Construction and Building Materials 160 (2018) 156–168

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Splice strength of steel reinforcement embedded in recycled aggregate concrete

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HIGHLIGHTS

- Bottom-cast scaled splice beam specimens with unconfined contact lap splices have been investigated.
- Bond behaviour of recycled aggregate concrete has been discussed.
- Descriptive bond strength equation for recycled aggregate concrete has been developed.

ARTICLE INFO

Article history:
Received 3 January 2017
Received in revised form 29 August 2017
Accepted 5 November 2017

Keywords:
Splice strength
Bond
Splice beam specimen
Recycled concrete aggregate
Recycled aggregate concrete

ABSTRACT

Splice strength of deformed steel bars embedded in recycled aggregate concrete was experimentally investigated using 24 bottom-cast scaled splice beam specimens detailed with unconfined contact lap splices and tested under four-point bending. The following variables were investigated: concrete grade (normal- and high-strength), recycled concrete aggregate replacement level (0%, 50% and 100%), rebar diameter (12 mm and 20 mm) and rebar surface characteristics. Bond behaviour and failure modes were noted to be similar in the natural and in the recycled aggregate concrete and a regression analysis of the experimental results in an expanded data base shows that $f_c'^{1/4}$ provides a good representation of the influence of recycled aggregate concrete grade on splice strength. A descriptive bond strength equation has been proposed for recycled aggregate concrete and it is noted that the ACI Committee 408R-03 model (for conventional concrete) gave relatively the most accurate and conservative bond strength predictions for the recycled aggregate concretes under investigation.

1. Introduction

Splice strength is the maximum load which can be transferred between overlapped discontinuous reinforcement bars through bond action and if the design strength of the reinforcement has to be developed at the spliced section then the required minimum overlap length is called as the splice length. According to Harajli and Salloukh [1], splice length and development length are equivalent for the same boundary conditions. Bond and anchorage characteristics of steel reinforcement bars embedded in conventional or Natural Aggregate Concrete (NAC) have been extensively investigated and the major factors which affect development or splice strength have been identified as: concrete grade, bar diameter, bar cover and spacing, rebar coating, area of transverse reinforcement, development length, state of stress and loading type (monotonic/cyclic) [2–5].

Bond behaviour has been experimentally investigated using either of the following four test specimen configurations: pullout specimens, beam-end specimens, beam anchorage specimens and splice specimens. Of these four options, pullout specimens have been widely used because of their ease of fabrication and simplicity of the test though according to the ACI Committee 408R-03 [6], these specimens are the least realistic because the stress fields in such specimens deviate significantly from those in actual construction. Relatively, the most realistic and convenient investigation of bond behaviour in full-size members is carried out using splice specimens and a majority of the development/splice length provisions in current design codes have been calibrated using data obtained from the testing of such specimens. Splice beam specimens provide the most realistic response for bond performance in a flexural stress state.

One of the possibilities being explored for reducing the environmental impact of concrete made using conventional materials is

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https://doi.org/10.1016/j.conbuildmat.2017.11.007
0950-0618/

the substitution of natural aggregates with aggregates derived from recycling of construction and demolition waste. This is not only expected to reduce pressure on natural sources of aggregates but is also likely to help in safe and sustainable disposal of the huge volumes of construction and demolition waste generated across the world. Till date, concrete containing recycled aggregates has been mostly used for non-structural applications and before designers can consider structural use of such concrete they would be keen to know its behaviour under actions like bending and shear and more importantly in bond, which underpins design for bending. It is well established that aggregate quality has a significant influence on bond strength and the use of high-strength aggregates improves the fracture energy of concrete which in turn can delay splitting failure and enhance bond strength. On the other hand, the porous and soft nature of the residual mortar layer which typically exists in a recycled aggregate concrete particle may render concrete containing such aggregates susceptible to crack propagation leading to possibly lower bond strengths.

Table 1
Physical properties of the Portland cement.

Property	Unit	Test result	Limiting values specified in IS 8112:1989 [23]
1	2	3	4
Specific gravity	–	3.14	–
Fineness by Blaine's Air permeability test	m^2/kg	285	≥225
Soundness, Le-Chatelier	mm	1	≤10
Standard consistency	%	28	–
Initial setting time	Minutes	74	≥30
Final setting time	Minutes	168	≤600
72 ± 1 hours' compressive strength	MPa	25.2	≥23
168 ± 2 hours' compressive strength	MPa	37.5	≥33
672 ± 4 hours' compressive strength	MPa	45.8	≥43

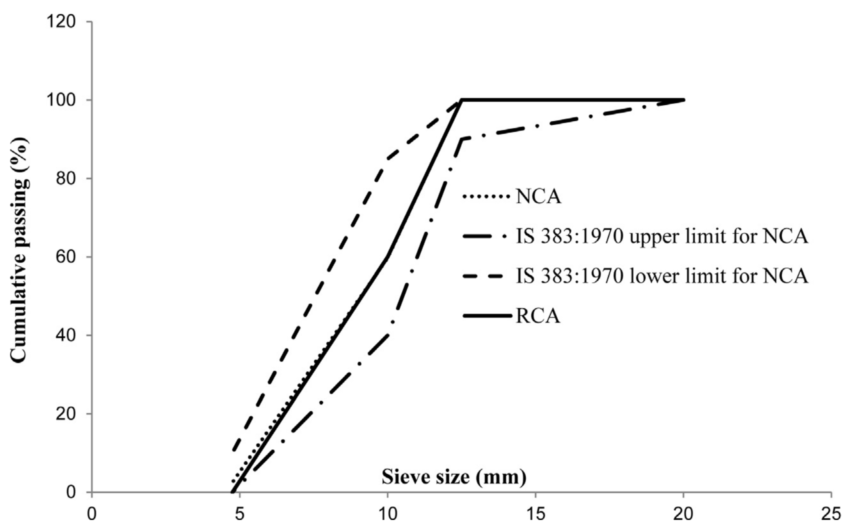

Fig. 1. Grading curves of the natural coarse aggregates and the coarse recycled concrete aggregates.

Table 2
Physical and mechanical properties of the aggregates.

Characteristic	Test result		
	Fine Aggregates	Natural Coarse Aggregates (NCA)	Recycled Concrete Aggregates (RCA)
1	2	3	4
Grading	Zone II	12.5 mm maximum size aggregate	12.5 mm maximum size aggregate
Fineness modulus	2.68	6.38	6.40
Bulk specific gravity	2.68	2.67	2.50
Density (Compacted) (kg/m^3)	1866	1630	1385
Density (Loose) (kg/m^3)	1675	1419	1230
Water absorption (%)	0.7	1	6
Crushing value (%)	–	21.2	21.7
Impact value (%)	–	17.3	22.2
Abrasion value (%)	–	18	20.2
Residual mortar content (%)	–	–	32.2