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POTENTIAL OF ALKALI SILICA REACTION IN CONCRETE USING KASHMIR AGGREGATE

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ABSTRACT

The mountainous belt of Kashmir, bearing complex geological formations, provides aggregates the have potential to be used in construction industry for both small as well as large scale projects. However, a very expansive reaction, known as Alkali-Silica Reaction (ASR) must be carefully evaluated to ensure their suitability and to minimize durability problems in concrete structures. The present study aims to analyze the potential of Alkali silica reactivity in aggregate samples collected from three different quarries of Kashmir region. These aggregates were examined through chemical analysis, petrographic analysis and standard test procedures, including ASTM C 227 and ASTM C1260. Based on the standard expansion limits for mortar bars, all the aggregates sources were identified as potentially reactive. Mortar cubes were also analyzed at different ages to determine the mechanical properties under different ASR conditions. The results reveal that reduction observed in the concrete properties varied among different aggregate sources, depending on their chemical and mechanical properties of aggregates. It was observed that the reduction in strength was found to be inversely proportional to the expansion observed in the mortar bars.

Keywords: Alkali Silica Reaction, Chemical analysis, Petrographic Analysis, Cubes, Prisms, Mortar Bars.

1. Introduction

The durability of Concrete is a performance-based property of concrete, in which concrete provides long term resistance against external environmental effects like chloride, sulfate, freeze-thaw, carbonation, Alkali Silica Reaction etc. Alkali-silica reaction (ASR) is a pronounced disease in concrete structures, which poses serious durability and safety problems in concrete structures globally. From decades, Alkali Silica Reaction has been damaging the different types of concrete structures particularly dams, bridges, and concrete pavements in many countries like Canada, Pakistan, Australia and others [1-3].

ASR is a detrimental reaction between the alkaline constituents in cement and reactive silica content present in reactive aggregates. The chemical reaction between alkali hydroxide and amorphous silica in pore solution leading to the formation of an expansive gel. In the presence of moisture this gel swells. Upon expansion, the gel volume increases in pore spaces and produces internal tensile stress. These tensile stresses lead to the cracking and deterioration in concrete. The formation and severity of alkali silica reaction depends on several factors: the existence of reactive silica in aggregates, the existence of alkalis (sodium and potassium) in the cement paste, and availability of sufficient moisture [4,5]. There are different test methods to evaluate the reactivity of aggregates in concrete mixes against alkali silica reaction. These standard test methods include the mortar bar test ASTM C-227, accelerated mortar bar method ASTM C1260, ASTM C 1295 and petrographic analysis ASTM C 295.

The geological constituents of aggregates are the major contributors to making this expansive reaction. Aggregates which contain silica such as opal, chalcedony, flint, and strained quartz are specifically responsible for exhibiting ASR potential. The reactivity of aggregates varies according to their geological source [7]. In the different quarry of mountainous regions like Kashmir has diverse mineralogical compositions. Studies have shown that certain aggregates from this region possess alkali silica reaction due to the existence of reactive silica content in aggregates [6]. Petrographic analysis shows that some aggregates contain reactive minerals, making them more prone to this deleterious reaction. It is important to investigate the mechanical properties of concrete that contain aggregates from unknown sources to assess the structural integrity and service life of concrete structures.

This research carries in two phases. Initially the chemical and physical properties of materials have been determined. In second phase, the ASR expansion in concrete was determined through ASTM 227 and ASTM 1260. This type of knowledge can help to understand the behavior of aggregates from specified Kashmir region before using concrete structures.

2. Materials

The aggregates used in this research are obtained from Kashmir. The selected source of aggregates is taken from mountains terrain located in Danga, Barnala, and chichian. These aggregates shown in Figure 1 were obtained after crushing large rock fragments at industrial crusher plants. After that the aggregates were crushed to required size available in standards. The locally available ordinary Portland cement was used in this research.


(a) (b) (c)

Figure 1. Illustration of aggregates: (a) Barnala aggregates, (b) Chechian aggregates, (c) Danga aggregates

3. Experimental methodologies

3.1 Assessment of materials properties

The composition of aggregates was investigated by petrographic analysis. The standard procedure in ASTM C 295 is used to investigate the mineralogical characteristics of aggregates.

For the physical properties of aggregates various tests were performed. The standard procedure in ASTM C 29 is used to measure the bulk density. Specific gravity and water absorption were evaluated according to ASTM C 127. Crushing value and impact value of aggregates were investigated by standard procedures of BS 812-110 and BS 812-112. The abrasion resistance was measured by loss angles abrasion test as per ASTM C 535.

The physical properties of cement were also examined by various tests. The consistency, setting time, fineness, and soundness were measured by following ASTM C187, ASTM C191, ASTM C 184 and BS-EN 196-3 procedure respectively.

3.2 Preparation of mortar expansion bars

The expansion characteristics of different sources of aggregates with cement were determined using ASTM C227 and ASTM C1260. For each source of aggregate, six mortar bars were cast in total, with three prepared for ASTM C227 and three designated for ASTM C1260 testing.

3.2.1 ASTM C227 and ASTM C1260 testing procedures

For both ASTM C227 and ASTM C1260 testing procedures, the mortar specimens were prepared using a cement-to-aggregate ratio of 1:2.25 and a water-to-cement ratio of 0.47.

Mixing of mortar was performed according to ASTM C305. The mortar was then poured into two gang prism molds having dimensions of 25 x 25 x 285mm^3. The mortar was poured into two layers and then consolidated on the vibration table. After molding stage, the specimens were covered with gunny bags and plastic sheets to prevent the loss of moisture for 24 hours. After carefully demolding the specimen, the initial length of each specimen was precisely recorded on each face of the bar. The length was measured using a digital length comparator (in accordance with ASTM C490), calibrated with reference bar prior to measuring the targeted specimen. After that, the specimens were placed in airtight water container (Figure).

(a) (b)

Figure 2. (a) Mortar Mixing, (b) Martar bars before demolding

Afterwards, the container holding six specimen was placed in an oven and maintained the temperature of 38^{0}C for 12 days, following the ASTM C227 testing procedure. Then, the temperature was reduced to 25^{0}C for 16 hours and length was measured over a 14-day period. Subsequent readings were measured at different intervals for up to six months. Each time, length was measured by following the same procedure as before, and the water was also replaced.

Following the ASTM C1260 procedure, after recording the initial readings, the container was placed at 80°C. After 24 hours, a zero reading was recorded. The specimens were then placed in a 1N NaOH solution at 80°C. Length measurements were taken at the desired ages of 14 and 28 days.

3.2.2 Mechanical testing procedures

To evaluate compressive strength, cubes with dimensions of 50 × 50 × 50 mm^3 were prepared and tested in accordance with ASTM C109. All specimens were properly consolidated using the tamping method described in the standard, and their surfaces were carefully finished to ensure uniformity across samples. After casting, Specimens were maintained under their respective curing environments until the scheduled testing intervals. Control specimens submerged in tap water were tested to serve as a comparison against ASR-affected specimens.

4. Results and discussion:

4.1.Characterization of cement

Table 1 presents the chemical properties of the cement. It was found that the alkali content (Na_2O equivalent) is 0.85%, which exceeds the specified limit of 0.6% as defined in ASTM C114. The alkali content in cement primarily depends on the chemical composition of the raw materials and manufacturing process [8].

Table 1: Chemical properties of cement

Constituents (%)	Ordinary Portland Cement	ASTM C 114 limits

SiO_2	20.90	20 min.
Al_2O_3	5.22	6 max.
Fe_2O_3	3.20	6 max.
CaO	61.32	-
MgO	2.40	6 max.
Free lime	1.22	2 max.
SO_3	2.23	3 max.
L.O.I	2.64	3 max.
Na_2O	0.44	-
K_2O	0.63	-
Na_2O_e	0.85	0.6 max.

The physical properties of the cement are presented in Table 2. All measured values were within the specified limits outlined in the relevant standards. The measured consistency satisfied the ASTM C187 requirements, and the initial and final setting times were within the specified limits of ASTM C150. The soundness of the cement met the specifications outlined in EN 197-1.

Table 2: Physical properties of cement

Properties	Value	Limit
Standard consistency	25%	-
Initial setting time	90 min.	>45 min
Final setting time	185 min.	>375 min
Fineness (passing sieve#200)	94.20 %	Min. 90%
Soundness	4 mm	Max. 10 mm

4.2. Petrographic results of aggregates

Figures 3, 4, and 4 illustrate the mineralogical composition of different aggregate sources. Quartzite is identified as the dominant component, comprising between 62% to 78% of the total aggregate composition with respect to different aggregate sources. In addition, other minerals such as acidic volcanics and quartz wacke were also present, contributing between 3% to 12% depending on the specific source. Previous studies have recognized that these minerals particularly quartzite containing strained quartz, volcanic glass from acidic volcanics, and microcrystalline silica in quartz wacke have been found as highly reactive to alkalis [9] [10]. Due to the presence of these potentially reactive minerals in aggregates, it becomes important to investigate the alkali-silica reactivity (ASR) potential of the aggregates before their use in concrete structures.

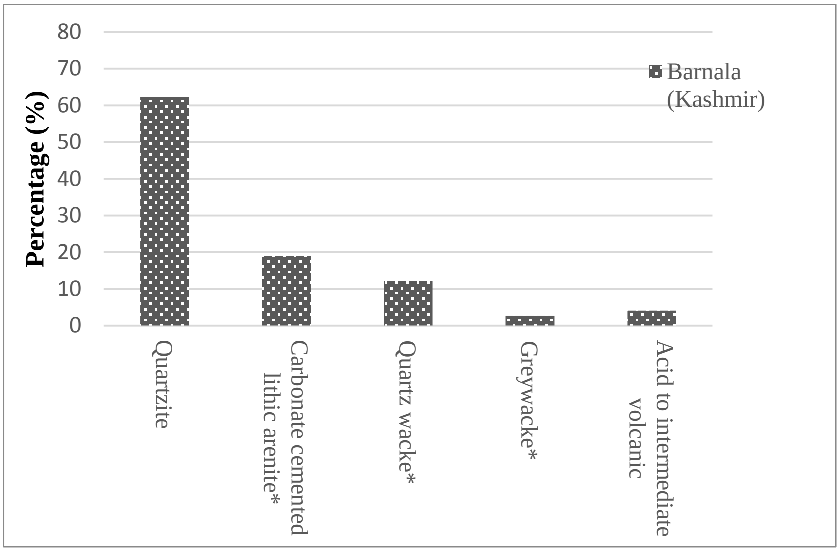

Figure 3: Petrographic results of Barnala Aggregates

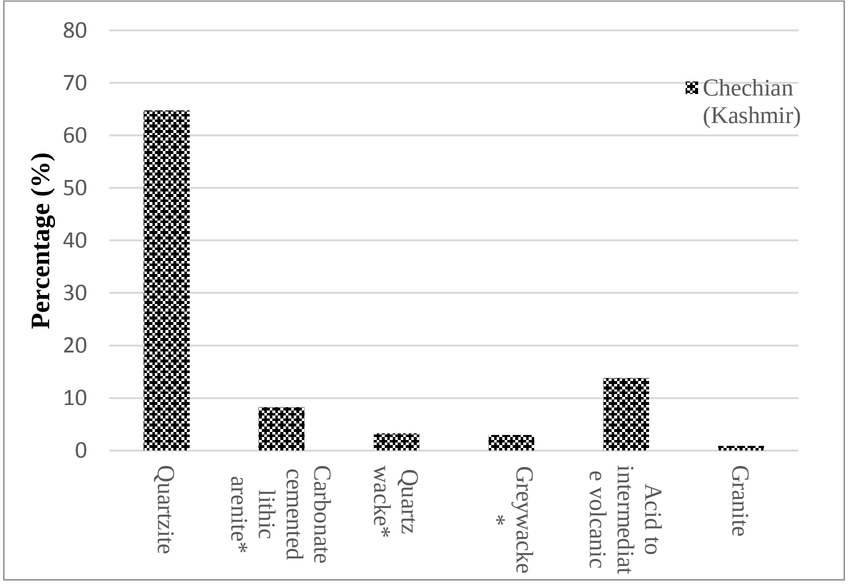

Figure 4: Petrographic results of Chechian Aggregates

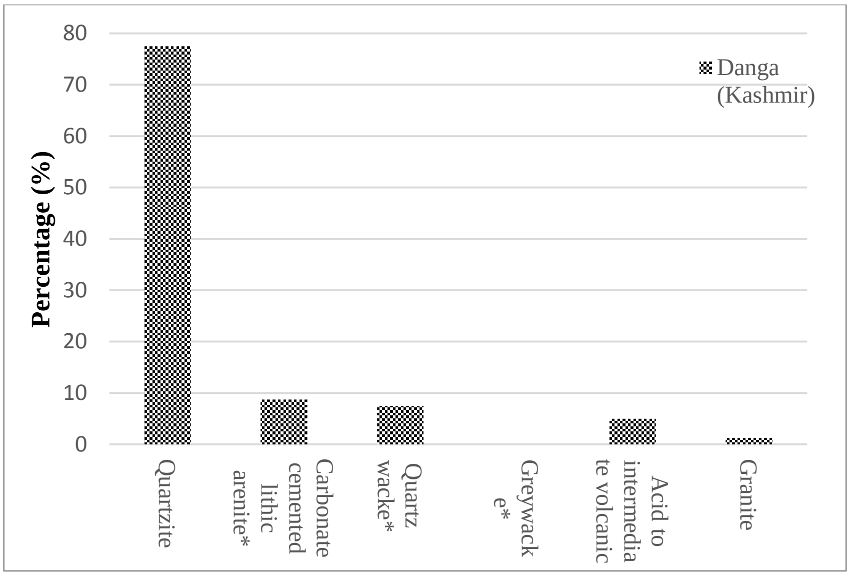

Figure 5: Petrographic results of Danga Aggregates

4.3. Physical properties of aggregates

Table 3 shows the physical properties of Barnala, Danga, and Chechian aggregates. The impact values of the aggregates range from 5.0% to 5.6%. Chechian aggregate has the lowest impact value, while Danga source has the highest. The impact value for good quality aggregates should typically be less than 25% [11,13].

The specific gravity varies between 2.55 and 2.60. The value for Chechian source was slightly higher than Barnala and Danga, suggesting it is less porous and likely to be more durable. Danga exhibits slightly higher absorption, indicating more porosity.

Crushing values range from 11.3% to 13.5%. Chechian has the lowest crushing value, indicating the highest resistance to crushing under gradual load. Abrasion values range from 19.18% to 24.98%. Chechian again shows the lowest abrasion value, indicating better resistance to surface wear. Danga with 1432.7 kg/m³ exhibits noticeably lower bulk density, suggesting relatively higher porosity and less compactness compared to Barnala and Chechian aggregates. It is concluded that all samples are within their permissible limit [13].

Table 4 shows the chemical properties of aggregates. The presence of high silica content showed that all three sources are belong to siliceous group.

Table Physical and chemical properties of aggregates

Table 3: Physical properties of aggregates

Properties	Barnala	Danga	Chechian	Limits [ASTM C33,11,12]
Bulk Density (Kg/m3)	1545.45	1432.7	1545.4	1200-1760
Specific Gravity	2.56	2.55	2.6	>2.5
Water Absorption (%)	0.99	1.02	0.93	<1
Crushing Value (%)	15.0	15.5	13.3	<25
Impact Value (%)	9.2	9.6	9.0	<25
Abrasion Value (%)	24.98	24.52	19.18	<50

Table 4: Chemical properties of aggregates

Constituents (%)	Barnala	Danga	Chechian
CaO	1.1	1.02	0.82
MgO	0.2	0.1	0.4
SiO2	95.75	96	95.42
SO3	2.23	0.2	0.27
Al2O3	0.52	0.65	1.2
Fe2O3	0.28	0.34	0.25
L.O.I	0.8	0.81	0.99

4.4. Mortar bar results

Figure 6 shows the expansion of mortar bars prepared with target aggregates tested under ASTM C227. The expansion continuously increased for all three sources up to 180 days. Among the samples, Danga aggregates exhibited the highest expansion, reaching approximately 0.08%. According to ASTM C33, the expansion limit for aggregates tested with ASTM C227 is 0.10% at 180 days. In this study, although the expansions rate of aggregates remained below the 0.10% threshold, the increase in expansion observed. Figure 7 shows the average expansion of aggregates tested under ASTM C1260 conditions at 14 and 28 days. The average expansion values of specimen were more than 0.1% and 0.2% on 14 and 28 days respectively. If an aggregate shows expansion greater than 0.10% at 14 days or greater than 0.20% at 28 days, it is considered potentially deleterious due to alkali-silica reaction [2].

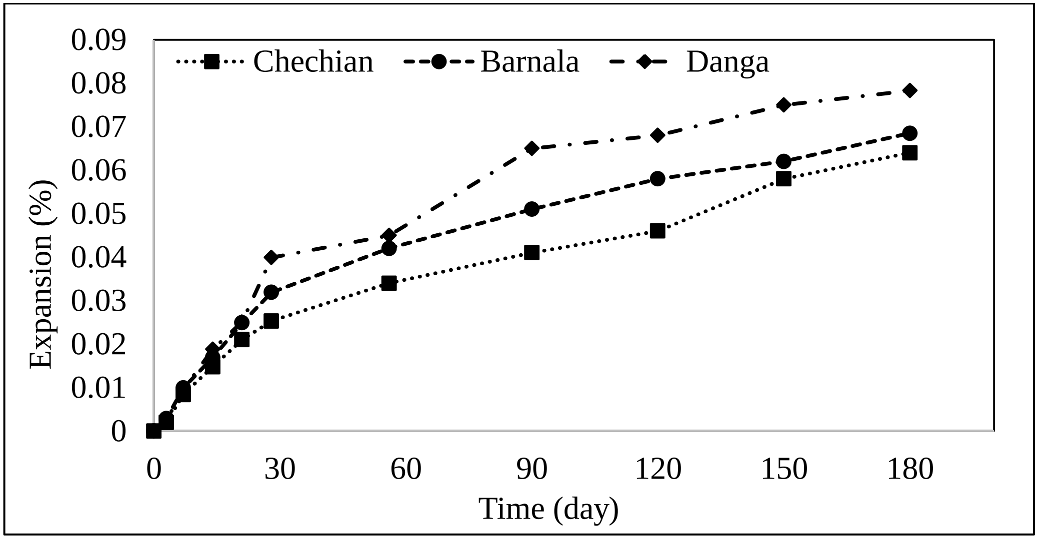

Figure 6: Mortar bar expansion according to ASTM C227

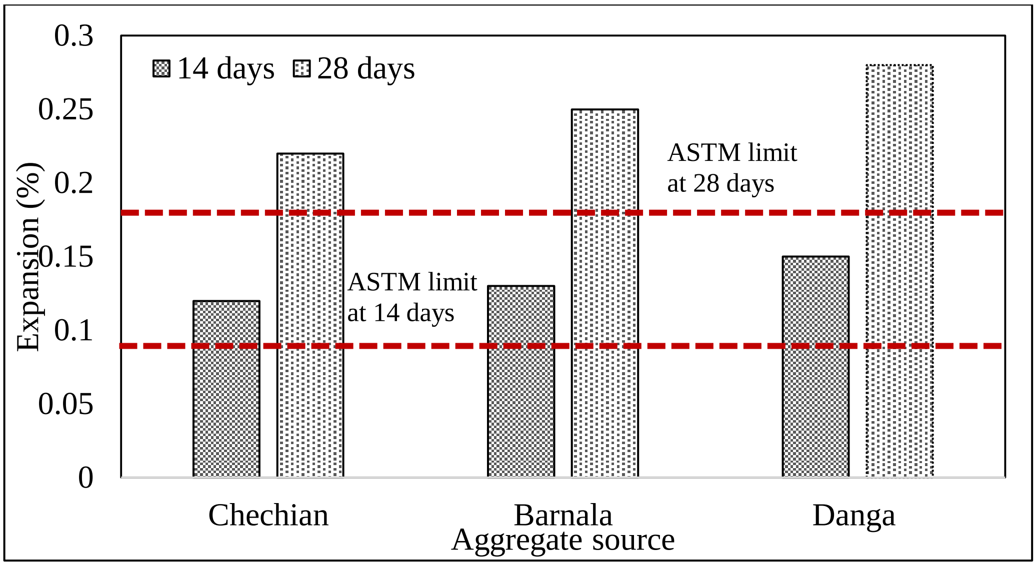

Figure 7: Mortar bar expansion according to ASTM C1260

4.5. Effect of ASR on compressive strength

The figure illustrates the compressive strength development of concrete samples made with targeted aggregates sources and cured under ASTM C227 conditions. The specimens are evaluated at 28, 90, and 180 days. The results are shown for both control specimen and under ASR exposure conditions. It is observed from results that Chechian aggregate source displays the highest compressive strength. However, the strength reduction under ASR exposure, Danga aggregate is more significant compared to Barnala and Chechian, indicating that Danga aggregates may be more vulnerable to ASR-related degradation. A similar trend can be seen in the figure in which specimens were cured according to ASTM C1260. The reduction in compressive strength was more significant in sample Danga. This behavior is consistent with the expansion results, where Danga exhibited the highest expansion due to alkali-silica reaction.

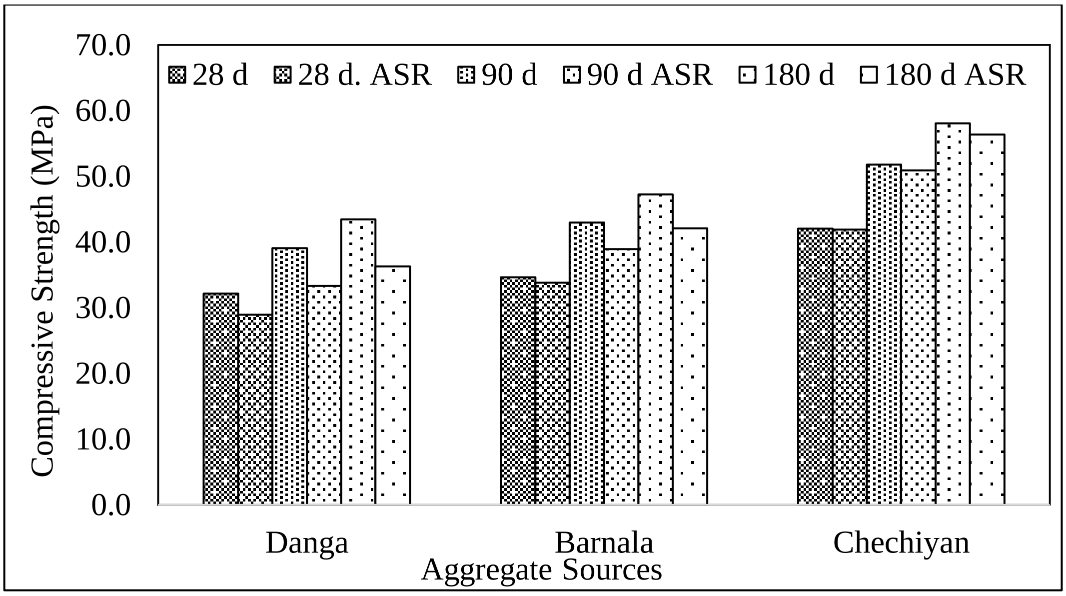

Figure 8: Comparison of compressive strength of specimen under ASTM C227

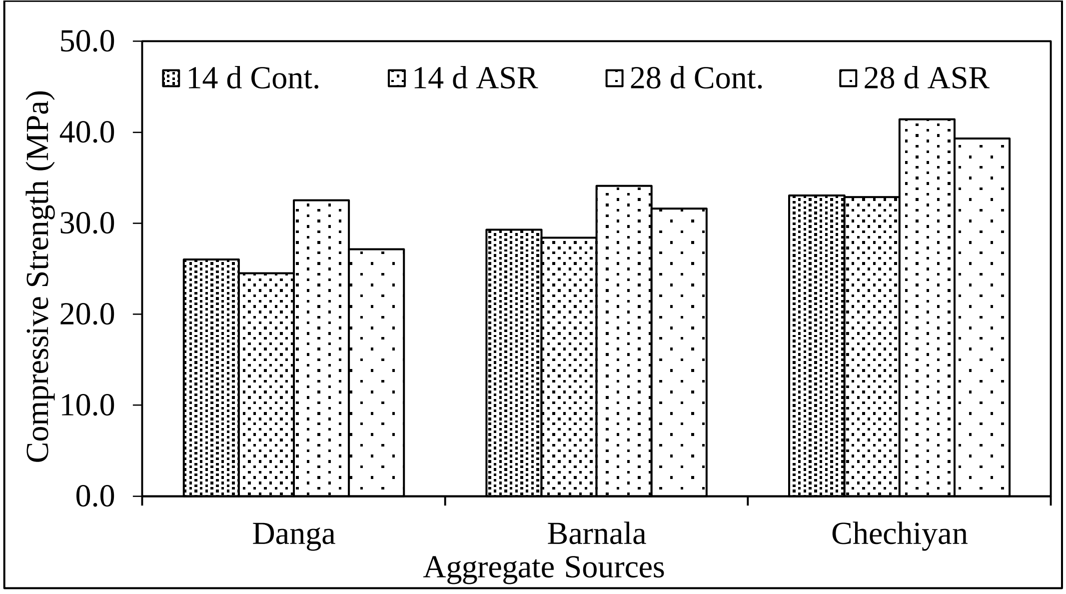

Figure 9: Comparison of compressive strength of specimen under ASTM C1260

5. Conclusions

Based on the experimental results and analysis, the following conclusions can be drawn:

1) The petrographic analysis of aggregates confirms the presence of reactive minerals in aggregates.

The aggregates from Danga, Barnala, and Chechiyan showed varying degrees of alkali-silica reactivity.

2) Accelerated mortar bar tests (ASTM C1260) confirmed that all aggregates crossed the critical expansion limit of 0.2%, indicating potential deleterious behavior.

3) The compressive strength under ASR exposure decreased more significantly in Danga aggregates compared to Barnala and Chechian. The maximum expansion value was observed in Danga aggregates, reaching at 0.28%.

4) Further long-term testing such as ASTM C1293 is recommended to confirm the long-term performance of these aggregates.

REFRENCES

[1] C. Rogers, P. E. Grattan-Bellew, R. D. Hooton, J. Ryell, and M. D. A. Thomas, "Alkali–aggregate reactions in Ontario," Canadian Journal of Civil Engineering, vol. 27, no. 2, pp. 246–260, Apr. 2000, doi: 10.1139/cjce-27-2-246.

[2] M. J. Munir, A. U. Qazi, S. M. S. Kazmi, A. Khitab, S. Z. Ashiq, and I. Ahmed, "A literature review on alkali silica reactivity of concrete in Pakistan," Pakistan Journal of Science, vol. 68, no. 1, pp. 53–62, Mar. 2016.

[3] A. Shayan, A. Xu, and F. Andrews-Phaedonos, "Implications of alkali-aggregate reaction for three concrete bridges," in Proceedings of Concrete 2013: Materials and Structures, Gold Coast, Australia, Oct. 2013, pp. 1–14.

[4] S. Abbas, A. Sharif, A. Ahmed, W. Abbass, and S. Shaukat, "Prospective of

sugarcane bagasse ash for controlling the alkali-silica reaction in concrete incorporating reactive aggregates," Structural Concrete, vol. 20, no. 6, pp. 1916–1928, 2019, doi: 10.1002/suco.201900284.

[5] J. A. Farny and S. H. Kosmatka, Diagnosis and Control of Alkali-Aggregate Reactions in Concrete. Skokie, IL, USA: Portland Cement Association, 1997.

[6] S. K. Bukhari, "Potential alkali silica reactivity of aggregates from different sources of Kashmir and mitigation measures thereof," Asian Journal of Civil Engineering, vol. 20, no. 3, pp. 437–442, 2019, doi: 10.1007/s42107-019-00117-1.

[7] M. A. Berubé, M. Thomas, and M. D. A. Thomas, "Alkali–silica reaction in concrete: A review of identified reactive silica forms," Cement and Concrete Research, vol. 36, no. 7, pp. 1223–1236, 2006, doi: 10.1016/j.cemconres.2006.01.013.

[8] H. F. W. Taylor, Cement Chemistry, 2nd ed. London, UK: Thomas Telford Publishing, 1997.

[9] M. Tapan, "Alkali–silica reactivity of alkali volcanic rocks," European Journal of Environmental and Civil Engineering, vol. 19, no. 1, pp. 94–108, 2015, doi: 10.1080/19648189.2014.939303.

[10] C. M. Majid, T. J. Bhatti, and M. N. Chaudhry, "Alkali silica reaction (ASR) potential of sand and gravels from NW-Himalayan rivers and their performance as concrete aggregate at three dams in Pakistan," Science International (Lahore), vol. 25, no. 4, pp. 893–899, 2013.

[11] M. Alexander and S. Mindess, Aggregates in Concrete, 13th ed., New York, NY, USA: Modern Concrete Technology, 2005.

[12] A. M. Neville, Properties of Concrete, 5th ed., Edinburgh, UK: Pearson Education Asia Pvt. Ltd., 2000.

[13] ASTM International, Standard Specification for Concrete Aggregates, ASTM C33/C33M-08, West Conshohocken, PA, USA: ASTM International, 2008.