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Research Article

Steel scrap added roller compacted concrete

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ABSTRACT

The purpose of this paper is to investigate the benefits of using steel slag as an additive in Roller Compacted Concrete (RCC) which is a promising material can be used in streets, local roads, residential streets, high-volume roads, industrial access roads, airports...etc. The mechanical performances of steel scrap added reinforced cementitious composites produced with an industrial punch scrap. In specimen mixtures two types of scraps with diameters of 5 mm and 7 mm were used. The additive was mixed with 1%, 1.5% and 2% ratios by weight. Due to the results of the study, it was obtained that flexural strength properties of the specimens have increased up to 11%. In addition, freeze thaw effect of the specimens was investigated and found that 2% percent of scrap usage was given the best results.

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1. Introduction

Beside the base pavement design performance, RCC pavement has cheaper and faster producibility than conventional concrete pavements due to its properties (PCA, 2010). RCC also has a high flexural strength, high abrasion resistance and a better resistance for high temperature compared to the traditional pavements (Rao et al., 2014). RCC is produced with cementitious materials, aggregate and a low amount of water that is applied with asphalt pavers, compacted by vibratory rollers and hardens into concrete (Hossain and Ozyildirim, 2015). In RCC pavement design there is no need for forming, finishing, joint sawing or surface texturing and in a short period of time the produced road can open to traffic (PCA, 2010; Hossain and Ozyildirim, 2015). RCC is easy in transporting, laying and compacting, comparing to conventional concrete pavement production (Toplicic-Ćurcic et al., 2015). RCC also have a higher percentage of fine aggregates than conventional concrete which allows for tight packing and consolidation. RCC has been used for pavements traditionally to carry heavy vehicle loads in low-speed areas, due to its relatively coarse surface (Wu et al., 2017). RCC can be used also in ports, airports, military installations, intermodal facilities, warehouses, manufacturing facilities commercial and industrial parking lots, maintenance and storage yards, highway frontage roads and shoulders, minor arterials, local streets and roads (ACPA, 2014; FHWA, 2016).

The first RCC pavement usage in United States was at an airfield in Yakima, WA, in 1942; however, at early 1930s RCCP construction was reported in Sweden and Australia (Modarres et al., 2018; Ludwig et al., 1994). RCC pavement construction projects started to increase in number after mid-1980's (Ludwig et al., 1994).

Normally there is no need a wearing course for RCC pavements however in some cases a Hot Mix Asphalt (HMA) overlay has been added for smoothness or rehabilitation (ACI 325, 2001). The use of RCC base with a HMA overlay as a composite system gaining popularity to improve ride quality and saving money while still providing a durable pavement structure (PCA, 2009).

The Vebe test provides for determining RCC workability. RCC workability can measure by Vebe test, a simple and fast evaluation technique, according to ASTM C1170. For RCC workability the field experiences shown that generally fall between 40 and 90 sec is adequate when RCC is placed (Khayat and Libre, 2014; ASTM C1170, 1998).

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RCC pavements have performed well and meet the required properties to carry heavy loads under both freezing conditions, such as in Canada, and in hot conditions such as in the southern United States (Delatte et al., 2003).

The study notes that non–air entrained RCC pavements can provide reliable and durable performance in F-T environments as long as the mix has adequate cement content, sound aggregates, proper mixing, adequate compaction, and proper curing. Field performance studies have indicated that RCC has performed well in harsh weather conditions. Studies in the United States and Canada indicate that RCC mixtures, whether air entrained or not, have performed well for more than three decades (Harrington et al., 2010).

There are also some studies on literature on steel additives for RCC. In a study, a new mix design method for determining the optimal water content, the modified light compaction method, is proposed for steel fibre reinforced, roller-compacted, polymer modified, bonded concrete overlays (Lin et al., 2013). Moreover, in Coventry University a new steel-fibre reinforced, roller compacted, polymer modified concrete mix was investigated and the results have addressed a suitable mixture for the structural repair of concrete pavements has been developed. The developed mixture has shown exhibiting high flexural, shear and bond strengths and high resistance to reflection cracking, the mixture also demonstrated unique placeability and compaction properties (Karadelis and Lin, 2015).

2. Materials and Method

2.1. Materials

In this study, river sand and crushed rock were used as fine and coarse aggregates. Material properties of the aggregates are given in Table 1.

Table 1. Material properties of aggregates.

Material Property	Coarse Aggregates	Fine Aggregates
Specific gravity, t/m3	7.8	2.64
Fineness modulus	2.73	2.68
Silt content, %	-	0.72
Water absorption, %	0.42	0.12
Total moisture, %	0.41	0.10

Aggregates were air dried and cleaned from any organic content. Potable water was added into the RCC mixtures. Aggregate gradation curves can be found in Fig. 1.

CEM I type Portland cement complying TS EN 196 standard was used as the binder component of the RCC mixes. Chemical and physical properties of the cement are presented in Table 2.

Table 2. Chemical and physical properties of the cement.

Chemical and physical property	
Fe_2O_3, %	3.52
CaO, %	60.22
MgO, %	2.30
SO_3, %	2.61
Al_2O_3, %	4.32
Free CaO, %	1.7
Loss on ignition	2.85
Specific gravity, t/m^3	3.12
Soundness	0.5
Blaine number, cm^2/g	3618
Setting time (initial, final), min.	172, 228

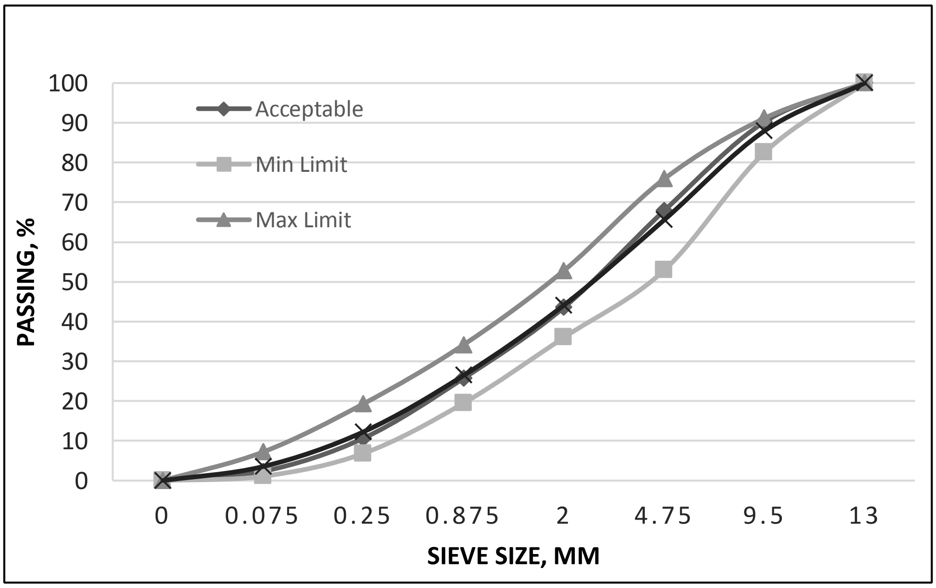

Fig. 1. Aggregate gradation curve.

AISI 304 type austenitic and stainless-steel staple scraps (5mm and 7 mm) were used in this study at 1%, 1.5% and 2% by weight. Chemical and mechanical properties of the scraps are given in Tables 3 and 4, respectively.

Table 3. Chemical properties of the scraps (AISI 304).

Material (% wt.)	AISI 304
C	0.58
Mn	1.62
Si	0.15
Cr	19.06
S	0.03
P	0.09
Ni	9.67
Balance / Fe	68.81

Table 4. Mechanical properties of the scraps (AISI 304).

Mechanical Property	
Tensile Strength (N/mm2)	505
Yield Strength (N/mm2)	215
Hardness (HRB)	70
Density (gr/cm3)	8

5 mm and 7 mm AISI 304 stainless steel pin scrap are presented in Figs. 2 and 3, respectively.

Fig. 2. 5 mm AISI 304 stainless steel pin scrap.

Fig. 3. 7 mm AISI 304 stainless steel pin scrap.

2.2. Preparation of test specimens

All RCC mixes have the same cement content as 310 kg/m3. Optimum water contents were determined according to the ASTM C1435 standard. Experimental sets and optimum water contents of the RCC mixes are given in Table 5.

Table 5. Experimental sets.

Mixture Code	W/C	Optimum water content, %	Scrap content, % wt.	Compaction ratio, %
R	0.44	5.30	0	100
S_{5-1}	0.45	5.43	1	99
$S_{5-1.5}$	0.46	5.57	1.5	100
S_{5-2}	0.47	5.67	2	99
S_{7-1}	0.48	5.45	1	100
$S_{7-1.5}$	0.50	5.60	1.5	100
S_{7-2}	0.51	5.68	2	100

Compaction process was applied to the RCC specimens with a compactor as per the requirements of the ASTM C 1435 standard. The F&T resistance of the mixes was recorded according to the ASTM C 666 standard. Compressive and flexural strength tests were applied to the specimens as per the regulations of EN 12390-3, EN 12390-5 standards. Workability of the RCC mixes was determined with the aid of Ve-Be test equipment. The mixer rate was kept constant at the rate of 350 r/min.

3. Experimental Results and Discussions

3.1. Compressive strength test results

Compressive strength test results are given in Fig. 4. Test results for 28 days vary between 39.64 MPa and 39.19 MPa. 2% punch scrap addition showed the best performance compared to the other scrap inclusions. Scrap addition slightly improved the compressive strength values. 7 mm scrap addition with the weight of 2% reflected the best performance as 39.64 MPa.

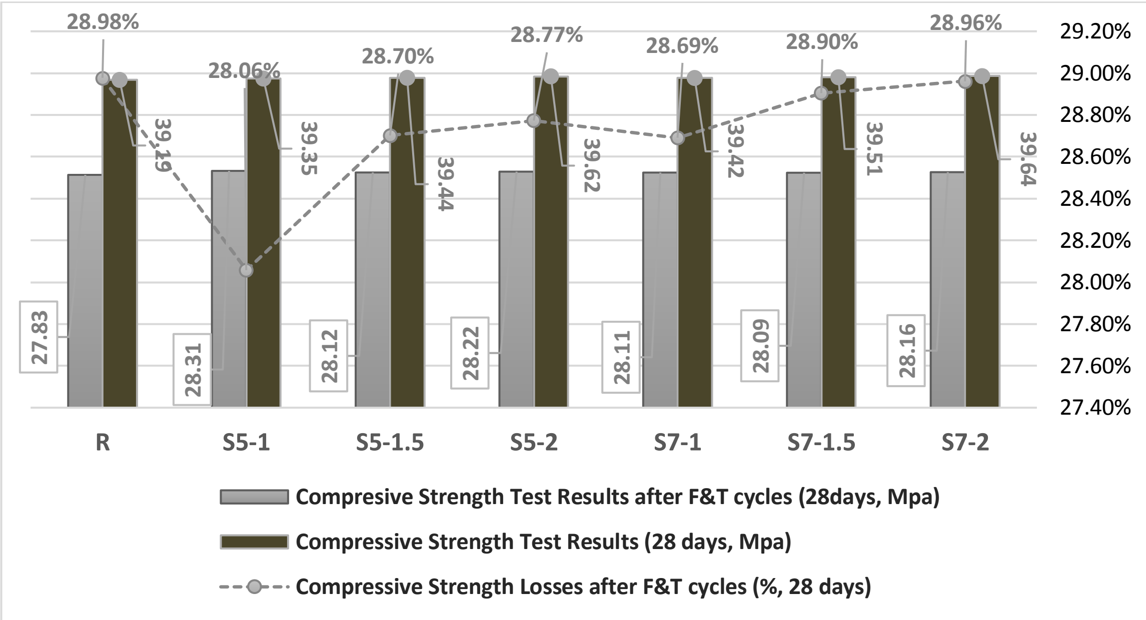

Fig. 4. Compressive strength losses after F&T cycles.

The compressive strength deformation curves of the RCC specimens are given in Fig. 5. It was observed that toughness values of the mixes slightly increased with the scrap addition.

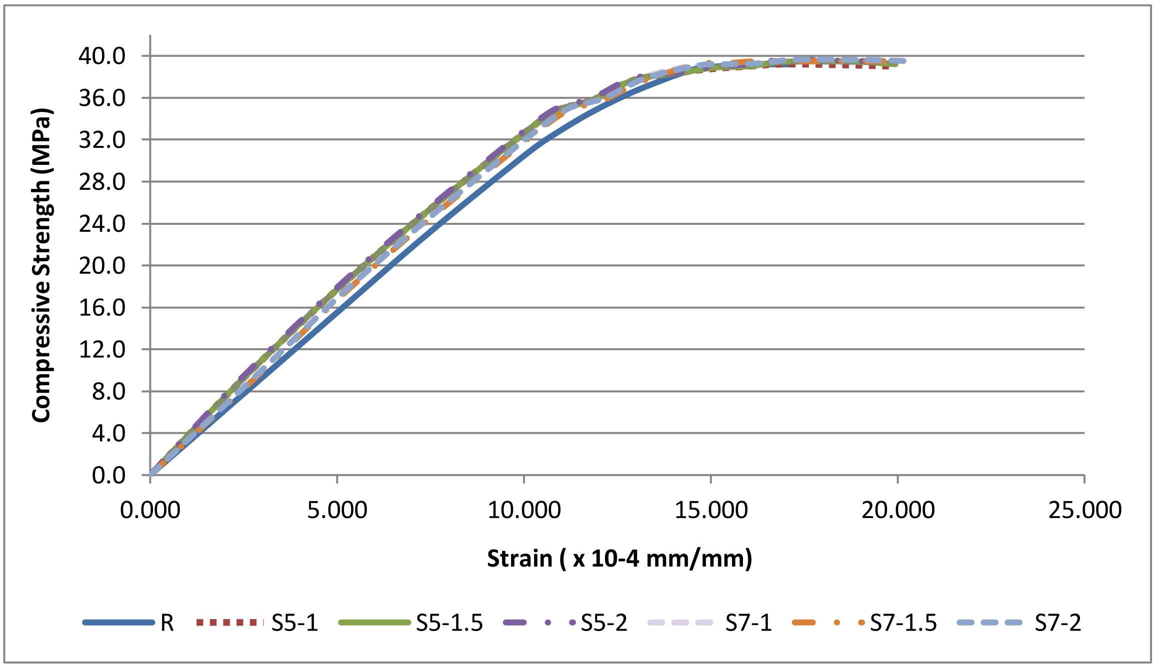

Fig. 5. Compressive strength and strain relation.

3.2. Flexural strength test results

The flexural strength test results are presented in Fig. 7. 28-days flexural strength values are increased by 10% with the 7 mm and 2% wt. Scrap addition. Scrap addition generally enhanced the flexural test results compared to the reference mix. The freeze and thaw resistance results can be found in Figs. 4 and 6 for both compressive and flexural tests. Scrap addition improved the F&T resistance of the RCC mixes

3.3. Ve-Be Results

Ve-Be test results are given in Fig. 7. Reference specimen with no scrap content showed the best performance. Obtained Ve-Be results decreased with the increasing scrap content of the RCC mixes.

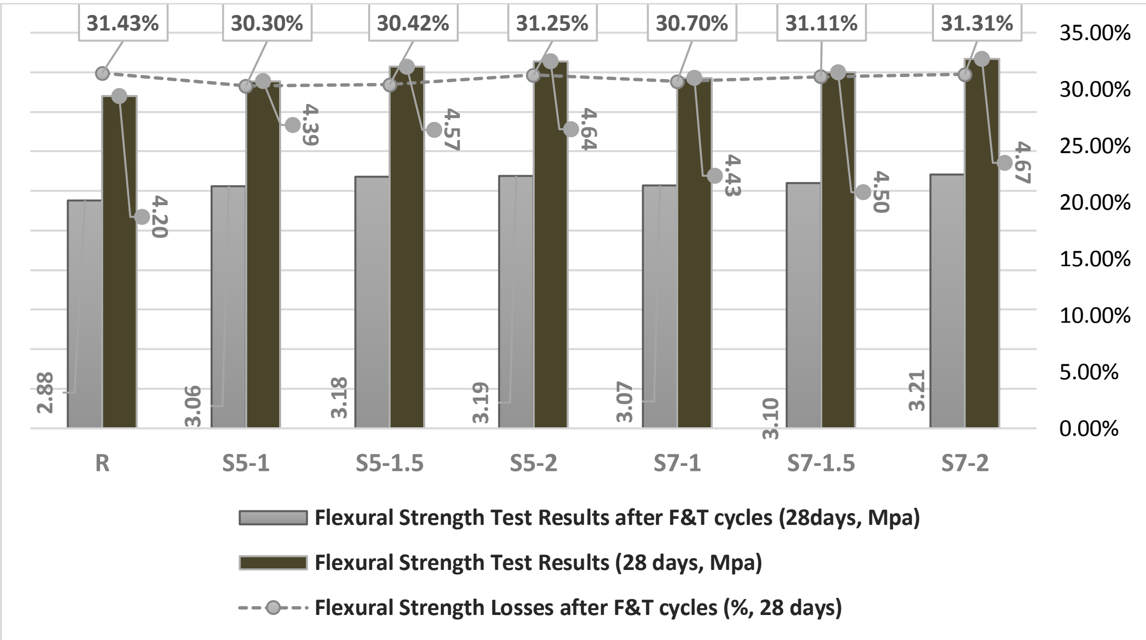

Fig. 6. Flexural strength losses after F&T cycles.

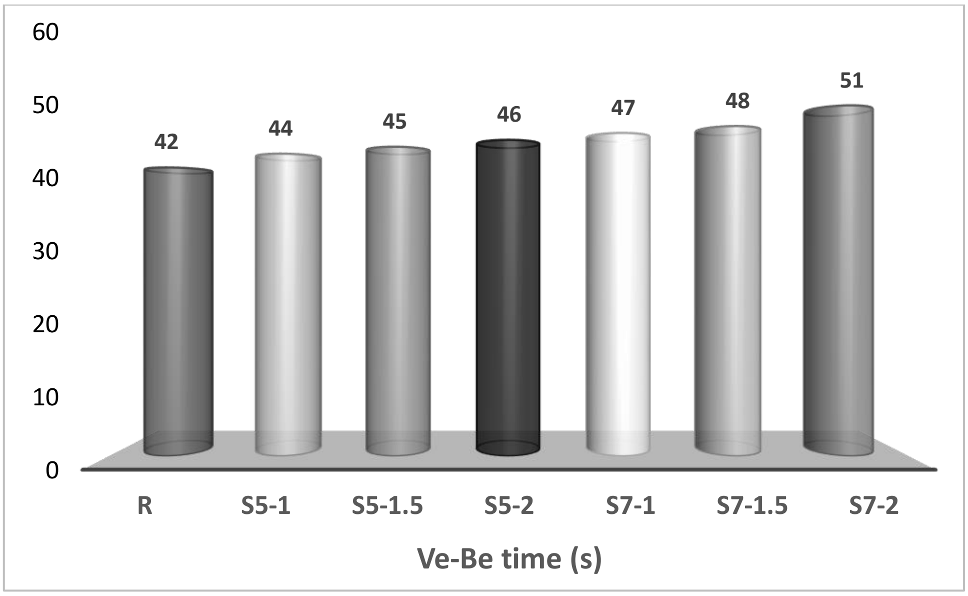

Fig. 7. Ve-Be test results.

4. Conclusions

The effect of industrial punch tool scrap on the mechanical and workability behavior of RCC mixes was studied within the scope of this research. The following findings can be concluded:

- The addition of scraps increased the water demand of the RCC mixtures. Water to cement ratio of the mixes was also increased.
- Scrap addition slightly increased the compressive strength test results. However, flexural strength performance of mixes significantly improved with the scrap addition.
- Scrap with 7mm diameter showed the best performance for all mechanical test compared to the reference and the mixes including 5 mm diameter scrap.
- Scrap addition slightly improved the F&T resistance of the RCC mixes.

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REFERENCES

ACI 325 (2001). Report on Roller-Compacted Concrete Pavements, 325, 10R-95. American Concrete Institute.

ACPA (2014). Roller-Compacted Concrete Pavements as Exposed Wearing Surface, Version 1.2. ACPA Guide Specification.

ASTM C1170 / C1170M (1998). Standard Test Method for Determining Consistency and Density of Roller-Compacted Concrete Using a Vibrating Table. American Society for Testing and Materials.

Delatte N, Amer N, Storey C (2003). Improved Management of RCC Pavement Technology. University Transportation Center for Alabama, UTCA Report 01231.

FHWA (2016). Roller-Compacted Concrete Pavement. Tech Brief HIF-16-003, Federal Highway Administration.

Harrington D, Abdo F, Adaska W, Hazaree CV, Ceylan H (2010). Guide for Roller – Compacted Concrete Pavements. National Concrete Pavement Technology Center, Iowa State University's Institute for Transportation.

Hossain MS, Ozyildirim C (2015). VDOT's first roller-compacted concrete pavement. *Transportation Research Board 94th Annual Meeting*, Washington DC, United States

Karadelis JN, Lin Y (2015). Flexural strengths and fibre efficiency of steel-fibre-reinforced, roller-compacted, polymer modified concrete. *Construction and Building Materials*, 93, 498–505.

Khayat KH, Libre NA (2014). Roller Compacted Concrete: Field Evaluation and Mixture Optimization. Center for Transportation Infrastructure and Safety/NUTC Program, Missouri University of Science and Technology.

Lin Y, Karadelis JN, Xu Y (2013). A new mix design method for steel fibre-reinforced, roller compacted and polymer modified bonded concrete overlays. *Construction and Building Materials*, 48, 333–341.

Ludwig D, Nanni A, Shoenberger JE (1994). Application of Roller-Compacted Concrete Technology to Roadway Paving. *Construction Productivity Advancement Research Program*, CPAR-GL-94-1.

Modarres A, Hesami S, Soltaninejad M, Madani H (2018). Application of coal waste in sustainable roller compacted concrete pavement-environmental and technical assessment. *International Journal of Pavement Engineering*, 19(8), 748-761.

PCA (2009). Thickness Design of a Roller-Compacted Concrete Composite Pavement System. PL633, The Portland Cement Association. Link: https://www.cement.org/docs/default-source/th-paving-pdfs/rcc/faqs/final-pl633-thickness-design-of-a-roller-compacted-concrete-composite-pavement-system.pdf?sfvrsn=4

PCA (2010). Roller-Compacted Concrete. 0020-11-105. The Portland Cement Association. Link: https://www.cement.org/docs/default-source/th-paving-pdfs/rcc/roller-compacted-concrete-pca-logo.pdf?sfvrsn=4

Rao SK, Sarika P, Sravana P, Rao TC (2014). Evaluation of properties of roller compacted concrete pavement. *International Journal of Education and Applied Research*, 4(Spl-2), 88-90.

Toplicic-Ćurcic G, Grdic D, Ristic N, Grdic Z (2015). Properties, materials and durability of rolled compacted concrete for pavements. *Zastita Materijala*, 56(3), 345-353.

Wu Z, Rupnow T, Mahdi MI (2017). Roller compacted concrete over soil cement under accelerated loading. Final Report 578, FHWA/LA.16/578, Louisiana Transportation Research Center.