Development Of Expanded Clay As An Internally Curing Concrete Aggregate

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ABSTRACT: Internal curing is an emerging technology in cement concrete industry to replace the conventional curing process by supplying excess water throughout the concrete mixture. Internally curing will outperform in road construction industry than conventional curing methods due to its convenience of use in harsh environmental conditions. The research mainly focuses on finding a suitable internal curing concrete aggregate (ICCA) in Sri Lanka to use in cement concrete applications. The study presents a summary of internally curing concrete aggregate types available globally. Expansive clay available in the selected locations were able to process and develop as internal curing aggregates.

Key Words: (ICC) internally curing concrete, (ICCA) internal curing concrete aggregates, (LWA) low weight aggregate

1 INTRODUCTON

Internal curing is an emerging technology used in cement concrete industry to replace the conventional curing process. The internally curing process supplies extra water throughout the concrete mixture in order to complete the cement hydration process. This can be done by using lightweight aggregate which replaces some of normal and conventional aggregate in the concrete mixture. Expanded lightweight aggregate that exist in the concrete mixture can provide additional water for curing process. Internal curing process is defined as a method of "Supplying water throughout a freshly placed cementitious mixture using reservoirs, via pre-wetted lightweight aggregates, that readily release water as needed for hydration or to replace moisture lost through evaporation or self-desiccation" (American Concrete institute,2010)
Internal curing process has more benefit to the road construction industry than the conventional curing. Closer of roads for curing of concrete is not practical in busy roads. According to (Jensen, 2007), internal curing process helps to prevent early age shrinkage, increases hydration process throughout the concrete. As a result of providing additional water through the internal curing process, it can reduce early age cracking, curling, warping, and lowers the permeability of the concrete, as well it can increase strength and durability of concrete. So internal curing is a revolutionary curing process

2 OBJECTIVES

Main objectives of this study are to;

- Review the internal curing aggregates types
- Identify readily available resources in Sri Lanka to produce ICCA
- Develop the properties of ICCA

3 LITERATURE REVIEW

3.1 *Materials*

Extensive literature survey was conducted to identify the suitable ICCA internationally. Various types of ICC aggregates are shown in Table 1.

3.1.1 Properties of suitable ICC aggregate Available in North America.

Aggregate with following characteristics are recommended as ICCA.

i. Water absorption is greater than 6%.
ii. 48 hours' water absorption exits within the range of {6%-31%}.
iii. Water desorption of ideal aggregates is greater than 90%.

(Castro at al, 2011)

3.1.2 Availability of ICCA materials in Sri Lanka.

Natural mines

Most of natural ICC aggregates are obtained from volcanic rocks. Naturally it becomes LWA due to the air filled pores and can be used as ICCA (Failla et.al. 1997). Unfortunately, there is no natural mines in Sri Lanka to obtain natural ICCA.

By products

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By products of coal combustion can be used as ICCA. By products of coal power plant at Norochcholi was investigated. Bottom ash of the power plant has been used to replace the fine aggregate of asphalt concrete mixtures. (Thalagahage .H & Dammika.R, 2014) However, the water absorption of the material was 0.41% so, bottom ash at Norochcholi is not suitable as ICCA.

Super absorbent polymers

Super absorbent polymers are available in polymer production industry. However, it is not a cost effective material to produce economical concrete

Natural organic Substances

Toughness of natural organic substances available in Sri Lanka are not sufficient to use in load bearing concrete constructions.

Products

In order to produce ICCA, it is necessary to use Shale, Clay or Slate natural mines. However, slate and shale mines are not locally available in order to produce expanded ICCA. Since various natural clay mines are available in Sri Lanka, Expansive clay types used in ceramic industry may be viable products for expanded clay ICCA.

3.1.3 Properties of Clay suitable for expanded clay production

Following characteristics are required to use expanded clay as ICCA.

i. Bloating coefficient Kp should be at least 2 (3 – 4, is desirable).
ii. Initial melting temperature no higher than 1300 °C.
iii. Bloating temperature should be lowered at least 50°C than the melting temperature. Composition of CaO should be lesser than 8 %.
iv. Good bloating properties are typical of the clays with a content of.
   a. SiO2 50 % – 60 %,
   b. Al2O3 15 % – 20 %,
   c. Fe2O3 7 % – 8 %,
   d. R2O 2 % – 3 %,
   CaO + MgO no larger than 5 %,
   Organic matter– 0.5 % – 3 %.

Above first three properties which mentioned under the section of 3.1.3, (i, ii, iii) are closely related to the chemical composition of clay. Some scientists consider that clay bloatability is impacted by the (Na_2O, K_2O, CaO, MgO, Fe_2O_3) oxide sum to SiO2 and Al_2O_3 ratio.
(Balandis et al, 1995: 438 p. (in Lithuanian)

4 EXPERIMENTAL DETAILS

4.1 *Materials*

Various ICC aggregate raw materials were tested and properties were evaluated based on available literatures.

4.2 *Production of expanded clay ICC aggregates*

Selected clay types were mixed and sieved. Clay samples were prepared and passed through a heating process. Heated samples were crushed into required sizes and ICC aggregates were produced.

4.3 *Test for water absorption*

Water absorption of ICCA was estimated as per the ASTM C128-07 -Standard Test Method for Density and Absorption for fine Aggregate.

4.4 *Mix proportioning and Compressive Strength*

Crushed aggregates were sieved and soaked for 24hours, after that soaked ICC aggregate were used for preparation of ICC concrete mixture. Concrete cubes were cast and compressive strength were measured: (1) 3 day external curing (2) internal curing, against the control sample prepared without ICCA.

4.5 *Test for water absorption as a function ICC aggregate formation temperature*

Prepared raw materials were kept in a laboratory Furnace and three samples at (800^{o}C, 900^{o}C ,1000^{o}C) temperature were prepared. These were

Table 1: Different ICCA types

Natural	Product	By product	polymer	Organic Substances
Porous structure created naturally (rapid cooling of lava hurtles through the air)	Porous structure created by heating through a rotary kiln	Porous structure created by heating (coal combustion)	Chemical process (absorbs water and converts it into gel)	Porous structure created naturally (grain arrangement)
pumice	Expanded clay	Bottom ash	Sodiumpolyacrylate	rice hulls
scoria	Expanded shale	Fly ash		straw
tuff	Expanded slate			peat
volcanic cinders				

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tested for the water absorption.

5 RESULTS AND DISCUSSION

5.1 *Production of expanded clay ICC aggregates.*

Finding a suitable expanded clay mine is necessary and difficult process it requires the knowledge of geological expertise and data from relevant authorities. After studying the relevant data, an expanded clay mine was found at Anuradhapura district.
Required properties can be achieved by mixing different clay types with main clay type. Selected clay types were mixed according to the steps given below to obtain required properties in order to produce ICC aggregate.

i. The extracted expanded clay was left in the open air in order to season for a number of months.
ii. Then it was broken up with grinding equipment and rolling mills. Mix different clay types in order to get required clay properties.
iii. Collected the mixed sample and passed it through the 5mm and 2mm rolling mill for further mixing and grinding.

Then the prepared raw samples were collected in order to conduct laboratory tests and in order to produce internal curing aggregates. Prepared clay tiles were kept in a dryer for 3 to5 days at 60 ^{o}C. Then it is moved into a firing kiln. It was passed through a step heating process (varying temperature from 200^{0} C-900 ^{0}C).
Burned tiles were crushed using a mechanical crusher and samples were collected (type A) in order to check the suitability as an ICC aggregate.
Another ICCA sample was prepared under the facilities of source B supplier. Samples were col elected (type B) in order to check the suitability as ICC aggregate.

5.1.1 Composition of expanded raw clay sample.

According to the tests conducted by source suppliers the compositions of each clay types were mentioned in table 2.

Table 2. Properties of raw materials

Compound Element	Required property	Type A	Type B
Silicon Dioxide SiO_2	50-60	65	57.72
Aluminium Oxide Al_20_3	15-20	19	21.38
Ferric Oxide Fe_20_3	7-8	6	13
Magnesium Oxide MgO	<5	1.49	1.72
Calcium Oxide CaO	<5	1.8	0.97

These two materials are suitable to produce and further develop the characteristics of ICC aggregate because it has required mineral composition as per the literature.

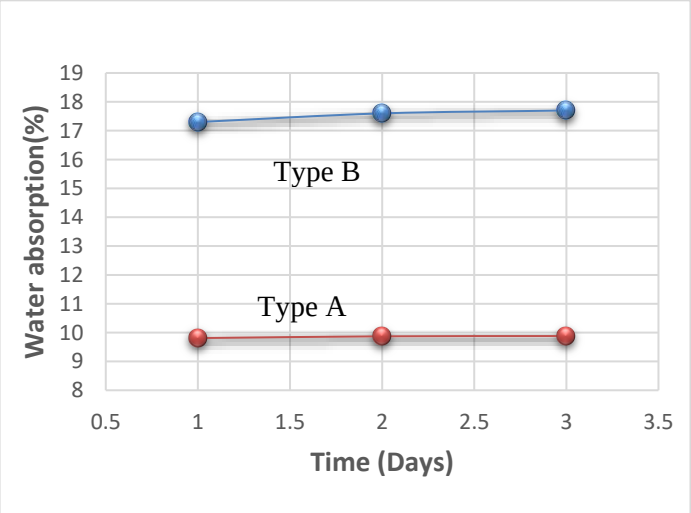
Table 3 Mean water absorption as function of time

Properties	Type B, No of Days			Type A, No of Days		
	1	2	3	1	2	3
Mean water absorption (%)	17.3	17.6	17.7	9.81	9.87	9.87

5.2 *Test for water absorption*

Two samples (type A, type B) were crushed and selected a range of fine aggregates from no 4 to no 7. Then three ICCA samples were prepared by using each ICCA type for each soaking period (day1, 2, 3) to find the water absorption of this aggregates in order to produce internal curing concrete mix. Results are shown in table 3 and
standard test, ASTM C128-07 was conducted to estimate water absorption of ICCA.

Fig; 1 Water absorption of ICCA sample



Both samples are within the acceptable range for water absorption and 24hr water absorption also within the acceptable range. So these two types of materials can be used as ICC aggregates.

5.3 *Mix proportioning and compressive strength*

M_{LWA} = mass of low weight aggregate

$$Mlwa = \frac{Cf \times CS \times \alpha max}{S \times \phi LWA} \quad \text{Equation 1}$$

Water absorption of type B aggregate sample is higher than that of Type A. So Type B was selected for the production of initial concrete mix for testing. The required amount of ICCA was calcu-

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lated using above theoretical equation 1. Then the mix proportion was prepared in order to conduct compressive strength test. (grade 30 concrete mix) Mean compressive strength of the concrete cubes (150mm x150 mm x 150mm) are shown in table 4.
Table 4; Compressive strength of cubes

Sample	A	B	C
7- day mean strength (N/mm2)	25	22	23
14- day mean strength (N/mm2)	32.5	27	27
28- day mean strength (N/mm2)	33.5	33	33

Sample A, B and C are control sample, internal curing only sample and 3-day external curing and internal curing respectively.
According to the test results of 28-day compressive strength, all samples reached to the same strength after the selected curing processes. It indicates the suitability of the selected expansive clay product as ICCA.
The characteristics of selected ICCA can further develop by changing their shape, formation temperature, aggregate sizes and bloating factors. So further studies are necessary to develop this ICCA in order to achieve best performance as internal curing aggregate.

5.4 *Test for water absorption as a function ICC aggregate formation temperature*

Three samples were prepared by varying temperature(800^{o}C,900^{o}C,1000^{o}C) under the laboratary facilities of university of Moratuwa in order to observe the water absortion as a function of temerature. The type A material was used. It indicate that the water absorption of this ICCA can be further developed to improve performance by reducing the amount of ICCA added to the concrete mixture.

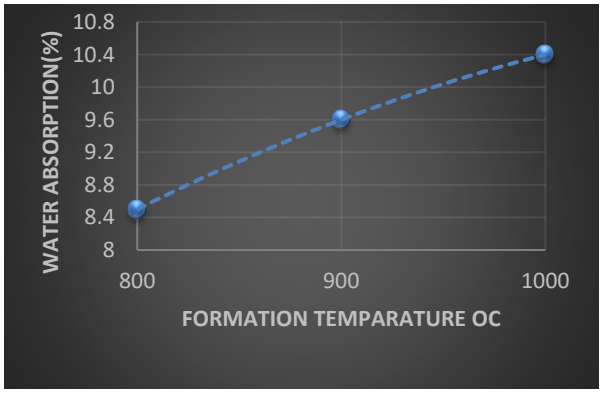
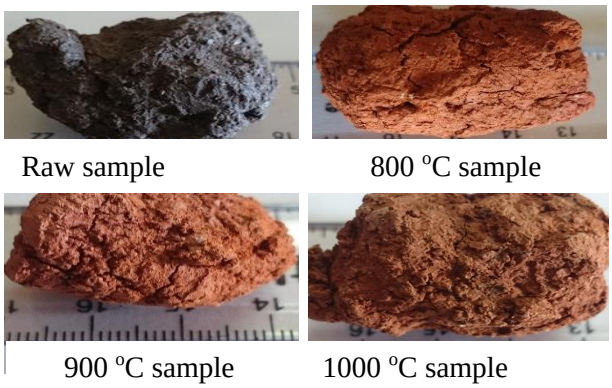


Fig2; water absorption & formation temperature

Fig 3: Bloating action



Raw sample — 800 ^{o}C sample

900 ^{o}C sample — 1000 ^{o}C sample

As the temperature increases, the bloating action increases. So, the porous structure formation can be observed visually according to the surface crack intensity. It indicates that the porous structure of the ICCA improved with the heating temperature.

6 CONCLUSION

Various ICCA types were presented based on the extensive literature survey carried out as a part of the research. Expanded clay internal curing aggregate production is the best and most available option for Sri Lanka. Suitable expanded clay mines can be found in Anuradhapura district and required properties can be achieved by mixing different clay types.
Produced aggregate has acceptable water absorption (24hr) as an ICCA and the water absorption of the ICC aggregates can be developed by varying the temperature at the production of ICCA. Experimental results of mix design using ICCA showed that the 28 day strength of the ICCA concrete mixtures were same as the concrete mixture produced with natural aggregates subjected to conventional water curing.

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