor range.

Introduction

The demand of aggregate is increasing due to upcoming and ongoing projects of the CPEC western route, so it is necessary to find out the new sources of aggregate in Khisor range, Trans Indus ranges, Pakistan. Aggregate is comprised of naturally or mechanically broken rock fragments that are the most important elements of construction industry, which are used in concrete structure, roads, asphalt bases and pavements. Aggregates are mainly evaluated on of its geological, chemical and physical properties. Physical properties include texture, grain size, absorption, specific gravity, abrasion, impact value, crushing value and shape etc. Chemical properties represent the chemical composition of aggregate which is most important to assure aggregate suitability in conditional environment. Naturally, aggregate occurs in shape of gravel, sand and muddy sediments deposited by various geological processes, such as fluvial, aeolian and glacial environments. Limestone as a crushed aggregate is easily available and frequently used rock for this purpose. Pakistan has different resources of aggregate used for the construction purpose and limestone is one of the most important sources of natural aggregate for construction industry. Limestone units are exposed in northern areas of Pakistan such as in Upper Indus basin including Wargal limestone, Samana Suk Formation, Kawagarh Formation, Lockhart limestone, Margala Hill limestone, Kohat Formation, Shekhan Formation and Sakessar limestone (Nizami, 2008; Rehman, 2009, 2017; Ahsan et al., 2012; Shah, 2009) and also in Lower Indus basin i.e. Chiltan limestone, Moghal Kot Formation and Dungan Formation (Shah, 2009). The demand for aggregate is increasing in Pakistan due to initiation of the mega project of CPEC (China Pakistan Economic Corridor) for construction of road and civil structures and thus, it is necessary for the exploration of the new quarries to meet the demand. The limestone units are exposed in different localities along the western route of CPEC, i.e. Margalla Hill limestone, Samana Suk Formation, Kawagarh Formation and Lockhart limestone can act as potential aggregates in Hazara and Mansehra areas (Shah, 2009). The Wargal limestone, Samana Suk Formation and Sakessar limestone cropped out along the western route of CPEC passing through Salt Range and Trans Indus ranges which may serve as good quality aggregates. The suitability of aggregates for construction works can be assessed by its geochemical, petrographic and physiochemical investigations (Berube and Fournier, 1993). Present study is about evaluating the aggregate perspective of the carbonates of Wargal limestone in Khisor and Trans Indus ranges of Pakistan.

Regional Geology and Stratigraphy

In north Pakistan, the Upper Indus basin includes the Kohat and Potwar plateaus, Hazara and Kalachitta ranges, Salt and Trans Indus ranges, which constitute the southernmost part of the Himalaya orogenic belt that formed as a result of collision between India and Eurasia (Kazmi and Jan, 1977; Tahirkheli et al., 1979). The Trans Indus and Salt ranges forms the leading thrusts of the Kohat and Potwar fold-thrust-belt in the outer Himalayas, whilst the Hazara and Kalachitta ranges are from the southern boundary of the lesser Himalayas (Fig. 1). Precambrian to Neogene strata is exposed along the Range front in various parts (Abassi et al., 2012).

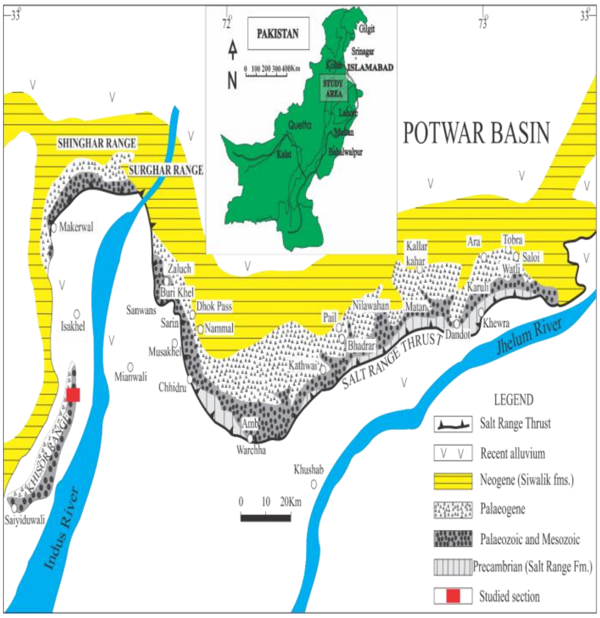

Fig. 1 Geological map of the Salt and Trans Indus ranges, north Pakistan, (Gee, 1989; Ghazi and Mountney, 2009; Jan and Stephenson, 2011).

The study area Kafar Kot in Chashma is a part of Khisor range in Trans Indus ranges. The regional structural style of Khisor range was presented by Blisnuik (1996), conducting the paleo-magnetic studies of the Siwalik sediments, by interpreting that the south verging fault system are responsible for the evolution of the Khisor range. Based on the outcrop data, the proposed structural model is thin skinned tectonics, involving decollment thrust system (Alam, 2008). The stratigraphic succession exposed in the study area ranges in age from Cambrian to Pliocene (Gee, 1989; Shah, 2009) (Fig. 2).

Material and Methods

The methodology of the current research work includes the field and laboratory work. The Kafar Kot area of Khisor range was selected for the sampling of the Permian Wargal limestone. The characteristics features i.e. lithology, texture, grain size, color, bedding pattern, thickness, fauna, lateral extension etc were recorded to find out the geological suitability, workability and economic potential. Ten samples were collected with equal intervals from the Wargal limestone at Kafar Kot in Chashma area of Khisor Range. All collected samples were subjected to different laboratory tests for evaluation of specific gravity, soundness, elongation and flakiness, Los Angeles abrasion value, water absorption, crushing value, impact value, unit weight, California bearing ratio, maximum value of lab density for sub base and base course, stripping and coating, optimum moisture content and petrographic analysis.

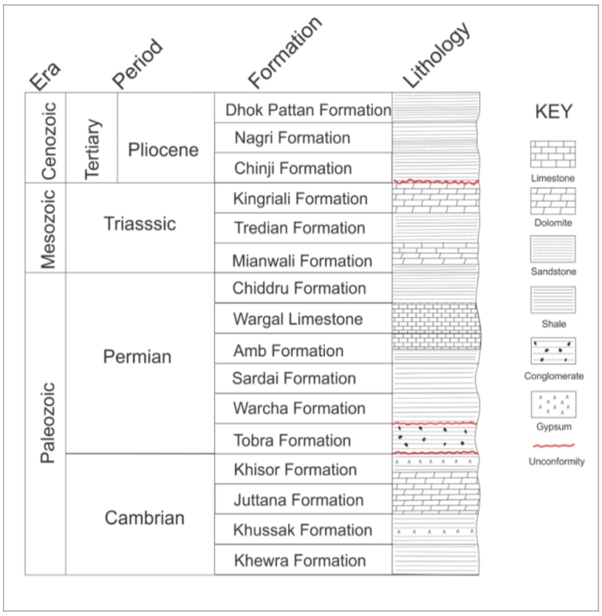

Fig. 2 Composite stratigraphic log of Khisor range, Trans Indus range, north Pakistan (Shah, 2009).

Thin sections were made from the selected samples for petrographic analysis to determine the mineralogy, fabric and deleterious contents of the Wargal limestone (ASTM C-295-1990). The engineering related properties of the asphalt/cement mix design and fine and coarse aggregates are the major factors which play vital role in the durability of civil engineering structures (Masad et al., 2006; Neville, 2012). Aggregate used in mega projects should have engineering properties suitable to resist destructive factors during its course of life (Naeem et al., 2014). In order to evaluate engineering properties of aggregate, the procedures described by ASTM (1990), BS 812 (1990) and American Association of State Highway and Transportation Officials (AASHTO, 2009) were followed.

Results and Discussion

The petrographic analysis was carried out to determine the mineralogy, grain size and types, fauna and rock fabric. The reactive contents of aggregate are hazardous which affect the strength, durability and bonding of aggregate. The reaction of aggregate is the

ASR (i.e. alkali silica reaction) and ACR (alkali carbonate reaction) when the aggregate interacts with water (Khan, 2000; Neville, 2012; Ahsan et al., 2012).

The petrography of selected samples of the late Permian Wargal limestone constitutes mainly of calcite, bioclasts (brachiopods, gastropods, echinoderms) while some are undifferentiated with minor dolomite. The calcite occurs in the form of sparite and micrite. The sparite is colorless with moderate relief having grain size ranging between 0.02 to 0.3 mm and also occur to fill the cavities in the rock. Micrite of the studied sample are generally colorless with variable relief having grain size less than 0.02mm. The skeletal fragments are distributed over the sparite and matrix, which are mainly composed of a mixture of bioclasts of brachiopods, bivalves and other undifferentiated forms as well as broken fragments. Dolomite occurs as a tiny rhomb varying from 3 to 5 % in dolomitic limestone and its contents is less than 1%.

The non-carbonate grains are limited to 2%, which comprised of quartz, hematite/ limonite and clay. The quartz is limited to 0.5% and occurs as a tiny detrital as well as authigenic grains. The hematite/limonite occurs in minor amount and is about 0.6% (Fig. 3c). The clay content is also 1.0% and occurs in the disseminated form in stylolites. The petrographic analysis of the Wargal limestone shows limited amount of deleterious content such as quartz, dolomite and clays, which suggests that the Wargal limestone has an insignificant threat of ACR and ASR. Thus, aggregate with ordinary Portland cement (OPC) and high alkali Cement of the Permian Wargal limestone at Kafar Kot Chashma area can safely be used. The limestone is hydrophobic. Thus, it makes a good bonding with the bitumen and is appropriate for the asphaltic concrete.

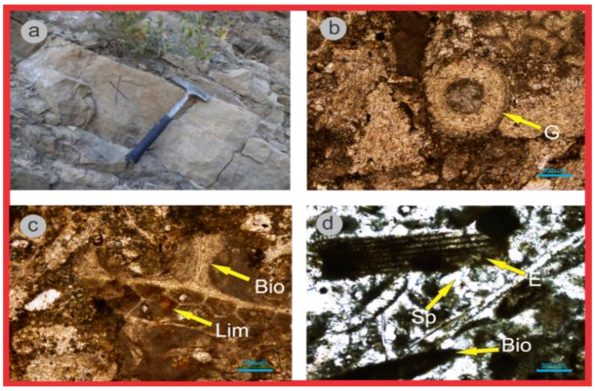

Fig. 3 (a) Grey color medium bedded limestone of the Wargal limestone. (b) Gastropod (G) allochems. (c) undifferentiated bioclasts (Bio) and limonite (Lim). (d) echinoid plates (E), spar (Sp) and undifferentiated bioclasts (Bio).

Flakiness Index Test

The basic purpose of this test is to evaluate the shape of individual particles as the roughly rounded particles have maximum strength. Samples were passed through opening of gauge and total weight of aggregate passed through opening were determined and expressed in percent of total sample weight. Deformation and breakage of aggregate under heavy traffic load affects the workability of road (Khan, 2000; Ahsan et al., 2012). The results of this test under study ranges between 6.4% and 6.6%. The average value of flakiness index is 6.5%. These results are in range of specification limits which shows that the aggregate under study could be used in concrete and asphalt.

Elongation Value

Elongated particles have low strength. In general, crushed particles have elongation index higher than the flakiness index by 1.5 times. The percentage of elongated particles is determined by the weight of aggregate based sample held in the elongated gauge. Elongation index test results for the samples under observation ranges from 6.5% to 7.7% with average value of 7.1%. These results are well within the standard specified limits (15% Max) which shows that the aggregate under study could safely be used in asphalt and cement concrete.

Specific Gravity and Water Saturation Value of Aggregate

Quality and strength of aggregate is well indicated by its specific gravity (Khan, 2000). Specific gravity is described as the ratio of weight of given volume aggregate in air to the weight of equal volume of water in air. Higher the specific gravity of aggregate, higher will be its strength (AASHTO T-84D11-2009). Results of specific gravity ranges between 2.703 and 2.715 with an average value of 2.70, which are within the standard limits.

Porosity of aggregate is indicated by its water absorption. Very high values of water absorption show that strength of aggregate is low (Neville, 2012). The more porous aggregate indicates more absorption compared with less porous aggregate (Lees and Kennedy, 1975). Aggregate absorbs some asphalt to make mechanical bond but water absorption should be within standard limits. Water absorption test varies from 0.41% to 0.61% with average value of 0.48% which is within the standard specified limit of (2%). The results of water absorption and specific gravity indicate that material under observation could be used safely in asphalt concrete, cement concrete and in base sub-base.

Los Angeles/ Abrasion Test (AASHTO T-96), (ASTM C-131)

Aggregate faces crushing, degradation and disintegration during course of life. The aggregate should be sound and durable enough to resist crushing, degradation and disintegration during service. Los Angeles test determines the ability of aggregate to resist against crushing, disintegration and degradation (Khan, 2000). The Los Angeles abrasion aggregate values varied from 20.1% to 26% with an average value of 23.37% which was well within the standard specified limits 35%, 40% and 50% of cement concrete, base course and sub-base, respectively. The Los Angeles low values of abrasion show that aggregate under study was sound and durable when subjected to abrasion.

Aggregate Impact Value (BS 812)

Aggregate Impact value is the resistance against the sudden shock which is not proportional to the steady and slowly applied compressive load (Neville, 2012). The aggregate toughness is evaluated from the impact value test of aggregate. This reveals resistance of material against the impact stresses when subjected to the load of heavy traffic (Ahsan et al., 2012). Impact value of aggregate must be less than to be used as a road aggregate. Aggregate Impact value of Late Permian Wargal limestone exposed at Kafar Kot Chashma area in Khisor Range varies between 15.4% to 16.3% which is a good quality aggregate.

Sodium Sulphate Soundness (AASHTO T-104)

The aggregate durability to chemical weathering is determined by the sodium sulphate soundness test under natural condition (AASHTO 104). Sodium sulfate is common chemical used to determine soundness of aggregate. In field, the aggregate is exposed to weathering condition like freezing, wetting, drying and thermal changes that damage the structure of aggregate and directly affect the life of civil structure (Al-Mansur and Kazi, 1980; Gondal et al., 2009; Ahsan et al., 2012). Quality of aggregate should be hard and durable enough to resist the weathering and erosion (Gondal et al., 2009). The soundness results for the aggregate samples under observation varied from 0.86% to 1.12% with average value of 1.007% which was within the standard specified limit (12% maximum). The range of results within the specified limit indicates that aggregate under study could safely be used in concrete and for other construction purpose.

Bearing Capacity

Material strength under the load in contacting with water is assessed by bearing capacity or California Bearing Ratio (CBR) test (AASHTO T-193). In this test the strength of aggregate under observation is compared with the strength of an excellent material having CBR value of 100. Samples under observation were subjected to CBR test under soaked conditions at 100% compaction. The CBR value for aggregate under the study varied from 88% to 98% with an average value of 93.6% which was well within the specified limits of standard specification. The suitable ranges of CBR value indicates that the aggregate under study could be used in subbase course and in base course as well.

Maximum dry Density and Optimum Moisture Content/Modified Proctor

This test defines the optimum moisture content and maximum dry density with the help of which maximum density can be obtained by compacting the material. Selected samples of aggregate were subjected to modified proctor test to calculate the optimum moisture content and maximum dry density by taking 60% coarse and 40% fine aggregates (AASHTO T-180). Test results indicate that the value of optimum moisture content ranged between 5.2% and 6.4% with an average value of 5.79% and maximum dry density varied from 2.226 to 2.342 with an average value of 2.307. The results indicate these aggregates could easily be used as a sub-base and base course.

Crushing value

The resistance of aggregate against the rupture is the crushing value (BS 812 Part 110.1990). When the aggregate is subjected to static and dynamic stresses like overburden and load of traffic rolling on the road (Khan, 2000; Ahsan et al., 2012). The aggregate higher crushing values are considered as best capable to bears the compressive stresses applied on them (West, 1996). The aggregate crushing value of the studied samples of late Permian Wargal limestone exposed at Kafar Kot Chashma area vary from 12.8% to 13.3%, which were comparable with good quality of aggregate as prescribed by ASTM (2004) and AASHTO (2009).

Unit weight

The unit weight of aggregate is evaluated by the weight to volume ratio and void ratio (AASHTO T-19). The aggregate unit weight plays an important role in mixed design and estimation of reserve stocks (Croney et al., 1997; Neville, 2012). The aggregate with higher of unit weight is of good quality because of less void ratio (Masad et al., 2006). The unit weight in the studied late Permian Wargal Limestone varies from 1.64 to 1.70.

Bitumen Coating and Stripping of Aggregate

This particular test settles the ability of the aggregate to retain the film of bitumen on its surface (AASHTO T-182; Croney et al., 1997). Aggregate used in asphalt must retain a thin film of bitumen on its surface under the action of water and moisture (Ahsan et al., 2012). Selected samples were subjected to this test according to the standard method i.e. AASHTO T-182 at temperature range of 25 Cº. The bitumen used in this test was of 60/70 grade and 80/100 grade. The Wargal limestone stripping value are below 5%. The test results show this aggregate is suitable for asphalt concrete with more than 95% coating.

Conclusion

Engineering properties of Wargal limestone at Khisor range, Trans Indus ranges indicate that the limestone is hard, tough and durable. Coating and stripping of bitumen aggregate mixture at 25ºC exhibited that limestone is hydrophobic. Various tests result also suggests that the Wargal limestone can safely be used as a base course, sub-base in asphalt and cement concretes. Thick bedded Wargal limestone can be used along embankment and in building construction. Limestone is accessible and can be transported to different areas. Limestone can be easily mined through open pit excavation. Development of crushing activities in the area will provide huge amount of potential aggregate for construction purpose.

Acknowledgement

The authors are thankful to all those who helped directly and indirectly throughout the completion of this research work.

References

Alam, I. (2008). Structural and stratigraphic framework of the Marwat-Khisor ranges, Trans-Indus Range, Pakistan. Unpublished Ph. D thesis submitted to NCEG University of Peshawar, Peshawar Pakistan. 1-145**.**

Abbasi, I. A., Haneef, M., Obaid, S., Daud, F., Qureshi, A. W. (2012). Mesozoic deltaic system along the western margin of the Indian plate: lithofacies and depositional setting of Datta Formation, North Pakistan. *Arabian Journal of Geosciences*, ***5***(3), 471-480.

Ahsan, N., Gondal, M. M. I. (2016). Aggregate suitability studies of limestone outcrops in Dhak pass, western Salt range, Pakistan. *International Journal of Agriculture and Applied Sciences (Pakistan)*, **4**(2), 69-75.

Ali, A. (2010). Structural analysis of the Trans-Indus ranges: Implications for the hydrocarbon potential of the NW Himalayas, Pakistan. Doctoral dissertation, National Centre of Excellence in Geology University of Peshawar, Pakistan.

American Association of State Highway and Transportation Official, (2009). Soundness test. AASHTO T-104.

American Association of State Highway and Transportation Officials, (2009). Coating and stripping of bitumen-aggregate mixture. AASHTO T-182.

American Association of State Highway and Transportation Officials, (2009). Bulk density (Unit weight) and voids in aggregate. AASHTO T-19.

American Association of State Highway and Transportation Officials, (2009). Specific gravity and absorption of fine aggregate. AASHTO T-84-D11.

American Association of State Highway and Transportation Officials. (2009). Los Angeles abrasion test. AASHTO T-96.

American Association of State Highway and Transportation Officials **(**2009). Modified procter test. AASHTO T-180.

American Association of State Highway and Transportation Officials (2009). CBR test. AASHTO T-193.

American Standard for Testing Material. (1990). Standard definition and terms relating to concrete aggregate. American Society for Testing and Material, West Conshohocken, Pennsylvania, USA. ASTM C-125.

American Standard for Testing and Material. (1990). Standard guide for petrographic examination of aggregate for concrete C-295.

American Standard for Testing Material. (2004). Annual book of ASTM standards. American Standard for Testing Materials Annual, Philadelphia, PA, USA (4) 04-08.

Bérubé, M. A., Fournier, B. (1993). Canadian experience with testing for alkali-aggregate reactivity in concrete. *Cement and Concrete Composites*, **15** (1-2), 27-47.

Blisniuk, M. P. (1996). Structure and tectonics of the northwest Himalayan frontal thrust system, Trans-Indus ranges, northern Pakistan. Unpublished Ph.D thesis, Dartmouth college, Hanover, New Hampshire, U.S.A.

British Standard Institute **(**1975). Testing aggregate. Methods for determination of mechanical properties, B.S., 812-3.

British Standard Institute **(**1985). Methods for determination of Flakiness Index, BS 812-105.1

British Standard Institute **(**1990). Method for determination of aggregate crushing value (ACV), BS 812-110.

British Standard Institute **(**1990a). Method for determination of elongation Index, BS 812.105.2.

Croney, P. Croney, D. (1997). The design and performance of road pavement, 3rd ed., MCGraw-Hill International Limited, UK, 1-375.

DiPietro, J. A., Pogue, K. R. (2004). Tectonostrati-graphic subdivisions of the Himalayas: A view from the west. *Tectonics*, **23** (TC5001), 1-20.

Dunham, R. J. (1962). Classification of carbonate rocks according to depositional texture, In Ham, W. E. (Ed.) Classification of carbonate rocks. *American Association of Petroleum Geologists*

Memoir, 108-121.

Fatmi, A. N., Hyreri, I.H., Anwar, M., Waliullah, (1999). Stratigraphy of the Khisor range and Shaikh Badin hills (Marwat range) D.I. Khan, NWFP, Pakistan. Geological Survey of Pakistan, Memoir, 1-14.

Fatmi, A.N., (1977). Mesozoic. In Shah, S.M.I (ed.) Stratigraphy of Pakistan. Geol. Suv. Pakistan. Mem., **12**, 29-56.

Gee, E. R. (1989). Overview of the geology and structure of the Salt Range, with observations on related areas of northern Pakistan. Geological Society of America Special Papers, **232**, 95-112.

Ghazi, S., Mountney, N. P. (2009). Facies and architectural element analysis of a meandering fluvial succession: The Permian Warchha Sandstone, Salt Range, Pakistan. *Sedimentary Geology*, **221**(1), 99-126

Gondal, M. M., Ahsan, N., Javed, A. Z. (2009). Engineering properties of potential aggregate resources from eastern and central salt range. *Geol Bull Punjab Univ.*, 44-52.

Jan, I. U. Stephenson, M. H. (2011). Palynology and correlation of the Upper Pennsylvanian Tobra Formation from Zaluch Nala, Salt range, Pakistan. *Palynology*, **35**, 212-225.

Kazi, A., Al-Mansour, Z. R. (1980). Influence of geological factors on abrasion and soundness characteristics of aggregates. *Engineering Geology*, **15**(3-4), 195-203.

Kazmi, A. H., Jan, M. Q. (1997). Geology and Tectonics of Pakistan. Graphic, Karachi, 225-231.

Khan Z. K. (2000). Study of the geology of Kirana Group, central Punjab and evaluation of its utilization economic potential as aggregate. Unpublished Ph.D. Thesis, 206 pages.

Lees, G., Kennedy, C. K. (1975). Quality, shape and degradation of aggregate. *Quarterly Journal of Engineering Geology*, **8** (3), 193-209.

Masad, E., Panoskaltsis, V., Wang, L. (2006). Asphalt concrete. Simulation, modeling and experimental characterization *(Geotechnical Special Publication No. 146 by ASCE)* 1-149.

Naeem, M., Khalid, P., Sanaullah, M., Din, Z. (2014). Physio-mechanical and aggregate properties of limestones from Pakistan. *Acta Geodaetica et Geophysica*, **49** (3), 369-380.

National Highway Authority (NHA). (1998). General specification, Ministry of Communication, Govt. of Pakistan.

Neville, A. M. (2012). Properties of Concrete (4th ed.). Pearson Education Asia Pte. ltd. Edinburgh, UK-872 pages.

Nizami, A. R. (2009). Sedimentology of the middle Jurassic Samana Suk Formation, Makarwal Section, Surghar ranges, Trans Indus Ranges, Pakistan, *Geol. Bull. Punjab Univ*., **44**, 11-25.

Rehman, S. U. (2009). Microfacies and depositional environments of Kawagarh Formation exposed at Chinali and Khariala, northwest Lesser Himalaya, Pakistan. Unpublished M. Phil thesis, University of the Punjab, Lahore, Pakistan, **97**.

Rehman, S. U. (2017). Sedimentology of Turonian-Maastrichtian Kawagarh Formation, Attock Hazara fold and Thrust belt, Northwestern Lesser Himalayas, Pakistan. PhD thesis, University of Sargodha, Pakistan 1-253.

Shah, S. M. I. (2009). Stratigraphy of Pakistan. Geol. Surv. Pakistan, Mem., **22**, 381 pages.

Tahirkheli, R. A. K., Jan, M. Q. (1979). Geology of Kohistan, Karakorum, Himalaya, northern Pakistan. *Geological Bulletin University of Peshawar*, **11,** 1-30.

West, G. (1996). Alkali-aggregate reaction in concrete roads and bridges, Thomas Telford, London. http://doi.org/10.1680/aricrab.20696.