EFFECT OF CRYSTALLINE CALCITE USAGE IN PREFABRICATED PRESTRESSED GIRDERS PRODUCTION OVER CONCRETE DURABILITY

S.Uluöz[1] , S.Düzbasan[2] , E.Yakıt[3] , T.Uluöz[4]

ABSTRACT

At the construction of V4 Viaduct in Ankara – Istanbul High Speed Train Project, it has been planned to use limestone aggregate for the production of 175.000 m³ concrete which are presently in different classes. At the examination carried out in stock area of aggregate manufacturers at an economic distance to the site field, it has been determined that there exists different proportions of crystalline calcite within limestone aggregate. There are 792 ea prestressed girders available in construction of V4 viaduct. Regarding the fact that C 40/50 class concrete shall be used in construction; it has been required to examine the effect of crystalline calcite inside the limestone aggregate over the concrete quality. Under the scope of performed R & D studies, different proportions of crystalline calcite have been placed inside obtained aggregates received from limestone rock pits which are located in economic distance from the site field and concrete design studies have been carried out and at the received samples, the following studies have been made; Pressure resistance has been determined, water permeation test has been performed in accordance with DIN 1048, geological thin cross section samples from concrete have been taken and inter surfaces in between aggregate particles and cement paste have been examined in microscope, limestone particles and crystalline calcite aggregate particles have been subjected to 200 ^{o}C heat shock at the same time and their behaviors at the high temperature effect have been compared. Whenever the results obtained under the scope of research are compared; it has been determined that crystalline calcite inside the limestone aggregate has a negative effect over the concrete quality and therefore it has been decided to use basalt aggregate which is supplied from a pit that is located in a longer distance to the site field in construction of 792 ea I 195 type prestressed girder.

[1] Chemical Engineer, Ilgaz Cons. Trad. Ltd. Co. Ankara – Turkey
[2] Civil Engineer, Ilgaz Cons. Trad. Ltd. Co. Ankara – Turkey
[3] Civil Engineer MBA, Railone Ilgaz Ankara – Turkey
[4] Msc. Structural Engineer, Warsaw University of Technology, Warsaw / Poland

Effect of Crystalline Calcite Usage In Prefabricated Prestressed Girders Production Over Concrete Durability

S.Uluöz[2] , S.Düzbasan[2] , E.Yakıt[3] , T.Uluöz[4]

ABSTRACT

At the construction of V4 Viaduct in Ankara – İstanbul High Speed Train Project, it has been planned to use limestone aggregate for the production of 175.000 m³ concrete which are presently in different classes. At the examination carried out in stock area of aggregate manufacturers at an economic distance to the site field, it has been determined that there exists different proportions of crystalline calcite within limestone aggregate. There are 792 ea prestressed girders available in construction of V4 viaduct. Regarding the fact that C 40/50 class concrete shall be used in construction; it has been required to examine the effect of crystalline calcite inside the limestone aggregate over the concrete quality. Under the scope of performed R & D studies, different proportions of crystalline calcite have been placed inside obtained aggregates received from limestone rock pits which are located in economic distance from the site field and concrete design studies have been carried out and at the received samples, the following studies have been made; Pressure resistance has been determined, water permeation test has been performed in accordance with DIN 1048, geological thin cross section samples from concrete have been taken and inter surfaces in between aggregate particles and cement paste have been examined in microscope, limestone particles and crystalline calcite aggregate particles have been subjected to 200 ^{o}C heat shock at the same time and their behaviors at the high temperature effect have been compared. Whenever the results obtained under the scope of research are compared; it has been determined that crystalline calcite inside the limestone aggregate has a negative effect over the concrete quality and therefore it has been decided to use basalt aggregate which is supplied from a pit that is located in a longer distance to the site field in construction of 792 ea I 195 type prestressed girder.

.

[1] Chemical Engineer, Ilgaz Cons. Trad. Ltd. Co. Ankara – Turkey.
[2] Civil Engineer, Ilgaz Cons. Trad. Ltd. Co. Ankara – Turkey
[3] Civil Engineer MBA, Railone Ilgaz Ankara – Turkey
[4] Msc. Structural Engineer, Warsaw University of Technology, Warsaw / Poland

Introduction

Approximately 200 crushed aggregate manufacturers having TSE certificate in Turkey produce crushed aggregate which are formed from 50 % limestone and dolomite rock. The most important problems faced in usage of limestone aggregate in concrete manufacturing are as follows;

a. Penetration of thin materials over clay bands located in between rocks inside rocked sand which is described especially as 0/5,
b. Penetration of crystalline calcites which are available in breaks and holes of limestone rocks inside limestone aggregate at different proportions and to impair the quality of the aggregate. [1]

Aforementioned 2 problems are the matters disturbing concrete manufacturers and concrete users. Technical personnel of Ilgaz Construction Quality Control Department have regarded this matter and have proposed basalt aggregate to be used in production of 792 ea prestressed girders of V4 Viaduct of Ankara - Istanbul High Speed Train Project instead of limestone aggregate including crystalline calcite and thin materials to be screened and removed before rocks are sent to rock crushers and have followed these matters in the process until the project is completed.

1. Formation of Crystalline Calcite

Limestone is formed in millions of years as a result of sedimentary calcium carbonate deposits at a sedimentation basin. Crystalline calcite veins inside limestone rocks are formed as calcium carbonate crystals are concentrated at breaks and holes inside limestone rocks formed as a result of tectonic motions and there are approximately 300 crystalline calcite at different shapes and colors are available. Figure 1, 2 and 3 crystalline calcite veins at Polatlı Mehmetli rock mines which are at 30 km distance to V4 Viaduct site are shown.

Figure 1, 2, 3. Crystalline calcite veins at Polatlı Mehmetli rock mines.

2. Usage of Limestone Aggregate in Concrete Design Studies

V4 Viaduct under the scope of Ankara Istanbul Railway High Speed Train Project starts at approximately 14th km after Polatlı exit and is connected to main route which shall pass over Sakarya River. At the project, 175.000 m³ concrete at different concrete classes have been used. [2] In order to provide concrete quality to be in conformance with project criteria, R&D studies have been performed while the site facilities are just at establishment stage to determine contributions of aggregate, cement, mixture water and chemical concrete contributions which shall be used in concrete production. The most important input of concrete is aggregate which has a 70-75 % share among the other inputs. Mineralogical structure, physical properties and geometric shape of aggregate directly affect the concrete quality. It has been determined that there are approximately 25 % of white colored, shiny and glazed, laminated, smooth geometric shaped crystalline calcite particles shown in Figure 4 and 5 available at TSE certified aggregate production facilities stock area which is at an economic distance to V4 Viaduct Site Area.


Figure 4, 5. Crystalline calcites at aggregate stock area.

In order to determine the effect of crystalline calcite inside limestone aggregate used in concrete production over concrete quality and durability and production speed of prestressed girder;

- Physical properties of limestone aggregate have been determined by performing tests,
- Alkali aggregate reactivity test has been performed by petrographic and chemical analysis,
- Concrete trial mixtures have been prepared by using limestone aggregate,
- Different proportions of granule crystalline calcite have been mixed inside limestone aggregate and concrete trial productions have been made and samples from these trial productions have been taken and pressure resistance, pressurized water permeability and water absorption tests have been performed.

Under the scope of the study, physical properties of crystalline calcite inside limestone aggregate taken from rock crushing facilities are shown in Table 1.

Table 1. Physical properties of crystalline calcite and limestone.

TSE Certified Facility No	Weight proportion inside the sample %		Test parameters: Specific weight g/cm³	Water absorption %	Los Angeles Depreciation loss % 100 Cycle	500 Cycle	$MgSO_4$ Freeze – thaw loss %
1	Limestone	89,5	2,680	0,8	4,3	17,8	5,6
	Crystalline calcite	10,5	2,675	0,9	12,8	35,4	12,8
2	Limestone	81,2	2,670	0,9	4,7	18,2	6,8
	Crystalline calcite	18,8	2,650	0,9	18,9	42,8	13,3

According to TS 3526, at the specific weight determination test, it has been observed that some of crystalline calcite particles which have been waited at oven dry temperature have been broken and chipped. In the case of a sudden heat shock over concrete, there shall be breaks and chipping over crystalline calcite particles and as a result, there shall be a weakening in adherence with cement paste surrounding the aggregate particle. As a result, pressure resistance of concrete shall decrease and durability of concrete shall be adversely affected. Since the aforementioned matter has been taken into consideration; granule limestone and crystalline calcite having the same gradation and amounts have been waited 1 hour at 200°C temperature and then screen analysis have been made and effect of high temperature over limestone and crystalline calcite particles have been examined. As is seen in Table 2 despite that there is no change in limestone aggregate gradation under the effect of high temperature, crystalline calcite particles have been broken and chipped under the effect of temperature so aggregate gradation has changed.

Table 2. Change in gradation of crystalline calcite under high temperature effect.

Medium at which aggregates are waited	Type of aggregate	Size of square hole screen (mm) % left									
		19,1	16	8,0	4,0	2,0	1,0	0,500	0,250	0,125	0,063
Under normal weather conditions	Limestone	25	50	75	100						
	Crystalline calcite	25	50	75	100						
1 hour at 200 °C	Limestone	25	50	75	100						
	Crystalline calcite	12	22	32	55	64	70	78	85	95	99

.

3. Concrete Design Studies

Aggregate: Samples received from rock crushing facilities which are located in an economic distance to beam production facility have been examined and rock crushing facility which produces the limestone aggregate with the least crystalline calcite ratio has been determined.
Cement: Analysis reports of 1 year of cement factories which are located in an economic distance to beam production facility have been examined and cement producing facility which produces the cement with the least total alkali, sulfide and tri calcium aluminate amount has been determined.
Concrete mixture water: Water in conformance with TS EN 1008 standard has been used in concrete production.
Chemical additive: It has been decided to use chemical additive including high ratio of water decreasing naphthalene sulphonate group at TS EN 934 – 2 and ASTM C 494 Type F.
After concrete components have been determined, concrete design studies have been started and the following studies have been performed;

- After concrete trial mixture is prepared by using limestone aggregate, definite amounts of granule crystalline calcite has been added into limestone aggregate and concrete trial mixtures have been made again and samples from concrete have been taken.
- Geological thin cross section samples received from concrete have been placed in benecular microscope and interim surfaces of limestone and crystalline calcite aggregate particles with cement paste have been examined.
- At the tests performed by using cement samples, 3, 7 and 28 days pressure resistance, water absorption ratios and pressurized water permeability tests according to DIN 1048 have been performed. Results obtained in concrete design are given at Table 3.

Table 3. Results of concrete design.

Concrete components		Concrete components used for 1 m³		
		Limestone (Sample)	At which crystalline calcite has been used	
			1st Mixture	2nd Mixture
Lime stone (0-4 mm) (kg)		880	880	880
Lime stone (4-12 mm) (kg)		464	348	325
Crystalline calcite (4-12 mm) (kg)		-	116	139
Lime stone (12-22 mm) (kg)		464	348	325
Crystalline calcite (12-22 mm) (kg)		-	116	139
Cement (CEM I PÇ 42,5 R) (kg)		450	450	450
Concrete mixture water (kg)		168	168	168
Chemical concrete additive (kg)		4,5	4,5	4,5
Tests performed at processed concrete				
Pressurized water permeability		1,9	2,8	3,2
Pressurized water permeability(mm)		14	19	21
Pressure resistance N/mm²	3 days	34,9	34,0	33,9
	7 days	44,9	43,6	43,3
	28 das	59,0	51,0	49,8

3.1. Evaluation of Test Results

At the study performed to determine the effect of crystalline calcite over the concrete quality, test results have been evaluated and the following inferences have been made.

a. Evaluation of pressure resistance test results;
At 3 days samples; breaks over samples subjected to pressure resistance test have been observed over the cement paste.
At 7 days samples; breaks over samples subjected to pressure resistance test have been started to be observed through crystalline calcite particles together with cement paste.
At 28 days samples; limestone particles have been steady at samples subjected to pressure resistance test but crystalline calcite particles have been chipped away. Besides; due to smooth geometric shape of external face and glazed and varnished structure of crystalline calcite, there is no adherence in between crystalline calcite and cement paste, it has been observed that there are breaks though crystalline calcite particles in samples subjected to test and as is shown in Figure 6 and 7 it has been seen that they are scraped.


Figure 6, 7. Smooth geometric structure of crystalline calcite inside concrete.

At Table 4, comparison of pressure resistances of concrete produced by crystalline calcite with pressure resistance of sample concrete produced by limestone aggregate has been shown.

Table 4. Decrease in pressure resistances compared to witness sample.

Mixture No	Crystalline calcite usage ratio	Decrease in pressure resistances compared to witness sample (%)		
		3 Days	7 Days	28 Days
1	% 12,8	2,6	3,2	13,6
2	% 15,4	2,9	3,6	15,6

b. Evaluation of results of pressurized water process depth and water absorption percentage; It has been determined that as the amount of crystalline calcite inside concrete increases, water absorption percentage and pressurized water process depth also increases. Considering laboratory test results; despite of the fact that it is possible to produce C 40/50 class concrete with limestone aggregate, it has been found out that concrete quality is adversely affected in parallel with the increase in crystalline calcite inside the limestone aggregate. At V4 Viaduct of Ankara - Istanbul High Speed Train Project, it has been decided to use basalt aggregate instead of limestone aggregate in production of prestressed girder regarding the following matters;

- There is a risk of having different proportions of crystalline calcite inside limestone aggregate,
- Applying steam cure in prestressed girder production,
- There shall be a negative effect over prestressed beams of cooper load at trains passing by 250 – 300 km/hour speed through high speed train route,
- There shall be a negative effect of adverse weather conditions over concrete quality and concrete performance at the area where the project is located.

4. Using Limestone Aggregate in Prestressed Girder

Since there is no rock crushing facility producing basalt aggregate at an economic distance to the site area, in order the production of prestressed beams to be completed according to planned time schedule limestone aggregate has been used in a controlled manner until basalt aggregate is started to be supplied. After concrete designs which have been prepared by Ilgaz Construction Quality Control Department are repeated together with technical personnel of consulting company and contracting company and after the conformance of these designs are approved, production of prestressed beam using concrete design given at Table 5 has been started. At the period passed up to supplying basalt aggregate, 50 ea prestressed girders have been produced by using limestone aggregate.

Table 5. Concrete mixture used in production of prestressed girder.

Concrete components	Weights for 1 m³ concrete production (kg)	Fresh concrete property	
Limestone (0 – 5 mm)	880	Slump (0 min)	17 cm
Limestone (5 – 12 mm)	464	Slump (15 min)	16 cm
Limestone (12 – 22 mm)	464	Slump (30 min)	14 cm
Cement (CEM I PÇ 42,5 R)	450	Air	% 1,1
Concrete mixture water	168	Temperature	19°C
Chemical additive	4,5	Density (kg/m³)	2.420

4.1. Precautions Taken During Supplying Aggregate

In order to prevent adverse effect of crystalline calcite inside limestone aggregate over quality of concrete, the following precautions have been taken in supply of aggregate.

- A separate stock area at the rock crushing facility from which limestone aggregate is supplied has been formed for aggregate to be delivered to Ilgaz Construction and aggregate required by the site has been delivered from this stock area.
- Quality control personnel have been assigned at the rock crushing facility in order to prevent crystalline calcite to be mixed inside limestone aggregate. As a result of taken precautions, the crystalline calcite particles which are shown in Figure 8 and 9 have been prevented to be sent to rock crushers.
- Thin substances available at clay bands of limestone rocks have been screened previously and have been removed.
- Limestone aggregate which has been brought to the site area has been controlled on truck before being unloaded and in the case that it is understood that there is crystalline calcite included in the aggregate, trucks carrying such samples have not been unloaded and have been returned to the supplier. After trucks are unloaded at temporary stock area, aggregate has been reexamined and limestone aggregate which has been found proper has been moved to main stock area.

Figure 8, 9. Crystalline calcite rocks mixed in limestone after explosion.

4.2. Precautions Taken During Production

After production of prestressed girder is completed, it is rested for 2 hours before giving steam to concrete and the followings are performed in conformance with TS 3480; Environment temperature is increased up to 65 °C in 3 hours, at 65 °C, concrete is subjected to saturated water steam cure for 5 hours, steam cure halls are removed 3 hours after steam cure is completed. After it is determined that pressure resistance of 15 cm cube samples which have been subjected to steam cure at the same environment with prestressed girder has reached at 37,5 N/mm², prestress ropes are cut and beams which are removed from molds and which are subjected to water are transported to main stock area by elephanties.

In order to provide 37,5 N/mm² transfer resistance at prestressed girder production in a short period of time; cement dosage which has been approved as 450 kg/m³ has been increased to 475 kg/m³ and steam cure which is applied in 65 °C for 5 hours has been started to be applied for 7 hours.

5. Basalt Aggregate Usage in Prestressed Girder Production

Screening system at Stone Crusher established in Polatlı to produce ballast by Spanish Obrascon Huarte Lain S.A.(OHL) company which is one of the main contractors of Ankara – Istanbul High Speed Train Project has been changed and basalt aggregate in 3 different gradation of which physical properties are given in Table 6 has been prepared to be used in concrete production.

Table 6. Physical properties of basalt aggregate.

Test parameters		Basalt aggregate		
		(0/5)	(5/12)	(12/22)
Specific weight g/cm³		2,850	2,852	2,850
Water absorbtion %		2,37	0,9	0,8
$MgSO_4$ frost experiment loss %		1,9	1,8	1,7
Los Angeles Depreciation loss %	100 cycle	-	2,9	
	500 cycle	-	11	

5.1. Effect of Using Basalt Aggregate Over Production

After basalt aggregate has been started to be used in prestressed girder production instead of limestone aggregate, the following results have been obtained;

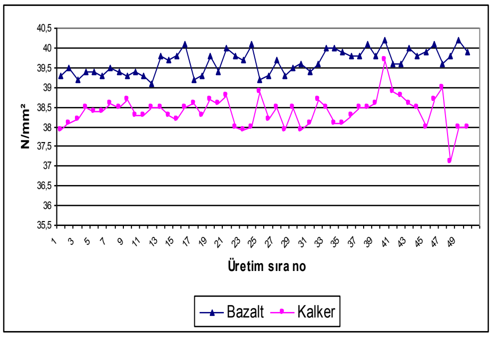
- 450 kg/m³ cement approved by consulting company has been started to be used in concrete mixture while 475 kg/m³ cement has being used in production performed by using limestone aggregate.
- Saturated steam cure at 65 °C has decreased from 7 hours to 5 hours. So, waiting period after the steam cure has decreased approximately 40 % then production of prestressed girders has been completed earlier than scheduled date.
- Homogeneity has been provided in between transfer pressure resistance and 7 and 28 days pressure resistances.
- During production of 792 ea prestressed girders which is used in Project, 9700 ea 15 cm concrete cubes have been taken as samples by technical personnel of inspection authority and their transfer pressure resistances and 7 and 28 days pressure resistances have ben determined. Despite of the fact that steam cure at 65°C has been applied 2 hours short;

  a. An increase of approximately 3,0 % at transfer resistances has been observed
  b. An increase of approximately 12 % at 28 days pressure resistance has been observed. [3]

Comparison made in between the compressive strengths of the samples taken from the concretes produced by limestone and basalt aggregate has been given in Table 7 and Figure 10 and 11. Images of the concretes produced by limestone and basalt aggregate in binocular microscope has been shown in Figure 12 and 13.

Table 7. Comparison of pressure resistance test results.

Age of concrete	Sample amount	Pressure resistance (N / mm²)		Increase in pressure resistance %
		Limestone aggregate	Basalt aggregate	
Transfer	150	38,7	39,7	2,6
7 days	150	42,0	50,2	19,5
28 days	150	53,7	61,6	14,7



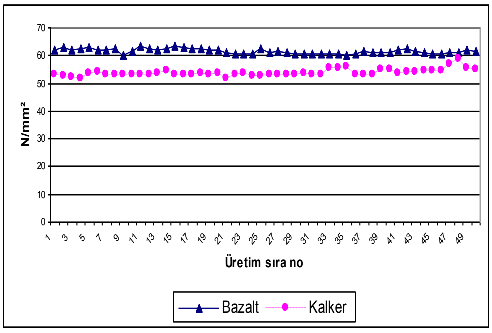


Figure 10, 11. Transfer and comparison of 28 days pressure resistances.

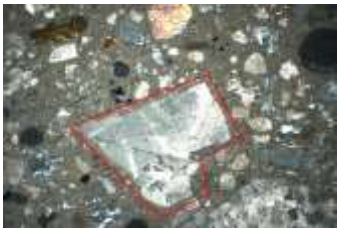
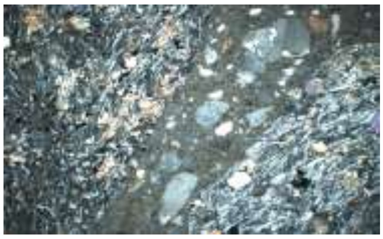



Figure 12, 13.Thin cross sections of concrete produced by limestone and basalt aggregate.

6. Test of Prestressed Girder Loading

Loading test over V4 – K191 numbered prestressed beam which has been produced on date of 19.09.2006 by basalt crushed aggregate has been applied as shown in Figure 14 and 15.

At loading test which has been applied in 2 stages;
At 1st stage; Load has been applied gradually over 1/3 and 2/3 sections of net clearances of prestressed beams and it has been waited for 5 minute and then deflection has been measured.
At 2nd stage; Loads over beams have been gradually removed and then deflection has been measured. According to the specification, it is required that minimum 90 % of deflection amount which has been measured when whole of test load has been placed during loading test should be recovered after whole of the load is removed. It has been determined that 97,5 % of deflection has been recovered at prestressed girder which has been produced by using basalt aggregate.



Figure 14, 15. Applying load over beams and deflection measurement.

Conclusion

At the end of R&D study performed to determine the effect of crystalline calcite inside the body of limestone aggregate in production of prestressed girder; the following matters have been observed;

- Crystalline calcite aggregate particles have a fragile and laminar structure,

- Outer surface is smooth, shiny and glazed,
- Some aggregate particles have a smooth geometric structure,
  So crystalline calcite inside concrete weaken cement paste interim surface. Due to this reason, usage of limestone having crystalline calcite in production of prestressed girder adversely affects concrete quality, durability, production speed and manufacturing cost.

Together with basalt aggregate usage in production;
- Dosage of cement has been decreased as 5,6 %.
- As a result of not using cement more than required amount, thickness of cement paste in between aggregate particles has been decreased then breaks have occurred over aggregate particles instead of cement paste during pressure resistance test.
- Since transfer pressure resistance has increased as 3,0 % despite of the fact that vapor cure has been applied 40 % less, prestressed girders have been removed from mold earlier.
- Pressure resistance of 28 days has increased approximately 13 %.
- Prestressed beam production cost has decreased, production has been completed in a shorter period of time and in parallel, assembly of beams has been started earlier.

Due to aforementioned matters, at the production of 792 ea prestressed girder used in Ankara - Istanbul High Speed Train Project V4 Viaduct, basalt aggregate has been used instead of limestone aggregate and production has been completed on planned time.

Acknowledgments

Authors thank to Prof. Dr. Fikret İşler from Çukurova Universty Geology Engineering Department due to his contributions in preparation of the presentation.

References

1. Uluöz,S., Düzbasan,S., Yakıt,E., “ Effect Of Filler And Clay Amount In Crushed Aggregate On Concrete Quality”, CONCRETE 2004 Conference, Istanbul, 2004.

2. Uluöz,S., Düzbasan,S., Yakıt,E., Camcıoğlu,M.“ Ankara-İstanbul Railway High Speed Train Project Construction of Viaduct of 2400 meters, International Association for Bridge Maintenance and Safety, Milano Italy, 2012.

3. Uluöz,S., Düzbasan,S., Yakıt,E., Camcıoğlu,M.,” The Production And The Quality Of The Prefabricated Prestressed Girders Used In The V4 Viaduct Built On The Sakarya River Within The Scope Of Ankara-Istanbul Railway High Speed Train Project.”, CONCRETE 2008 International Ready Mixed Concrete Congress Proceedings, Istanbul, 2008.