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Susceptibility of Jhelum river bed aggregate to alkali silica reaction and its potential as construction aggregate

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Abstract

Durability and suitability of concrete aggregates are influenced by mineralogical composition. This paper therefore discuses the mineralogical composition of Jhelum river aggregates and identifies the deleterious components responsible of ASR expansion, when used in normal weight concrete. Accelerated Mortar Bar Test (ASTM C-1260) and petrographic analysis were performed to determine the durability aspects of river aggregate. Aggregate Suitability was assessed by aggregate quality tests i.e. specific gravity & absorption, Loss Angeles abrasion, sulfate soundness, shape test, fineness modulus and sand equivalent .On obtaining satisfactory results of coarse aggregate tests, concrete mix designs for class-A, class-B, class-C and class-D were devised by absolute volume method (ACI- 211.1). Projected UCS (Unconfined Compressive Strength) considered 4000Psi for A-type, 3000Psi for B-type , 2000Psi for C-type and 1500Psi for D- type concrete at the at 28days. Results of 24 casted cylinders show that achieved average UCS at the age of 28 days is , 4921 Psi, 3773 Psi, 2780 Psi and 2432Psi for A, B, C and D-type concrete respectively. Jhelum River Aggregate is found mechanically fit and suitable for normal weight concrete. There are about 40% samples which deviate from the suitability standard of Accelerated Mortar Bar Test. Mineralogical studies of Jhelum river aggregate revealed that most of the aggregate components (Sandstone, Quartz Arenite) are suitable for construction but some of these are highly susceptible to alkali silica reaction due to the presence of highly strained quartz. The studied river aggregate is economical while used with slag cement and additives.

Keywords: River bed aggregate, Alkali Silica Reaction (ASR) susceptibility, Accelerated mortar bar test, Normal weight concrete, Aggregate durability.

1. Introduction

Although the river bed material has gotten high potential for being a natural aggregate, it is rarely used as a concrete material. It is approved that the volume of concrete is contained of 65-80% of crushed rocks or river aggregate used as construction material (Methew et al., 2013; Chandrasheka and Maneeth. 2014). Two types' aggregate constituents; micro and macroscopic aggregates are commonly rivers and estuaries (Ezekie et al., 2011). Composition and size of aggregate fluctuate significantly along the longitudinal profile of running waters (Zimmermann-timm., 2002). The significant changes in the quality and quantity of fine grained sediments within the rivers exist due to the anthropogenic activity. Coarse aggregates of river can be used for filling material and concrete as well as road embankment (Owens et al., 2005; Maharjan et al., 2007; Naeem et al., 2014).

Cements of high alkali content and aggregate from river bed are subject to the ASR (alkali silica reaction) when used in normal weight concrete. There are three essential factors that cause the Alkali-Silica Reaction: alkalis, certain alkaline reactive amorphous silica minerals, and moisture having the role of the reagent and a transport media (Marku. 2015; Majid et al., 2013). Northwest Himalayan rivers have many rock types prone to ASR in concrete identified by petrographic analysis. Application of expansion test (Mortar bar ASTM C1260) on river aggregate hematite was found highly reactive (Niedźwiedzk et al., 2015; Batalla et al., 2010). ASR does not affect the durability of concrete, but the susceptibility of the concrete may enhance the risk of reaching steel reinforcements and Free-thaw attack of concrete (Marku, 2015; Ahsan et al., 2009). The compressive strength of concrete is principally contingent upon mix ratios and the texture of coarse & fine aggregate. Aggregate size demonstrates a strong influence on the concrete strength (Sanaullah et al., 2017; Aginam et al., 2013; Nemati, 2015).

Present investigations aims to assess the reactive constituents present in the river bed material of Jhelum river. Study area lies in Dina district of Jhelum (33° 10' 9.96" N to 33° 0' 32.33" N and 73° 33' 4.16" E to 73° 46' 5.18" E). Jhelum river originates from the Kashmir and forms its boundary on East and South across which lies Azad Kashmir on East and districts of Gujrat and Sargodha on South and district of Chakwal is on its West (Fig. 1.). The total area of the district is 3,587 square kilometers. Dina is commercially important town having a junction with the road to Mangla reservoir and Rohtas fort (Sheikh, 2012).

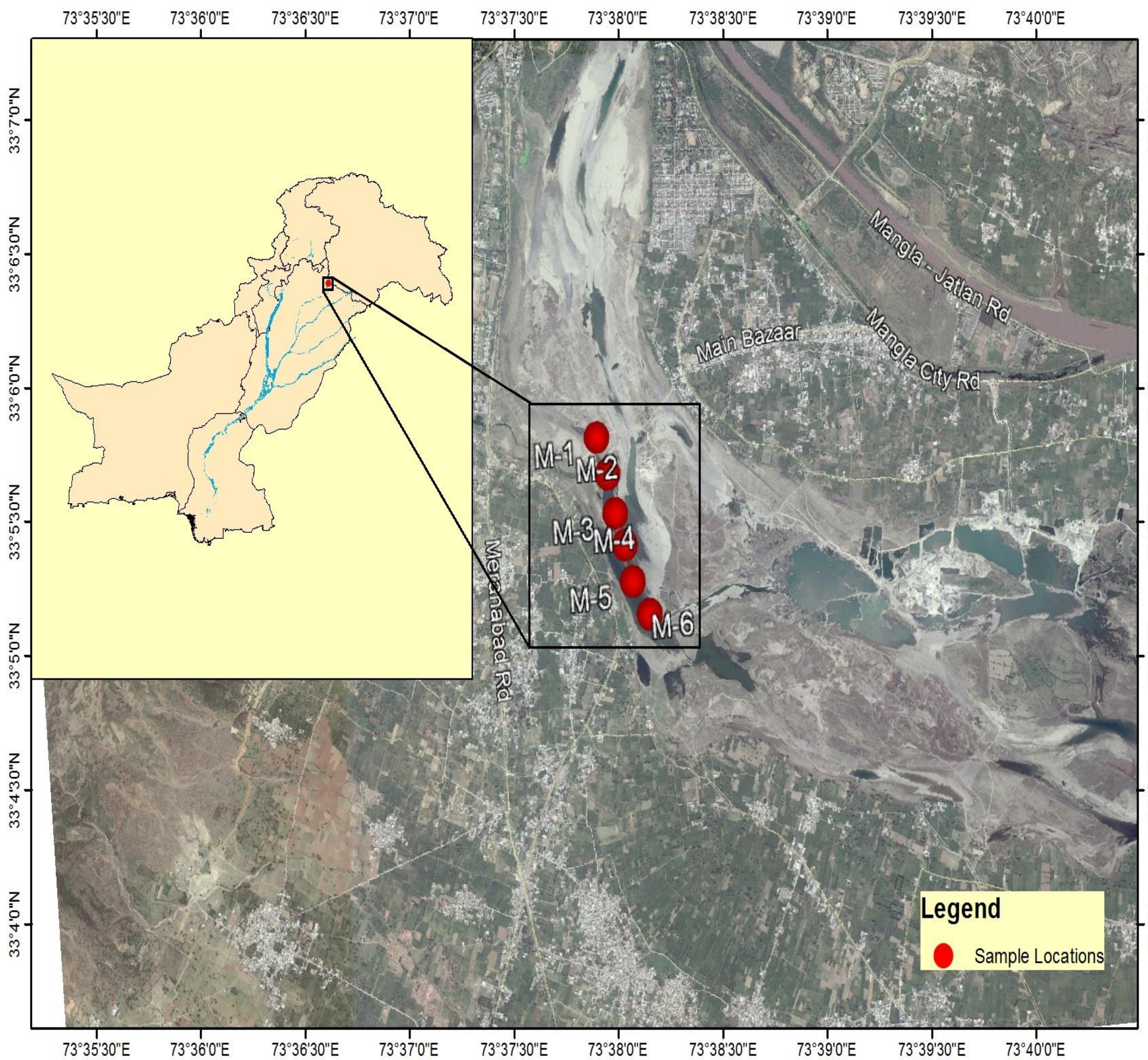


Fig. 1. Sampling locations of the study area.

2. Geological settings

The dominant deposits of rocks in the study area are of Siwalik group which is comprised of Quaternary age sediments. In Pleistocene, Jhelum river study area can be classified into the deposits of stream channel, younger flood plain, older flood plain, clay deposits, sub-piedmont deposits and terrace gravels successively of 3m to 20m thick. Three dominant formations Nagri, Dhokpathan and Soan formation are abundant of sand and gravel sediments. In terrace alluvium, the Quaternary constituents (clay and silty clay) are common (Qureshi et al., 2004).

3. Method and materials

Selection of good quality aggregate used in construction requires a detailed determination physio-mechanical characterization of aggregate. Laboratory tests: bulk specific gravity and water absorption (ASTM C127-88), Los Angeles abrasion value (ASTM C-131), sodium sulphate soundness (ASTM C-88), flakiness and elongation Index (BS 812) were performed for physical characterization of coarse aggregate of Jhelum river bed from Dina . Some chemical tests on coarse aggregate (Sulphate Soundness ASTM C-88) and concrete (Accelerated Mortar Bar test ASTM C-1260) were conducted to identify the reactive aggregates. Mineralogical analysis (ASTM C- 289) of these aggregates was carried out to predict the potential for Alkali Silica Reaction (ASR) and compressive strength of Concrete (ASTM C-39) was determined to conform the achieved strength of concrete cylinders. Fineness Modulus, Specific gravity Test, Absorption (%), Organic Impurities, Sand Equivalence, Loose Unit weight and Rodded Unit weight were estimated for fine aggregates (Qibla Bandi sand & Chenab river sand).

3.1. A-Physical tests

*Bulk Specific Gravity (*AASHTO T-85*)*: This method is useful to determine the specific gravity and water absorption of coarse aggregate. The bulk specific gravity (SSD) and absorption is assessed by soaking aggregate in water for 15 hours. This is not a valid method for lightweight aggregates. Bulk specific gravity is generally determined to calculate the volume of aggregate in several mixtures of aggregate.

Los Angeles Abrasion value (ASTM C- 131): The Los Angeles (L.A.) abrasion test is good to designate aggregate toughness and its abrasion features. It is thought that L.A. can gauge the relative quality of mineral aggregates. Its procedure requires 4kg sample and different number of steel balls different aggregate classes. Also the abrasive charge and the standard steel balls (48mm diameter and 290g weight) are rotated 33 cycles per minute for up to 500 revolutions. The loss percentage of aggregate is calculated by passing the abrasive material from # 12 sieve.

Flakiness and Elongation Index (BS 812): Shape test for aggregates is carried out by the calculating percentages of flakiness & elongation of particles. A fraction of aggregates is passed in to the designated slot on flakiness gauge. The width of slot is such that to isolate the flaky particles in the fraction tested. Same is the case for elongation index for which each fraction is measured separately in length gauge by passing the aggregate particle at maximum dimension of length. The allowable parameters of flakiness index ranges from 35 to 40% while for elongation index ranges from 40 to 45%.

3.2. B- Compressive strength of concrete (ASTM C-39)

Compressive strength of concrete is of significant importance in characterizing concrete types. This test for compressive strength defines how closely the strength of concrete specimen meets the target strength of concrete set for the project. Results of this test are used in evaluation of the concrete mix designs. The compressive strength test based on the assessment of concrete strength upon which the cylinder of concrete breaks.

3.3. C- Chemical tests

Accelerated Mortar Bar test (ASTM C-1260):

ASTM C 1260 standard is used as industry standard for identifying the reactive aggregate. This method does not well estimate the aggregate combinations with cementitious materials and the environment of aggregates used in such combinations. Mortar bars (25*25*285 mm) of samples aggregates are casted after graduation and then it will place into water bucket at a temperature of 80˚C for 24 hours. After removal from water bucket the initial length of the bars are measured and place it into highly alkaline solution of 1N NaOH at 80˚C for 14 days. After removal from solution the length of the bars is again determined and the final results are used to evaluate the reactivity of samples. Specification for interpretation of test results can be given as < 0.1% nonreactive, 0.1 to 0.2% potentially reactive and >0.2 as reactive.

Sulphate Soundness (ASTM C-88):

Chemical stability of aggregates measure in terms of soundness. Sulphate soundness test provides an environment to the aggregate as it is under weathering action. Categorized sample is dipped into the solution of Na_2SO_4 (specific gravity of 1.71 to 1.54) for eighteen hours. Similarly this cycle is repeated for 4 to 5 times more. According to the standard guidelines, the loss% of aggregate to Na_2SO_4 should not exceed 12%.

3.4. D- Mineralogical analysis (ASTM C-289)

The petrographic (Mineralogical) analysis of samples under polarized microscope provides mineralogical compositions of the rocks. The method of mineral identification and its % age estimation aggregate is handy to classify more durable aggregates as construction material along with the variations occur in the physical and strength characteristics of aggregates in different rock types.

4. Results and discussion

The sampling of river bed material was carried out along right abutment and the downstream of Jhelum river (Dina, Jhelum). Various laboratory tests; Sulphate soundness test, water absorption, specific gravity and Los Angeles abrasion value for coarse aggregate were conducted. Mineral compositions of coarse aggregate were identified by petrographic studies (ASTM C-289). Fine aggregate having 70% of Qilabandi sand and 30% of Chenab sand was introduced in concrete mix designs. Four no. of concrete mix design were formulated for Class-A, B, C and D per guidelines of ACI-211.1. A blend of fine aggregate (70% Qibla Bandi and 30% of Chenab river sand) having fineness modulus of 2.49 and Specific gravity of 2.68 was introduced in concrete mix design (Table1-B). The target UCS (Unconfined Compressive Strength) of concrete cylinders was considered 4000, 3000, 2000 and 1500 Psi for, A, B, C and D-type concrete respectively at the time of 28 days. UCS was investigated for 7 & 28 days for a total of 24 concrete cylinders (6-cylinders from each mix). Results of the all the mix designs have attained the minimum mandatory compressive strength at 7-days.

The target compressive strength of cylinders for normal weight concrete was set 4000 Psi at 28-days for A-class while 3000 Psi, 2000Psi and 1500 Psi for B, C and D-class respectively. Trial mixes used for concrete were performed by absolute volume method (ACI 211.1, 2005) for different classes of normal weight concrete (Table.1-A). 70% compressive strength achieved at 7 days is considered sufficient (ASTM C 39). It has been observed that designed concrete mixes are very appropriate for target UCS. Slump of trial mix was achieved well according to the desire value for class A, B, C and D. Aimed strength for A-class of concrete after 28 days was set 4000 Psi but the obtained values of UCS are more than the target compressive strength at the time of 28 days.

A-type concrete trial mix includes ordinary Portland cement (OPC) with specific gravity of 3.150kg/ m^3 and the pozzolonic material of slag (specific gravity 2.830 kg/m^3) along with admixture of sika brand. Slump of the concrete mix was recorded as Initial of 110mm, after 15 minutes of 90mm and after 30 minutes 85mm (Table.2). Investigations for B-class concrete were made for target strength of 3000 psi along with slump limit of 50-75mm. Initial slump recorded was 75mm, after 15 minutes it was 65mm while at 30 minutes was 60mm. The achieved strength for B-type was found 3702Psi on 28 days. Proposed mix design for Class-C concrete was set at W/C ratio of 0.47 (Table. 2). The observed slump of the concrete mix was recorded 60mm after 30 minutes time span. Results for Class-D concrete at W/C ratio of 0.35 achieved required strength (2338 Psi) at 28 days (Table.3).

All samples tested for physical tests were subjected to mortar bar test (ASTM C1260). Mortar bar expansion for river bed samples JRB-1 of 0.2% JRB-2 of 0.21% exceeds the set criteria (ASTM C 1260; Table. 3.1).Therefore these two components of river bed aggregate would be considered as reactive or prone to ASR. Three samples (JRB-3, JRB-4 and JRB-5) have showed a bit expansion below the permissible limit to start ASR. According to ASTM C 1260, 0.1 % of expansion of aggregates mortar bar test is permissible (Fig.3).

3.1. Petrographic analysis

3.1.1. Schist (Plate: M-1 and M-2)

The petrography of the two schist samples (M-1 and M-2) demonstrates the presence of deleterious material. M-1 contains 60% quartz out of which 25 % is identified as strained quartz along with the other minerals magnetite (3%), feldspar (15%) and Mica (11%). Petrographic Plate M-2 comprises of major composition of quartz as 61% in which 27 % is strained quartz, other minerals present in sample slide are 5% magnetite, 16% feldspar and 18% mica. Strained quartz was observed with undolose extinction (Fig. 4, Table. 4). Studies sample specifies the presence of deleterious strained quartz to initiate alkali silica reaction (ASR).

3.1.2. Quartzite (Plate: M-4, M-7, M-9, M-6)

Thin section studies of four samples of quartzite have their compositions as: Plate M-4 contains 85% quartz out of which 30% occurs as strained quartz; other minerals present in rocks are 4% magnetite, 7% feldspar and 4% of mica while M-7 holds 90% quartz out of which 12 % occurs as strained quartz. The thin section plate no M-9 is comprised of 92% quartz out of which 17 % occurs as strained quartz along with other minerals in the rock (magnetite 2% and Feldspar 4% (Fig. 5, Table. 4).

The micrograph M.6 contains high composition (89%) in which 15 % is strained quartz while the other minerals identified are magnetite, feldspar and mica. Strained quartz was observed with undulatory extinction. Mica shows flakes and feldspar indicates twinning. Magnetite was identified through its opaque nature and has replaced quartz .These aggregate samples indicate the presence of strained quartz which susceptible to ASR.

Table.1- A Laboratory tests for physical properties of coarse aggregate.

S. No	Sample #	Gradation %age passing by weight						Los Angles Abrasion Value %	Specific Gravity	Water Absorption %	Sulphate Soundness %	Flakiness Index %	Elongation Index %
		3″	**2 1/2″**	**2″**	**1″**	**1/2″**	**#4**						
1	CA-1	-	100	96	55	18	1	25	2.78	0.51	1.11	13	13
2	CA-2	-	100	97	56	17	1	15	2.84	0.58	1.11	6	07
3	CA-3	-	100	95	54	15	1	21	2.75	0.60	0.99	12	10
4	CA-4	-	100	99	56	17	2	28	2.72	0.62	1.32	17	18
5	CA-5	-	100	99	55	17	1	22	2.71	0.65	1.09	12	13
6	CA-6	-	100	97	56	21	1	26	2.73	0.55	1.76	13	14
Average		**-**	**100**	**97**	**55**	**18**	**1**	**23**	**2.75**	**0.58**	**1.23**	**12**	**13**
Specified Limit		**-**	**100**	**95-100**	**35-70**	**10-30**	**0-5**	**35**	**2.5-.30**	**2%**	**12**	**35-40**	**40-45**

Table.1-B Laboratory tests for fine aggregate (Qibla Bandi sand and Chenab sand).

	Qibla Bandi sand	Chenab river sand
Fineness Modulus	2.873	1.600
Specific gravity Test	2.690	2.660
Absorption (%)	1.060	1.260
Organic Impurities	NIL	NIL
Sand Equivalence (%)	80	89
Loose Unit weight (kg/m^3)	1590	1340
Rodded Unit weight (kg/m^3)	1750	1450

Table 2. Concrete Mix designs and their fresh concrete tests.

Concrete class	**Cement 70%**	**Pozzolanic Material 30%**	**Admixture**	**Aggregate (kg)**				**Sand (kg)**		**W/C Ratio**	**Temp ˚C**	**Slump (mm)**		
			Qty (ltrs)	**3″**	**2-1/2″**	**1-1/2″**	**1″**	**Q.B 70%**	**Chenab sand 30%**			**Initial**	**15 mint**	**30 mint**
A	245	105	4.45	-	-	643	643	478	201.4	0.42	20.4	110	95	85
B	210	90	4.07	-		643	643	521.9	219.6	0.47	21.2	75	65	60
C	161	69	3.12	-	-	-	1166	612.0	257.4	0.50	20.4	75	65	60
D	210	-	2.49	-	-	-	1166	635.2	267.2	0.35	22.2	100	85	80

Table 3. Compressive strength of normal weight concrete.

Concrete Class	Required Strength (PSI)	Achieved Compressive Strength (Psi)				Achieved Compressive Strength (Psi)			
		7 days				28 days			
		1	2	3	Mean	1	2	3	mean
A	4000	3817	4547	3430	3598	5095	4513	5156	4921
B	3000	2518	2871	2759	2716	3793	3825	3702	3773
C	2000	2036	1956	2101	2031	2860	2791	2689	2780
D	1500	1794	1631	1508	1644	2529	2449	2338	2432

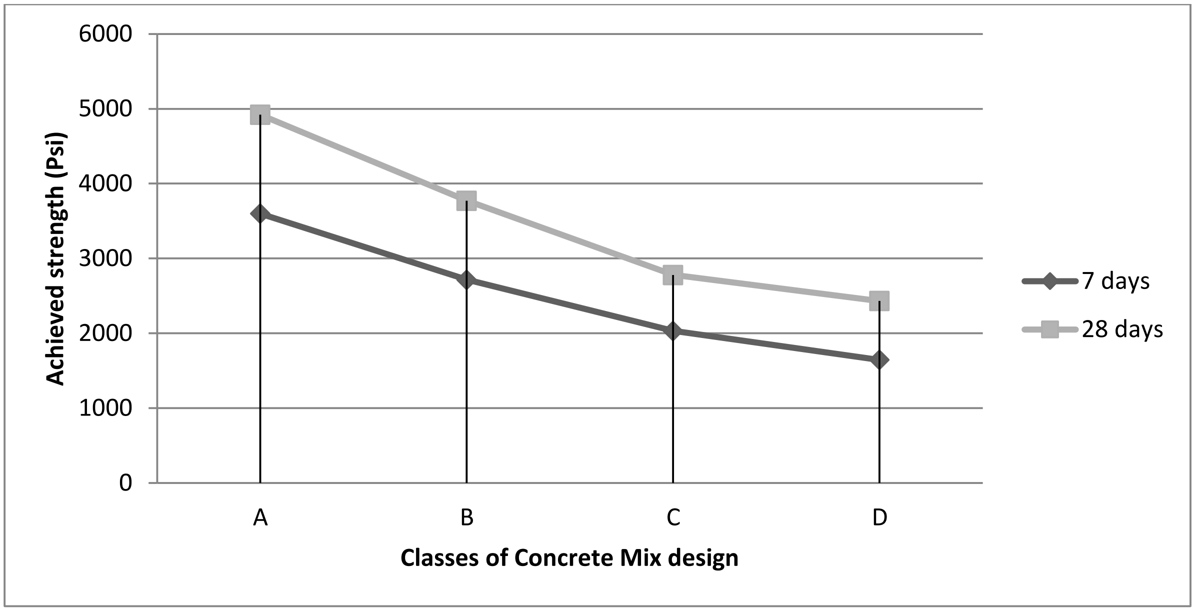


Fig. 2. Achieved strength of normal weight concrete after 7 and 28 days.

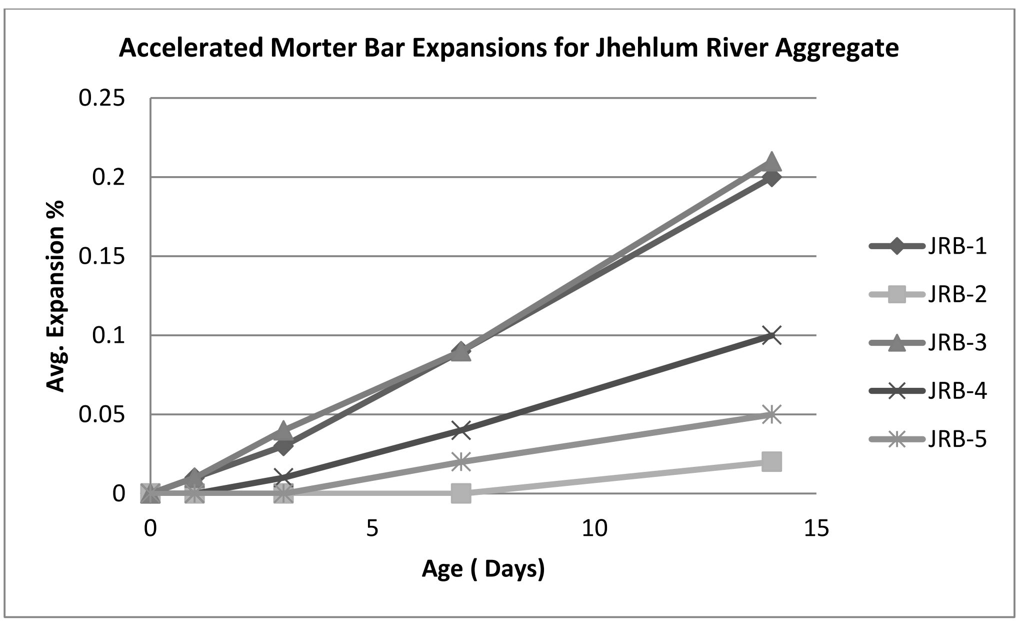
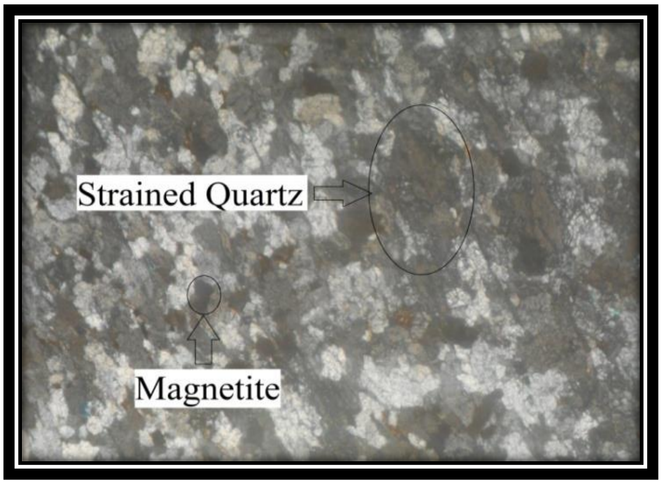


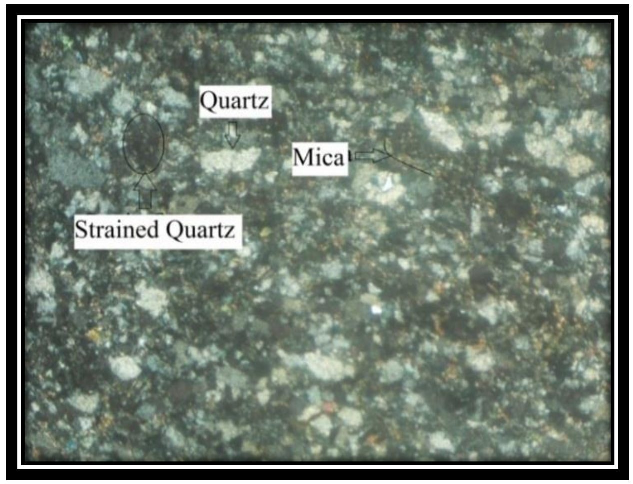
Fig. 3. Accelerated mortar bar expansions for Jhelum river aggregate.

Plate: M-1



Highly strained quartz and magnetite in schist.

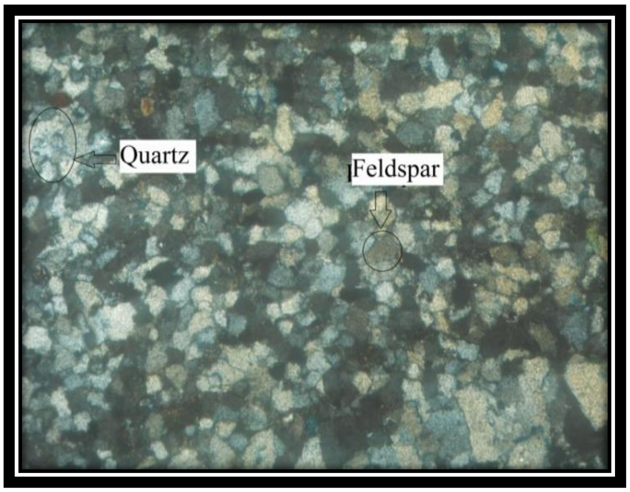
Plate: M-2



Strained quartz, mica and quartz in schist.

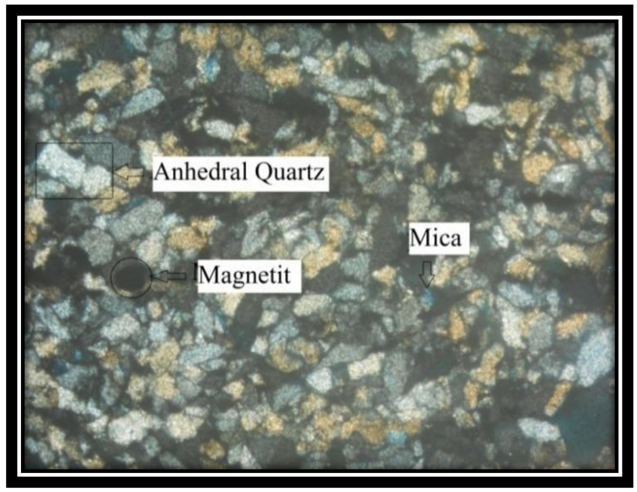
Fig. 4. Photomicrographs of schist from Jhelum river bed aggregate

Plate:M-4



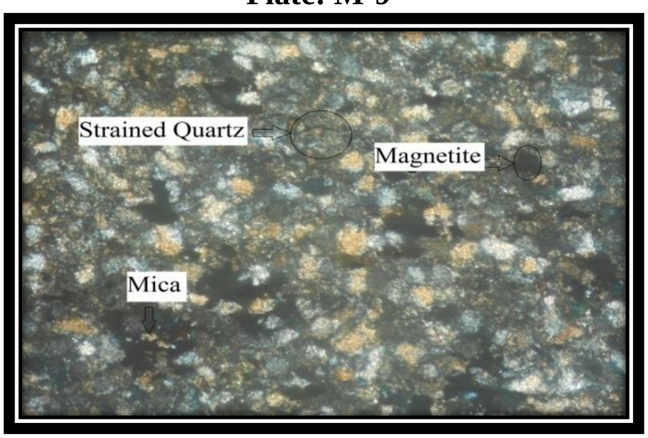
Highly strained quartz and feldspar in quartzite.

Plate: M-7



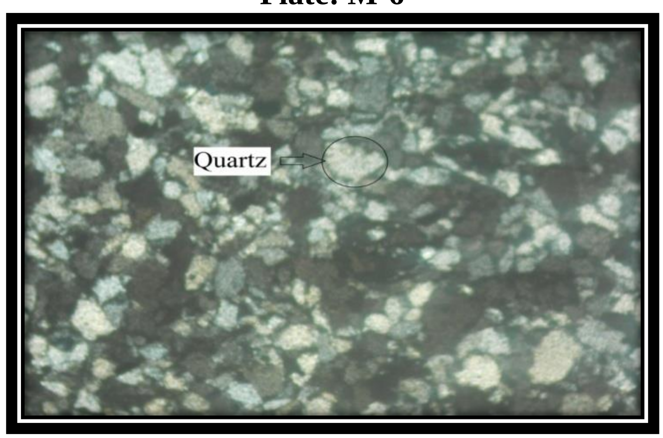
Anhedral quartz, magnetite and mica in quartzite.

Plate: M-9



Strained quartz, magnetite and mica in quartzite.

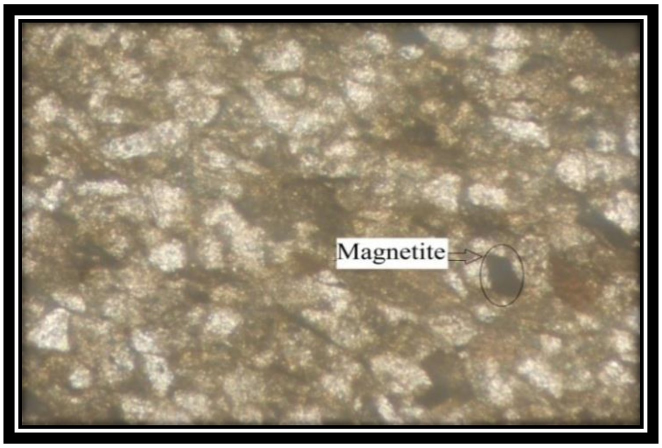
Plate: M-6



Microphotograph shows quartz in quartzite.

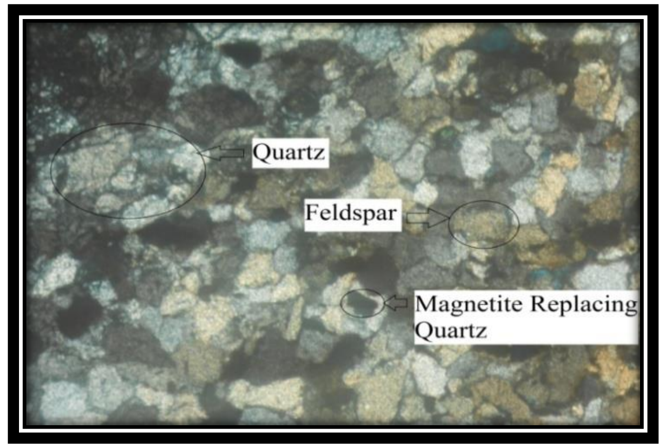
Fig. 5. Photomicrographs of Quartzite from Jhelum river bed aggregate

Plate: M-3



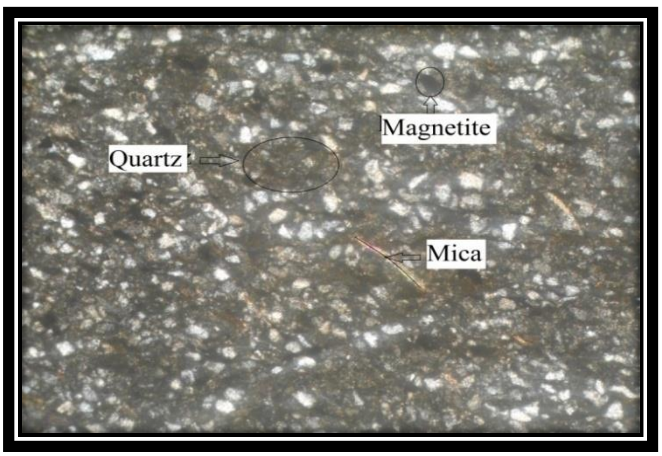
Magnetite in sandstone (PPL)

Plate: M-8



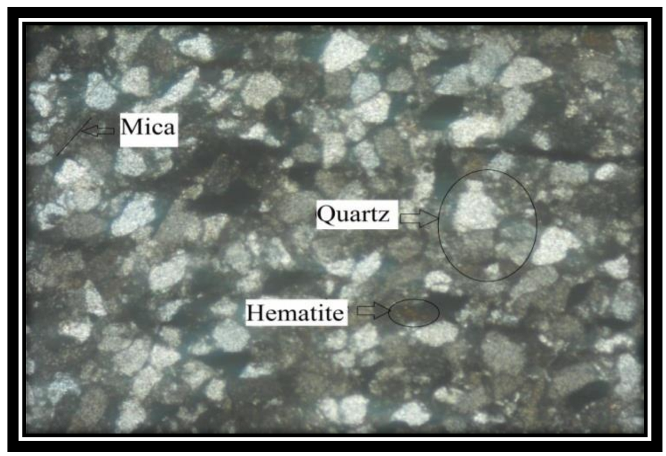
Quartz, feldspar and magnetite replacing quartz in sandstone.

Plate: M-5



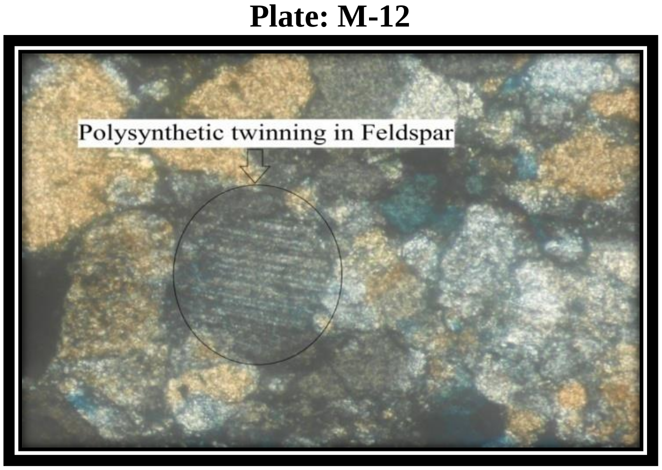
Quartz, magnetite and mica in sandstone

Plate: M-11



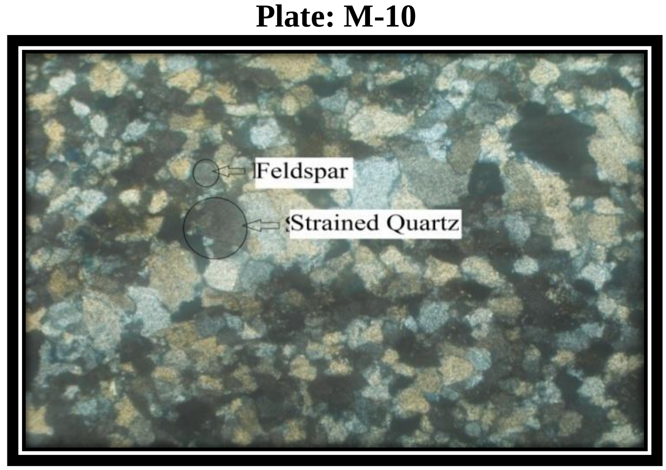
Mica, quartz and hematite in sandstone.

Plate: M-12



Polysynthetic twinning in plagioclase feldspar in sandstone.

Plate: M-10



Strained quartz and feldspar in quartz arenite.

Fig. 6. Photomicrographs of sandstone from Jhelum river bed aggregate.

Table. 4. Mineralogical analysis of aggregate.

Sample No.	Quartz %	Magnetite %	Hematite %	Feldspar %	Mica %	Classification	Strained Quartz %	ASR
M-1	60	3	-	15	11	Schist	25	Prone to ASR
M-2	61	5	-	16	18	Schist	27	Prone to ASR
M-3	80	5	-	15	-	Sandstone	3	Suitable
M-4	85	4	-	7	4	Quartzite	30	Prone to ASR
M-5	91	4	-	3	2	Sandstone	4	Suitable
M-6	89	2	-	5	4	Quartzite	15	Prone to ASR
M-7	90	2	-	6	1	Quartzite	12	Prone to ASR
M-8	88	5	-	5	2	Sandstone	6	Suitable
M-9	92	2	-	2	4	Quartzite	17	Prone to ASR
M-10	89	5	-	4	2	Quartz Arenite	4	Suitable
M-11	75	2	-	21	2	Sandstone	15	Prone to ASR
M-12	80	5	3	11	-	Sandstone	6	Suitable

5. Conclusions

The achieved compressive strength for concrete classes of A, B, C and D at the age of 7 days and 28 days falls within specified guidelines and suggests its suitability for mechanical behavior of normal weight concrete. Mineralogical investigations of Jhelum river aggregates revealed that majority of aggregate components like sandstone and quartz arenite neither contain strained quartz nor showed any expansion in mortar bar test are not prone to ASR. Whereas, some of the component rocks of river aggregate such as schist, quartzite and sandstone contain an average of 15% strained quartz also exceeding the mortar bar specified limits are prone to ASR. It is recommended that those aggregates having low concentrations of strained quartz can be used in concrete as aggregate with ordinary Portland cement. As deleterious material exceeds the limits (33%) in Jhelum river bed aggregate so it can only be used for normal weight concrete as coarse aggregate by using it with slag cement or additives i.e. Fly Ash, GGBFS etc. On using with slag cement, the approximate cost of concrete per cubic meter will be 9500 PKR.

Authors' contribution

Muhammad Sanaullah did research hypothesis, write up and establishing conclusions from the results of study. Zakir Hussain involved in Sample collection and testing. Zaheer Yousaf helped in validation of results to the ASTM standards. Sajid Rashid Ahmad reviewed the manuscript for technical corrections. Menal Zaheer did statistics of the manuscript and Literature review.

References

Aginam, C. H., Chidolue, C. A., Nwakire, C., 2013. Investigating the effects of coarse aggregate types on the compressive strength of concrete, International Journal of Engineering Research and Applications (IJERA), 3(4), 2-6.

Ahsan, N., Chaudhry, M.N., Gondal, M.I., Khan, Z.K., 2009. Allai Aggregate for Rehabilitation and Reconstruction of October 8, 2005 Earthquake affected Allai-Banan area, NWFP, Pakistan. Geol. Bull. of Punjab University, 44, 43-54.

Batalla, R.J., Vericat, D., Gibbins, C.N., Gacia, C.G., 2010. Incipient Bed-

Material Motion in a Gravel-Bed River: Field observations and measurements. Published online in 2010 as part of U.S. geological survey scientific investigations report, 2010-5091, 2.

Chandrashekar, A., Maneeth. P.D., 2014. Performance appraisal of river stone as a coarse aggregate in concrete, Int. Journal of Engineering Research and Applications, ISSN: 2248- 9622, 4(1), 1-10.

Maharjan, S., Tamrakar, N.K., 2007. Evaluation of gravel for concrete and road aggregates, Rapti River, Central Nepal Sub-Himalaya, Bulletin of the Department of Geology, Tribhuvan University, Kathmandu, Nepal, 10, 1.

Majid, C. M., Bhatti, T. J., Chaudhary, M. N., 2013(a). Alkali Silica Reaction (ASR) Potential of Sand and Gravels From NW-Himalayan rivers and their Performance as Concrete Aggregate At Three Dams In Pakistan, Sci. Int.(Lahore),25(4), 893-899.

Majid, C. M., Bhatti, T. J., Chaudhry, M. N., 2013(b). Alkali silica reaction (ASR) potential of sand and gravels from NW-Himalayan rivers and their performance as concrete aggregate at three Dams In Pakistan, ISSN 1013-5316; CODEN: SINTE 8, Sci. Int.(Lahore), 25(4),893-899.

Marku, J., 2015. Alkali-silica expansion potentiality of Erzeni river bed aggregates (Albania) and the risk of corrosion in concretes produced with them, 56, 5.

Naeem, M., Khalid, P., Sanaullah, M., Din, Z., 2014. Physio-mechanical and aggregate properties of limestone from Pakistan. Acta Geod. Geophys., 49 (3), 369-380.

Nemati, K.M., 2015. Aggregate for concrete, Concrete Technology: University of Washington, 1-4.

Niedźwiedzk, D. J., Glinnick, M.A., Gibas, K., Jaskulsk, R., Denis, P., Garbacik, A., 2015. Alkali-Silica Expansion of Heavy Aggregates Used for Nuclear Shielding Concrete, Proc. Int. Symp. Brittle Matrix Composites, Institute of fundamental technological research, 1.

Owens, P. N., Batalla, R. J., Collings, A. J., Gomez, B., Hicks, D. M., Horowitz, A. J., Kondolf, G. M., Marden, M., Page, M. J., Peacock, D. H., Petticrew, E. L., Salomons, W., Trustrumi, N. A., 2005. Fine-grained sediment in river systems: environmental significance and management issues, 1-2.

Qureshi, M.K.A., Shiehk, M.I., Khan, M.A., 2004. Geology and Environmental Concerns of the Jhelum area, Punjab, Pakistan. Geological survey of Pakistan, 699, 1-7.

Sanaullah, M., Ahmad, S.R., Yousaf, Z., Abbas, Z., Akhtar, Z. H., Zaheer, M., Hamza, A., 2017. Effect of Course Aggregate and Slag Type on the Mechanical Behavior of High and Normal Weight Concrete Used at Barrage Structure". Int. J. Econ. Environ. Geol. 8(2), 21-27.

Timm, H.Z., 2002. Characteristics, Dynamics and Importance of Aggregates in Rivers. An Invited Review, Institute for Ökologie, AG Limnologie, Friedrich-Schiller-Universität Jena, Winzerlaerstrasse, 10, 1.