InternationalJournalofResearch in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 6 Issue 2 ǁ 2018 ǁ PP. 35-39

Capillary Moisture Content of RCA-Based Concretes with Different Powdery Components

Karol Urban[1], Alena Sicakova[2]
[1]Institute of Construction Technology and Management, Faculty of Civil Engineering Technical University of Kosice, Vysokoskolska 4, 042 00, Kosice, Slovakia,
[2]Institute of Environmental Engineering, Faculty of Civil Engineering, Technical University of Kosice, Vysokoskolska 4, 042 00, Kosice, Slovakia
CorrespondingAuthor:Karol Urban

ABSTRACT:*Waste aggregates fall into the scope of "alternative aggregates" for concrete production. They can be generally specified as that of being different from natural aggregates and include manufactured aggregates, recycled aggregates and reused by-product. Recycled concrete aggregate represents a major environmental burden in the affected area and use as aggregate in concrete production is widespread in many countries. However, such aggregates have worse characteristics and strength than those of natural aggregate. In particular they have a higher absorption rate than normal aggregate, need much more water for mixing, and cause a high slump loss rate depending on the elapsed time. In this context, it is possible to monitor globally extensive research aimed on the elimination of improper properties of alternative aggregates which are an obstacle to their application in concrete. The sorptivity expressed by capillary moisture content is a characteristic of moisture transport into material, and recently it has been recognized as an important performance characteristic of durability. The paper is focused on specific approach to concrete mixing as a way of improvement of recycled aggregate´s surface using4 variations of powders as coating materials. Changes in capillary moisture content are compared and discussed.It is clear that the kind of coating material can influence this performance parameter significantly, so careful design of mixing process together with selection of powdery materials, is essential.*
***KEYWORDS** -concrete, capillary moisture content, Recycled Concrete Aggregate, triple-mixing method*

DateofSubmission: 27-02-2018Dateofacceptance: 15-03-2018

I. Introduction

The quality and durability of concrete is strongly dependent on the kind, properties, and dosage of the basic components (cement, water, and aggregates) and the additives and admixtures. The alternative materials play an important role in current concrete technology. Almost three quarters of the volume of concrete is composed of aggregates. To meet the global demand of concrete in the future, it is becoming a more challenging task to find suitable alternatives to natural aggregates for preparing concrete. Therefore the use of alternative sources for natural aggregates is becoming increasingly important [1]. However, such aggregates have worse characteristics and strength than those of natural aggregate. In particular they have a higher absorption rate than normal aggregate, need much more water for mixing, and cause a high slump loss rate depending on the elapsed time [2, 3, 4].

Recycled aggregates are composed of original aggregates and adhered mortar [5]. The major problems with the use of recycled aggregates in structural concrete are their high water absorption capacity, porosity and lower strength. The presence of RCA and the porous nature of the old cement mortar affect the bond between the RCA and cement paste when used in new concrete. That is why the poorer quality of RCA often limits its utilization [6].

Several research reports can be recently found worldwide, dealing with various surfacetreatments of recycled aggregates in order to improve their surface properties. Excepting methods of cleaning such aggregates from adhered mortar, methods dealing withimpregnation/coating are investigated [2], [7]. Moreover, for improving the unsuitablesurface of waste aggregates, various mixing methods are investigated worldwide. Majority of researchers utilized un-processed recycled aggregate in various mixing techniques namely two-stage mixing [8, 9] and three-stage mixing [10].

Sorptivity is an index of moisture transport into unsaturated specimens, and recently it has also been recognized as an important index of concrete durability [10]. During the sorptivityprocess, the driving force for water ingress into concrete is capillary suction within the pore spaces of concrete [12]. Martys and Ferraris have shown that the sorptivity coefficient isessential to predict the service life of concrete as a structural material and to improve itsperformance [13].

Water absorption through capillarity is a phenomenon that occurs due to the differencebetween the fluid's surface capillary pressure and its gravity pressure, which induces fluid movement until balance is established. Capillary pressure increases with decreasing capillary diameter and is most relevant at the boundaries of concrete elements. The process isparticularly visible in dry–wet conditions and has the most relevance near the element'ssurface [14].

The paper is focused on the evaluation of changes in capillary water content of concrete based on Recycled Concrete Aggregate. The specific approach in terms of dividing the mixing process into the defined sequence was applied for preparing the concrete samples. For typical step within this mixing – coating of aggregate by powdery materials - 4 variations were used: the fly ash, recycled concrete powder, cement and combination of fly ash and cement. Capillary water content as an important performance characteristic is discussed, while measured after 28 days of setting and hardening. Results are discussed in terms of impact of individual coating materials.

II. AbsorptionPropertiesOfMaterials

2.1. Liquid Diffusivity

To calculate the average liquid diffusivity from the water absorption coefficient (A_w), it is necessary to establish the relationship between the A_w value and the average liquid diffusivity. Using equation 1, with the assumption of a constant value of D_w, the average value of liquid diffusivity can be expressed as [15]:

$$D_w \approx \left(\frac{A_w}{w_c}\right)^2 \qquad (\mathrm{m^2/s}) \qquad (1)$$

A_w - water absorption coefficient (kg/m^2.s$^{1/2}$),
w_c - the saturated volumetric moisture content of the material.

2.2. Water Absorption Coefficient

A material that allows liquid moisture diffusion through its boundary surface would change its weight with time when it is brought in contact with liquid water. The increase in weight of the test specimen versus the square root of the time indicates that the specimen weight increases linearly before it comes close to the saturation limit. The slope of this linear variation is called the water absorption coefficient (A_w) and can be mathematically written as [16]:

$$\mathrm{A_w} = \left(\frac{\mathrm{m_t - m_i}}{\mathrm{A}\sqrt{\mathrm{t}}}\right) \qquad (\mathrm{kg/(m^2.s^{1/2})}) \qquad (2)$$

m_t - weight of the specimen after time 't' (kg),
m_i - initial mass of the specimen (kg),
A - liquid contact area of the specimen (m^2),
t - time (s).

Water absorption coefficient expresses the rate of capillarity action in certain time. A_w is mathematically defined as a tangent to capillary water content function.

2.3. Capillary moisture content

The capillary absorption test allows the characterization of the porous structure and is an indicator of the concrete durability. Samples (usually of 40 x 40 x 160 mm) are dried to constant mass, and then one face of the specimens is immersed in water at a depth of 5–10 mm for a specific period of time (normally 10 and 90 min.). Capillary moisture content is characterized by water absorption coefficient A_w according to Equation (3) [17].

$$\mathrm{m_c} = \mathrm{A_w} \,.\, \sqrt{\mathrm{t}} \qquad (\mathrm{kg/m^2}) \qquad (3)$$

A_w - water absorption coefficient (kg/m^2.s$^{1/2}$),
t - time (s).

III. MaterialsAnd Methods

Four kinds of concrete mixtures were tested, depending on the kind of coating powder. Mixtures were prepared by "triple mixing" approach; while the standard mixing involves the pre-mixing of dry components first, following by addition of water with plasticizer, the principle of triple mixing lies in dividing the mixing process into the three steps, differing in the order and timing of concrete´s components addition. It results in coating the aggregate in the first stage of mixing by specific coating material, thus improving the surface character of aggregate. The mixing approach allows for lot of variations within the whole mixing process, like given in [10, 18, 19].In this experiment, the own course was applied, differing in details as for fine aggregate and water dosage – see fig. 1. The materials and their parameters were as follows:

- Aggregates:

- Natural aggregate (NA): fraction 0/4 was used in all mixtures (water absorption 1.2%apparent density ρ_0 = 2650 kg/m^3).
- Recycled concrete aggregate (RCA): fractions 4/8 (water absorption 6.8% and apparent density ρ_0 = 2200 kg/m^3) and 8/16 (water absorption 5.3% and apparent density ρ_0 = 2300 kg/m^3).

* Coating materials:
  - Cement CEM I 42.5 R, ρ_0 = 3100 kg/m^3.
  - Fly ash (FA), coming from the energy segment of the steel-making factory. The original granulometry of fly ash was $d_{(0.9)}$ = 95 μm; ρ_0 = 2100 kg/m^3.
  - Recycled concrete powder (RCP): Particles under 125μm were separated from unsorted C&DW by sieving.
  - Combination of fly ash and cement in a 80:20 ratio
* Binder: Cement CEM I 42.5 R, ρ_0 = 3100 kg/m^3.
* Admixture: polycarboxylate type of plasticizer.

The compositions of concrete were designed keeping the limiting amounts of cement and water for specific class of exposure, in accordance to standard for concrete production (min. 300 kg of cement and max. w/c ratio = 0.5). Amounts of real mixing water (W_1 and W_2) were adjusted taking into account the actual absorption capacity of aggregates, i.e. effective amount of water W_{ef} was increased by water absorption value during mixing. For calculation of additive amount, the thickness of coating layer was considered as δ = 0.150 mm. The compositions were calculated taking into account densities of individual components to keep the constant volume 1m^3. Compositions of concrete mixtures are given in Table 1.

Table 1 Composition of tested concrete mixtures for 1m^3 of ready mix concrete

Component [kg]		Concrete sample			
		RCA_{CEM100}	RCA_{FA100}	RCA_{RCP100}	$RCA_{FA80-CEM20}$
CEM I 42.5 R		310	310	310	310
NA	0/4	898			
RCA	4/8	224			
	8/16	545			
Material for coating		80	68		
Admixture		2.5			
Water	W_{ef-1}	39.8	33.8		
	W_{ef-2}	155	155		
	Total	232	226		

The mixing method applied in this experiment is illustrated in fig. 1. The triple mixing method was applied such that the coarse aggregatewas mixed with addition of a certain amount of water to obtain soakedaggregates. Then the powdery material (4 variations as given above) was added and agitated, in order to form the coating layer on the grain´s surface (1st stage). Then, the cement and fine aggregates were added and mixed (2nd stage) and finally the rest water together with the plasticizer (3rd stage).

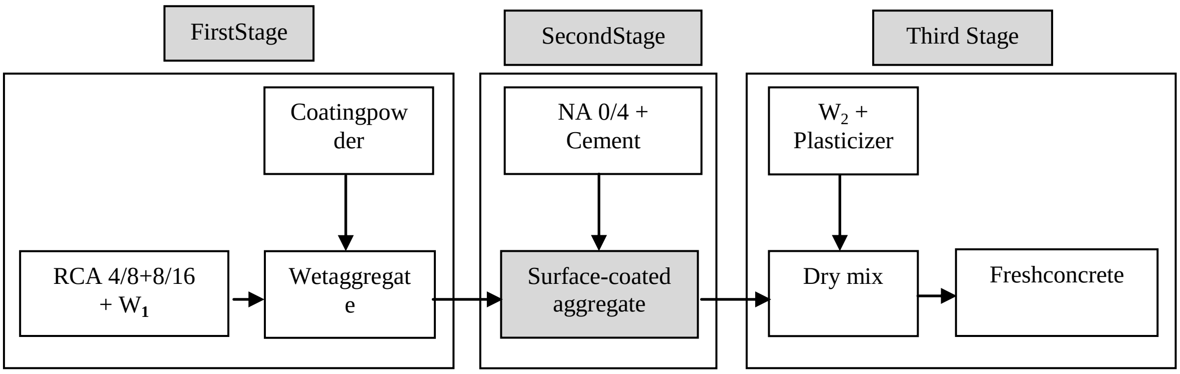

Figure 1 Scheme of the triple mixing method used

Cube samples of 100x100x100 mm were prepared and cured under standard conditions. After 28 days,the capillary water content was tested. For this experiment, measurements were done at the following intervals: 10, 20, 30, 40, 50, 60, 70, 80, 90, 110, 130 and 150 min, to show the development of this parameter in time.

IV. Results And Discussion

The comparison of capillary moisture content of tested concretes prepared by triple mixing method after 28 days of curing is shown in fig.2. For exact comparison of capillary water content values, the data are summarized in Table 2.

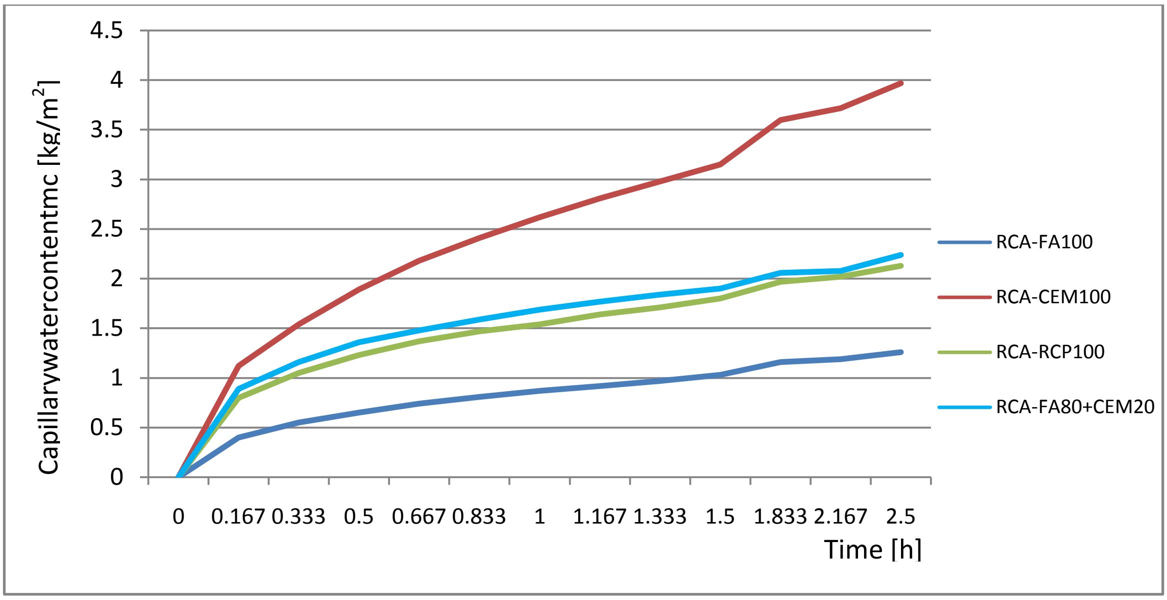

Figure 2 Capillary water content of concrete samples

Table2 Capillary water content of concretes

Samples	Time [h]												
	0.000	0.167	0.333	0.500	0.667	0.833	1.000	1.167	1.333	1.500	1.833	2.167	2.500
	Capillarywatercontentm$_c$ [kg/m^2]												
RCA_{CEM100}	0.00	1.12	1.54	1.89	2.18	2.41	2.62	2.81	2.98	3.15	3.60	3.72	3.97
RCA_{FA100}	0.00	0.40	0.55	0.65	0.74	0.81	0.87	0.92	0.97	1.03	1.16	1.19	1.26
RCA_{RCP100}	0.00	0.80	1.05	1.23	1.37	1.47	1.54	1.64	1.71	1.80	1.97	2.02	2.13
$RCA_{FA80+CEM20}$	0.00	0.89	1.16	1.36	1.48	1.59	1.69	1.77	1.84	1.90	2.06	2.08	2.24

Up to 2.5 hours of testing, the samples showed still increasing tendency of capillary moisture content. It is clear that the lowest capillary water content shows sample having fly ash as coating material (RCA_{FA100}), while the highest one was achieved by sample having cement as coating material (RCA_{CEM100}). Samples having recycled concrete powder and combination of fly ash and cement ($RCA_{RCP100}$and $RCA_{FA80+CEM20}$)have very similar results of capillary water content. Comparing values in standard period time (90 minutes), the difference in capillary moisture content between the fly ash-based and other samples is following: + 304%(RCA_{CEM100}), +177% (RCA_{RCP100}) and +190% ($RCA_{FA80+CEM20}$).

V. Conclusion

The concretes with following powdery materials: cement, fly-ash and recycled concrete powder applied in the first stage of triple-stage mixing in order to form the coating layer on the grains of recycled concrete aggregate were tested. The capillary water content, as a durability parameter, was measuredup to 150 min, to show the development of this parameter in time. The lowest capillary water content had mixture containing fly ash as a coating powder while the use of other materials has led to significant increases in values. It is clear that the kind of coating material can influence this performance parameter significantly, so careful design of mixing process together with selection of materials is essential.

Acknowledgements

The results presented in this article have been carried out within the project of Slovak Scientific Grant Agency VEGA (grant number 1/0524/18)and by the project NFP 26220220051 Development of progressive technologies for utilization of selected waste materials in road construction engineering (European Union Structural funds).

References

[1]. K. G. Hiraskar,Ch.Pati, Use of Blast Furnace Slag Aggregate in Concrete,*International Journal of Scientific & Engineering Research*, *4(5),* 2013,95-98.

[2]. J. S. Ryou, Y.S. Lee, Characterization of recycled coarse aggregate (RCA) via a surface coating method,*International Journal of Concrete Structures and Materials*, *8(2)*,2014, 165-172.

[3]. S. W. Tabsh, A. S.Abdelfatah, Influence of recycled concrete aggregates on strength properties of concrete,*Construction and Building Materials*, *23*, 2009, 1163-1167.

[4]. K.Eguchi, et al, Application of recycled coarse aggregate by mixture to concrete construction. *Construction and Building Materials, 21*, 2007, 1542-1551.

[5]. M. Etxeberria, et al, Influence of amount of recycled coarse aggregates and production process on properties of recycled aggregate concrete,*Cement and Concrete Research*,*37,*2005, 735-742.

[6]. V.Spaeth,A.D. Tegguer, Improvement of recycled concrete aggregate properties by polymer treatments,*International Journal of Sustainable Built Environment, 2*,2013, 143-152.

[7]. J. Li, H.Xiao,Y. Zhou, Influence of coating recycled aggregate surface with pozzolanic powder on properties of recycled aggregate concrete,*Construction and Building Materials, 23,* 2009, 1287-1291.

[8]. V. W. Y. Tam, X. F. Gao, C. M.Tam, Microstructural analysis of recycled aggregate concrete produced from two-stage mixing approach, *Cement and Concrete Research*, *35*, 2005, 1195-1203.

[9]. S. C. Kou, C. S. Poon, M. Etxeberria, Influence of recycled aggregate on long term mechanical properties and pore size distribution of concrete,*Cement and Concrete Composites*,*33*, 2011, 286-291.

[10]. D.Kong, etal,Effect and mechanismofsurface-coatingpozzalanicsmaterialsaroundaggregate on properties and ITZ microstructureofrecycledaggregateconcrete. *Construction and BuildingMaterials*, 24(5),2010, 701–708.

[11]. W. P. S. Dias, Reduction of concrete sorptivity with age through carbonation, *Cement and Concrete Research, 30(8)*, 2000, 1255-1261.

[12]. C.Hall, Water sorptivity of mortars and concretes: a review, *Magazine of Concrete Research, 41(147),* 1989, 51–61.

[13]. N. S. Martys, C.F. Ferraris, Capillary transport in mortars and concrete, *Cement and concrete research, 27(5),* 1997, 747-760.

[14]. L. Evangelista, J. de Brito, Durability performance of concrete made with fine recycled concrete aggregates, *Cement and Concrete Composites, 32*,2010, 9-14.

[15]. M.Krus, H. M.Kűnzel, *Determination of D_w from A-value*(IEA Annex XXIV, Report T3-D-93/02, 1993).

[16]. P.Mukhopadhyaya, et al, Effect of surface temperature on water absorption coefficient of building materials, *Journal of Thermal Envelope and Building Science, 26(2),* 2002, 179-195.

[17]. C. J. Zega, D. Maio, Use of recycled fine aggregate in concretes with durable requirements, *Waste Management, 31*,2011, 2336-2340.

[18]. M.Surya, VVL. KantaRao, P. Lakshmy, RecycledAggregateConcreteforTransportationInfrastructure,*Procedia - Social and BehavioralSciences*, *104*, 2013, 1158–1167.

[19]. S.-H.Lee, K.-N.Hong, J.-K.Park, J. Ko, InfluenceofAggregateCoatedwithModifiedSulfur on thePropertiesof Cement Concrete,*Materials*, *7*(6), 2014, 4739–4754.

Karol Urban, Alena Sicakova “CapillaryMoistureContentofRCA-BasedConcreteswithDifferentPowderyComponents” InternationalJournalofResearch in Engineering and Science (IJRES), vol. 06, no. 02, 2018, pp. 35–39.