INFLUENCE OF DOLOMITE POWDER FINENESS ON HYDRATION OF BLENDED CEMENTS AT DIFFERENT CURING TEMPERATURES

DENG CHEN^{1, 2, 3*}, TAO YANG⁴, KAI-WEI LIU⁵, AI-GUO WANG⁵

¹College of Civil Engineering, Suzhou University of Science and Technology, Suzhou 215011, China; Tianping College, Suzhou University of Science and Technology, Suzhou 215011, China; ³Jiangsu Technology Industrialization and Research Center of Ecological Road Engineering, Suzhou 215011, China; College of Materials Science and Engineering, Yancheng Institute of Technology, Yancheng 224051, China; ⁵Anhui Province Engineering Laboratory of Advanced Building Materials, Anhui Jianzhu University, Hefei 230601, China.

The effects of dolomite powder (DM) with different fineness on the hydration of Portland cement (PC) are investigated by using a multi-method approach. Results show that the addition of DM decreases the hydration heat and compressive strength of PC. However, at the same replacement of PC by DM, the hydration heat and compressive strength can increase with increasing the fineness of DM. When cured at 20 °C, an increase in the fineness and amount of DM can promote the formation of carboaluminate due to the improvement of the reaction degree of DM. When cured at 60 °C, hydrotalcite (Ht) is observed in the samples containing DM, and Ht may be formed in the surface layer of DM particles. With the increase of the DM fineness and amount, the Ht strongly increases.

Keywords: dolomite powder; fineness; hydration products; curing temperatures

1. Introduction

Dolomite is an anhydrous carbonate mineral in nature composed of calcium magnesium carbonate $(CaMg(CO_3)_2)$, which has a widespread distribution all over the world, with more than 4 billion tonnes reserves in China [1,2]. It has been used into concrete as aggregates for many years, but in the alkaline pore solution of concrete, dolomite aggregate may react with calcium anions to generate calcite and brucite, which is known as the dedolomitization reaction. The dedolomitization reaction was believed to be responsible for the destruction of many concretes as a part of an alkalicarbonate reaction [3-5]. Thus, the amount of dolomite aggregate needs to be restricted in concrete. Additionally, dolomite has also been widely used as a source for manufacturing magnesium oxide which is a well acknowledged and already commercialized shrinkage-compensating additive of concrete [6].

Recently, dolomite powder (DM) has received considerable attention for use as a filler or admixture to Portland cement (PC), as is done with limestone powder (LS) [7-10]. Previous studies have shown that DM may participate in the hydration reaction of PC forming hemicarbonate (Hc) and monocarbonate (Mc), and has a similar effect on strength development as LS additions[11,12]. Furthermore, the combination of DM and calcined clay in cement also enhances the formation of carboaluminate, and yields a positive synergistic effect that leads to finer pore structure and higher compressive strength [13-16]. However, there are some distinct differences between DM and LS in PC pastes when cured at elevated temperatures. Zajac et al. [11] and Xu et al.

[12] observed that in addition to Hc and Mc phases, the DM reaction in PC at 40 °C and 60 °C produces hydrotalcite (Ht) and calcite, and Ht can lead to an increase in compressive strength. Machner et al. [17] found that the formation of Ht is strongly limited by the alkalinity of the pore solution and portlandite content of PC paste. In addition, some studies [18-20] demonstrated that Ht in Portland-dolomite cement has a significant positive effect on durability properties, such as resistance to sulphate attack and carbonation as well as binding of chloride ions. Therefore, curing temperature seems to influence significantly the properties and hydrate assemblages of Portland-dolomite cement. However, there is still a lack of detailed investigation on the effect of DM on the hydration of PC.

To the best of our knowledge, there are no detailed data regarding the effect of DM with different fineness on hydration reaction of Portlanddolomite cement at different curing temperatures. The objective of this paper is to extend the existing research and systematically study the influence of the grinding fineness of DM on hydration of Portlanddolomite cement. In this study, the effects of various fineness, replacement levels of DM on the hydration, strength and microstructure of PC cured at 20 °C and 60 °C were investigated, and the reaction mechanism of DM in PC was also discussed based on the experimental results.

2 Experimental

2.1 Raw materials

PC of grade 52.5 was provided by China Cement Company in Jiangsu, China. DM was obtained from Yuyuan Mining Company in Hebei, China. The chemical compositions of PC and DM

^{*} Autor corespondent/Corresponding author,

E-mail: deng2928326@163.com

_	Chemical compositions of PC and DM (wt %)											
		SiO ₂	Fe_2O_3	Al_2O_3	CaO	MgO	K ₂ O	Na ₂ O	Loss on ignition			
	PC	22.18	3.76	3.98	62.47	0.87	0.85	0.10	2.28			
	DM	2.00	0.25	0.88	29.73	21.89	0.04	0.02	44.69			

Mix proportions of blended cements w/%								
No.	PC	DM-I	DM-II	DM-III				
100C	100	0	0	0				
80C20DM-I	80	20	0	0				
60C40DM-I	60	40	0	0				
40C60DM-I	40	60	0	0				
80C20DM-II	80	0	20	0				
60C40DM-II	60	0	40	0				
40C60DM-II	40	0	60	0				
80C20DM-III	80	0	0	20				
60C40DM-III	60	0	0	40				
40C60DM-III	40	0	0	60				

are presented in Table 1. Figure 1 shows the mineralogical compositions of DM which was examined by an X-ray diffractometer (XRD). As is shown in Figure 1, the mineral compound of DM is mainly dolomite, DM contains about 98% dolomite, determined by thermal analysis. Additionally, DM was mechanical ground by a ball mill for 10 min, 20 min and 40 min, and they were marked as DM-I, DM-II and DM-III, respectively. Figure 2 shows the particle size distributions of raw materials. The mean particle sizes (d₅₀) of PC, DM-I, DM-II and DM-III are 12 μ m, 11 μ m, 6 μ m and 3 μ m, respectively. The specific surface area of PC, DM-I, DM-II and DM-III are 358 m²/kg, 373 m²/kg, 483 m²/kg and 616 m²/kg, respectively.



2.2 Sample preparation

396

Blended cements containing 0%, 20%, 40% and 60% DM by weight replacement of PC were prepared, and the mix proportions and identifications of the blends are shown in Table 2. The water/binder mass ratio (W/B) was kept as 0.5. The fresh pastes were poured into plastic tubes and cured in a curing box with a humidity of 98% at 20 °C and 60 °C. The plastic tubes were sealed to avoid any carbonation of the samples during their



Table 1

Table 2

hydration. After different days of curing, the hydration of cement pastes was stopped by immersion of the cut slices of hardened paste in an ethanol solution for one day. Finally, the slices were dried in a vacuum drying oven at 40 °C for two days to remove the ethanol.

2.3 Test methods

The heat evolution of the different pastes with a W/B of 0.5 was followed at 20 °C using a TAM-Air isothermal calorimeter according to ASTM C 1702-09 [21].

The compressive strengths of the samples were tested according to the Chinese standard GB/T 17671-1999 [22]. The results were the averages of six replicate mortar prisms.

The hydration products of the PC-DM pastes cured at different ages and different temperatures were examined by using XRD and thermogravimetric analysis (TGA).TGA analysis was also conducted to measure the contents of unreacted DM and portlandite in various cement paste samples. The calculated weight losses were then normalized to the sample weight at approx. 550°C, which was assumed to be the dry binder weight, and remained constant during the cement hydration. The contents of portlandite and

unreacted DM were calculated by measuring the mass loss 400-470 °C and 550-800 °C, respectively, as presented in Eqs.(1) and (2) [23,24].

$$Ca(OH)_{2} \ content \ (wt\%) = \frac{Mass \ loss \ (400 - 470^{\circ}C)}{Mass \ loss \ 550^{\circ}C} \times \frac{Molar \ mass \ of \ Ca(OH)_{2}}{Molar \ mass \ of \ H_{2}O}$$
(1)
Unreacted DM content (wt%)

$$=\frac{Mass loss (550-800^{\circ}C)}{Mass loss 550^{\circ}C} \times \frac{Molar mass of CaMg(CO_3)_2}{2 \times Molar mass of CO_2}$$
(2)

In addition, the slices of the hydrated cement paste samples were dried, cast in epoxy and polished, and then the microstructure was examined by backscatter scanning electron microscope (BSEM) (JSM-6150) equipped with an energy dispersive spectrometer (EDS).

3 Results and discussion

3.1 Hydration heat

The hydration heat curves for the different samples are shown in Figure 3. The hydration of the 100C sample is historically divided into four periods according to heat flow: (1) initial reaction period, (2) induction period, (3) acceleration period, and (4) deceleration period [25]. The initial reaction occurred approximately in 30 min. The heat flow was not completely collected in the stage of initial reaction due to the extend stirring. However, it is well known that gypsum reacts with C₃A to form ettringite in the initial reaction period. In the acceleration period, the heat flow increases with hydration time, and reaches the maximum rate. The 100C sample has a pronounced peak at about 10 h, presenting significant hydration of clinker phases in PC. With the increase of DM addition, the heat evaluation peak declines obviously. However, at the same replacement of PC by DM, the heat peak increases with increasing the fineness of DM due to the nucleation effect of DM. In the deceleration period, the hydration heat of all the samples

decreases with increasing the hydration time, and reaches stability at about 50 h.

According to Figure 3(b), by comparing the normalized heat evolution of the different samples after 72 h, it is clear that the ultimate hydration heat decreases with increasing the contents of DM. However, at the same replacement of PC by DM, blended cement containing DM-III has the highest ultimate hydration heat.

3.2 Compressive strength

Figure 4 shows the compressive strengths of the mortars cured at 20 °C and 60 °C. When cured at 20 °C, the compressive strengths of the 100C mortars are obvious higher than those of the mortars containing 20% DM at all ages. However, at the same replacement of PC by DM, the compressive strength increases obviously with increasing the fineness of DM. Similar to strengths at 20 °C, the increase of DM fineness also improves the strengths of the mortars containing 20% DM at 60 °C, especially the 90-day compressive strengths of the 80C20DM-III mortars even surpass those of the 100C mortars.

3.3 Hydration products 3.3.1 XRD analysis

Figures 5 and 6 show the XRD patterns in the range of 2θ from 8 to 12° for the samples containing DM with different fineness cured for different ages at 20 °C and 60 °C, respectively. The main reflections in the XRD patterns reflect the influence of DM with different fineness on hydration products at different temperatures.

For the samples cured at 20 °C, obvious diffraction peaks of ettringite can be observed in all the samples cured for different ages. For the 100C sample, only ettringite is generated at 3 days. With ongoing hydration, a small peaks of Hc and Mc are found at 28 days, and gradually increased up to 90 days, which is due to the limestone (<5% wt%) contained in PC used. For the 80C20DM-I, 80C20DM-II and 80C20DM-III samples, the peaks of Hc is found at 3 days and the peaks of Mc are more intense than that of the 100C sample at 90



Fig. 3 - Isothermal calorimetry curves of cement pastes.



(a) 20 C (b) 60 C Fig. 4 - Compressive strengths of the mortars containing 20% DM with different fineness cured for up to 90 days at 20 °C and 60 °C.



Fig. 5 - XRD patterns of the samples containing 20% DM with different fineness cured at 20 °C. Et: ettringite; Hc: hemicarbonate; Mc: monocarbonate

days. It indicates that the addition of DM promotes the formation of Hc and Mc obviously. The results of comparisons with Figures 5(b), (c) and (d) show that the peak ratio of Mc/ettringite in the 80C20DM-III sample is obvious higher than those of the 80C20DM-I and 80C20DM-II samples cured at 90 days. Furthermore, the 80C20DM-I and 80C20DM-II samples still contain a small trace of Hc as reference at 90 days, while the 80C20DM-III sample show no Hc but only Mc precipitation, suggesting that the increase of DM fineness may facilitate the transformation of Hc into Mc.

The samples cured at 60 °C clearly show the differences with those cured at 20 °C. The peaks of monosulphate are found in all the samples, but no ettringite, Hc and Mc are detected, as shown in Figure 6. It indicates that ettringite, Hc and Mc are not stable at 60 °C, this is agreement with the



Fig. 7 - XRD patterns of the samples containing different amount of DM-II cured for 90 days at 20 °C and 60 °C. Et: ettringite; Hc: hemicarbonate; Mc: monocarbonate; Ms: monosulphate; Ht:hydrotalcite

previous studies [11, 26]. Compared with the reference 100C sample, the 80C20DM-I, 80C20DM-II and 80C20DM-III samples show in addition to monosulphate, and also the presence of Ht. It is also observed that the monosulphate peaks of the samples containing DM are smaller than that of the 100C sample, and furthermore the monosulphate peaks decrease with increasing DM fineness. Meanwhile, the intensity of Ht peak strongly increase with increasing DM fineness and

curing ages, indicating the formation of Ht can be stimulated by increasing DM fineness.

Figure 7 shows the XRD patterns of the samples containing DM-II in different amount cured for 90 days at 20 °C and 60 °C. At 20 °C, the peak of Mc is more intense with higher DM additions. Furthermore, the reference 100C and 80C20DM-II samples still contain a small amount of Hc, while the 60C40DM-II and 40C60DM-II samples show no Hc. It indicates that the increase in the content of DM

400 Deng Chen, Tao Yang, Kai-Wei Liu, Ai-Guo Wang / Influence of dolomite powder fineness on hydration of blended cements at different curing temperatures

may facilitate the conversion from Hc to Mc. This is due to that the higher DM content increases the CO_2/Al_2O_3 ratio in the sample which stabilizes Mc over Hc. At 60 °C, the 100C and 80C20DM-II samples show the obvious diffraction peaks of monosulphate, but no monosulphate is observed in the 60C40DM-II and 40C60DM-II samples. Furthermore, the intensity of Ht peak strongly increases with increasing the DM content, indicating that the conversion from monosulphate to Ht can be promoted by increasing the amount of DM.

3.3.2 TGA analysis

Figure 8 presents the DTG curves of the 100C, 80C20DM-I, 80C20DM-II and 80C20DM-III samples cured for 90 days at 20 °C and 60 °C. Some main endothermic peaks are found in the DTG curves, corresponding to calcium silicate hydrate (C-S-H) gel and ettringite (about 100 °C), Hc and Mc (about 150 °C), Ht (about 220 °C and 370 °C)[11], portlandite (about 400-470 °C) and carbonates (about 550-800 °C). As is shown in Figure 8, the decomposition peaks of Hc and Mc are detected in the 80C20DM-I, 80C20DM-II and 80C20DM-III samples cured at 20 °C, which are higher than that of the reference 100C sample. Ht is only observed in the 80C20DM-I, 80C20DM-II and 80C20DM-III samples cured at 60 °C. Moreover, at the same replacement of PC by DM, the decomposition peaks of Ht increase with increasing the fineness of DM. The results also correspond to XRD analysis in section 3.3.1.

Figure 9 presents the portlandite contents of the samples containing DM with different fineness cured for 3 days and 90 days at 20 °C and 60 °C. It is clear that the content of portlandite is reduced with the addition of 20% DM due to the lower clinker factors. At 20 °C, at the same replacement of PC by DM, the portlandite contents of the samples are increased with increasing the fineness of DM at 3 days. This is due to that the increase of DM fineness facilitates cement hydration, as is shown in Figure 3, and then provide more nucleation sites for the formation of hydration products. However, the portlandite contents of the samples are reduced with increasing the fineness of DM at 90 days. This may be due to that the increase of DM fineness promotes the reaction of DM. The previous literatures[11,27] demonstrated that DM can react with C₃A and portlandite to form Hc and then transfoms to Mc at 20 °C. Therefore, the content of portlandite is reduced with increasing the fineness of DM at the later age, which may be due to the high reaction degree of the fine DM particles. At 60 °C, with the increase of DM fineness, the contents of portlandite are reduced gradually at 3 days and 90 days. According to the previous studies [12,17], dolomite can react with AI and portlandite in the cement matrix to form Ht and calcite at 60 °C. Therefore, with the increase of DM fineness, portlandite is



Fig. 8 - DTG curves of the samples containing 20% DM with different fineness cured for 90 days at 20 °C and 60 °C. Et: ettringite; Hc: hemicarbonate; Mc: monocarbonate; CH: portlandite; Ht:hydrotalcite.

consumed continually in the reaction of dolomite and the formation of Ht.

The unreacted dolomite contents of the samples containing DM with different fineness are shown in Figure 10. The unreacted dolomite contents of the samples cured at 60 °C are lower than those cured at 20 °C, indicating that the higher curing temperature improves the reaction degree of DM. Additionally, at the same replacement of PC by DM, the amount of unreacted dolomite decreases obviously with increasing the fineness of DM. It also indicates that the increase of DM fineness promotes the reaction of DM in the cement pastes.

3.4 Microstructure

Figures 11 and 12 show the BSE images and elemental maps of Mg, Al, Ca and Si for the 80C20DM-II sample cured for 90 days at 20 °C and 60 °C. The BSE images show large, uniformly grey particles, which the elemental maps show are rich

Deng Chen, Tao Yang, Kai-Wei Liu, Ai-Guo Wang / Influence of dolomite powder fineness on hydration of blended cements at different curing temperatures



Fig. 9 - The portlandite contents of the samples containing 20% DM with different fineness cured for 3 days and 90 days at 20 °C and 60 °C.



Fig. 10 - The unreacted dolomite contents of the samples containing 20% DM with different fineness cured for 3 days and 90 days at 20 °C and 60 °C.

in Mg and Ca, but poor in AI and Si. The contents of AI, Ca and Si are higher in the cement matrix due to the generation of C-S-H and the AI-bearing products attributed to cement hydration. However, no significant amount of Mg could be detected in the cement matrix. Additionally, it can be found that the surface layer of DM particle at 60 °C is richer in AI than that of DM particle at 20 °C. According to XRD and TGA analysis, carboaluminate (Hc and Mc) and Ht are the mainly reaction products of DM at 20 °C and 60 °C, respectively. It indicates that Ht as the mainly product riches in Mg and AI may be only formed in the surface layer of DM particle due to the low mobility of Mg in the cement matrix [17].

3.5 Discussion

At the same replacement of PC by DM, the hydration reaction of PC can be improved with increasing the fineness of DM at 3 days, as is shown in Figure 3. This may be attributed to that the fine DM particles facilitate cement hydration by providing of more nucleation sites for the formation of hydration products [28]. Therefore, the contents of portlandite in the cement pastes are increased with increasing the fineness of DM at 3 days, as is shown in Figure 9(a). According to the results from XRD and DTG, DM has also participated in the hydration reaction of PC at 20 °C, resulting in higher peaks of Hc and Mc, this is agreement with that of PC with LS [29]. This can be explained by the additional carbonate ions provided by DM, which leads to the enhanced formation of carboaluminate. With the extension of curing ages, an increase in the fineness of DM can facilitate the conversion from Hc to Mc. This is due to that the reaction degree of DM is improved, as is shown in Figures 9 and 10. Further reaction of DM increases the CO_2/Al_2O_3 ratio which stabilizes Mc over Hc, and improves the strength[11].

At 60 °C, the hydrate assemblages differ significantly from those at 20 °C. No ettringite, Hc and Mc are detected in all the samples. Compared with the reference 100C sample, the samples containing DM show in addition to monosulphate, and also the presence of Ht. Moreover, with the increase of the DM fineness and amount, the monosulphate peaks decrease and the Ht peaks strongly increase. This may be due to that high curing temperature and an increase in DM fineness can accelerate the dissolution of Mg²⁺ in the DM particles, and then the Al in the cement pastes to

Deng Chen, Tao Yang, Kai-Wei Liu, Ai-Guo Wang / Influence of dolomite powder fineness on hydration of blended cements at different curing temperatures



(d)Elemental map of Ca

100µm

Г

٦

100µm (e) Elemental map of Si

Fig. 11 - BSE image and elemental maps of Mg, Al, Ca and Si for the 80C20DM-II sample cured at 20 °C for 90 days.

Deng Chen, Tao Yang, Kai-Wei Liu, Ai-Guo Wang / Influence of dolomite powder fineness on hydration of blended cements at different curing temperatures



(a)BSE image



Fig. 12 - BSE image and elemental maps of Mg, Al, Ca and Si for the 80C20DM-II sample cured at 60°C for 90 days.

combine preferentially with Mg²⁺ to precipitate Ht. The generation of Ht may result in the decomposition or reduction of the Al-bearing products such as Hc, Mc, monosulfate and ettringite due to the lower solubility of Ht. Furthermore, the generation of Ht also promotes an increase in the strength [12]. Additionally, according to the BSEM analysis, Ht may be formed in the surface layer of DM particles due to a low mobility of Mg in the cement matrix[17].

4 Conclusions

This paper investigated the effect of DM with different fineness on the hydration heat, compressive strength, hydration products, and microstructure of PC cured at different temperatures. The following conclusions can be drawn:

(1) The addition of DM decreases the hydration heat and compressive strength of PC. However, at the same replacement of PC by DM, the hydration heat and compressive strength can increase with increasing the fineness of DM due to the enhancement of hydration effect of fine DM.

(2) At 20 °C, an increase in the fineness and amount of DM can promote the formation of carboaluminate due to the improvement of the reaction degree of DM. Moreover, further reaction of DM increases the CO_2/Al_2O_3 ratio which facilitates the conversion from Hc to Mc.

(3) At 60 °C, Ht can be observed in the samples containing DM, no ettringite, Hc and Mc are detected. With the increase of the DM fineness and amount, the monosulphate decreases and the Ht strongly increases. This may be due to that the generation of Ht results in the decomposition or reduction of the Al-bearing products such as Hc, Mc, monosulfate and ettringite. Furthermore, Ht may be formed in the surface layer of DM particles due to a low mobility of Mg in the cement matrix

Acknowledgments

This work is supported by the Natural Science Foundation of the Jiangsu Higher Education Institution of China (20KJB560007), CRSRI Open Research Program (CKWV2019757/KY), National Natural Science Foundation of China (51778003, 52078002), the Open Research Program of Anhui Province Key Laboratory of Advanced Building Materials (JZCL006KF), Natural Science Foundation of Anhui Higher Education Institutions(KJ2020A0476), and Natural Science Foundation of Suzhou University of Science and Technology (XKZ2019001).

REFERENCES

- [1] M. Feng, P. Wu, Z. Qian, X. Liu, Y. Duan, M. Xia, Hydrothermal dolomite reservoir in the Precambrian Dengying formation of central Sichuan Basin, southwestern China, Marine and Petroleum Geology, 2017, 82, 206.
- [2] R. Gabrovsek, T. Vuk, V. Kaucic, Evaluation of the hydration of Portland cement containing various carbonates by means of thermal of thermal analysis, Acta Chimica Slovenia, 2006, 53, 159.
- [3] T. Prinčič, P. Štukovnik, S. Pejovnik, G.D. Schutter, V.B. Bosiljkov, Observations on dedolomitization of carbonate concrete aggregates, implications for ACR and expansion, Cement and Concrete Research, 2013, 54, 151.
- [4] M. Deng, M. Tang, Mechanism of dedolomitization and expansion of dolomitic rocks, Cement and Concrete Research, 1993, 23(6), 1397.
- [5] P. Stukovnik, V.B. Bosiljkov, M. Marinsek, Detailed investigation of ACR in concrete with silica-free dolomite aggregate, Construction and Building Materials, 2019, 216, 325.
- [6] L. Xu, M. Deng, Dolomite used as raw material to produce MgO-based expansive agent, Cement and Concrete Research, 2005, 35(8), 1480.
- [7] M. Szybilski, W.N. Wczelik, The effect of dolomite additive on cement hydration, Procedia Engineering, 2015, 108, 193.
- [8] M. Zajac, M. Ben Haha, Hydration of limestone and dolomite cement, Proceedings of the 14th International Congress on the Chemistry of Cement, 2015.
- [9] S. Barbhuiya, Effects of fly ash and dolomite powder on the properties of self-compacting concrete, Construction and Building Materials, 2011, 25, 3301.
- [10] H.A. Nguyen, T.P. Chang, J.Y. Shih, H.S. Djayaprabha, Enhancement of low-cement self-compacting concrete with dolomite powder, Construction and Building Materials, 2018, 161, 539.
- [11] M. Zajac, S.K. Bremseth, M. Whitehead, M. Ben Haha, Effect of CaMg(CO₃)₂ on hydrate assemblages and mechanical properties of hydrated cement pastes at 40 °C and 60 °C, Cement and Concrete Research, 2014, 65, 21.

- [12] J.T. Xu, D.Y. Lu, S.H. Zhang, Z.Z. Xu, R.D. Hooton, Reaction mechanism of dolomite powder in Portlanddolomite cement, Construction and Building Materials, 2021, 270, 121375.
- [13] S. Krishnan, S. Bishnoi, Understanding the hydration of dolomite in cementitious systems with reactive aluminosilicates such as calcined clay, Cement and Concrete Research, 2018, **108**, 116.
- [14] A. Machner, M. Zajac, M. Ben Haha, K.O. Kjellsen, M.R. Geiker, K. De Weerdt, Portland metakaolin cement containing dolomite or limestone - similarities and differences in phase assemblage and compressive strength, Construction and Building Materials, 2017, 157,214.
- [15] S. Krishnan, S.K. Kanaujia, S. Mithia, S. Bishnoi, Hydration kinetics and mechanisms of carbonates from stone wastes in ternary blends with calcined clay, Construction and Building Materials, 2018, **164**, 265.
- [16] J.T. Xu, D.Y. Lu, S.H. Zhang, K. Ling, Z.Z. Xu, Pore structures of mortars with dolomite and limestone powders cured at various temperatures, Journal of Chinese Ceramic Society, 2017, 45(2), 268.
- [17] A. Machner, M. Żajac, M. Ben Haha, K.O. Kjellsen, M.R. Geiker, K. De Weerdt, Limitations of the hydrotalcite formation in Portland composite cement pastes containing dolomite and metakaolin, Cement and Concrete Research, 2018, **105**, 1.
- [18] J. Lu, A.W. Xu, J.T. Xu, D.Y. Lu, Z.Z. Xu, Sulfate resistance of Portland dolomite cement: performance and mechanisms, Materials ans Structures, 2020, 53, 125.
- [19] A. Machner, M. Zajac, M. Ben Haha, K.O. Kjellsen, M.R. Geiker, K. De Weerdt, Chloride-binding capacity of hydrotalcite in cement pastes containing dolomite and metakaolin, Cement and Concrete Research, 2018, **107**, 163.
- [20] A. Machner, M. Zajac, M. Ben Haha, K.O. Kjellsen, M.R. Geiker, K. De Weerdt, Stability of the hydrate phase assemblage in Portland composite cements containing dolomite and metakaolin after leaching, carbonation, and chloride exposure, Cement and Concrete Composites, 2018, 89, 89.
- [21] ASTM C1702-09A, Standard test method for measurement of heat of hydration of hydraulic cementitious materials using isothermal conduction calorimetry, ASTM Int. West Conshohocken, PA, 2009.
- [22] GB/T 17671-1999, Method of testing cements-determination of strength, China Committee for Standardization, Beijing, 1999.
- [23] M. Aqel, D.K. Panesar, Hydration kinetics and compressive strength of steam-cured cement pastes and mortars containing limestone filler, Construction and Building Materials, 2016, **113**, 359.
- [24] S. Zhang, Effect of dolomite powders on the properties of cement and its mechanism, (Master, Thesis, Nanjing Tech University), 2016.
- [25] J.W. Bullard, H.M. Jennings, R.A. Livingston, A. Nonat, G.W. Scherer, J.S. Schweitzer, K Scrivener, J.J. Thomas. Mechanisms of cement hydration, Cement and Concrete Research, 2011, **41**, 1208.
- [26] B. Lothenbach, T. Matschei, G. Möschner, F.P. Glasser. Thermodynamic modeling of the effect of temperature on the hydration and porosity of Portland cement, Cement and Concrete Research, 2008, **38**,1.
- [27] D.H Wang, C.J. Shi, N. Farzadnia, Z.G. Shi, H.F. Jia, Z. Ou. A review on use of limestone powder in cement-based materials : mechanism, hydration and microstructures, Construction and Building Materials, 2018, **181**, 659.
- [28] E. Berodier, K.L. Scrivener, Understanding the filler effect on the nucleation and growth of C-S-H, Journal of the American Ceramic Society, 2014, 97, 3764.
- [29] J. Tang, S.F. Wei, W.F. Li, S.H. Ma, P.H. Ji, X.D. Shen, Synergistic effect of metakaolin and limestone on the hydration properties of Portland cement, Construction and Building Materials, 2019, **223**, 177.