Volume change of limestone and its effects on drying shrinkage of concrete

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Abstract. Recently, the cracks of concrete by drying shrinkage become one of the problems in the construction industry in Japan. The drying shrinkage decreases when the concrete is produced with limestone aggregate. However, it is not clear why the drying shrinkage is decreased. The purpose of this study is to clarify the relation between the drying shrinkage of concrete and the limestone aggregate. In this study, the experiments about the strength, elasticity and drying shrinkage of concrete and the physical properties and shrinkage of coarse aggregates were conducted. It is thought that the volume change of aggregates affects directly the drying shrinkage in concrete.

Introduction

Limestone has been one of protagonist in the construction industry, being the main raw material to produce ordinary Portland cement and one of the most used aggregates in concrete. However, the usage of limestone in Japan is not so common [1], Japanese construction companies frequently use sandstone as aggregate for concrete. Recently, the construction industry in Japan has been decreasing (like in many other countries in the world) but the usage of limestone has increased [1]. Limestone has many benefits that cannot be provided by sandstone. Japan is a country with many limestone deposits, and the change from the traditional construction practice of sandstone to limestone has to be sustained with the appropriated studies and change benefits. This study provides the knowledge tools to the constructors, informing the benefits that could be obtained with limestone aggregate. Previous studies [2,3] proved the reduction in drying shrinkage of limestone concrete but in those studies are not yet clear the mechanism that affect this reduction. This paper deals with the volume change of limestone itself and it is thought that this could be a reason of the reduction in drying shrinkage of concrete. Additionally, limestone provides a higher strength and more elasticity to the concrete.

Experiments

Materials. The cement used was ordinary Portland cement produced by Taiheiyo Cement Corp., complying with the Japanese Industrial Standard (JIS R 5201), with density of 3.16g/cm^3 and Blaine of 3260 cm^2/g. Three types of limestone from different quarries in Japan and sandstone were used as coarse and fine aggregates. All of them comply with the Japanese Industrial Standard (JIS A 5005) with a grain size between 5 mm and 20 mm. The admixtures were High Performance Water Reducer and Standard type I Air Reducer (Polycarboxylic Acid Polymer) to control the slump and entrained air. These admixtures comply with the Japanese Industrial Standard (JIS A 6204).

Mixture. 8 different mixtures were produced with the combination of 4 types of coarse and fine aggregates. Three different coarse limestone were mixed with fine sandstone and three different fine limestone were mixed with coarse sandstone. Additionally, one mix of coarse and fine sandstone and one mix of coarse and fine limestone were produced. Table 1 shows the mix factors and mix proportions.

Table 1:Mix factors and mix proportions

Mix name	Mix factors	W[1]	C[2]	Coarse aggregate(G)		Fine aggregate(S)		Admixture	
				Type	[kg/m^3]	Type	[kg/m^3]	Water[3]	Air[3]
GN-SN	W/C 55% s/a 46%	165	300	Sandstone	787	Sandstone (N)	838	1050	2400
GN-SLa				Limestone a	787		848	300	1200
GN-SLb				Limestone b	787		848	300	900
GN-SLc				Limestone c	787		870	300	900
GLa-SN				Sandstone	1006	Limestone a	838	600	900
GLb-SN					1010	Limestone b	838	600	900
GLc-SN					1036	Limestone c	838	1200	780
GLa-SLa				Limestone a	1006	Limestone a	848	150	300

1) Water[kg/m^3] 2)Cement[kg/m^3] 3)Units in cc/m^3.

The water/cement ratio and the sand aggregate ratio were same in the all mixture to compare the effect of the limestone aggregates. The water/cement ratio was 55%, slump target of 8±1.5cm, entrained air target of 5±1.5% and the fine aggregate ratio was 46% for all specimens.

Methods. The experiments were conducted according to the Japanese Industrial Standard (JIS). The Tests and its standard methods are shown on Table 2.

Table 2:Standard methods

Test	Standard	Test	Standard
Dry density	JIS A 1109	Compression strength	JIS A 1108
Water absorption	JIS A 1110	Tension strength	JIS A 1113
Slump	JIS A 1101	Flexural Strength	JIS A 1106
Entraind air	JIS A 1128	Modulus of elasticity	JIS A 1149
		Drying shrinkage	JIS A 1129-2

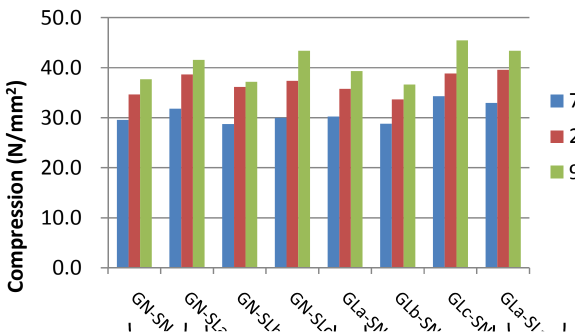
Results and Discussions

Aggregates. The density and water absorption in all aggregates were verified. The density results were similar for all aggregates. However, the water absorption was varied for all aggregates. Possibly, the water absorption is related with the volume change in aggregates and the drying shrinkage in concrete could be a consequence of it. Table 3 shows the physical properties of aggregates.

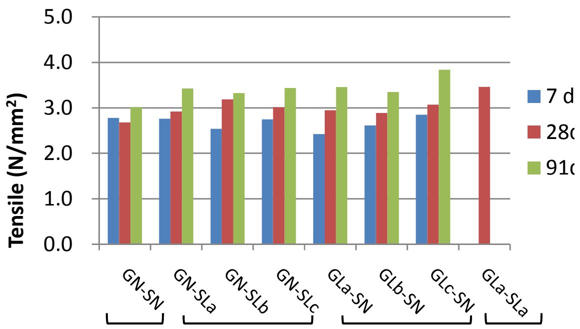
Table 3:Physical properties of aggregates

	Unit	JIS A 5005	Fine aggregate			
			Sandstone	Limestone a	Limestone b	Limestone c
Dry density	[g/cm^3]	>2.50	2.65	2.67	2.67	2.74
Water absorption	[%]	<3.00	1.84	1.17	0.99	0.87
	Unit	**JIS A 5005**	**Coarse aggregate**			
			Sandstone	Limestone a	Limestone b	Limestone c
Dry density	[g/cm^3]	>2.50	2.66	2.70	2.71	2.78
Water absorption	[%]	<3.00	1.30	0.34	0.31	0.81

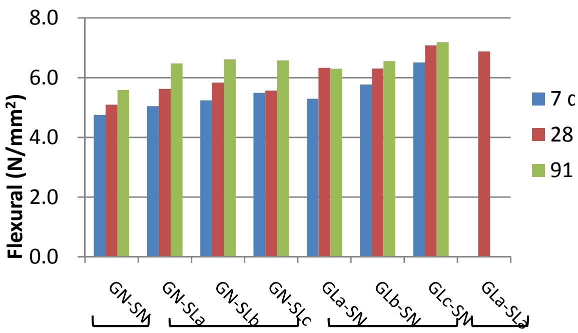
Strength and modulus of elasticity. The strength and modulus of elasticity tests were carried out at 7 days, 28 days and 91 days of concrete maturity. Fig. 1 shows the results of the strength and modulus of elasticity tests. The strength of the specimens produced with limestone aggregate was equivalent or higher than the sandstone specimens. The use of limestone aggregates increases the tensile and the flexural strength more than the compression strength.



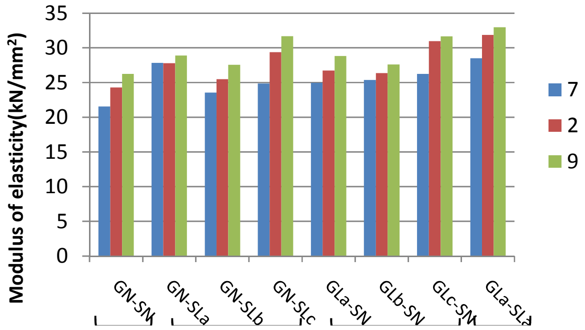
(a) Compression



(b) Tensile



(c) Flexural



(d) Modulus of elasticity

Figure 1: Strength and modulus of elasticity results

Drying shrinkage in concretes. Fig. 2 shows the results of the drying shrinkage test. The drying shrinkage of six different concretes which were made with either coarse or fine aggregate was almost equivalent. Those concretes which contain either coarse of fine limestone decreased the drying shrinkage by 30% compared with the concrete containing coarse and fine sandstone. The drying shrinkage of the concrete made with coarse and fine limestone decreased from the specimen made with sandstone aggregate by 56.6%. It proves that not only coarse aggregate but also fine aggregate decreased the drying shrinkage in concrete. The shrinkage of the all specimens made with limestone aggregate on this experiment is about 420μ~680μ. It complies with the Japanese Architectural Standard Specification 5 (JASS5: The shrinkage of the concrete should be less than 800μ. It is the strictest standard about shrinkage in Japan.).

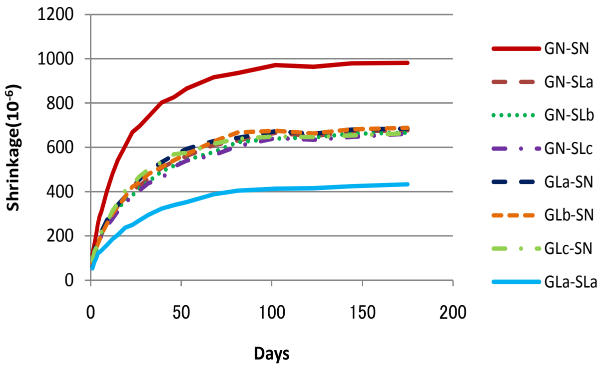


Figure 2: Drying shrinkage test results

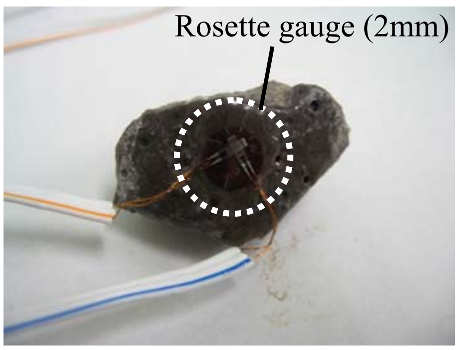


Figure 3: Measurement of volume change in aggregates

Volume change of coarse aggregates. The coarse limestone and sandstone were sampled and completely dried for 24 hours. After the aggregates were dried, its surface was planed and one rosette gauge (2mm) was attached on its surface (see Fig. 3). The gauge was attached to a data logger equipment which was measuring its volume change. The aggregates were submerged into water for 1 week and then drying for 6 days in a temperature and humid controlled room (20°C, RH=60%). Fig. 4 shows the results of the volume change in limestone and sandstone. The initial point on Fig. 4 was the time when the aggregates were removed from the water, the starting point of drying. All limestone shrunk lesser than sandstone and their shrinkage difference was between 20% and 30%. This 30% of different is similar to that presented in drying shrinkage of concrete.

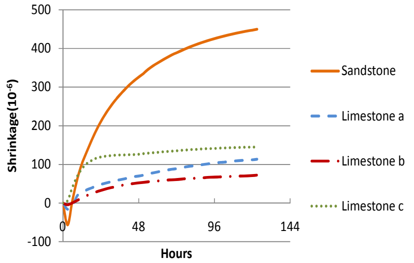


Figure 4: Volume change of aggregates

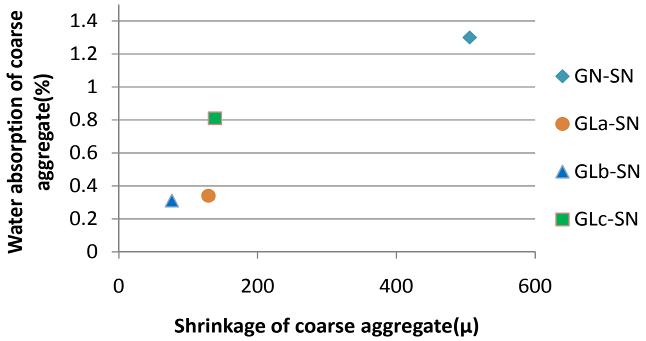


Figure 5: Volume change and water absorption of aggregate

The cause of shrinkage in concrete specimens made with the same mortar could be the shrinkage in the coarse aggregate. Consequently concretes produced with sandstone may shrink more than those produced with limestone. The cause of the volume change in aggregate may be the water absorption in this study. Fig. 5 shows the relation between the shrinkage of coarse aggregate and water absorption. The water absorption results in coarse aggregates follow the same pattern than the volume change results and the drying shrinkage in concrete. According to previous study [2], the cause of the volume change in the aggregate is the meniscus in the pore of concrete. The meniscus is made by the pore and water so the water absorption of the aggregate is an important property.

Conclusion

In this paper, the physical properties of limestone produced from various quarries in Japan were studied, and the influence that the limestone gave to the strength and the drying shrinkage of concrete was experimented and discussed. The conclusions of this study are shown as follows:

1. The strength of the specimens produced with limestone aggregate was equivalent or higher than the sandstone specimens. The limestone aggregate increases the tensile and the flexural strengths higher than the compression strength.
2. The drying shrinkage of the concretes made with coarse or/and fine limestone aggregate was lower than the concrete made with sandstone aggregate.
3. The limestone shrinks less than sandstone and their shrinkage difference is between about 20% and 30%.

The reduction of the drying shrinkage in concrete made with limestone was possibly caused by the volume change of aggregate. Aggregates with small volume change such as limestone could be one of the solutions of the drying shrinkage of concrete.

References

[1] Limestone association of Japan, Limestone aggregate and concrete, (2005) pp. 18
[2] Y.Goto and T.Fujiwara: Volumetric change of aggregates by absorption and drying, Japanese Society of Civil Engineering, Vol. 247, No. 3 (1976), p. 97-108.
[3] Y.Goto and T.Fujiwara: Effect of aggregate on drying shrinkage of concrete, Japanese Society of Civil Engineering, Vol. 286, No. 6 (1979), p. 125-137.