Sustainable Structures and Materials, *Vol. 6, No. 1, (2023) 127-131*
DOI: https://doi.org/10.26392/SSM.2023.06.01.0127

Effect of Casting Pressure on the Properties of 100% Recycled Aggregate Concrete Pavers

Muhammad Umer Farooq*[1], Rashid Hameed[1], Muhammad Ahmad[1]

[1]*Department of Civil Engineering, University of Engineering & Technology Lahore, Pakistan*
*Corresponding author/ E-mail: muhammadumerf2@gmail.com

(Received April 6, 2023, Revised May 9, 2023, Accepted June 4, 2023)

ABSTRACT. *The construction and demolition (C&D) waste is required to be recycled for sustainable development and to save natural resources. In this study, the influence of casting pressure on the properties of pavers made using Recycled Aggregate Concrete (RAC) was investigated. RAC mix having 60% fine and 40% coarse recycled aggregates was prepared using 20% cement (by weight of total aggregates). The same mix was used in making concrete pavers of size 200 mm x 100 mm x 60 mm by employing Compression Casting Technique (CCT). For this casting technique, six different values of applied pressure from 5 MPa to 30 MPa were investigated. For comparison purposes, pavers of same size were also prepared using Natural Aggregate Concrete (NAC) under same casting pressure. Pavers were tested to determine their density, initial rate of water absorption, porosity and efflorescence. The tests were performed after 28 days of casting. The results showed that above mentioned properties of RAC pavers are improved with the increase of casting pressure; by increasing the casting pressure from 5 to 30 MPa, density, initial rate of water absorption and porosity of RAC was improved up to 2.01%, 83.6% and 51.7%, respectively. The results further indicated that compared to NAC pavers, RAC pavers exhibit inferior properties. No efflorescence was observed in RAC and NAC pavers.*

Keywords: Concrete pavers, C&D waste, recycling, casting pressure, porosity

1. INTRODUCTION

Sustainability has emerged as one of the primary concerns in the construction industry of Pakistan. It must take into account not only reduction in carbon footprint but also the preservation of the natural resources necessary for ongoing development [1].

Construction and demolition (C&D) waste is generated by the construction industries on a massive scale each year in many countries on the globe. It is necessary for these wastes to be recycled to produce Recycled Concrete Aggregates (RCA) and use them in the new concrete commonly known as Recycled Aggregate Concrete (RAC). According to predictions made by the World Bank Group, the amount of C&D waste produced would reach 2.59 billion tonnes by 2030 and 3.40 billion tonnes by 2050 [2]. Recycling of concrete waste is acknowledged as a practical solution for managing C&D waste because it decreases the use of natural resources and reclaims the land for agricultural purposes. The potential of using RAC as a structural material has already been demonstrated by previous research [3].

The RAC has inferior mechanical and durability properties due to its higher porosity and lower strength. The performance of the recycled aggregate is dependent on the amount and homogeneity of the bonded mortar. The transverse property and strength are mostly governed by the higher porosity of the old mortar attached to the RCA. One of the methods to overcome the problem of porosity is to employ compression casting technique. In a study by Hameed et al [4], concrete mixes having 100% RCA were made by CCT and it was observed that with the increase of casting pressure, water absorption is decreased which shows the positive impact of CCT on the sorptivity of the concrete mixes. In another study by Kazmi et al [5], compression casting technique was used to make cylindrical specimen using RAC containing tyre rubber. This approach was found to increase compressive strength and at the same time also allowing for a reduction in cement content.

Keeping in view the positive impact of CCT, in this study 100% RAC was used to manufacture concrete pavers by this technique and their properties including density, initial rate of water absorption, porosity and efflorescence were evaluated and compared with 100% NAC pavers.

2. MATERIALS AND METHODS

2.1 Materials

In this study, concrete mixes were prepared using Ordinary Portland Cement (OPC), Sargodha crush as coarse natural aggregate, Lawrencepur sand as fine natural aggregate and recycled concrete aggregates. The Recycled Aggregates (RA) were obtained by crushing of concrete cubes and cylinders with compressive strengths ranging from 3000 psi (21 MPa) to 4000 psi (28 MPa). After crushing, the material was sieved through #4 sieve to separate fine and coarse aggregates. Commercially available concrete admixture “SP-303” (1% by weight of cement) was used as superplasticizer and normal tap water was used to prepare all concrete mixes.

2.2 Concrete mix and casting of pavers

The RAC pavers having 60% fine and 40% coarse with w/c ratio of 0.25 and 20% cement dosage (by total weight of aggregate) were made. The effect of casting pressure on the performance of RAC pavers was investigated and compared with the NAC pavers. Specially designed metallic moulds were used to cast pavers of required size. Through trials, quantity of material to get required height of paver under applied pressure was determined. After applying the casting pressure with the help of Universal Testing Machine (UTM) on the concrete pavers, the pavers were demoulded. After 24 hours of air drying the pavers were placed in water for three days and then sprinkled with water for the remaining days before their testing at the age of 28 days. Complete process of paver production is shown in Fig-1.

2.3 Testing methods

The weight and actual dimensions of RAC and NAC pavers were recorded to calculate their density. The porosity of the pavers in terms of volume of pores was determined as per standard ASTM C642 [6]. For this purpose, SSD weights, oven dry weights, soaked-boiled SSD weights and apparent weights of the concrete pavers were measured.

The initial rate of water absorption and efflorescence tests were performed as per ASTM standard C67 [7]. For initial rate of water absorption two metal rods were used as supports for samples while placing the samples in the tray as shown in Fig-2. A reference paver was saturated, and its bottom was marked to the height of 1/8inch (3.18 mm). All the samples of paver were also marked to the height of 1/8inch (3.18 mm). The samples were placed in water for one minute and the height of water was maintained to 1/8inch (3.18 mm). The SSD weight of samples was recorded in order to calculate the initial rate of water absorption.

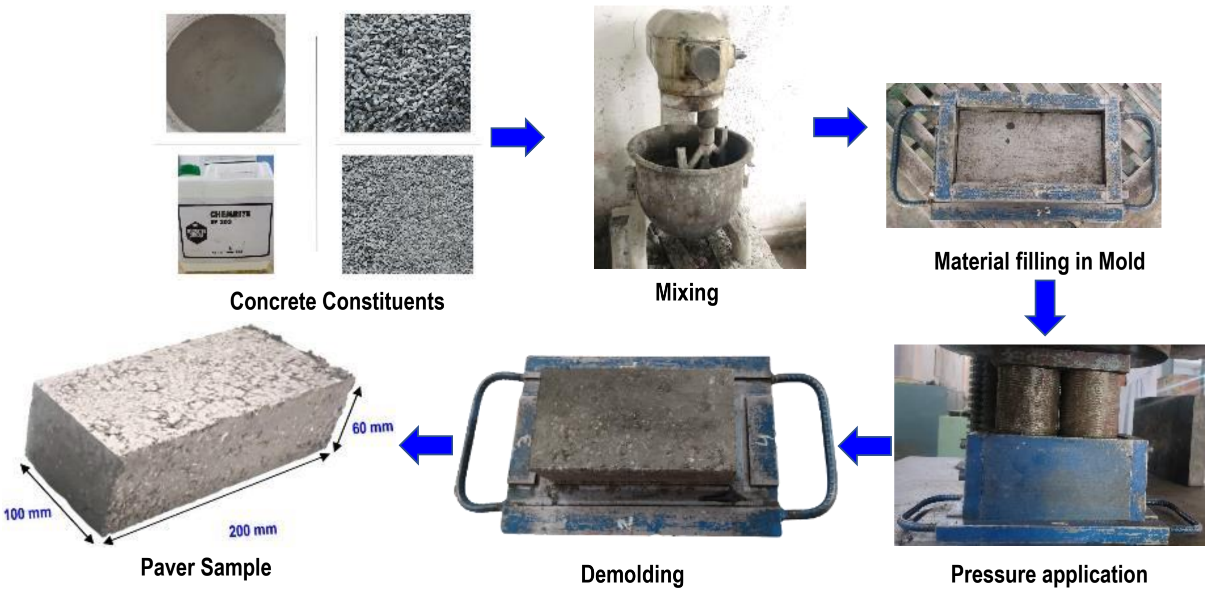

Fig-1: Production process of RAC paver


Setting the reference saturated sample on supports | Pouring water into the tray to the required height | Setting the sample on supports while maintaining the water height of 1/8inch

Fig-2: Testing setup of Initial rate of water absorption

3. RESULTS AND DISCUSSION

3.1 Density

Density of RAC & NAC pavers are presented in the Fig-3. It is observed in these results that with the increase of casting pressure, density of the pavers is decreased. For all casting pressure values investigated in this work, density of NAC pavers was higher than RAC pavers in the range of 1.3% to 1.81%. By increasing casting pressure from 5 MPa to 30 MPa, density of RAC pavers was increased by 2.01% while this increase was 1.98% for NAC pavers. Increase in density with the increase of casting pressure is mainly attributed to expulsion of air voids and better packing of particle as a result of applied pressure. Accordingly, to get the required size of paver more material was required.

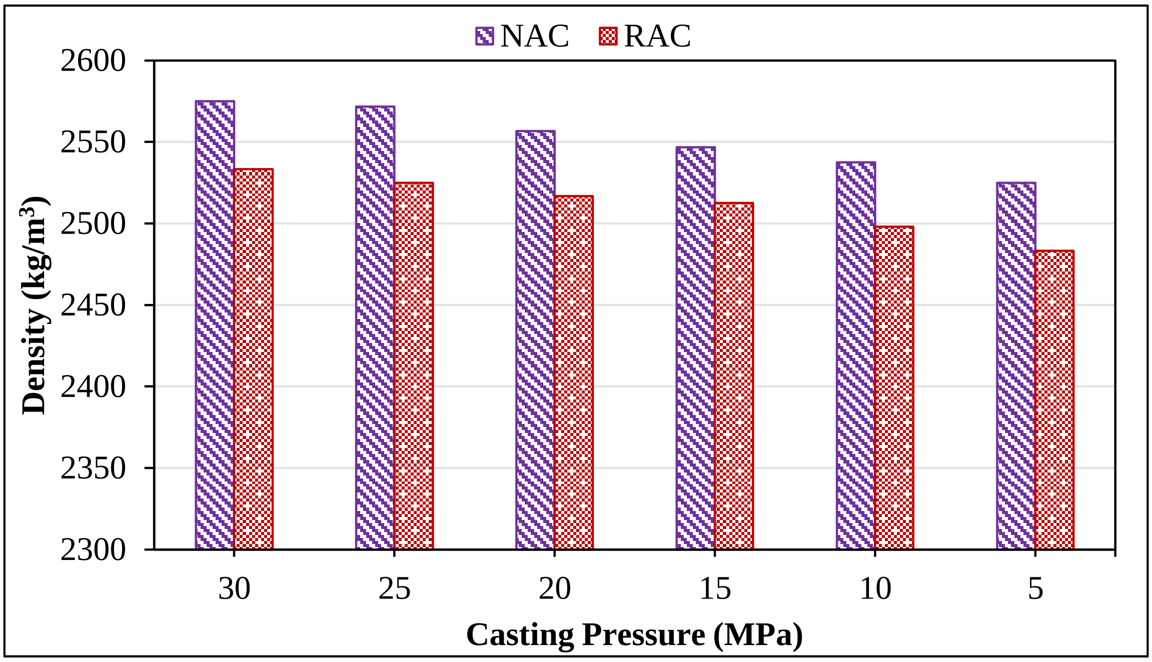

Fig-3: Effect of compression casting pressure on the density of pavers

3.2 Initial rate of water absorption

The initial rate of water absorption of pavers has been reported in g/min/30inch2 in the Fig-4. It is evident from the results that RAC pavers have higher rate of initial rate of water absorption than NAC pavers. The rate of initial water absorption was observed to be decreased with the increase of casting pressure; this observation was true for both NAC & RAC pavers. With the increase of casting pressure from 5 MPa to 30 MPa the initial rate of water absorption was reduced by 83.6% for RAC pavers and 87.7% for NAC pavers. Reduction in initial rate of water absorption with the increase of casting pressure could be considered a good indicator for desired durability performance of RAC pavers. The results presented in Fig-4 made it possible to propose the two equations given on graph based on linear regression which can be used in field to predict initial rate of water absorption based on casting pressure for the concrete mix studied in this work.

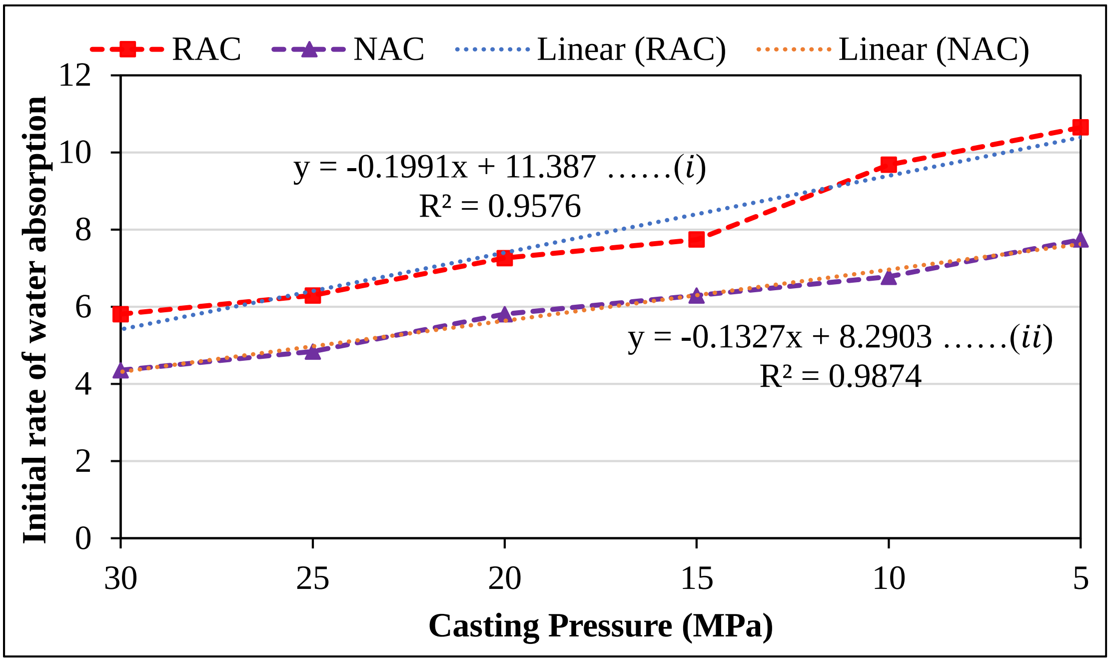

Fig-4: Effect of compression casting pressure on the initial rate of water absorption

3.3 Porosity

The effect of casting pressure on the porosity (in terms of volume of pore spaces) is shown in Fig-5. It is evident from these results that with the increase in casting pressure, volume of pore spaces was decreased for both NAC and RAC pavers. At all pressure values, volume of pore spaces of RAC was more than NAC pavers. This may be due to more angularity of the recycled aggregates resulting in less packing. By increasing casting pressure from 5MPa to 30 MPa, volume of pore spaces was decreased by 51.7% and 48% for RAC and NAC pavers, respectively.

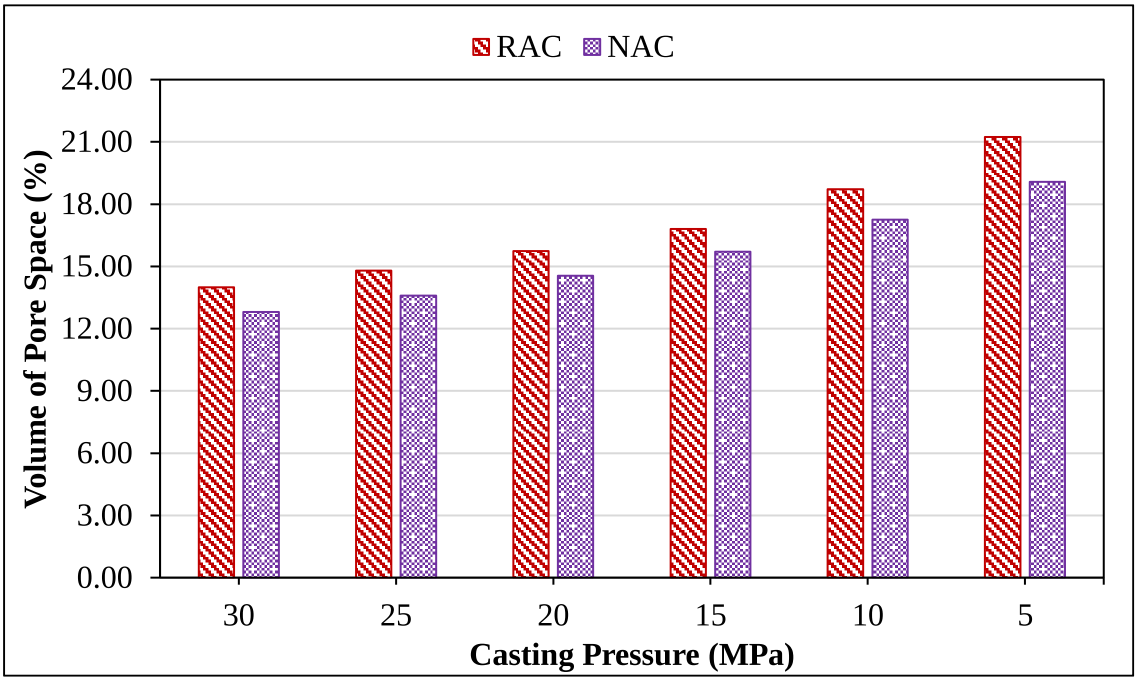

Fig-5: Volume of pore space in RAC and NAC pavers

3.4 Efflorescence

As shown in Fig-6, RAC and NAC pavers made in this study and tested as per ASTM C67 [7] did not show any problem of efflorescence.

Samples in a tray maintaining 1inch depth of water | Sample after 7 days of immersion | Untested sample | Tested sample after drying

Fig- 6: Efflorescence test setup

4. CONCLUSIONS

The analysis of the results obtained by testing RAC and NAC pavers prepared by employing compression casting technique with pressure values ranging from 5 MPa to 30 MPa made it possible to draw the following conclusions:

- Density of RAC and NAC pavers is slightly increased with increasing casting pressure. For all casting pressure used in this study, density of RAC pavers was less than density of NAC pavers with maximum difference of 1.85%.
- Initial rate of water absorption (IRWA) of RAC and NAC pavers is gradually decreased with increasing casting pressure. IRWA of RAC pavers was higher than that of NAC pavers at all casting pressure used in this study.
- For RAC and NAC pavers, equations are proposed to predict IRWA using casting pressure which could be considered a good tool for practicing engineers to get idea about durability performance based on value of IRWA calculated using casting pressure.
- Porosity of RAC pavers is decreased with the increase of casting pressure. 51.7% decrease in volume of pore spaces in RAC pavers was achieved by increasing casting pressure from 5 MPa to 30 MPa. RAC pavers exhibited higher porosity compared to NAC pavers.
- No efflorescence was observed on the surfaces of RAC and NAC pavers.

5. ACKNOWLEDGEMENTS

The financial support to carry out this research study provided by the Higher Education Commission (HEC) of Pakistan under HEC-NRPU Project No. 9764 is highly acknowledged.

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