INVESTIGATION OF THE PROPERTIES OF LIMESTONE CONCRETE

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Abstract: More than seventy percent of the volume of concrete is occupied by aggregates. Aggregates with undesirable qualities will have an adverse effect on durability and structural performance of concrete. Though gneiss is normally used as coarse aggregates in production of concrete, due to their unavailability in the region, limestone is used as coarse aggregate for production of concrete in Northern Sri Lanka, without appropriate investigations.

In this study, impact of limestone aggregates on concrete properties such as slump, initial setting time compressive strength, flexural strength, etc. were investigated under laboratory conditions and the results were compared with the concrete made with normal aggregates. Two types of limestone aggregates were used for this purpose, red limestone which was collected from Walikamam west, Jaffna and white limestone, which was collected from Chavakachcheri area.

It was found that water absorption of limestone aggregates is 50% higher than that of the normal aggregates. Also, workability and compaction ability in limestone concrete are significantly lower for a given w/c ratio compared to normal aggregate concrete. However, compressive strength and flexural strength are found to be the same as the normal aggregates. Also, results indicate that red limestone aggregates have better performance than the white limestone aggregates.

Key words: Limestone aggregates, slump of concrete, compressive strength, flexural strength

1. Introduction

Concrete is a composite material made with cement, aggregates (fine and coarse) and water. More than seventy percent of the volume of concrete is occupied by aggregates. Hence aggregates play a major role when it comes to the properties of a concrete. Aggregates are not used in a concrete for merely economic purposes but also will provide higher volume stability and higher durability for a concrete (Neville, 2006). Aggregates with undesirable qualities will have an adverse effect on durability and structural performance of concrete.

Concrete requires a lot of natural resources. Because of that, in recent times, greater attention has been paid to find substitute materials for production of concrete. Use of limestone aggregates is one such alternative and many studies have focused on the suitability of limestone (Alhozaimy, 2009).

In Sri Lanka, river sand is mainly used as fine aggregates and crushed gneiss as the coarse aggregates in production of concrete. However, in the northern region of Sri Lanka gneiss is not freely available and higher costs of transport from the other regions is a concern in production of concrete. As a result, use of limestone aggregate for production of concrete has become a practice in this region.

Two types of limestone are available in Jaffna region called Red and White which have been named based on the texture of the aggregates. They have been crushed into two different sizes large (3/4 ") and small (5/8"). Small limestone aggregates are mainly used for production of concrete.

Limestone is a crystalline rock which has been formed with crystals of calcite (contain 90%) and small amounts of alumina, silica, magnesium and iron oxide (Abeysinghe,

[n.d.]). It has been used for production of concrete by many in different parts of the world. However, suitability of limestone available in Jaffna has not been investigated sufficiently to promote it as a building material.

In this study, properties such as compressive strength, flexural strength, workability and initial setting time of limestone concrete have been studied and compared with the properties of concrete with normal aggregates. Two types of limestone aggregates were used for this purpose, red limestone which was collected from Walikkanam west, Jaffna and white limestone, which was collected from Chavakachcheri area. Since two different types of limestone aggregates are produced, effects of the maximum size of aggregates were also studied.

2. Methodology

2.1. Materials

In order to verify the suitability of Jaffna limestone as a coarse aggregate for preparation of concrete, a series of experiments were used. Large and small red limestone aggregates, large white limestone aggregates and normal gneiss aggregates were used in this study. As the initial step for concrete mix designing, density, water absorption and initial moisture content were determined. Results obtained are given in Table 1. Concrete mix design was done according to the BRE mix design method considering normal aggregates targeting (characteristic) compressive strength of 25 N/mm^2 at 28 days and slump of 150 mm. Concrete mixes with limestone aggregates were prepared by replacing the volume of normal aggregates by limestone aggregates. Water/cement ratio of 0.58 was used and amount of water needed to be added was corrected by considering water absorption and moisture content of the coarse aggregates. Ordinary Portland cement and sand available in the local market were used.

Four concrete mixes were tested to determine slump, wet density, compaction factor and setting time. Concrete cubes of 150 mm x 150 mm x 150 mm were used to determine compressive strength and concrete beams of size 150 mm x 150 mm x 750 mm were used to determine flexural strength of concrete. Testing was done according to the relevant standards.

Table 1: Characteristics of aggregates

Aggregate type	Water Absorption %	Relative density on saturated and surface dry basis	Moisture content %
Red limestone (5/8″)	1.9	2.63	0.95
Red limestone (3/4″)	1.68	2.63	0.8
White limestone (3/4″)	1.8	2.62	0.63
Gneiss (3/4″)	0.49	2.75	0.14

3. Results and Discussion

3.1. Slump

Though the target slump of the mixes was 150 mm, results obtained for concrete prepared with limestone aggregates were significantly different. Values obtained for four concrete mixes are given in Table 2.

Table 2: Slump of different concretes

Aggregate type	Slump (mm)
Red limestone (5/8″)	35
Red limestone (3/4″)	65
White limestone (3/4″)	15
Gneiss (3/4″)	150

It can be noted that concrete made with gneiss have achieved the expected slump of the mix. However, concrete made with limestone have more than 50% less slump than the targeted value. For the limestone aggregates with same size, concrete made with red limestone has higher slump than the concrete made with white limestone aggregates. Also concrete

made with small red limestone has a lower value than the concrete made with larger red limestone aggregates.

Free water content of a concrete mix has a significant effect on the slump of a fresh concrete. In addition, shape of aggregates and surface roughness also are concerns. Compared to normal aggregates, limestone aggregates have higher water absorption capacity. Also, limestone aggregates are more irregular in shape, which results in higher surface area (more water is needed to wet the surface). Surface roughness of limestone aggregates is also higher than the normal granite aggregates. Combination of all the above factors may have resulted in lower values of slump of the limestone concrete.
This factor is not unique with Jaffna limestone and has been reported by many researchers (Abeysinghe, [n.d.]).

3.2. Compacting factor

Variation of compacting factor is very much similar to the slump. Results obtained are given in Table 3.

Table 3: Compacting factor

Aggregate type	Compacting factor
Red limestone (5/8")	0.861
Red limestone (3/4")	0.939
White limestone (3/4")	0.856
Gneiss (3/4")	0.962

Highest compacting factor is given by normal aggregate concrete and white limestone concrete gives the lowest compacting factor value. When considering limestone aggregates with same size, concrete made with red limestone aggregates have higher compaction ability than the white limestone concrete. Factors which have been discussed earlier have affected the results of the compaction factor too.

2.1 Initial setting time

Initial setting times of the concrete mixtures were determined according to the ASTMC403 2008.The values obtained are given in Table 4.

Penetration resistance variations with elapsed time are shown in Figure1.

Table 4: Initial setting time of concrete

Aggregate type	Initial setting time (minutes)
Red limestone (5/8")	235
Red limestone (3/4")	233
White limestone (3/4")	232
Gneiss (3/4")	264

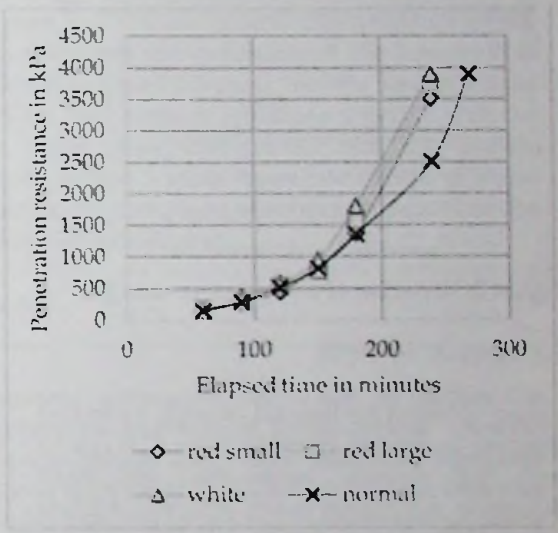

Figure 1: Penetration resistance variations with elapsed time

Limestone aggregates will absorb more water leaving less effective water in the mix. This will help the mortar to set quicker. In normal aggregate mix, effective water in the mix will be higher resulting in extended setting time compared to limestone concrete mixes.

2.2 Compressive Strength

Variation of compressive strength with time is shown in Figure 2. It can be seen that concrete mixtures with larger particles have little strength gain after 14 days, whereas mixes with small particles have continued strength gain. Also, it can be see that concrete made with large red limestone aggregates has gained slightly higher strength than the concrete

made with normal aggregate. Concrete made with small red limestone aggregates also has gained a similar strength to that of the concrete made with normal aggregate. However, concrete with white limestone has the lowest strength of all. However, strength variations with respect to aggregate types are marginal it can be seen that red limestone aggregates are better than the white limestone aggregates.

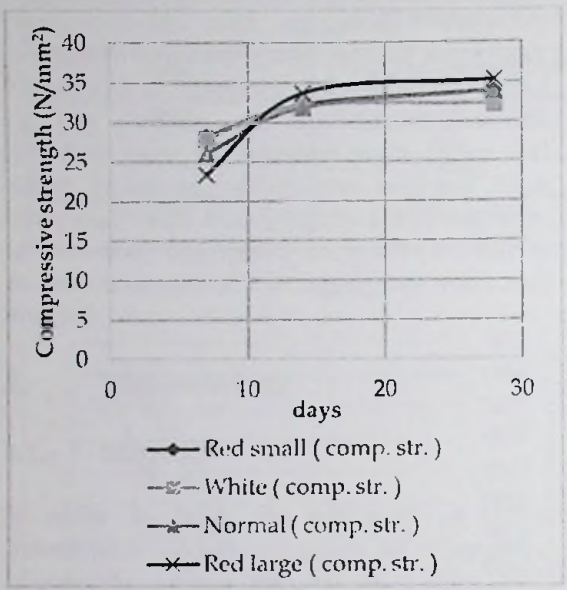

Figure 2: Variation of compressive strength

2.3 Flexural Strength

Values obtained for flexural strength by testing concrete beams are given in Table 4. It can be seen that concrete made with red small limestone aggregates have achieved highest value. Overall performances of the concrete with red limestone aggregates are better than the others.

Table 4. Flexural strength

Aggregate type	Flexural strength (N/mm2)
Red limestone (5/8")	4.2
Red limestone (3/4")	3.7
White limestone (3/4")	3.2
Gneiss (3/4")	3.2

3. Conclusions

It was found that, limestone aggregates have higher water absorption capacity than the normal aggregates. This has a significant influence on the properties of concrete made with limestone concrete. Workability and compaction ability are significantly low in limestone concrete for a given w/c ratio compared to normal aggregate concrete. This reduction is less when maximum aggregate size increases. Initial setting time of limestone concrete is also lower than that of normal concrete. These results highlight that it is necessary to use suitable admixtures to improve these properties.

Despite the negative effect on the workability and compaction, compressive strength and flexural strength are found to be the same as the concrete with normal aggregates. Also, results indicate that red limestone aggregates have better performance than the other types. Therefore, it can be concluded that use of white and red limestone are possible alternatives for normal aggregates in concrete production. However, it is necessary to do further studies on issues related to durability under harsh environmental conditions, as well as possible chemical reactions between limestone aggregates and various chemicals present in admixtures.

Therefore based on the results the use of red limestone with proper particle variation is recommended for production of concrete.

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