Acoustic emission monitoring of the fracture behavior of mortar specimens fabricated using recycled concrete aggregates

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Introduction

The environmental impacts of the process and transfer of raw materials from the resource location to the construction site is enormous

Additionally, the natural resources become more limited and harder to obtain

develop an alternative solution, like the process of Recycled Concrete Aggregate (RCA)

Coarse (CRCA)

recycled concrete aggregate

Fine (FRCA)

Introduction

In the present study we wish to monitore the fracture behavior of recycled mortar specimens using the acoustic emission technique

Acoustic Emission has been used for the fracture investigation of mortars fabricated with different types and combinations of Fine recycled concrete aggregates (FRCA), limestone, natural, and standard sand as components of the specimens tested as well as the addition of fiber reinforcement

To produce the recycled mortar beams, a portion of fine recycled concrete aggregates has been used, and the specimens were tested in three-point bending

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This work led to a comparison between the fracture behavior of recycled mortar specimens with steel fiber-reinforced and baseline mortars fabricated with 100% natural sand

Experimental part

(a) Limestone
(b) Natural Sand
(c) Straight Dhaped Steel Fiber
(d) Recycled Concrete Aggregate
(e) Standard Sand

Experimental part

Four groups of three specimens per 40x40x160mm

RCxS mortar from 20% per weight from **fine recycled concrete aggregates** see and 80% from **standard sand**

RCxL and consists of mortar from 20% per weight **fine recycled concrete aggregates** and 80% from **limestone**

PxT and consists of a mortar fabricated from 100% **natural crushed sand**

Sx, consists of **steel fiber** reinforced mortar also fabricated from 100% **natural crushed sand**

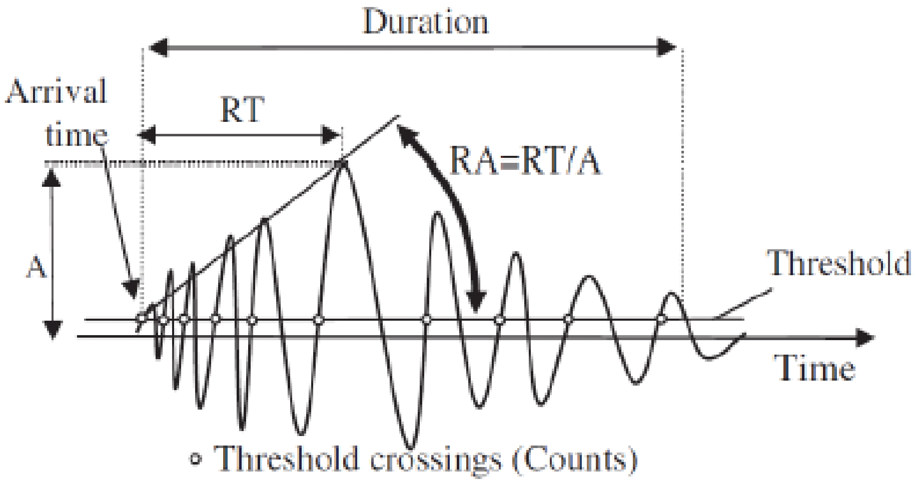
Experimental part (3-P bending)

- BS EN EN 13892-2:2002
- Displacement rate 50N/s until the fracture
- Two piezoelectric sensors named (R15, Mistras)/ 150 kHz

Materials:
- Ratio W:C:A, 0.5:1:3 by mass
- Cement (type II 42.5N)
- Same grain size in between 1.19 mm - 0.841 mm with16 – 20 Sieve Designation
- Straight-Steel Fibers used for reinforcement with 39,3 kg/m3 with a diameter of 0.6 mm and length of 25 mm and density was 7.85 kg/dm3

Experimental part (Acoustic Emission)

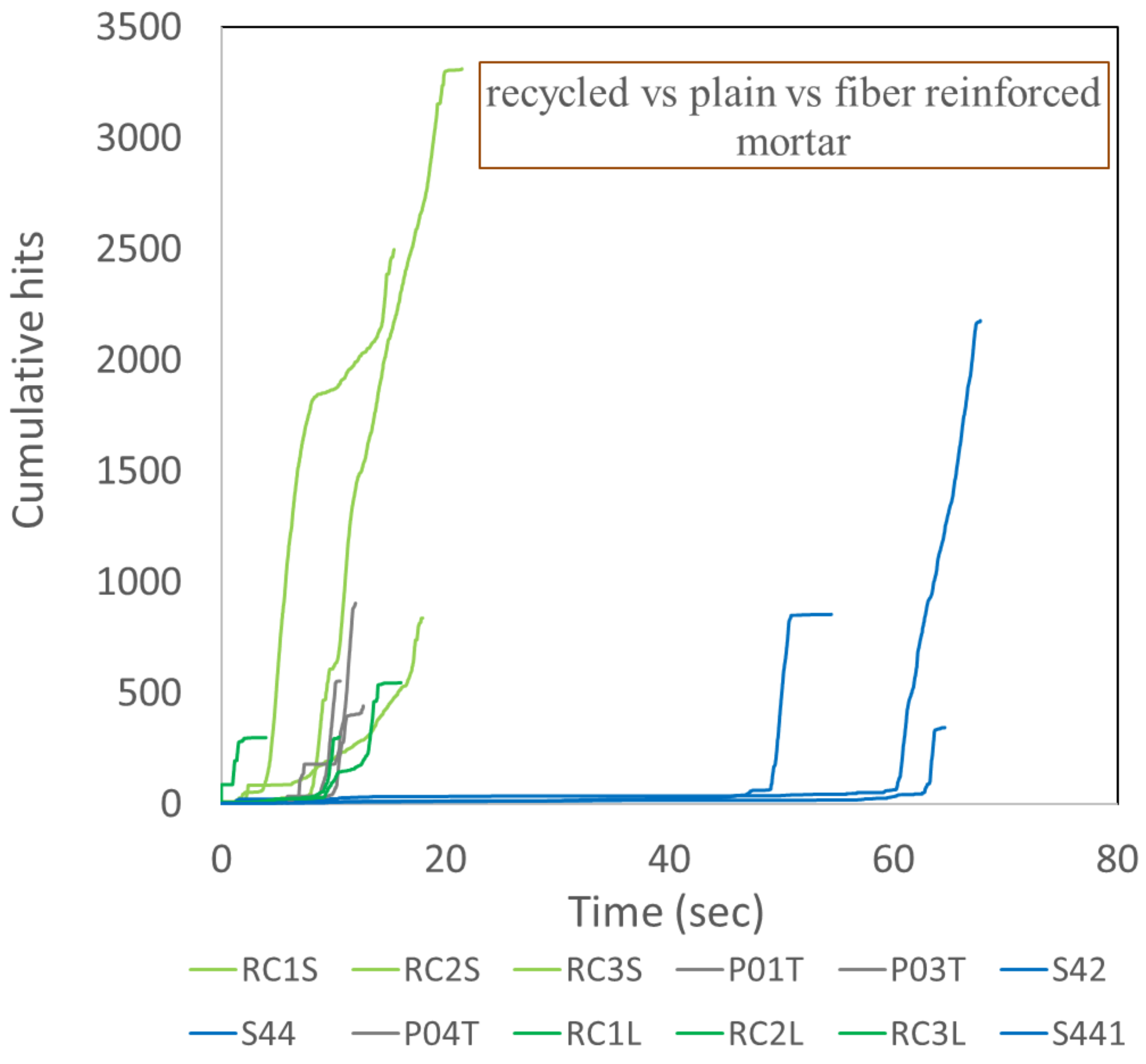
A schematic representation of a waveform



Main features

- the duration DUR (the period between the first and the last threshold crossing),
- the maximum amplitude AMP (dB).
- the "rise time" (RT) (which is the time between the first threshold crossing and the point of peak amplitude in μs). Rise Time is related to the fracture mode of the crack, and so is the inverse of the slope of the initial part of the signal (RA value, RT/A in μs/V).
- AF (average frequency) can be measured by the total number of threshold crossings divided by the duration and can characterize the Frequency content

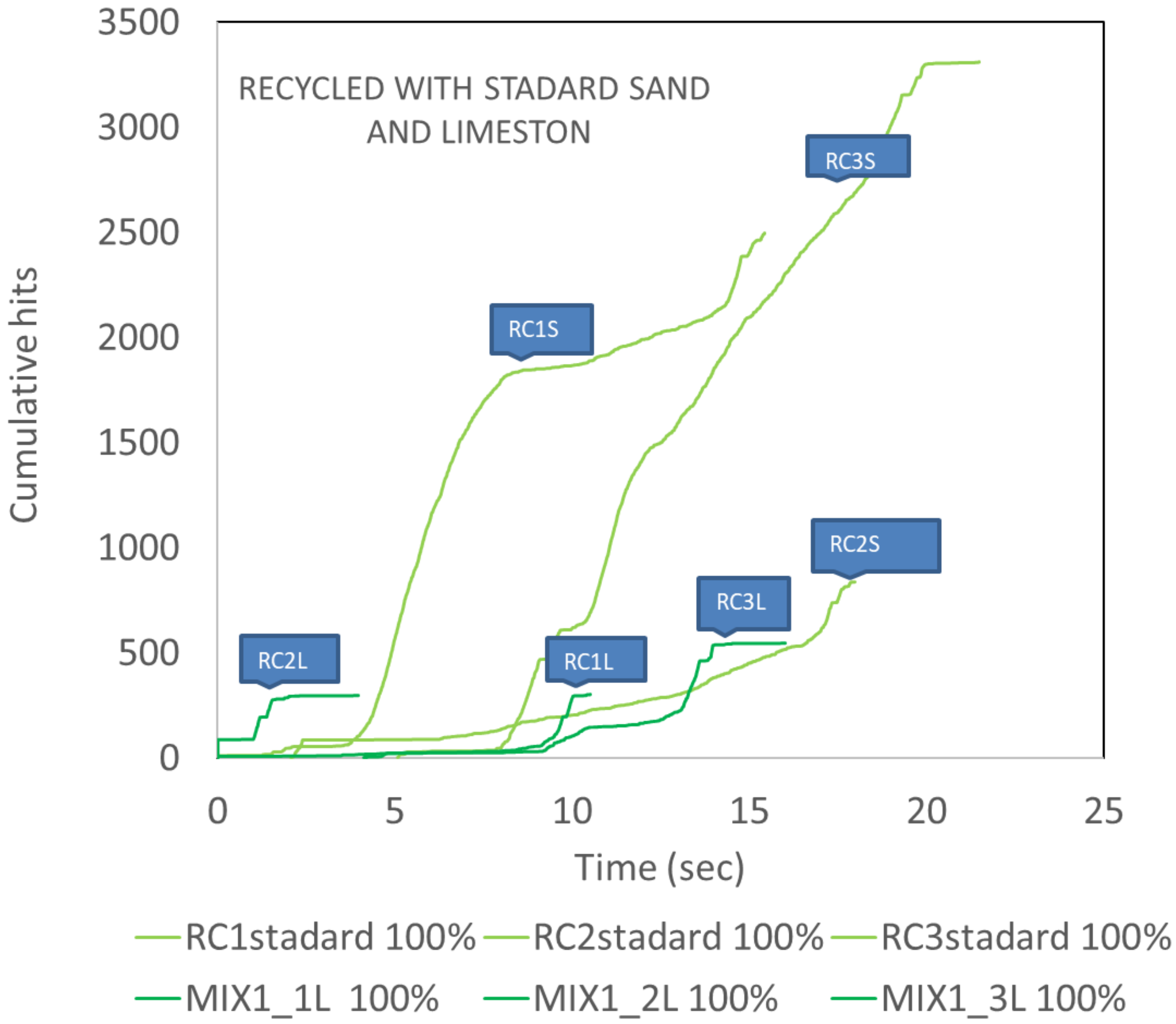
Results



- RCxS and the Sx groups achieve the maximum **acoustic activity**

- because of the fiber pull out at the cement-paste matrix that emits extra energy for the Sx specimens during the loading condition

Results



The microcrack propagation path appears more extensive in the RCxS group compared with the RCxL justifying the higher acoustic emission activity

Harsh and stiffer grains of the standard sand group tend to release a more significant amount of energy, making the fracture more brittle

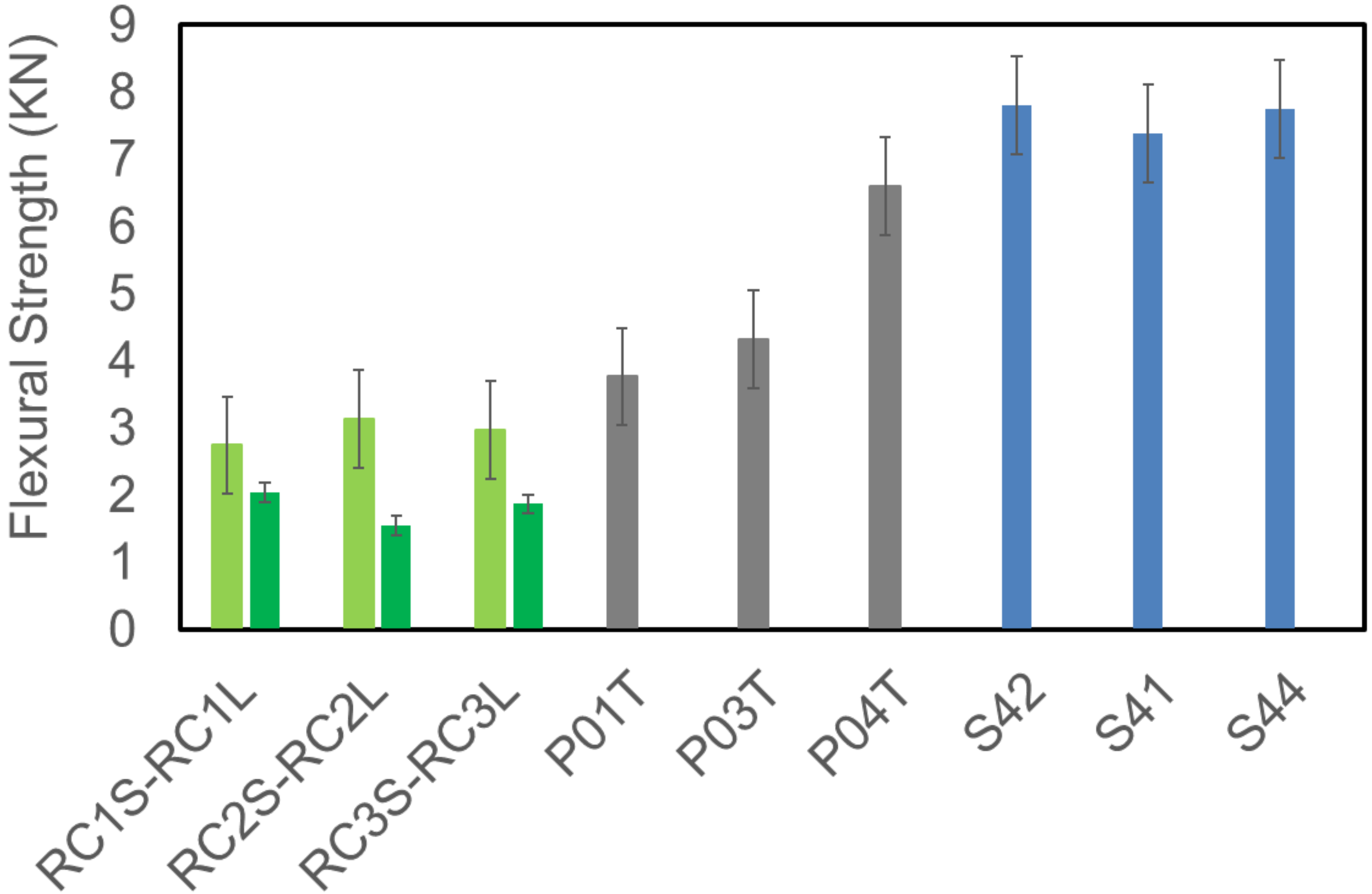
Results (3P bending)

mechanical testing and the essential acoustic emission parameters

The AE parameters are mean values from both sensors representing the total hits population of the signals emitted during the loading condition.

Mortar Type	Maximum Load (kN)	Sum COUNT	Sum ENERG	AMP (dB)	AF (kHz)	RA (μs/V)
RC1S	2,74	86421	25518,	52,02	54,36	4554,38
RC2S	3,14	31823	12535	53,35	67,83	3244,55
RC3S	2,97	193853	110784	54,29	47,02	3941,49
RC1L	2,04	10063	3246	50,44	50,98	6354,95
RC2L	1,55	12082	3396	51,21	49,08	7420,88
RC3L	1,87	19570	5803	50,89	49,65	4846,11
P01T	3,77	23227	6811	47,25	33,79	9515,60
P03T	4,33	28021	8819	47,80	33,51	12625,61
P04T	6,60	40225	14318	50,23	41,67	14205,75
S42	7,80	72414	31225	49,65	44,99	6343,10
S41	7,39	39107	17858	51,04	44,99	7962,24
S44	7,75	14472	4643	50,57	43,93	7196,15

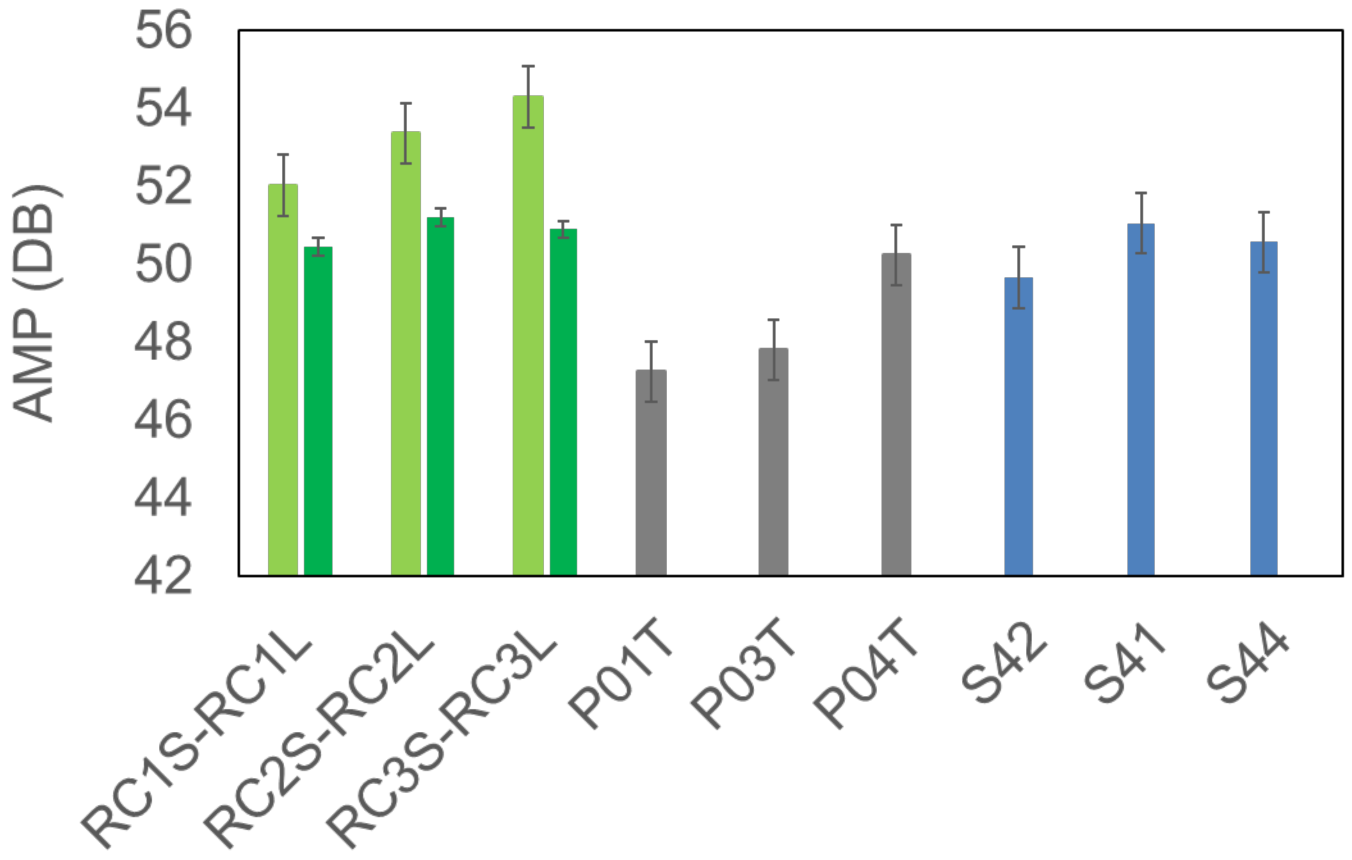
Results (3P bending)



The fiber-reinforced specimens (Sx group) exhibit higher flexural strength amongst all types, and they are followed by the plain mortar (PxT group) as expected.

The two groups of recycled concrete aggregates have minor Flexural strength

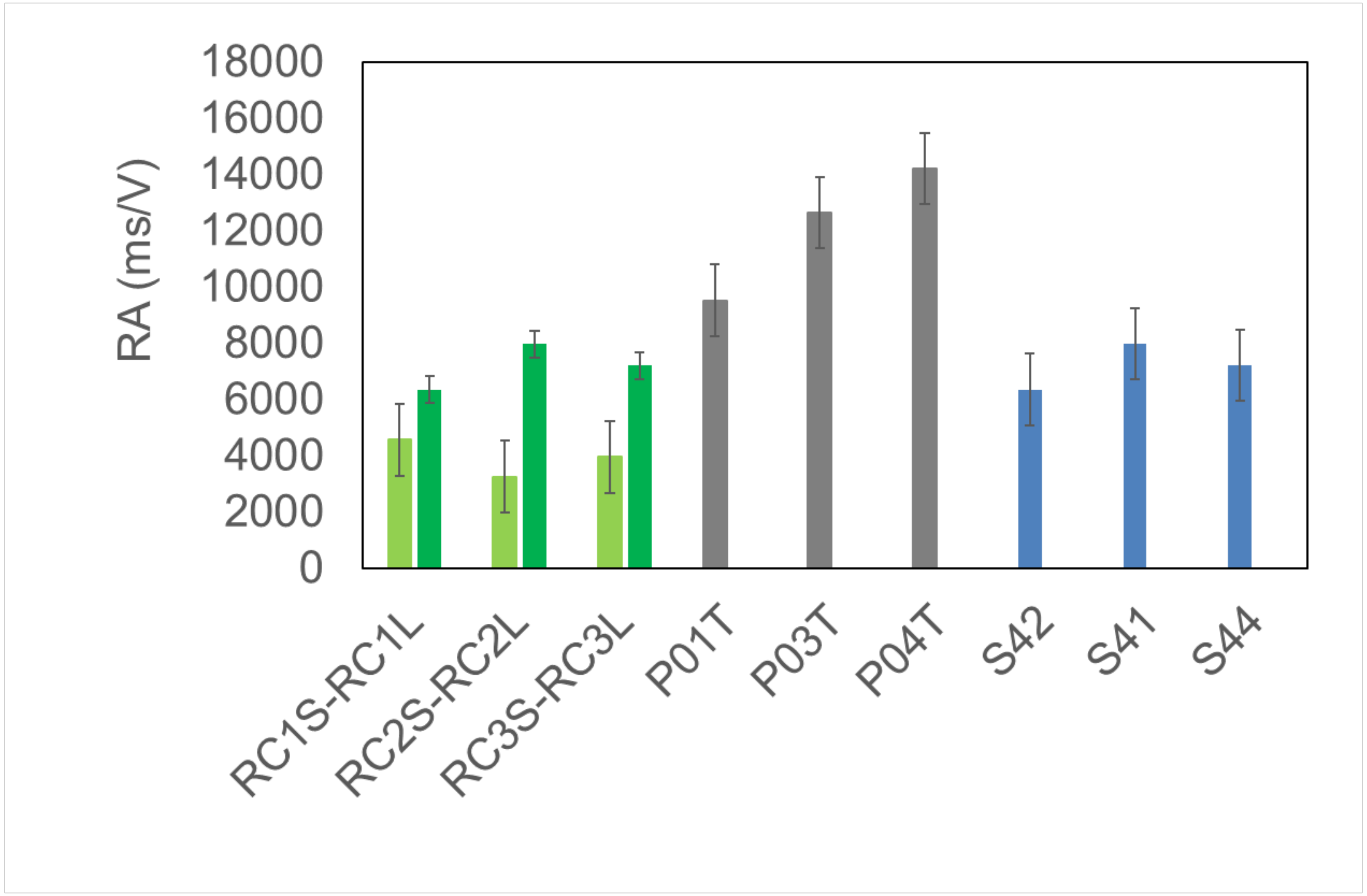
Results (3P bending)



The two recycled groups exhibit higher AMP values

The specimens from the RCxS group shows the highest AMP values with not overlap

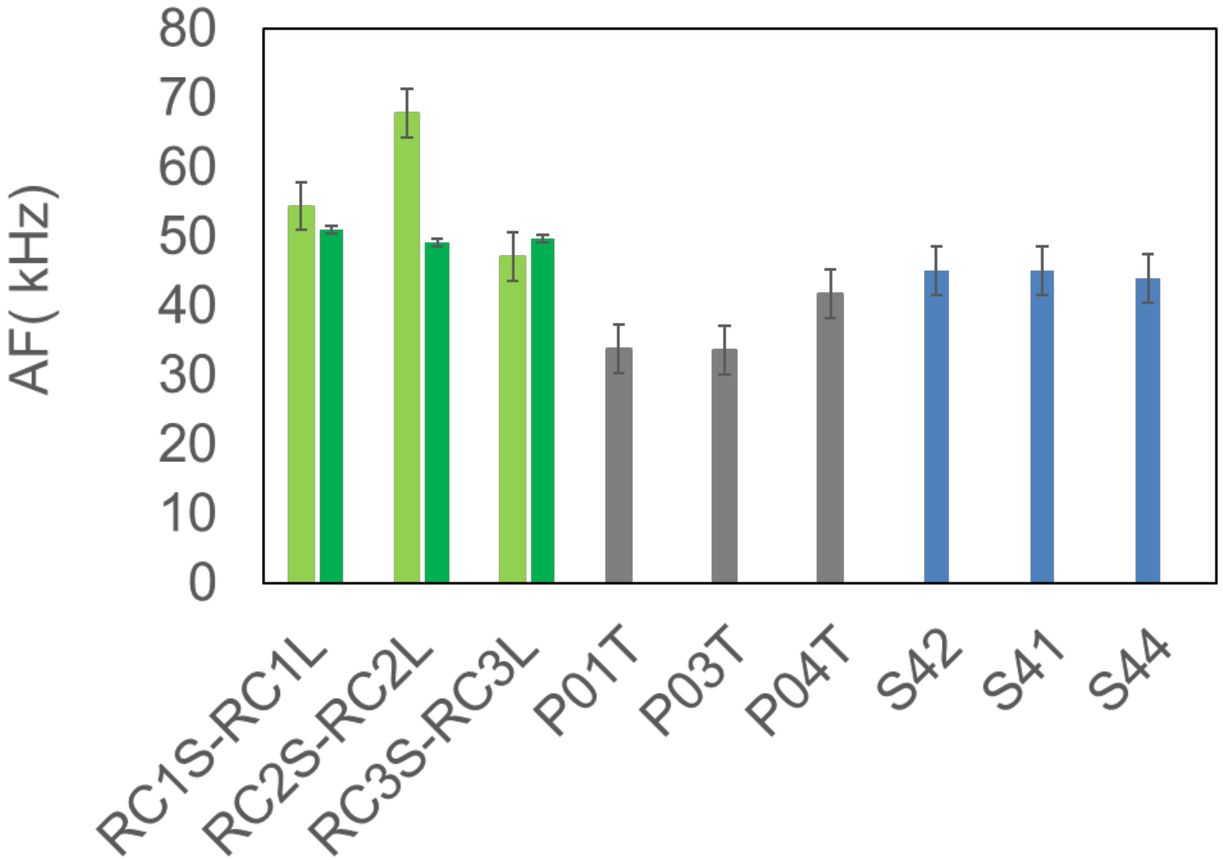
Results (3P bending)



The specific behavior of Mode I tensile microcracking of the two groups of the recycled concrete aggregate mortars, appear more evident

The lower values of the RA, together with the high AMP, can confirm the more **tensile** microcracking emitted by the two groups that represent the recycled concrete aggregates samples

Results (3P bending)



The higher values of the AF, together with the high AMP, can confirm the more tensile microcracking emitted by the two groups that represent the recycled concrete aggregates samples

The trend is more obvious for the RCxS that also have the addition of the standard sand which also favors the more brittle fracture and the tensile microcracking

Conclusions

The maximum flexural strength of the four groups corresponds well with the literature. The fiber-reinforced mortars exhibit better performance followed by the mortars fabricated with 100% natural sand, and lastly, by the recycled concrete aggregates mortars.

The difference between the flexural strength of the standard and the limestone recycled mortars groups is being justified by the stiffer nature of the standard sand grains compared with the limestone ones.

The Fiber-reinforced mortar, except for the better mechanical properties, doesn't seem to follow a specific AE trend. Even though a Mode II shear cracking is expected because of the fibers pull out from the matrix, the AE monitoring hasn't proved a precise type of failure at the microstructure because of the fiber's straight shape.

Conclusions

The higher acoustic emission activity of the RCxS group compared with the RCxL, can be explained by the potentially extensive microcrack propagation path generated. More investigation should be made with a scanning electron microscope for proofing the crack network grow.

The higher water absorption of the recycled aggregates leads to increased porosity at the mortar specimens, respectively. The specific tensile microcracking behavior of the recycled mortars microstructure is being favored by the expanded porosity.

- More specifically, the volumetric change at the microstructure because of the pore's increment affects the microcrack initiation and propagation network that is responsible for the increase at longitudinal elastic waves emitted during loading.
- Moreover, the remaining touched old cement paste at the surface of the recycled grains preventing the shear microcracking because of the friction resistance increment.

The more spherical grains of the limestone mortar tends to slip each other at the microcracks initiating the shear movement with results, the increase of the RA, and the decrease of the AF values if directly compared with the standard sand samples, which exhibits much more clear Mode I tensile microcracking.

Thank you

Any questions?

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