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Research on Suitability of Crushed Andesite-Basalt Rock Aggregates in Ardahan Province for Concrete Production

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Abstract: In this study, suitability of aggregates, obtained from an aggregate quarry of Balıkçılar village meeting significant portion of crushed stone aggregate demand of construction sector and used in constructions in central town of Ardahan province, for concrete production and concrete compressive strength were investigated. Samples taken from the selected quarry were subjected to physico-mechanical analyses to determine their compliance with the relevant standards on sufficiency, physical, mechanical characteristics, chemical and mineralogical properties. Then, concrete was produced from these aggregates in a laboratory and strength tests were conducted on concrete specimens. Cement dosage was taken as 270 kg/dm^3 for C20/25, 300 kg/dm^3 for C25/30 and 360 kg/dm^3 for C30/37. Results revealed that majority of the values were within the limit values specified in relevant standards. Although the amount of fine materials and alkali-silica reaction were close to limit values, concrete tests did not reveal any negative effects and concrete strength values were found to be above the limits specified in relevant standards. Thus, aggregates should be used through taking relevant measures. It was concluded that aggregates should be washed through and separated in different granulometric portions to produce quality and strong concrete. Further research is recommended for mineral admixtures to control alkali-silica reaction.

Keywords: Aggregate, crushed stone aggregates, concrete, Ardahan, andesite-basalt

Ardahan İli Andezit-Bazalt Kırmataş Agregaların Beton Yapımında Kullanılabilirliğinin Araştırılması

Öz: Bu çalışmada, Ardahan ili Merkez ilçesinde kırmataş agrega gereksiniminin önemli kısmını karşılayan Balıkçılar köyü agrega ocağından elde edilen kırmataş agregaların beton üretimi ve dayanımı yönünden önemli teknik özellikleri belirlenmiş, mühendislik özellikleri ve beton yapımında kullanılabilirliği araştırılmıştır. Bu amaçla seçilen agrega ocağından alınan örnekler üzerinde standartlara uygunluk, yeterlilik deneyleri yapılarak agregaların fiziksel, mekanik özellikleri ile kimyasal ve mineralojik özellikleri belirlenmiş, bu agregalarla laboratuvar ortamında beton üretilerek mukavemet deneyleri gerçekleştirilmiştir. Elde edilen sonuçlardan agregaların önemli özelliklerinin uygun sınırlar içerisinde kaldığı gözlenmiştir. Agregalardaki ince madde miktarı ve alkali silika reaktifliği sonuçları istenilen koşulları zorlasa da, ocaktan elde edilen agregalarla üretilen betonlar üzerinde yapılan gözlem ve deneylerde olumsuz etki görülmemiş, beton dayanım değerleri standartlarda önerilen değerlerin üzerinde çıkmıştır.

Anahtar Kelimeler: Agrega, kırmataş agrega, beton, Ardahan, andezit-bazalt

* This study presents partial results of a Graduate Thesis.

1. Introduction

Aggregates are sand and gravel-like materials able to form a massive body when they were mixed and hardened with binding materials. Fine aggregates are used together with binding materials to produce internal or external floor surfaces or road pavements. Beside houses and infrastructures under abrasion, impact, freeze-thaw processes, aggregates are also commonly used in construction of dams, irrigation structures and animal housings. They are the primary component of constructions and play significant roles in mechanical behavior of concrete and in resistance against adverse environmental conditions in time. Aggregate quality is the key parameter to be considered for a quality concrete. About 70% of a regular concrete is composed of aggregates. Thus, physical characteristics and composition and granulometry of aggregates have significant impacts on concrete quality. So, for a quality concrete, such characteristics of aggregates should be analyzed in detail and tested through standard test procedures before to use them in concrete manufacture.

Crushed stone aggregate production is increasing to meet the aggregate demands of ever-growing construction industry. Natural washed-sieved aggregates of sand-gravel quarries are now insufficient in meeting current demands. Thus, crushed stone aggregates are supplied from quarries instead of natural ones.

In current research site, new buildings are constructed in urban and rural sections to meet sheltering needs of increasing population and housing needs of livestock. Therefore, province-wide concrete demands are increasing and modern concrete plants are being constructed to meet such demands with quality concrete meeting the current regulations and standards. Increased competitive atmosphere, construction inspection system, inspections of accredited laboratories all increased the quality of concrete produced in these plants. Concrete manufacturers started to open aggregate quarries for production of quality and cost-effective concrete. Industrialization, urbanization, ever-increasing building demands, infrastructures and location of the region over seismic belts even increased the significance of aggregates to be used in constructions.

Although concrete is used as the construction material in majority of agricultural buildings in Ardahan region, there aren't any studies carried out about aggregate characteristics and effects of such characteristics on concrete quality. Therefore, rational use of construction materials should be investigated in province for both long-life and low cost constructions. Characteristics of crushed stone aggregates should be determined for reliable use of these aggregates in concrete production.

In this study, suitability of crushed stone aggregates of an aggregate quarry meeting a large portion of crushed stone aggregate demands of Ardahan province was investigated. The samples taken from the selected quarry were subjected to standard compliance and sufficiency tests to determine their physical, chemical and mineralogical characteristics and concrete samples produced from these Andesite-Basalt aggregates were subjected to strength tests. Recommendations were provided to improve the characteristics not complying the relevant standards, current problems in concrete production for rural structures were identified and possible solutions were proposed.

2. Material and Method

Aggregate samples were taken from a crushed stone aggregate quarry located in Balıkçılar village locality of Çamlıçatak section of Ardahan province (Figure 1); as cementing agent, Portland Calcareous Cement (Table 1) (CEM I/42,5 R) (TS EN 196-2, 2014) (Anonymous, 2015) was supplied from Tokat Cement Factory.

Representative aggregate samples were taken from different sections of the quarry through quartering method in accordance with TS EN 932-1 (1997) and TS EN 932-2 (1999). Granulometric analysis, loose and compacted bulk densities, specific weight, water absorption, fines ratio, organic matter content, frost resistance, resistance, alkaline-silicate reaction, mineralogical analyses and concrete strength tests were performed on these samples. Each test was performed in triplicates and average of these three measurements was taken.

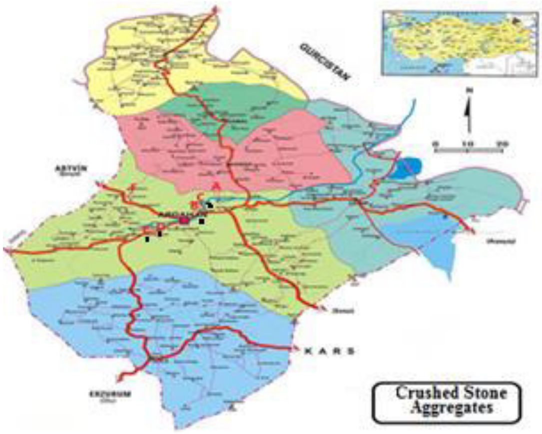

Figure 1. Distribution of aggregate quarries of the region

Sieve analysis and fineness modules were determined in accordance with the principles specified in TS 706 EN 12620+A1(2009), TS ISO 3310-1 (2009), TS EN 933-1 (2012) and TS ISO 3310-2 (2015). Loose and compacted bulk densities were determined in accordance with TS EN 1097-3 (1999); specific weight and water absorption tests with TS EN 1097-6 (2013) and TS EN 1097-2 (2015); organic matter content with Ekmekyapar and Örüng (2001) and TS EN 1744-1 (2013); frost resistance with TS EN 1367-1 (2008); abrasion resistance with TS EN 1097-2 (2015). Ratio of fines was determined through three different methods as of washing, sand-equivalent and methylene blue methods (TS 706 EN 12620+A1, 2009; TS EN 933-10, 2010; TS EN 933-1, 2012; TS EN 933-9+A1, 2014; TS EN 933-8, 2015e). Aggregate potential reactivity was determined with a mortar bar in Karadeniz Concrete Technologies and Construction Materials Laboratory through accelerated mortar bar test in accordance with TS 13516 (2012) and ASTM C-1260-94 (1994). Chemical and abrasion mineralogical characteristics of the aggregates were determined in Technology Center of Erciyes University (TEKMER) with X-ray florescence (XRF) spectrophotometer and X-ray diffractometer (XRD) (Lachance and Traill, 1966; ASTM C88, 1997; ASTM C14694a, 2000).

Table 1. Physical and chemical characteristics of the cement used in this research

CHEMICAL ANALYSES		
COMPONENTS (%)	TEST RESULT	TS EN 197-1 VALUES
MgO	1.17	5.0 Max.
SO_3	2.60	4.0 Max.
Chloride (CI)	0.034	0.1 Max.
Ignition loss	2.96	5.0 Max.
Insoluble matter	0.43	5.0 Max.
PHYSICAL ANALYSES		
TESTS	TEST RESULT	TS EN 197-1 VALUES
Blaine	3657	
Specific weight (g/cm^3)	3.10	
Fineness (90 μ)	0.5	
“Initial set (minute)	121	60 Min.
Final set (minute)	240	600 Max.
Volume expansion (mm)	1.0	10 Max.
STRENGTHS (N/mm²)		
	TEST RESULT	TS EN 197-1 VALUES
2-day (12-18.01.2015)	29.2	20 Min.
7-day (05-11.01.2015)	41.9	-
28-day (15-21.12.2014)	50.9	42.5 Min.

The maximum aggregate size to produce a concrete was selected as 25 mm and cement dosage was selected as 270 kg/dm^3 for C20/25, 300 kg/dm^3 for C25/30 and 360 kg/dm^3 for

C30/37 (TS 802, 2009). Cube samples were casted. The principles specified in Tutmaz (2009), TS 3323 (2012), TS EN 12390-3/AC (2012), TS EN 1097-2 (2015d) were followed for cement dosage, mixture production, sample preparation and curing. Three specimens were produced for each test. Specimen unit weights at 28th day were determined in accordance with Postacıoğlu (1987).

3. Result and Discussion

Aggregate tests

Characteristics of aggregates supplied from Ardahan aggregate quarries are provided in (Table 2).

Table 2. Aggregate chemical analyses (%)

Test		
Fineness modules		2.87
Compacted bulk density (kg/dm³)		1.70
Loose bulk density (kg/dm³)		1.52
Impact resistance (%)		9.60
Dry specific gravity (kg/dm³)	Fine aggregate	2.61
	Coarse aggregate	2.70
Saturaed surface-dry specified gravity (kg/dm³)	Fine aggregate	2.68
	Coarse aggregate	2.73
Apparent specific gravity (kg/dm³)	Fine aggregate	2.68
	Coarse aggregate	2.77
Water absorption (%)	Fine aggregate	2.73
	Coarse aggregate	0.90
Frost resistance (%)	Coarse aggregate	14.29
Abrasion resistance (%)		16.80
Fines ratio (%)		2.00
Sand equivalent (%)		58.00
Methylene blue (gr/kg)		3.18
Drying shrinkage (%)		0.04
Alkali-silica reaction (%)		0.467
Organic matter		none

Compacted and loose bulk density; Compacted bulk density of aggregate samples was measured as 1.71 kg/dm³ and the loose bulk density was measured as 1.52 kg/dm³. Since bulk density values of the aggregate samples were within recommended values, they were considered as suitable for concrete production.

Aggregates with a bulk density of between 1.50-1.85 kg/dm^3 are recommended to be used in concrete production (Batmaz, 2006). Minimum aggregate bulk density was recommended as 1.1 kg/dm^3 (Murdock et al., 1991). Ekmekyapar and Örüng (2001) recommended bulk density of spherical round aggregates as between 1.6-1.8 kg/dm^3 and Yıldırım and Yılmaz (2002) recommended that loose bulk density of concrete aggregates should be higher than 1.35 kg/dm^3.

Specific gravity and water absorbance; Specific gravity was calculated as 2.68 kg/dm^3 for coarse aggregates and 2.73 kg/dm^3 for andesite-basalt aggregates. Since the values were within the recommended limits, aggregates were considered as suitable for concrete production.

Specific gravity of aggregates should be between 2.4-2.8 kg/dm^3. The aggregates with a specific gravity smaller than 2.4 kg/dm^3 are classified as light-weight aggregates (Erdoğan, 1995; Baradan, 1996). Akman (1990) recommended saturated surface-dry specific gravity as between 2.55-2.80 kg/dm³ and Kocataşkın (1975) and Batmaz (2006) recommended these values as between 2.2-2.7 kg/dm^3.

Water absorption ratio was measured as 2.73% for fine aggregates and 0.90% for coarse aggregates. According to TS EN 1008 (2003), the aggregates with a water absorption ratio of less than 1% were considered as resistant to freeze-thaw cycles. However, Çomak (2007) indicated higher water absorption ratios as resistant to freeze-thaw cycles, but the ratios over 1% were considered as low quality aggregates.

Fines ratio; Test were carried out to determine silt and clay content of the aggregates and silt-clay ratio was identified as 2%. In ASTM standards, allowable fines ratio was specified as 3% for concretes exposed to abrasive forces and 5% for the other concretes. In TS 706 EN 12620+A1 (2009), maximum fines ratio was specified as 3% for fine aggregates and such a value should be proved by TS EN 933-9+A1 (2014), methylene blue test or sand-equivalent TS EN 933-8 (2015) test results. Sand-equivalent value was identified as 58% in this study and since this value was below the limiting value (60%), the aggregate was found to be unsuitable. TS EN 933-8 (2015e) methylene blue value was observed as 3.18 gr/kg. The value was expected to be lower than 2 (MB<2 gr/kg) according to TS EN 933-9+A1 (2014). Higher sand-equivalent and methylene blue values indicated that present samples had harmful clay contents. For aggregates with high methylene blue values, special polycarboxylic chemical additives can be used in concrete production.

Organic matter content; Hydroxide solution was used to determine organic matter content of the aggregates and test liquid had a light yellow color. Since this color indicated that test samples did not contain harmful organic matters, aggregates were found to be suitable for concrete and reinforced concrete production.

Frost Resistance; Weight loss in aggregate samples exposed to frost resistance test was observed as 14.29%. In ASTM C88 (1994) and TS 706 EN 12620+A1 (2009), maximum weight loss was specified as 18% for coarse aggregates and 15% for fine aggregates (Batmaz, 2006). Current values were below the recommended the limit values.

Abrasion resistance; Los Angeles abrasion test was applied to determine abrasion resistance of aggregate samples and the weight loss at 500 rotations was observed as 16.8%. According to ASTM standards, weight loss at 500 rotations should not exceed 50% for concrete aggregates. Since current values did not exceed recommended limits, aggregate were found to be suitable with regard to abrasion resistance (TS EN 1097-2, 2015).

***Mineralogical analysis*;** X-ray diffractogram showing the mineralogical structure of the aggregates is presented in Figure 2. Albite, a sodium feldspar, ($Na\ Al\ Si_3\ O_8$) was identified as the dominant mineral and it was respectively followed by calcite and quartz minerals. It was thought that calcite ($CaCO_3$) minerals came from surrounding limestones; quartz (SiO_2) and feldspar minerals ($K_2O.Al_2O_3.6SiO_2$, $Na_2O.Al_2O_3.6SiO_2$) came from surrounding volcanic and metamorphic rocks.

Beside calcite, there were some quartz minerals. Calcite and quartz minerals in crushed stone aggregates may not pose any problems for concrete (TS 706 EN 12620+A1, 2009). Quartz is quite hard (with a Mohs hardness value of 7) and resistant to decomposition. However, feldspar and calcite are not resistant to decomposition. Therefore, aggregates of the present study were found to be suitable for concrete production at medium level. Calcite (with a Mohs hardness value of 3) may pose some problems in concrete production; calcite usually is not desired in aggregates (Tutmaz, 2009).

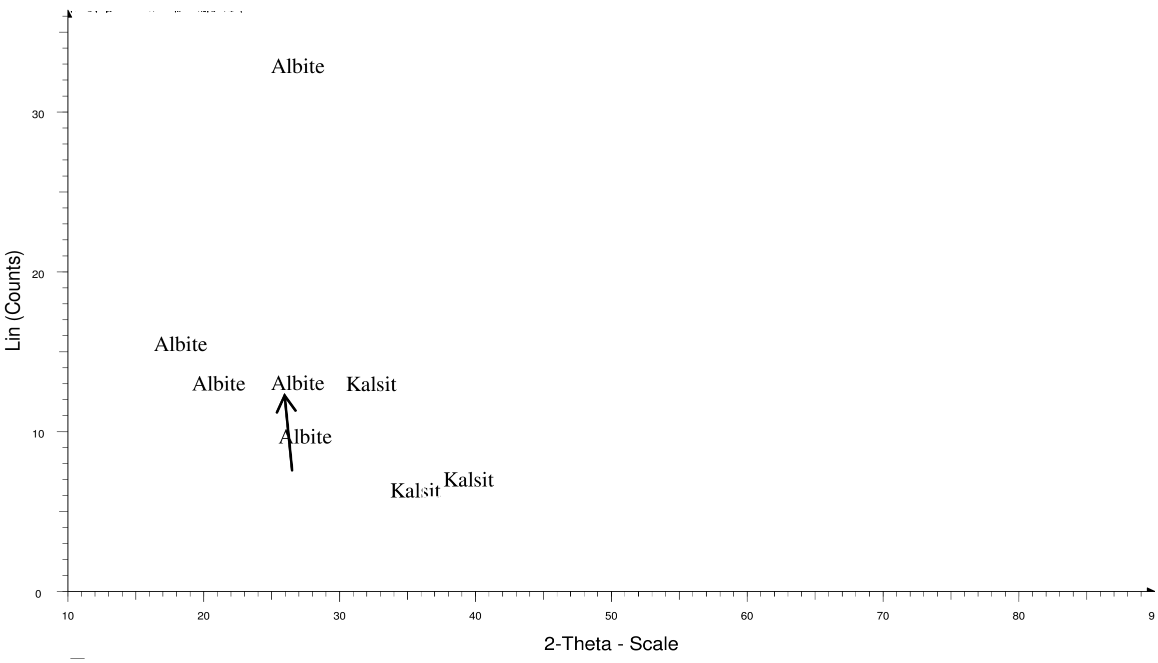

Figure 2. X-Ray diffractogram for mineralogical analysis of the aggregates

Chemical analysis revealed that aggregates had limestones. MgO ratio of aggregates was less than 3% (1.81%), therefore lime content did not pose any problems on concrete production. In aggregates, MgO indicate the existence of dolomite and excessive Fe_2O_3 indicated the existence of hematite, magnetite or iron minerals. SiO_2 usually comes from quartz. SiO_2 content gives acidic and abrasive characteristics to the rock, thus may get a chemical characteristics harmful to reinforcement steel. The rocks with CaO content above 55% are assessed as pure lime (Şenbil et al., 2014). Current analysis revealed that CaO content of aggregates was way below this limit (Table 3).

Table 3. Aggregate chemical analyses (%)

SiO_2	AI_2O_3	Fe_2O_3	CaO	Na_2O	MgO	K_2O	TiO_2	P_2O_5	MnO
55.51	16.33	9.04	7.97	3.40	1.81	1.70	1.28	0.43	0.13
SrO	**SO_3**	**BaO**	**ZrO_2**	**Cr_2O_3**	**Cl**	**PbO**	**ZnO**	**Rb_2O**	**-**
0.10	0.07	0.06	0.03	0.02	0.02	0.01	0.01	0.00	

Alkali-silica reaction; Current tests revealed that 3-day expansion was 0.142%, 7-day expansion was 0.261% and 14-day expansion was 0.467%. The aggregates with an average expansion ratio of lower than 10% are assessed as safe, the ones with an expansion ratio of between 0.10-0.20% are assessed as potentially harmful and the ones with an expansion ratio of over 0.20% are assessed as hazardous with regard to alkali-silica reaction (TS 13516, 2012). While 3-day expansion of the aggregates was assessed as potentially harmful, 7 and 14-day expansions were assessed as harmful (Figure 3).

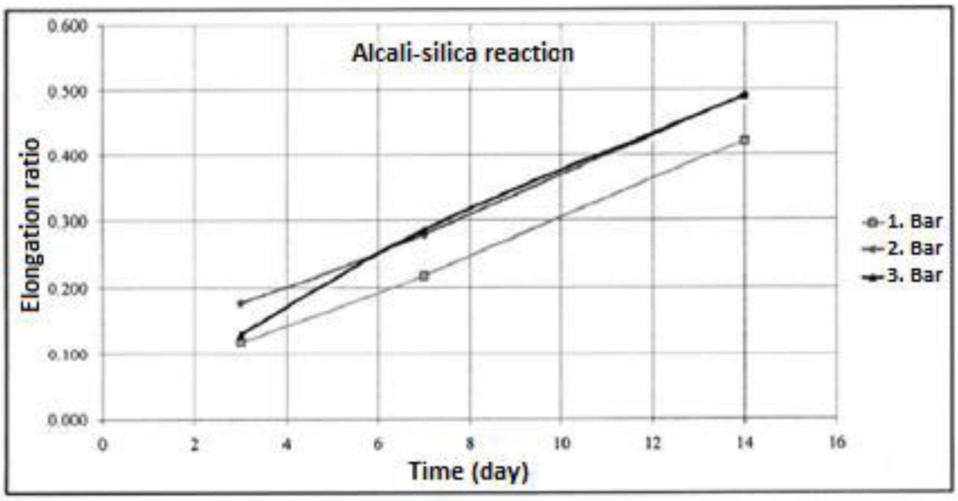

Figure 3. Alkali-silica reaction

Harmful aggregates may create problems based on type and amount of alkali-sensitive components, grain size and distribution and the amount of alkali hydroxide within the pores of concrete. Active silica in aggregates will react with cement alkaline and create a gel paste, resultant alkali-silica gel will absorb more water and destroy concrete volume stability, will result in segregation of alkali-sensitive aggregate grains close to surface, will also result in swells, expansions, micro-cracks, fragmentations and deformations in concrete and reinforced concrete members.

Sieve analysis and granulometry; Aggregate granulometric curve is presented in Figure 4. Granulometry curve of the aggregates was just above the lower limit of standard 0.25-4.00 mm curve, stayed within standard region until 4.00 mm and yielded optimum (average) value. Following 4.00 mm, the curve went down and dropped below the minimum limit after 8.00 mm. The aggregate sizes were not suitable between 8.00-25.00 mm and suitable between 0.25-8.00 mm. Since concrete cover was taken as 25.00 mm, aggregate sizes larger than 25.00 mm are not used in concrete production.

Since the aggregates did not have any materials between 8.00-25.0 mm, sieve application should be performed for this portion. High ratio of fines increases total surface area and thus reduces concrete workability. Such a case then requires more mixing water and the resultant empty spaces through evaporation of more water after concrete hardening will reduce concrete strength.

Compared to standard recommended values, grain size distribution of the aggregates was not found to be suitable. For a quality aggregate, granulometry curve should lie between standard curves. Therefore, present aggregates should not be used in concrete production without bringing them into suitable size distribution.

Since the investigated crushed stone aggregates of the present study were taken as under-band sieved, grain size distribution was fine for concrete production. Therefore, aggregates should be sieved through different size sieves and separated into proper size groups and brought to suitable mixture percentages for concrete production. Size distribution of proposed mixture is presented in Figure 5.

The aggregates should not be used without any separation procedures. They should be separated into at least three size groups. The proper mixture ratios of 14-22 mm and 4-12 mm crushed aggregates and 0-4 mm crushed sand should respectively be 31, 20 and 49%. Those are proposed mixture ratios. Experimental mixtures should be produced by using these ratios. Since the other characteristics of experimental aggregates were suitable for concrete production, normal and high-strength concretes can be produced by using different water/cement ratios.

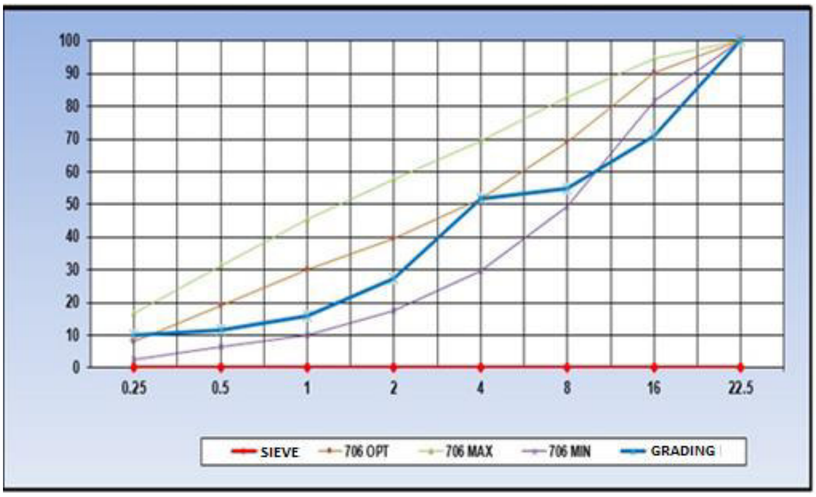

Figure 4. Granulometry curve

Fineness modulus was also determined to get more detailed knowledge about the granulometric composition of the aggregates. The value was identified as 2.87 and it was within recommended limits. Uluata (1981) indicated that fineness modulus should be between 5.50-7.50 for coarse aggregates and the fine aggregates with a fineness value below 2.50 should not be used in concrete production.

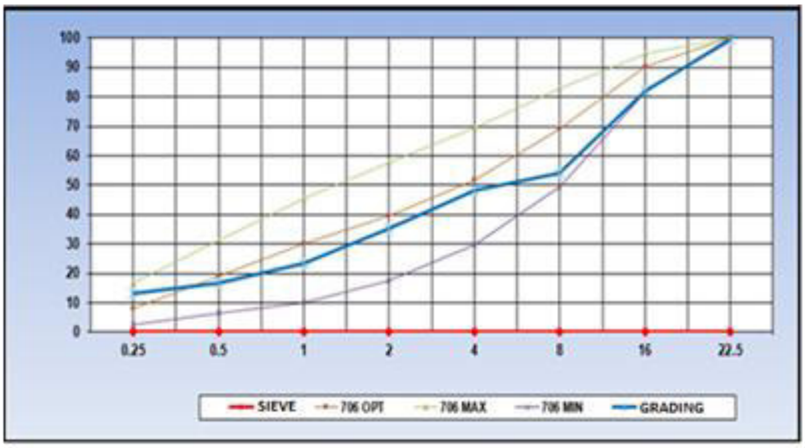

Figure 5. Granulometry curve for proposed mixture

Concrete tests

Concrete compressive strength; Concrete samples prepared with the aggregates supplied from the aggregate quarry were subjected to 7 and 28-day compressive strength tests (Table 4). Average 7-day compressive strength of C20, C25 and C30 concretes were respectively observed to be 23.6-32.2-35.1 N/mm² and 28-day compressive strengths were respectively observed as 26.6-38,7-40.4 N/mm². It is recommended in TS EN 1097-6 (2013) that 28-day compressive strength should not be less than 25 N/mm² for C20, 30 N/mm² for C25 and 37 N/mm² for C30. Ministry of Environment and Urbanization recommends that 7-day compressive strength should not be less than 70% of 28-day compressive strength.

Table 4. Concrete compressive strengths (N/mm^2)

Concrete Class	C 20/25		C 25/30		C 30/37	
Specimen no:	7 day	28 day	7 day	28 day	7 day	28 day
1	23.1	30.1	31.8	38.4	35.4	40.6
2	23.4	29.1	32.0	39.5	35.4	40.4
3	23,6	29.2	32.0	38.1	35.2	40.6
4	23.6	29.4	32.5	38.3	34.8	40.2
5	24.0	29.8	32.5	38.9	35.1	39.6
6	23.9	29.8	32.6	39.1	35.1	41.2
Average	23,6	29.6	32.2	38.7	35.1	40.4

Concrete specimens met the 7 and 28-day compressive strength standards and concretes produced from the aggregates had normal strengths. Concrete bulk density of C20, C25 and C30 were respectively measured as 2.351; 2.356 and 2.404 kg/dm^3. Bulk densities of normal concretes vary between 2.00-2.80 kg/dm^3 and the concretes with a bulk density less than 2.00 kg/dm^3 are classified as light-weight concrete and the ones with a bulk density higher than 2.80 kg/dm^3 are classified as heavy-weight concretes (Akman, 1990). Based on this classification criterion, current concretes were classified as normal concretes.

4. Conclusion and Recommendations

Aggregate physical and mineralogical characteristics were found to be suitable for concrete production. Concrete specimens produced from these aggregates had sufficient compressive strength. Therefore, it was concluded that crushed stone aggregates of the present study could reliably be used in production of normal concrete. Aggregate grain size distributions should definitely be inspected whether or not they stay within standard curves. If not, they should be brought into standard sizes through sieve analysis. Alkali-silica reaction should also be checked for a quality concrete production. Some quite fine particles like clay, silt or stone dust were detected in current aggregates. Thus, such fine particles should be removed through washing. Fine particles may increase the amount of mixing water and creates shrinkage cracks when the concretes were hardened. Siliceous minerals were detected in current aggregates. Thus, researches should be carried to elucidate the effects of alkali aggregate reactions on concrete quality.

For quality concrete production, local aggregates should comply with the standards for granulometric composition, fine ratios and alkali-silica reactivity. While using aggregate quarries in concrete production, reactive aggregates should be determined with petrographic tests and the aggregates to be used in tests should fully represent the quarry.

References

Akman, S., 1990. Yapı Malzemeleri. İTÜ. İnsaat Fakültesi Ders Notları, No: l408, 162 s. İstanbul (in Turkish).

Anonymous, 1994. Standard Test Method for Potential Alkali Reactivity of Aggregates, (Mortar Bar Method). ASTM C-1260-94, Annual Book of ASTM Standards, Concrete and Mineral Aggregates, American Society for Testing and Materials, PA, 4 (2), 650-653, Philadelphia, USA.

Anonymous, 1994. ASTM C88, Standart Test Method for Soundness of Agregates by Use of Sodium Sulfateor magnesium Sulfate. Annual Book of ASTM Standarts.

Anonymous, 2000. Standard Test Methods for Chemical Analysis of Glass Sand ASTM C146-94a, Volume 15.02.

Anonymous, 2015. Adoçim Tokat Cement Factory. Tokat.

Baradan, B., 1996. Yapı Malzemesi II. Dokuz Eylül Üniversitesi, Mühendislik Mimarlık Fakültesi Yayınları, No:207. 4. Baskı, s.42-195, İzmir (in Turkish).

Batmaz, A., 2006. The investigation of the feasibility of the use of aggregates obtained from the streams in Rize and the nearby areas in the manufacturing of concrete, (Masters Thesis), Firat University, Institute of Sciences and Technology, Department of Construction Sciences., 85 p. Elazığ.

Ekmekyapar T. ve İ. Örüng, 2001. İnşaat Malzeme Bilgisi. Atatürk Üniversitesi, Ziraat Fakültesi Yayınları, Yayın No:145, 234 s., Erzurum (in Turkish).

Erdoğan, T.Y., 1995. Betonu Oluşturan Malzemeler; AGREGA. Türkiye Hazır Beton Birligi Yayını, 110 s., İstanbul (in Turkish).

Kocataşkın, F., 1975. Yapı Malzemesi Bilimi. Birsen Kitapevi, 132 s. İstanbul (in Turkish).
Lachance, G.R., Traill, R.J., 1966. Practical Solution to The Matrix Problem in X-ray Analysis, Canadian Spectroscopy 11, 43-48.
Murdock, L.J., Brook, K.M., Dewer, J.D.,1991. Concrete, Materials and Practice. Sixth Edition, Edward Arnold, London, 27.
Postacıoglu, B., 1987. Beton-Bağlayıcı Maddeler, Agregalar. Beton, Cilt 2, Teknik Kitaplar Yayınevi, 404 s, İstanbul (in Turkish).
Şenbil, U.E., Bağdatlı, Ö., Köseoğlu, K., Çakır, Ö.A., 2014. Characterization of crushed sands has different methylene blue value and effects on concrete performance. Engineer and Machinery, 55 (649),74-80.
TS 10088 EN932-3, 1997. Tests for general properties of aggregates-Part 3: Procedure and terminology for simplified petrographic description. Turkish Standards Institution, 12 p., Ankara.
TS 3530 EN 933-1, 1999. Tests for geometrical properties of aggregates-Part 1: Determination of particle size distribution-Sieving method. Turkish Standards Institution, 11 p., Ankara.
TS 706 EN 12620+A1, 2009. Aggregates for concrete. Turkish Standards Institution, 50 p., Ankara.
TS 802, 2009. Design Concrete Mixes. Turkish Standards Institution,18 p. Ankara.
TS 3323, 2012. Concrete-Making, accelerated curing and testing concrete compression test specimens. Turkish Standards Institution, 16 p., Ankara.
TS 13516, 2012. Standard test method for potential alkali reactivity of aggregates (mortar bar Method). Turkish Standards Institution, 8 p., Ankara.
TS EN 932-1, 1997. Test For General Properties of Aggregates part 1 methods for sampling. Turkish Standards Institution, 23p., Ankara.
TS EN 932-2, 1999. Tests for general properties of aggeragates Part 2: Methods for reducing laboratory samples., Turkish Standards Institution, 20 p., Ankara.
TS EN 1097-3, 1999. Tests for mechanical and physical properties of aggregates- Part 3: Determination of loose bulk density and voids. Turkish Standards Institution, 20 p., Ankara.
TS EN 1008, 2003. Mixing water for concrete - Specifications for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete. Turkish Standards Institution, 18 p., Ankara.
TS EN 1367-1, 2008. Tests for thermal and weathering properties of aggregates-Part 1: Determination of resistance to freezing and thawing. Turkish Standards Institution, 14 p. Ankara.
TS EN 933-10, 2010. Tests for geometrical properties of aggregates - Part 10: Assessment of fines-Grading of filler aggregates (air jet sieving). Turkish Standards Institution, 12 p., Ankara.
TS EN 933-1, 2012. Tests for geometrical properties of aggregates - Part 1: Determination of particle size distribution-Sieving method. Turkish Standards Institution, 18 p., Ankara.
TS EN 12390-3/AC, 2012. Testing hardened concrete-Part-3: Compressive strenght of tests specimens Turkish Standards Institution, 2 p., Ankara.
TS EN 1744-1:2009+1, 2013. Tests for chemical properties of aggregates-Part 1: Chemical analysis. Turkish Standards Institution, 64 p., Ankara.
TS EN 1097-6, 2013. Tests for mechanical and physical properties of aggregates - Part 6: Determination of particle density and water absorption. Turkish Standards Institution, 43 p. Ankara.
TS EN 196-2, 2014. Method of testing cement-Part 2: Chemical analysis of cement, Turkish Standards Institution, 67 p., Ankara.
TS EN 933-9+A1, 2014. Tests for geometrical properties of aggregates-Part 9: Assessment of fines-Methylene blue test. Turkish Standards Institution, 16 p., Ankara.
TS EN 1097-2, 2015. Tests for mechanical and physical properties of aggregates - Part 2:Methods for the determination of resistance to fragmentation._Turkish Standards Institution, 31 p., Ankara.
TS EN 933-8:2012+A1, 2015. Tests for geometrical properties of aggregates - Part 8: Assessment of fines-Sand equivalent test. Turkish Standards Institution, 21 p., Ankara.
TS ISO 3310-1, 2009. Test Sieves-Technical requirements and testing- Part 1: Test sieves of metal wire cloth. Turkish Standards Institution, 19 p., Ankara.
TS ISO 3310-2, 2015. Test sieves-Technical requirements and testing - Part 2: Test sieves of perforated metal plate. Turkish Standards Institution, 18 p., Ankara.
Tutmaz, Ş.İ., 2009. Possible utilization of natural aggregate resources in Central town of Tokat as concrete aggregate. (Masters Thesis), Gaziosmanpasa University, Department of Farm Structures and Irrigation, Graduate School of Natural and Applied Science. 86 p. Tokat.
Uluata, A.R., 1981. Beton Malzemeleri ve Beton. Atatürk Üniversitesi Ziraat Fakültesi (Ders Notu) s.25-74., Erzurum (in Turkish).
Yıldırım, M. ve Yılmaz, I., 2002. Investigation of the usefullness of the yıldız ırmak sediments as the cement aggregates. Bulletin of Faculty of Engineering of Cumhuriyet University, Serie A-Earth Sciences, 19 (2), p. 181-192, Sivas (in Turkish).