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COMPOSITES THEORY AND PRACTICE

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STUDY ON IMPACT OF SHREDDED POLYPROPYLENE ON SELECTED PROPERTIES OF CEMENT COMPOSITE

The subject of the studies was the assessment of polypropylene utilization possibilities by using shredded polypropylene as a mortar component. The article presents the research results of the impact of shredded polypropylene on selected properties of the cement composite. The assessed material was cement mortar, the composition of which included an additive - a polymer plastic in the quantity of up to 2%. The scope of the studies included assessing the impact of the polymer plastic waste on the obtained properties of the cement composite and in particular, changes in the compression and bending strength, absorbability and capillary rise of water. The studies were meant to assess the possibilities of using additives originating from polypropylene production waste and to indicate the direction for further studies on cement composites.

Keywords: cement composites, shredded polypropylene, compression strength, bending strength, absorbability, capillary rise of water

BADANIA WPŁYWU ROZDROBNIONEGO POLIPROPYLENU NA WYBRANE WŁAŚCIWOŚCI KOMPOZYTU CEMENTOWEGO

Przedmiotem badań była ocena możliwości utylizacji polipropylenu poprzez zastosowanie rozdrobnionego polipropylenu jako składnika zaprawy. W artykule przedstawiono wyniki badań oddziaływania dodatku w postaci rozdrobnionego polipropylenu na wybrane właściwości kompozytu cementowego. Ocenie poddano zaprawę cementową, do której składu wprowadzano dodatek tworzywa polimerowego w ilości do 2%. Zakres badań obejmował ocenę wpływu odpadów tworzywa polimerowego na uzyskiwane właściwości kompozytu cementowego, a w szczególności zmianę wytrzymałości na ściskanie, zginanie, nasiąkliwości i kapilarnego pociągania wody. Badania miały na celu ocenę możliwości wykorzystania dodatków z polipropylenowych odpadów produkcyjnych oraz wskazanie kierunku dalszych badań nad kompozytami cementowymi.

Słowa kluczowe: kompozyty cementowe, rozdrobniony polipropylen, wytrzymałość na ściskanie, wytrzymałość na zginanie, nasiąkliwość, kapilarne podciąganie wody

INTRODUCTION

The constantly increasing quantity of industrial waste, and in particular plastics and their biodegradation-related problem, is a serious challenge for environmental protection. Proper waste management helps reduce the problem and is a priority direction of pro-ecological activities.

Shaping the properties of cement matrix materials by including various additives in their composition is currently a way to enable, among others, industrial waste management. It is concrete technology that creates great opportunities for their application, having a positive impact on the environment by decreasing waste storage area, reducing the harmful impact of waste and decreasing the cost of industrial waste storage [1, 2]. A balanced development strategy is one of the most basic factors influencing economic development, and "environment-friendly concrete" fits well into the strategy. Increasingly higher requirements that civil engineering structures must meet, make it necessary for the used materials to have better properties. Successful attempts at applying waste materials in the production of building materials [3-7] has been observed for many years and, in many publications [8-11], one can find presentations of studies on the possibilities of applying waste materials as constituents for producing new building elements. The application of waste plastics in the technology of cement matrix materials enables the management of wastes being a significant problem for environmental protection shredded polypropylene can constitute a useful material making it possible to obtain a composite of relatively advantageous functional properties. Putting this additive in composites, in addition to the structure-related change, will also modify the functional properties of

composites. What matters in characterising composite properties and assessing composite resistance to external factors is the quantitative description of the structure. Cement matrix materials are composites whose significant property is the structure, i.e. the type of components and their interrelations.

INVESTIGATIONS AND DISCUSSION OF RESULTS

The conducted studies were meant to assess the possibilities of applying production waste in the form of shredded polypropylene (PP) as an ingredient of a cement composite. Verifying and assessing the possibilities of PP use in the cement mortar composition included tests of composites containing various quantities of the additive. The test was performed on 7 series of mortars modified with an additive of shredded polypropylene (Fig. 1) in various quantities.

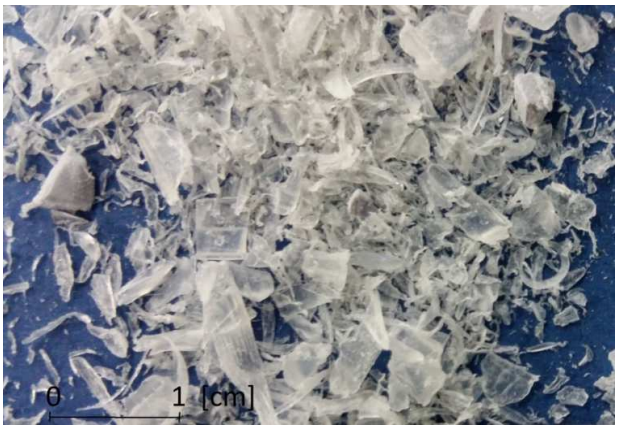

Fig. 1. Polypropylene used for test purposes (measure [cm])
Rys. 1. Polipropylen używany do badań (miara [cm])

The composition of the tested cement composites is presented in Table 1. The control mortar (series marked as K0) was made according to the formula for standard cement mortar [12].

TABLE 1. **Working composition of one batch of mortar [g]**
TABELA 1. **Skład roboczy jednego zarobu zaprawy [g]**

Mortar series		Cement	Water	Standard sand	Shredded polypropylene
control	**K0**	450	240	1350	-
With shredded PP additive	**K03**				1.5
	K06				3.0
	K1				4.5
	K13				6.0
	K16				7.5
	K2				9.0

Then during the mixture preparation stage, shredded polypropylene was added to the control mortar (K0) composition, in quantities of 0.3; 0.6; 1.0; 1.3; 1.6 and 2.0% to the ratio of cement mass.

ASSESSING FRESH MORTAR CONSISTENCY

The series consistency was tested according to PN-EN 1015-3:2000 [13]. The test results of the mortar consistency in this method is the mortar distribution influenced by dynamic shock. Table 2 presents the tests results of mortar distribution.

TABLE 2. **Mortar distribution test results**
TABELA 2. **Wyniki badania konsystencji zaprawy**

Mortar series	Average mortar distribution [mm]
K0	160
K03	160
K06	155
K1	150
K13	150
K16	145
K2	140

Figure 2 shows the impact that the quantity of shredded PP additive has on the change in fresh cement mortar consistency.

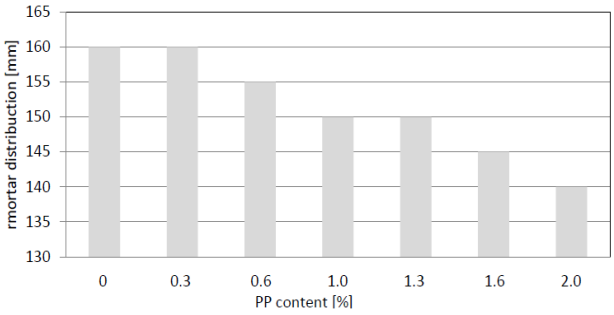

Fig. 2. Impact of shredded PP on mortar fluidity
Rys. 2. Wpływ ilości rozdrobnionego PP na ciekłość zaprawy

The obtained test results of mortar distribution prove that polypropylene added in quantities of up to 1% of cement mass does not have a significant adverse impact on mortar workability. Polypropylene in the quantity of 0.33% of cement mass did not cause changes in the consistency, as compared to the control batch. Increasing the additive quantity affected a gradual worsening of the consistency of the tested mortars and the smallest distribution - 140 mm - was obtained in the case of the 2% polypropylene dose. This proves worsened workability of fresh mortar as a result of increased polypropylene quantity in the content of the tested composite.

COMPRESSION AND BENDING STRENGTH ASSESSMENT

Strength tests were performed according to the PN-EN 1015-11:2001 standard [14]. Assessment of the mechanical characteristics was conducted after 28 days of concrete curing in laboratory conditions, on samples in various moisture conditions:

- in water saturation condition after 28 days of curing,
- in dried condition, as a stable mass, after curing,
- in dried condition, subjected to the impact of the temperature of 175°C.

The samples for strength tests, after drying, were subjected to the temperature of 175°C, which reflected the softening temperature of the applied PP, for a period of 15 minutes. The strength characteristics test results are presented in Table 3.

TABLE 3. **Strength characteristics results of tested cement composites**

TABELA 3. **Wyniki badań wytrzymałościowych badanych kompozytów cementowych**

Series	K0	K03	K06	K1	K13	K16	K2
Bending strength [MPa]							
After 28 days	6.5	6.6	6.6	6.5	6.5	6.6	6.3
In dry condition	8.8	8.9	8.7	9,0	8.4	8.6	8.5
After holding at 175ºC	7.1	7.5	7.2	7.5	7.4	7.0	6.8
Compression strength [MPa]							
After 28 days	42.5	44.1	42.2	44.8	44.9	44.1	43.3
In dry condition	54.3	54.0	53.8	53.3	54.4	52.9	53.4
After holding at 175ºC	54.9	54.4	54.0	53.7	55.5	54.9	53.0

The use of the shredded polypropylene additive did not have a negative influence on the tested bending strength. The control series (K0) value was 6.5 MPa and in the tested composites the same or an insignificantly higher value was obtained, in comparison to the strength value of the control series. Only the PP additive in the quantity of 2% cement mass (K2 series) resulted in an insignificant decrease in the tested property to the value of 6.3 MPa.

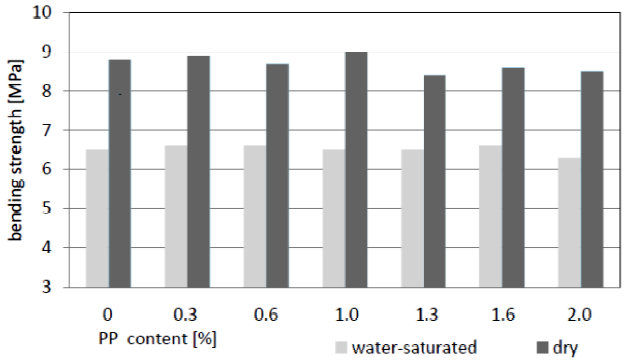

Fig. 3. Impact of shredded PP quantity on bending strength after 28 days of curing water-saturated and dried to solid mass samples

Rys. 3. Wpływ ilości rozdrobnionego PP na wytrzymałość na zginanie po 28 dniach dojrzewania próbek nasyconych wodą oraz wysuszonych do stałej masy

Figure 3 presents the impact of the added shredded PP on the compression strength of water-saturated samples, as well as after drying them to a solid mass.

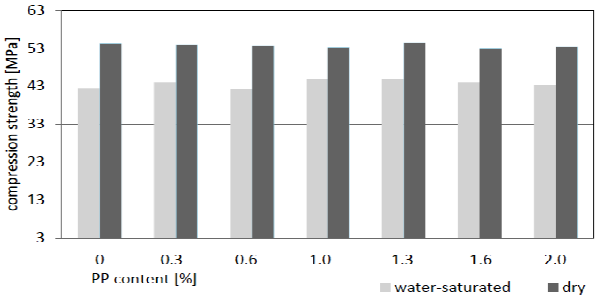

Fig. 4. Impact of shredded PP quantity on compression strength after 28 days of curing water-saturated and dried to solid mass samples

Rys. 4. Wpływ ilości rozdrobnionego PP na wytrzymałość na ściskanie po 28 dniach dojrzewania próbek nasyconych wodą oraz wysuszonych do stałej masy

Figure 4 presents the PP impact of the compression strength of the tested composites. One can notice a lack of significant impact of up to 2% PP in relation to the cement mass (in all the tested series) on the compression strength. No negative PP impact on the tested property was observed.

Figure 5 shows the impact of subjecting the tested composites to the temperature of 175ºC reflecting the PP softening temperature.

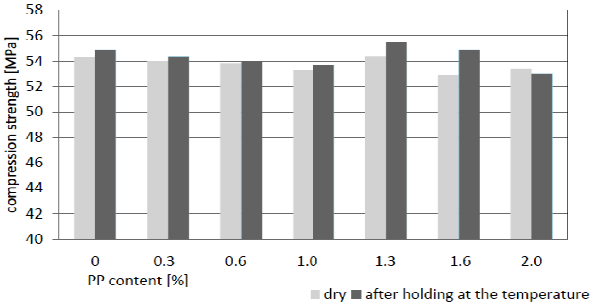

Fig. 5. Impact of PP softening temperature on compression strength

Rys. 5. Wpływ oddziaływania temperatury mięknienia PP na wytrzymałość na ściskanie

In the tested series of PP content up to 1.6%, a small improvement in the compression strength was noticed. Only the strength of the K2 series, of PP content up to 2% of the cement mass, when subjected to the temperature of 175ºC, was lower.

ABSORBABILITY AND CAPILLARITY TESTS

The capillary rise of water and absorbability were determined according to PN-85 B-04500 standard [15]. The determination results are presented in Table 4.

The use of shredded polypropylene, when compared to the control series, insignificantly improved the capillary rise of water. Visible improvement of the tested property was observed, especially when using the additive in the quantity of 1.3% of the cement mass.

TABLE 4. **List of absorbability and capillarity results**
TABELA 4. **Zestawienie wyników badania nasiąkliwości i kapilarności**

Series	K0	K03	K06	K1	K13	K16	K2
Capillary rise of water after 24 h [mm] / [%]							
In dry conditions	19	19	18	18	16	19	18
	2.9	2.8	2.6	2.6	2.8	2.9	2.7
After holding at 175°C	16	18	18	18	16	17	17
	2.7	2.6	2.5	2.5	2.5	2.4	2.5
Absorbability [%]							
In dry conditions	8.2	8.0	8.1	8.0	8.1	7.9	8.0
After holding at 175°C	8.1	8.1	8.2	8.0	8.1	8.0	8.1

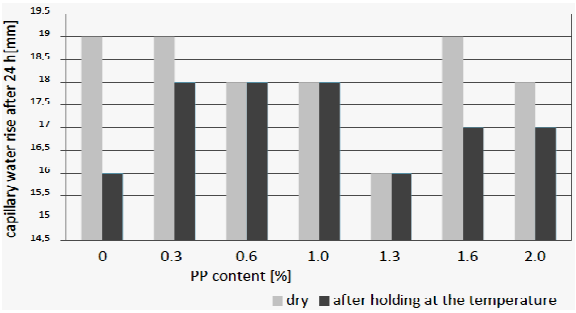

Fig. 6. Impact of PP quantity on capillarity of tested composites
Rys. 6. Wpływ ilości PP na kapilarność badanych kompozytów

The tests conducted on samples subjected to the PP softening temperature revealed lower values of capillary rise, especially in the case of the 1.6 and 2% additive in relation to the composite not subjected to holding at the temperature.

Figure 7 shows the impact of the PP quantity on the absorbability of the tested cement mortars.

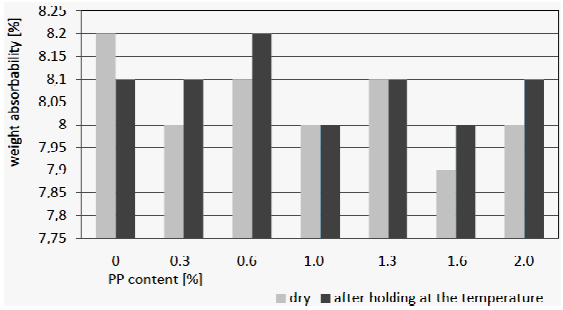

Fig. 7. Impact of PP quantity on absorbability of tested composites
Rys. 7. Wpływ zawartości PP na nasiąkliwość badanych kompozytów

In the absorbability test a small improvement in the property was noted after adding PP. The lowest absorbability was obtained when adding PP in the quantity of 1.6% of the cement mass.

SUMMARY

The obtained test results of the cement composite with the additive of shredded polypropylene proved it could be used as an additive to improve selected properties of the cement composite.

Using the shredded polypropylene additive as an ingredient of cement composites requires considering fluidizing admixtures in order to improve worsened workability.

The applied quantity, up to 2% of additive in the content of the tested composites, does not have a significant impact on changing the mechanical characteristics.

A positive impact of the additive on absorbability and capillary rise of water was observed in the tested composites.

Further studies meant to verify the conditions of effective application of shredded PP polypropylene as an additive for materials of cement matrices are postulated.

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