New design method for C30 recycled concrete using mixed source concrete coarse aggregates

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Keywords: coarse recycled concrete aggregates (CRCA); recycled concrete with CRCA; two mixed source concrete (SC); compressive strength; splitting tensile strength; proposed weighted mean strength.
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Abstract: The present study proposes a new mix design method for C30 recycled concrete. Its dosage of cement, water, sand and coarse recycled concrete aggregates (CRCA) are kept the same as the corresponding components in natural concrete. Its weighted mean strength has a value of 43.1 MPa for two strengths source concrete (SC). Compressive and splitting tensile strength tests on recycled concrete with CRCA (100% substituting limestone aggregates) made from two mixed SC with varying strengths, have been implemented to acquire the mix design method. For investigating the influence of CRCA from two strengths SC on recycled concrete performance, test parameters of mechanical behavior including compressive strength of SC, strength difference between two mixed SCs and proportion of two mixed CRCA were taken into account. Test results indicated that when one of the two mixed SCs' strength is similar to target strength, two requirements, i.e., the second mixed SC's strength is more than 10MPa higher than the target strength and the proportion of the higher strength SC is larger than 75% in weight of total CRCA, have to be satisfied to achieve the target compressive strength. The results gathered will form a part of useful information for recycling multiple strength SCs.

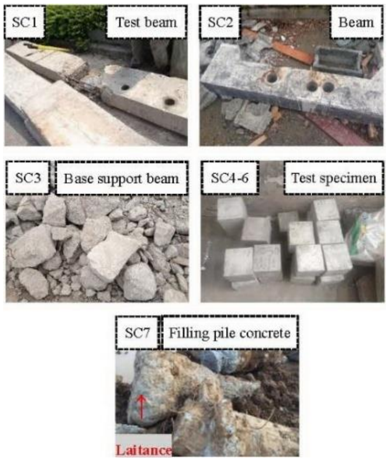

Figure 1. Source concrete from SC1 to SC7.

Figure 2. Corse recycled concrete aggregates (CRCA).

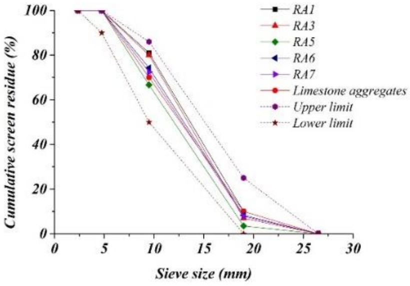

Figure 3. Grading curves of coarse aggregates.

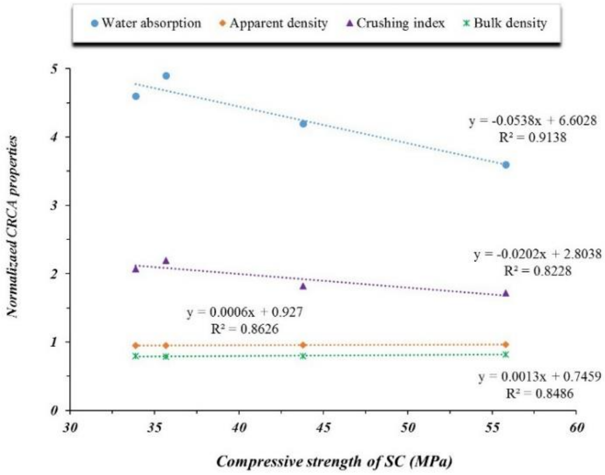

Figure 4. Relationship between SC strength and CRCA properties.

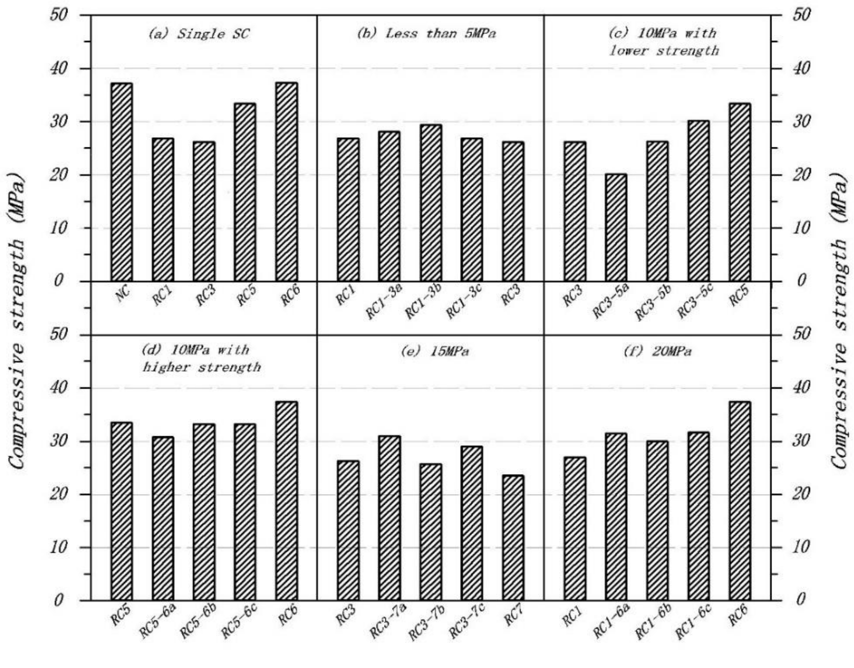

Figure 5. Compressive strength of recycled concrete with CRCA from mixed SCs.

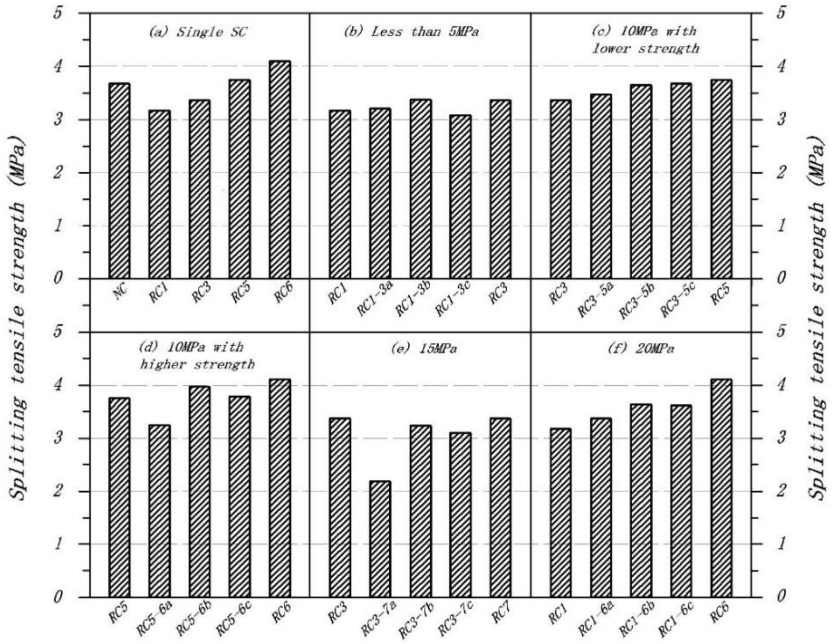

Figure 6. Splitting tensile strength of recycled concrete with CRCA from mixed SCs.

(a) (b)

Figure 7. (a) Failure within compression; (b) splitting tensile specimens.

Table 1. Overview of experimental studies on recycled concrete with CRCA from different SC.

Author, Year (Reference no)	Type of SC	Properties of CRCA					Factors considered and properties of recycled concrete				
		Psr (mm)	*Mc (%)*	*Wa (%)*	*Sg (kg/m³)*	*Cv (%)*	*Ts (MPa)*	*Sr (%)*	*W/C*	*Mechanical property*	*Durability property*
Pedro et al. (2017) [8]	L (73.2MPa); D (74.5MPa)	–	–	√	√	√	–	25, 50, 100	–	↓ (relative to Sr)	↓
Andreu & Miren (2014) [12]	L (60MPa); P (40, 100MPa)	10 (N)	–	↓	↑	√		20, 50, 100		↑ (relative to SC strength); ↓(relative to Sr)	Same to the left
Tabsh & Abdelfatah (2009) [28]	L (30 and 50MPa); D (unknown strength)	25 (M)	–	Abrasion and soundness tests conducted; ↓ (relative to SC strength)			30, 50	100	–	↑ (relative to SC strength)	–
Duan & Poon (2014) [30]	R and L	5–10 10–20	√	↑	↓ (relative to Mc)	↑	30, 45, 60, 80	100	√	↓ (relative to Mc)	↓
McGinnis et al. (2017) [31]	13 sources around U.S.	25 (M)	–	√	√	√	48.3–68.9	50, 100	–	↓ (relative to Sr)	–
Kou & Poon (2015) [32]	L (30, 45, 60, 80 and 100MPa)	20 (M)	–	↓	No evident law	–	45, 65	100	–	↑ (relative to SC strength)	↑

Gonzalezcorominas & Etxeberria (2016) [33]	L (40, 60, 100MPa)	–	–	↓	–	↓	–	20, 50, 100	–	↑ (relative to SC strength); ↓(relative to Sr)	Same to the left
Liu, K et al (2016) [34]	L (from 35 to 57MPa)	4.75–26.5	–	↓	–	↓	–	100	–	–	↑ (relative to SC strength);

Note: Psr, Mc, Wa, Sg, Cv (La), Sr, Ts, L, P, R and D represent particle size range, mortar content, water absorption, specific gravity, crushing value (Los Angeles wear), substituting ratio, target strength, laboratory, precast concrete company, recycling plant and dump site, respectively. The symbols "√" and "–" represent the property tested or not; " ↑ " and " ↓ " represent the quality of CRCA and CRCA concrete increase or decrease, respectively as Mc (or SC strength) and substituting ratio increases. M and N in brackets represent maximum and normal size, respectively.

Table 2. Compression strength of source concrete mixes.

Specimen	Compressive strength (MPa)	Test method
SC1	35.7	Core sampling method
SC2	35.6	
SC3	33.9	
SC4	34.2	Cube compression test
SC5	43.8	
SC6	55.8	
SC7	48.7	Core sampling method

Table 3. Properties of coarse aggregates.

Properties	NA	RA1	RA3	RA5	RA6	RA7
Water absorption 30 minutes (%)	1.0	4.9	4.6	4.2	3.6	4.6
Apparent density (kg/m^3)	2680	2536	2548	2563	2578	2544
Bulk density (kg/m^3)	1500	1178	1193	1198	1227	1176
Void ratio (%)	44	53.5	53.2	53.3	52.4	53.8
Crushing index (%)	5.6	12.3	11.6	10.2	9.6	11.9

Table 4. Details of concrete mixes.

Specimen	Incorporation of RA1, RA3, RA5, RA6 and RA7	Strength difference between two mixed SCs
NC	–	–
RC1	RA1	0
RC3	RA3	0
RC5	RA5	0
RC6	RA6	0
RC7	RA7	0
RC1–3a	RA1: RA3=3: 1	Less than 5MPa
RC1–3b	RA1: RA3=1:1	Less than 5MPa
RC1–3c	RA1: RA3=1: 3	Less than 5MPa
RC3–5a	RA3: RA5=3: 1	10MPa with lower strength

RC3–5b	RA3: RA5=1: 1	10MPa with lower strength
RC3–5c	RA3: RA5=1: 3	10MPa with lower strength
RC5–6a	RA5: RA6=3: 1	10MPa with higher strength
RC5–6b	RA5: RA6=1: 1	10MPa with higher strength
RC5–6c	RA5: RA6=1: 3	10MPa with higher strength
RC3–7a	RA3: RA7=3: 1	15MPa
RC3–7b	RA3: RA7=1: 1	15MPa
RC3–7c	RA3: RA7=1:3	15MPa
RC1–6a	RA1: RA6=3: 1	20MPa
RC1–6b	RA1: RA6=1: 1	20MPa
RC1–6c	RA1: RA6=1: 3	20MPa

References: Prince and Singh (2015), Fathifazl *et al* (2009), Sagoe-Crentsil *et al* (2001), Hansen and Narud (1983), Evangelista and De Brito (2007), Evangelista and De Brito (2010), Khatib (2005), Pedro *et al* (2017), Güneyisi *et al* (2016), Xiao *et al* (2005), Topcu (1997), Andreu and Miren (2014), Tavakoli and Soroushian (1996), Gupta *et al* (2016), Knaack and Kurama (2011), Fonseca *et al* (2011), Ajdukiewicz and Kliszczewicz (2002). Liu *et al* (2011), Fan *et al* (2014), De Juan and Gutiérrez (2009), Padmini *et al* (2009), Nagataki *et al* (2004), Letelier *et al* (2017), Miličević *et al* (2017), Sheen *et al* (2013), Kou *et al* (2012), Pedro *et al* (2014), Tabsh and Abdelfatah (2009), Tavakoli and Soroushian (1996), Duan and Poon (2014), McGinnis *et al* (2017), Kou and Poon (2015), Gonzalezcorominas and Etxeberria (2016), Liu *et al* (2016), Xiao *et al* (2008), Etxeberria *et al* (2007), Limbachiya *et al* (2000), Fathifazl *et al* (2009), ACI Committee 211. (1991), Gupta, *et al* (2016), Ravindrarajah, and Tam. (1985), Kou *et al* (2012).