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EVALUATION OF CALCAREOUS AGGREGATE USABILITY FOR FROST RESISTANCE CONCRETES

Abstract

The durability of concrete structures exposed to water and frost action depends, among others, on physical properties of coarse aggregate, primarily on its porosity, dimensions, shapes and pores continuity.
The paper presents the results of investigations into the diversified physical properties of the rock and calcareous aggregate from the same deposit with respect to their durability under cyclic freezing and thawing conditions.

Keywords: concrete frost resistance, calcareous aggregate

1. Introduction

The freeze/thaw resistance of the concrete is decisive for the durability of structures of this material exposed to water, frost action, and often also deicing salts. Deterioration of concrete structures under winter conditions is related to the microstructure of hardened concrete. Obtaining frost resistance structure of the cement paste by means of its aeration and also proper quantitative and qualitative selection of components causes hardly any problems in practice. On the other hand, the choice of appropriate coarse aggregate, which constitutes approx. 50% of the total concrete volume, often presents serious difficulties and may result in many unpredictable defects that are revealed in the operation of such structure [1], [2].

Physical properties, in particular porosity, absorbability or size and geometrical arrangement of pores are decisive as regards aggregate usability for frost resistance concretes. For practical purposes, the stability of those parameters in different aggregate batches is also important. It is often difficult to satisfy the above-mentioned condition for mines quarrying stratified deposits of different origin and various physical properties. That refers particularly to calcareous rocks.

The paper presents results of investigations into physical features of calcareous aggregate from a deposit of diversified properties with respect to aggregate usability for frost resistance concretes. Aggregate and rock material samples used in investigations were taken from one of limestone deposits, in operation for a few dozen years, in the Swietokrzyski Region.

2. Range and methods of investigations

The range of investigations covered the assessment of changeability of physical properties of calcareous aggregate from the same deposit as regards its usability for concretes exposed to the action of water and low temperatures. Investigations were conducted for a randomly selected aggregate sample of 8-16 mm fraction and rock taken directly from the excavations, which corresponded to aggregate grains in colour and texture.

As indicated in the introduction, aggregate usability for frost resistance concretes is, to a large extent, determined by its porosity, absorbability, size and geometrical arrangement of pores, therefore investigations focused on the assessment of those features changeability, both in the aggregate and the corresponding rock material.

As regards changes in colour and texture, due to macroscopic assessment of the aggregate and rock samples, it was possible to identify 4 groups of the material, whose colour and texture were similar. For each group, absorbability, specific density, volumetric density, porosity, freeze/thaw resistance, pore size distribution investigations were conducted. Freeze/thaw resistance investigations of aggregate grains and rock samples were carried with direct freeze/thaw test method (25 cycles of freezing in air and thawing in water), whereas pore size distribution was examined with mercury porosimetry method.

3. Description of investigations and results obtained

The aggregate under consideration originates in calcareous rocks, light to dark grey in hue and of much diversified texture. Macroscopic examination of the aggregate and rock samples revealed considerable heterogeneity of the aggregate and rock grains, caused by significant diversification of the stratum in operation. An overall view of the aggregate sample is shown in Fig. 1, whereas in Fig. 2 one can see the view of grains similar in hue and texture, identified in the sample assessed, together with their mass fraction in the whole sample.

Fig. 1. Overall view of aggregate sample

Grains making up the aggregate and the corresponding rock material were divided into 4 groups marked by letters A, B, C and D. A-marked grains, which came from porous limestone, light grey in hue with rough fracture, constituted 64% of the sample mass. B-marked grains, which originated in broken limestone, were similar in light grey hue to A-marked grains, but with smooth vitreous fracture. Those constituted 15% of the sample mass. C- and D-marked grains came from broken limestone with smooth vitreous fracture, grey (C-marked grains) or dark grey in hue with numerous calcite crystals (D-marked grains). Their mass fractions in the total aggregate mass amounted to 12% and 9% for C- and D-marked grains, respectively.

Fig. 2. View of aggregate sample after grouping grains of similar hue and texture, mass fraction of each group in the sample is provided

Table 1 presents physical properties of the rock material from the deposit assessed.

Macroscopically, examined rock samples corresponded to aggregate grains marked A, B,

Table 1. Physical properties of the aggregate and rock material

Item	Examined property	Examination result			
		A	B	C	D
1	Density, g/cm^3 *	2.68			
2	Volumetric density, g/cm^3	2.36	2.40	2.56	2.60
3	Porosity, %	11.9	10.4	4.5	3.0
4	Mass absorbability, %	4.5	4.2	1.9	1.1
5	Direct freeze/thaw resistance of: - rock, - aggregate	 cracks no cracks	 cracks no cracks	 cracks cracks	 no cracks no cracks

* the rock specific density was determined for averaged material sample in accordance with the Polish standard PN-76/B-06714

C and D. In spite of macroscopic differences, A- and B-marked rocks were characterised by low volumetric density (approx. 2.36-2.40 g/cm^3), high porosity (above 11%) and high absorbability (above 4%), and also low freeze/thaw resistance (Fig. 3). Aggregate grains originating in those rocks, however, did not demonstrate damages due to freeze/thaw resistance tests (Fig. 4). The C-marked rock had low porosity and absorbability (approx. 2%), as well as insufficient freeze/thaw resistance, which resulted in visible cracking of frozen/thawed rock samples (Fig. 5) and crumbling of aggregate grains (Fig. 6). The D-marked rock sample was characterised by good resistance to freezing/thawing cycles (no cracks or crumbling were noted), although its porosity and absorbability were similar to those in C-marked rock. Such behaviour was demonstrated by both rock samples and aggregate grains.

Fig. 3. Crack in A-marked rock sample caused by freeze/thaw resistance tests

Fig. 4. View of aggregate sample from A-marked rock following freeze/thaw resistance tests

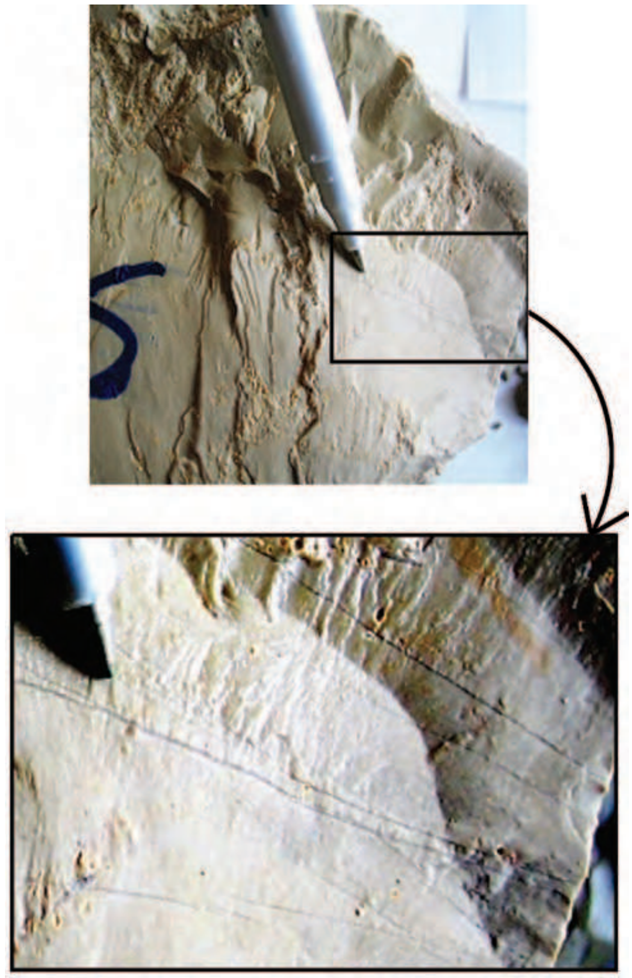

Fig. 5. Crack in C-marked rock sample

Fig. 6. View of C-marked aggregate sample following freeze/thaw resistance tests

Aggregate freeze/thaw resistance depends, to a large extent, on the distribution of pore sizes inside aggregate grains. This opinion was followed in the F annexe titled “Guidelines for Aggregate Freeze/Thaw Resistance Assessment” to the Polish standard PN EN 12620:2004 “Aggregates for Concrete”.

In order to determine pore size distribution in aggregate grains mercury porosimetry investigations into aggregate grains from A, B, C and D-marked rocks were conducted. The results of pore size distribution investigations are presented, in the form of integral curves, in Figs. 7-10.

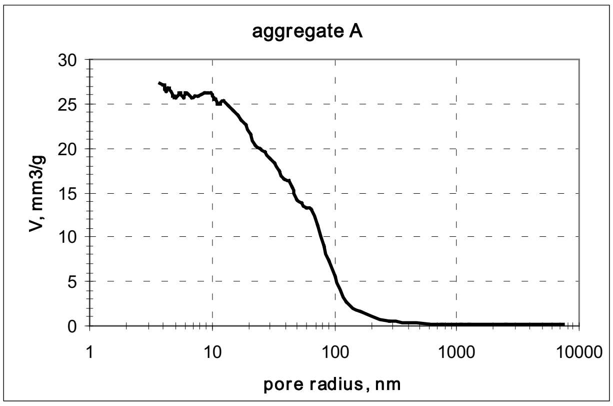

Fig. 7. Pore size distribution in aggregate from A-marked rock

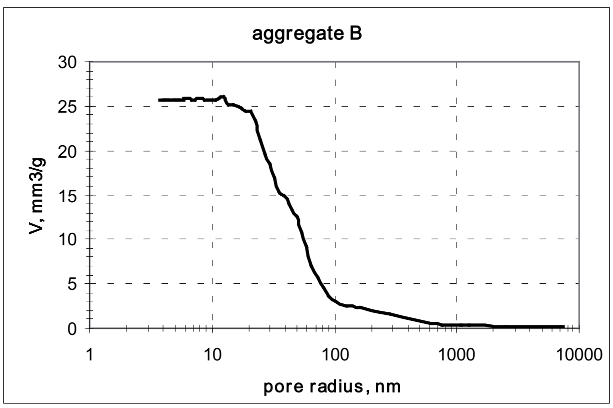

Fig. 8. Pore size distribution in aggregate from B-marked rock

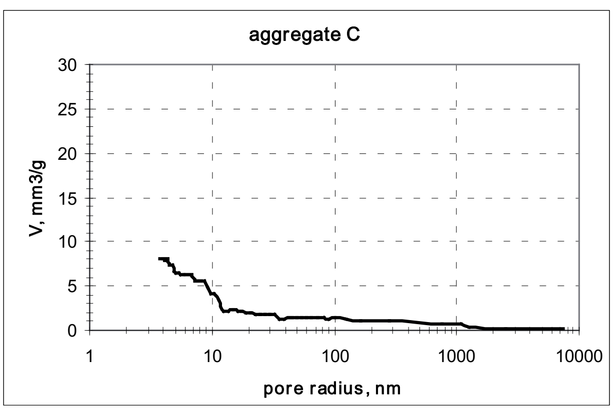

Fig. 9. Pore size distribution in aggregate from C-marked rock

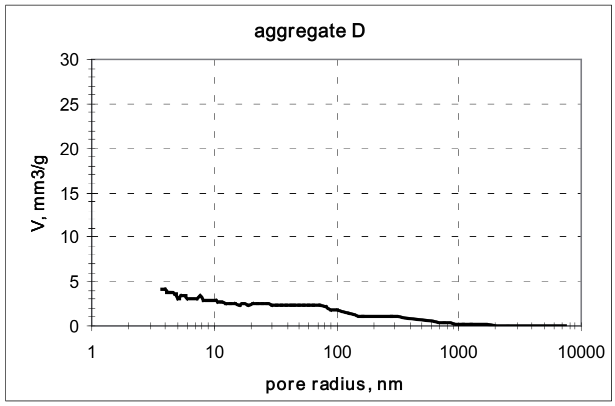

Fig. 10. Pore size distribution in aggregate from D-marked rock

On the basis of pore size distribution curves in Figs. 1-4, it can be observed that aggregates from A- and B-marked rocks (Figs. 7 and 8) are characterised by similar total porosity and high content of pores that range 10-100 nm in radius, which may be the reason for damages to concrete exposed to the action of water and low temperatures. With respect to concrete freeze/thaw resistance, aggregate capillary pores of radiuses ranging 5-100 nm are thought to be detrimental. Such pores are easily filled with water, which when frozen, exerts hydraulic pressure on the inside of grain thus causing its damage, as well as damage to the surrounding paste [1], [3]. Total porosity in the aggregate from C-marked rock (Fig. 9) is almost three times lower when compared with aggregates A and B, yet both its rock samples and aggregate grains were damaged in direct freeze/thaw resistance tests. The reason for that is a high content of small pores of less than 10 nm radius, as well as their proportion to larger pores. Water in pores of radius as above is strongly affected by surface phenomena, which increases hydraulic resistances in flow and causes considerable increase in pressure inside grain when it is frozen due to quick temperature drop. On the other hand, the aggregate from D-marked rock (Fig. 10) stands out due to the lowest total porosity and proportional distribution of pore sizes in the whole range examined. That indicates advantageous properties of aggregate obtained from a rock of this kind as regards concrete freeze/thaw resistance.

4. Conclusions

In addition to granulometric features of aggregate, they are physical and mechanical properties of rock material from which it is produced, that decide about its usability for construction industry and, in particular, concrete technologies. Granulometric features such as graining, grain shapes, the content of over- and under-grain, or finally impurities content can be modified in the course of aggregate production due to the application of appropriate technological solutions. Physical and mechanical properties of rock material, however, were determined by nature and differ for various quarrying sites and even within the same stratum.

The calcareous aggregate being assessed is characterised by high changeability of physical properties. The examined sample was composed of grains originating in 4 kinds of calcareous rocks. Those of their properties which are important for the durability of concrete exposed to the action of water and low temperatures were highly diversified. Therefore, it is very probable that freeze/thaw resistance of concrete produced with such aggregate will vary greatly, depending on proportions of different rock kinds in the aggregate composition. Furthermore, when such aggregate is used to produce cement concrete, differences in consistency or strength of the concrete can occur, which also affects its durability. The significance of this phenomenon grows with a higher class of concrete produced.

As the demand for concrete aggregate grows, it is expected that the use of aggregate from calcareous rocks for the production of concretes exposed to harsh operational conditions will tend to increase. In order to ensure high durability of concrete with such aggregates, in addition to the choice of material of proper physical properties, it is also necessary to account for their retaining stability through time.

References

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Ocena przydatności kruszywa wapiennego do betonów mrozoodpornych

1. Wstęp

O przydatności kruszywa do betonów mrozoodpornych decydują jego właściwości fizyczne, a w szczególności porowatość, nasiąkliwość czy wielkość i układ geometryczny porów [1], [2]. Z praktycznego punktu widzenia istotna jest również stabilność tych parametrów dla poszczególnych partii kruszywa. Warunek ten jest często trudny do spełnienia w przypadku kopalni eksploatujących złoża uwarstwione, o różnym pochodzeniu i różnych właściwościach fizycznych. W szczególności dotyczy to skał wapiennych.

2. Metodyka badań i uzyskane wyniki

Oceniane kruszywo pochodziło ze skał wapiennych o barwie od jasno do ciemnoszarej i mocno zróżnicowanej teksturze. Na podstawie makroskopowych oględzin kruszywa i próbek skały stwierdzono znaczną niejednorodność ziaren kruszywa i skały, spowodowaną zróżnicowaniem eksploatowanego pokładu. Na rys. 1 przedstawiono widok wyodrębnionych, z ocenianej próbki, ziaren o zbliżonej barwie i teksturze wraz z ich udziałem wagowym w całej próbie.

Wchodzące w skład kruszywa ziarna oraz odpowiadający im surowiec skalny podzielono na 4 grupy oznaczone literami A, B, C i D. Ziarna oznaczone literą A stanowiły ziarna porowatego wapienia o jasnoszarej barwie i szorstkim przełomie, stanowiące 64% masy próby, literą B oznaczono ziarna ze zbitego wapienia o zbliżonej do ziaren A jasnoszarej barwie, lecz gładkim, szklistym przełomie, stanowiące 15% masy próbki. Ziarna oznaczone literami C i D stanowiły ziarna zbitego wapienia o gładkim szklistym przełomie, barwie szarej (ziarna C) lub ciemnoszarej z licznymi kryształami kalcytu (ziarna D). Ich udział w całkowitej masie kruszywa wynosił odpowiednio 12% dla ziaren C i 9% w przypadku ziaren D.

Mrozoodporność kruszywa zależy w dużej mierze od rozkładu wielkości porów wewnątrz ziaren kruszywa. Pogląd ten znalazł się w załączniku informacyjnym F zatytułowanym „Wskazówki dotyczące oceny mrozoodporności kruszywa” normy PN EN 12620:2004 „Kruszywa do betonu”. W celu określenia rozkładu wielkości porów w ziarnach kruszywa wykonano badania metodą porozymetrii rtęciowej ziaren kruszywa ze skał A, B, C i D.

Z przeprowadzonych badań rozkładu wielkości porów wynika, że kruszywa ze skał oznaczonych literami A i B mają zbliżoną porowatością całkowitą i dużą zawartością porów o promieniach z przedziału 10-100 nm. co może być przyczyną uszkodzeń betonu narażonego na działanie wody i ujemnych temperatur. Poddane bezpośredniemu zamrażaniu próbki skały A i B uległy uszkodzeniu. Porowatość całkowita kruszywa ze skały oznaczonej literą C jest ponad trzykrotnie mniejsza w porównaniu do kruszyw A i B, jednak zarówno próbki skały jak i ziarna kruszywa uległy uszkodzeniu w badaniu mrozoodporności bezpośredniej. Przyczyną tego jest duża zawartość porów drobnych o promieniach poniżej 10 nm oraz ich proporcje w stosunku do porów większych. Woda w porach o takich promieniach podlega silnym oddziaływaniom powierzchniowym, co zwiększa opory hydrauliczne przepływu i powoduje znaczny wzrost ciśnienia wewnątrz ziarna podczas zamrażania [2]. Kruszywo ze skały oznaczonej literą D wyróżnia się najniższą porowatością całkowitą i proporcjonalnym rozkładem wielkości porów w całym badanym zakresie. Wskazuje to na korzystne z punktu widzenia mrozoodporności betonu właściwości kruszywa pozyskanego z tego rodzaju skały.

3. Podsumowanie

Oceniane kruszywo wapienne cechuje się znaczną zmiennością właściwości fizycznych. Analizowana próbka złożona była z ziaren pochodzących z 4 rodzajów skał wapiennych o mocno zróżnicowanych właściwościach, istotnych z punktu widzenia trwałości betonu narażonego na działanie wody i niskich temperatur. Istnieje zatem wysokie prawdopodobieństwo znacznej zmienności mrozoodporności betonu wykonanego z tego rodzaju kruszywem w zależności od wzajemnych proporcji poszczególnych rodzajów skały w stosie okruchowym. Ponadto w przypadku wykorzystania tego rodzaju kruszywa do produkcji betonu cementowego mogą wystąpić różnice w konsystencji czy wytrzymałości produkowanego betonu, co również nie pozostaje bez wpływu na jego trwałość. Znaczenie tego zjawiska rośnie wraz ze wzrostem klasy produkowanego betonu.

W związku ze wzrostem zapotrzebowania na kruszywo do betonu, należy spodziewać się coraz szerszego wykorzystania kruszyw ze skał wapiennych do produkcji betonów narażonych na trudne warunki eksploatacyjne. Dla zapewnienia wysokiej trwałości betonu z tego rodzaju kruszywami należy, oprócz wyboru surowca o odpowiednich właściwościach fizycznych, zwrócić również uwagę na zachowanie ich stabilności w czasie.