

## Reaction behaviour of dolomite powder in Portland cement pastes cured at different conditions

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### Abstract

*For developing low carbon Portland dolomite cement (PDC) and exploring the behaviour and mechanism of alkali-dolomite reaction, the deformation behaviour of PDC pastes was examined by curing at four different conditions, i.e. in water at 40, 60 and 80 °C, in 1 mol/L NaOH solution at 80 °C, with Portland limestone cement (PLC) as a comparison. Hydration products in the pastes were examined by XRD and BSEM. Results indicate that there are obvious differences between PDC and PLC both in length change patterns and hydrates formation depending on the dosages of carbonate powders and curing conditions. When cured in water at 40 and 60 °C, both PDC and PLC develop small expansion and no notable difference is found. In water at 80 °C, the expansion of PDC is comparable to that of PLC before 90 days, but after then, PDC with 20% and 30% dolomite develop larger expansion than those of PLC. The higher the dosage of dolomite, the larger the expansion developed. In NaOH solution at 80 °C, PDC with high dolomite dosages also develop larger expansion than PLC, and with earlier expansion than those cured in water.*

*There are significant differences in hydrates between the PDC and PLC. In addition to carboaluminates which forms in both systems, hydrotalcite is found in PDC cured at four curing conditions. The typical dedolomitization with brucite and calcite formation is not the prior process in PDC, but secondary to hydrotalcite formation and upon the consumption of free aluminum. The formation of hydrotalcite shows no effect on expansion of PDC pastes. The "abnormal" expansion observed in PDC is mainly associated with brucite and calcite formation in the typical dedolomitization, and the process is promoted with additional alkalis. The expansion caused by dolomite reaction in PDC is about 0.05% even upon the complete consumption of 30% dolomite powder, which is not harmful to the long-term volume stability of PDC pastes.*

*It is confirmed that typical dedolomitization, which is supposed to be a solid volume-reducing process, could cause expansion by forming brucite and calcite crystals.*

**Keywords:** alkali-carbonate reaction; deformation; dolomite reaction; hydration products; mechanism

## 1. INTRODUCTION

Portland dolomite cement (PDC) has recently attracted intense interest due to its potential benefits on sustainability of cement industry [1-3]. Several studies have established that it is practical to use dolomite powder, instead of limestone powder, fly ash and slag, to manufacture self-compacting concrete with acceptable fresh and strength properties [4, 5]. PDC can achieve similar mechanical strength to Portland limestone cement (PLC) [6, 7], and even have better strength properties when cured at elevated temperatures [7, 8]. Regarding durability properties, except a potential higher frost susceptibility, PDC is similar or superior to those of PLC in the resistance to sulphate attack, chloride penetration and carbonation [6, 9, 10].

Unlike limestone, nevertheless, dolomite is unstable in the high-alkaline pore solution in concrete, and a dedolomitization reaction can occur to form brucite and calcite [11, 12]. The dedolomitization reaction is recognized to be involved in the harmful alkali-carbonate reaction (ACR) in concrete. ACR is a chemical reaction between certain dolomite-bearing carbonate aggregates and alkali hydroxides in concrete pore solution that leads to deleterious expansion and cracking of concrete. Since the first ACR was discovered in Kingston, Canada, similar cases have been reported in USA, China, Austria and Argentina as well [13-15]. Although numerous researches have been conducted, there is still a continuous controversy in the expansion mechanism of ACR, and the focus of the debate is the role of dedolomitization [16, 17]. Some researchers advocate that dedolomitization itself can produce expansion due to the crystallization pressure associated with the formation of brucite and calcite phases in limited spaces [18]. Others proclaim that dedolomitization is a solid volume-reducing reaction which

does not cause expansion and only provides channels for ionic diffusion to trigger other expansion mechanisms, such as clay swelling [19] and alkali-silica reaction [20].

It is easily visible that there are significant differences in the property and function between dolomite powder in PDC and dolomite-bearing aggregate in concrete. Dolomite mineral, either in powder or in coarse aggregate form, is unstable in high alkaline media and can be involved in the reaction with concrete pore solution. Recent studies [3, 7, 21] report that in PDC with dolomite powder, typical dedolomitization does not take place or is modified. It seems that dolomite powder in PDC react primarily with aluminate from Portland cement to form carboaluminates and hydrotalcite, rather than brucite and calcite. However, the reaction mechanism and its effects on the long-term stability of PDC is not yet well understood.

In order to explore the mechanism of dolomite reaction in PDC and shed some light on understanding of the mechanism of alkali-carbonate reaction in concrete, in this study, the hydration products and deformation behaviours of PDC pastes were investigated by curing under four different conditions, i.e. in water at 40, 60 and 80 °C as well as in 1 mol/L NaOH solution at 80 °C, with PLC as a comparison. High temperature and high alkalinity were adopted by reference to ACR studies [24] for accelerating the reaction of dolomite and amplifying the effect of dolomite on deformation performance. The hydrated phases were examined by X-ray diffraction (XRD) and backscattered scanning electron microscope (BSEM).

## 2. MATERIALS AND TEST METHODS

### 2.1 General

All the experiments were carried out using a Type P·II 52.5R (Chinese standard) Portland cement. Commercial dolomite and limestone powders from a natural carbonate quarry were used to prepare blended cements. The chemical compositions determined by X-ray fluorescence and physical properties of these materials are shown in Table 2.1. The purity of the dolomite and limestone used are relatively high, with 95.4%  $\text{CaMg}(\text{CO}_3)_2$  and 95.5%  $\text{CaCO}_3$  respectively, determined by thermogravimetric analysis.

Table 1: Chemical composition and physical properties of the raw materials

Materials	PC	Dolomite	Limestone
CaO	65.35	31.21	54.93
SiO <sub>2</sub>	18.14	0.89	0.17
Al <sub>2</sub> O <sub>3</sub>	4.28	0.22	0.12
Fe <sub>2</sub> O <sub>3</sub>	2.93	0.10	0.03
MgO	0.60	21.78	1.08
SO <sub>3</sub>	2.90	0.01	
K <sub>2</sub> O	0.80	0.05	0.01
Na <sub>2</sub> O	0.10		0.08
LOI	2.96	45.67	43.17
D50 (μm)	15.5	14.6	14.1
Blaine surface (m <sup>2</sup> /kg)	347	437	433

Portland cement was replaced by dolomite at 10, 20 and 30% (by weight). Equivalent mixtures with limestone were also prepared as comparison. The blended cements were designated as PDC10,

PDC20 and PDC30 as well as PLC10, PLC20 and PLC30, which represented cement blends with dolomite and limestone, respectively. A constant water-to-binder ratio of 0.32 was maintained for all mixtures. For each mixture, cement pastes were initially mixed for about 120 s at a slow speed (140 r/min), and then mixed for another 120 s at a medium speed (285 r/min). Fresh slurries after mixing were poured into 20 mm × 20 mm × 80 mm molds for length change and 20 mm × 20 mm × 20 mm molds for hydration products, which were covered with plastic film and stored in a standard moisture room ( $20 \pm 2$  °C and 95% relative humidity). After 1 day, the samples were demoulded and stored in water at room temperature for approximately 2 h, and their lengths were then recorded as the initial length. Thereafter, samples were stored in water at 40, 60 and 80 °C and in 1 mol/L NaOH solution at 80 °C, respectively.

## 2.2 Methods

The length of paste prisms was monitored periodically using a comparator. Before taking each measurement, the samples were first cooled down to about 20 °C by placing the containers at ambient temperature for about 3 hours. The mean value of three samples was adopted to determine the deformation. The phase compositions and microstructural characteristics of the hydrated pastes were characterized by means of XRD and BSEM. At the appropriate time, paste cubes were crushed to small pieces with a diameter of about 3 mm, and then soaked in excess ethanol for 24 h to stop hydration. Subsequently, the samples were dried in a vacuum desiccator at 40 °C for 24 h and maintained in a desiccator until the time of measurement.

XRD was performed using a Rigaku SmartLab™ X-ray diffractometer ( $\text{CuK}\alpha$ ,  $\lambda=1.5406$  Å), with operating conditions of 40 kV and 30 mA, a scanning speed of 2 °/min, and a step size of 0.02 °. To quantify the phase evolution of hydration products, 10% analytical grade corundum (purity 99.99%), as an internal standard, was intermixed with the dried samples and lightly ground in an agate mortar. The Rietveld refinement technique was performed using HighScore Plus software.

The microstructure of the hardened pastes was examined by a ZEISS Ultra-55 field emission scanning electron microscope coupled with EDS. The samples were epoxy impregnated, polished and coated with carbon, and then investigated by Backscattered Electronic microscopy (BSEM).

## 3. RESULTS

### 3.1 Expansion of paste prisms

Figures 3.1 and 3.2 show the linear expansion of paste prisms with dolomite or limestone cured in water at 40 and 60 °C, respectively. At 40 °C (Figure 3.1), the PDC and PLC prisms display quite similar deformation behaviours at all replacement levels, with a rapid increase in expansion during the first 28 days and then reaching a plateau. The expansions of all the prisms are very small, ranging from 0.01 % to 0.02 %. When cured at 60 °C (Figure 3.2), the expansion is slightly greater than the prisms at 40 °C. In general, before 120 days, there is no apparent discrepancy in expansion between the PDC and PLC prisms. After 120 days, the expansion of the PLC prisms remains stable, while the expansion of PDC20 and PDC30 still increase. Finally, at 180 days, PDC20 and PDC30 develop a slightly larger expansion than PLC. Additionally, the expansion is increased marginally as the replacements of dolomite and limestone increase. This is probably associated with the fact that the higher carbonate additions in cement can result in a greater increase in thermal expansion as a result of the extension of cell volume at elevated temperatures [25].

Figures 3.3 and 3.4 show the linear expansion of paste prisms with dolomite or limestone cured in water and in 1 mol/L NaOH solution at 80 °C, respectively. After 28 days of curing in water (Figure 3.3), regardless of the replacement level, the PLC prisms reach a steady state at low expansion rates, which is consistent with the results of 40 and 60 °C. For the PDC prisms, PDC10 follows an almost identical trend to PLC10 but with a slightly greater expansion. Before 90 days, PDC20 and PDC30 also exhibit a similar pattern of expansion as the PLC. However, after 90 days, in contrast to PDC10 and the PLC, the expansion in PDC20 and PDC30 is triggered, and increases with the dolomite dosage and curing age. Finally, at 180 days PDC20 and PDC30 record expansion levels of about 0.036% and 0.051% respectively, which are 0.021% and 0.035% larger than those of PLC20 and PLC30. When cured at 80 °C in 1 mol/L NaOH solution (Figure 3.4), a similar expansion development profile is also observed, with the exception of time to onset of the expansion, which takes place as early as about 7 days. After 42 days of curing in alkaline media, the expansion levels of PDC20 and PDC30 are about 0.027% and 0.040% respectively, which are 0.020% and 0.031% larger than those of PLC20 and PLC30. From the

above results, it is therefore suggested that in both cases the expansion of PDC is similar to that of PLC at a replacement level of 10%. At replacement levels of 20% and 30%, however, the PDC prisms are characterized by a larger expansion compared to the PLC prisms. Moreover, the higher the replacement level, the larger the difference in expansion between PDC and PLC.

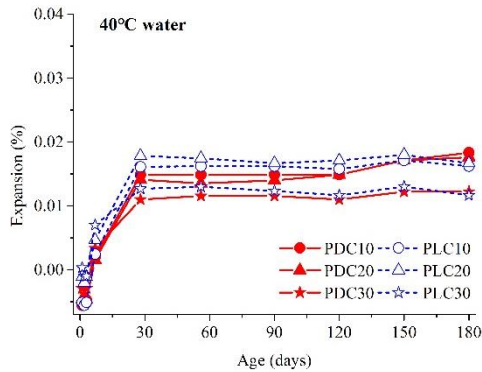


Figure 3.1: Deformation of paste prisms with dolomite and limestone cured at 40 °C in water.

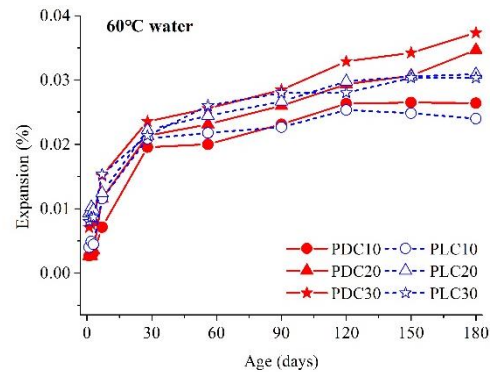


Figure 3.2: Deformation of paste prisms with dolomite and limestone cured at 60 °C in water.

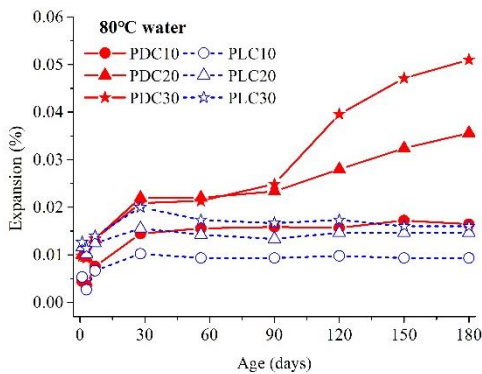


Figure 3.3: Deformation of paste prisms with dolomite and limestone cured at 80 °C in water.

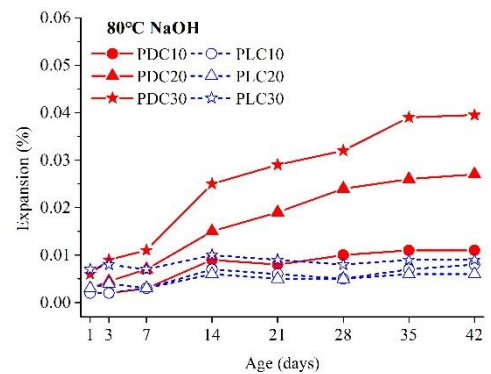


Figure 3.4: Deformation of paste prisms with dolomite and limestone cured at 80 °C 1 mol/L NaOH.

### 3.2 Hydration products

Figures 3.5 and 3.6 show the low angle X-ray diffractograms (8 to 20° 2θ) of paste samples with dolomite and limestone cured in water at 40 and 60 °C, respectively. For the PDC and PLC samples at 40 °C (Figure 3.5), obvious reflections of ettringite, monocarbonate, portlandite and residual ferrite are observed. The main difference between both samples is that the PDC exhibits a decreased intensity of monocarbonate reflection at 180 days, and also the presence of hydrotalcite. This is consistent with our previous investigation in which the reaction of dolomite in cement results in the formation of hydrotalcite, which consumes reactive aluminate and thus in turn provokes the decomposition of monocarbonate [7]. At 60 °C (Figure 3.6), monosulfate is observed instead of monocarbonate, as latter is thermally unstable at elevated temperatures [24]. Similarly, the hydrotalcite formation has been also established in the PDC samples, but it occurs earlier and more intensely at 60 °C than at 40 °C. The reflection of hydrotalcite is observed at 28 days, and strongly enhanced with the increasing of the dolomite content and curing age. Meanwhile, the ettringite reflection decreases and even completely disappears at 180 days. This may be similarly attributed to the insufficient free aluminum in the matrix associated with the formation of hydrotalcite [7]. Besides, there is a small trace of brucite that precipitates in PDC30 after 180 days. In comparison to PLC30, PDC30 shows no ettringite but a fair amount of hydrotalcite formation.

Figures 3.7 and 3.8 show the low angle X-ray diffractograms (8 to 20° 2θ) of paste samples with dolomite and limestone cured at 80 °C in water and in 1 mol/L NaOH solution. When cured at 80 °C in water (Figure 3.7), the hydration products of hardened paste samples are substantially different compared to those at 40 and 60 °C. Etringite is no longer stable, transforming to monosulfate, and hydrogarnet appears instead. This is in line with other literature that showing hydrogarnet becomes a main hydrate phases as the temperature rises [25, 26]. For the PLC samples, the monosulfate reflection diminishes and disappears with time, while the hydrogarnet reflection gradually increases. For the PDC samples, in addition to weaker reflections of monosulfate and hydrogarnet, the diffraction reflection of hydrotalcite is visible at 7 days and beyond, and it becomes more pronounced at higher dolomite additions. An obvious reflection corresponding to brucite is formed in PDC30 after 90 days of hydration, whereas even after 180 days such reflection cannot be clearly identified in PDC10, indicating that the dolomite dosage in PDC affects the types of hydration products formed. Similarly, hydrotalcite and brucite are also detected for the PDC samples cured in alkaline solution (Figure 3.8), but they appear earlier than in water. The ages for the appearance of hydrotalcite and brucite are 3 days and 7 days, respectively. Likewise, brucite is again only detected in PDC30 in which its reflection is progressively enhanced over time.

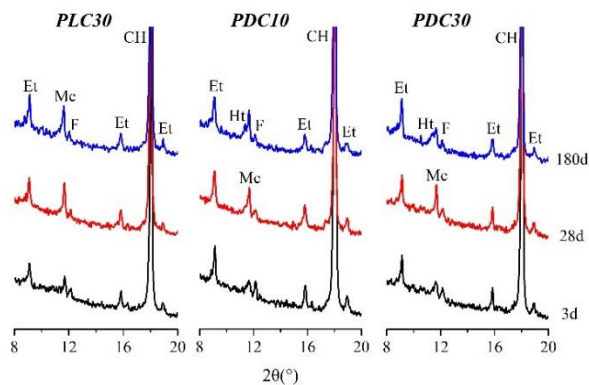


Figure 3.5: XRD patterns of paste samples cured at 40 °C in water. Et: ettringite, Ht: hydrotalcite, Mc: monocarbonate, F: ferrite, CH: portlandite.

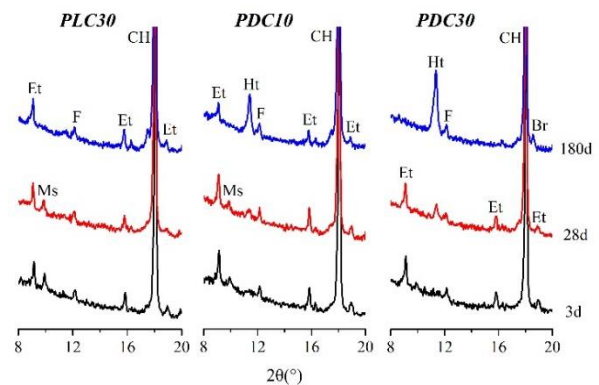


Figure 3.6: XRD patterns of paste samples cured at 60 °C in water. Et: ettringite, Ms: monosulfate, Ht: hydrotalcite, F: ferrite, CH: portlandite, Br: brucite.

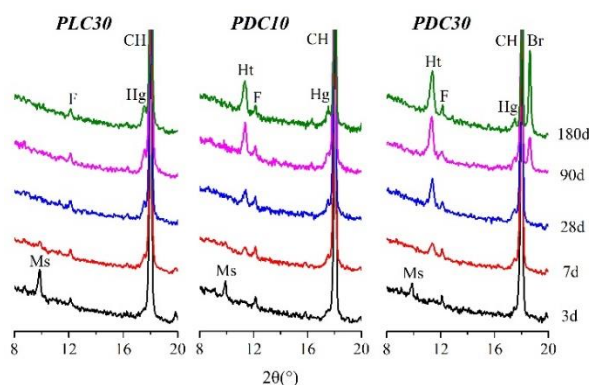


Figure 3.7: XRD patterns of paste samples cured at 80 °C in water. Ms: monosulfate, Ht: hydrotalcite, F: ferrite, Hg: hydrogarnet, CH: portlandite, Br: brucite.

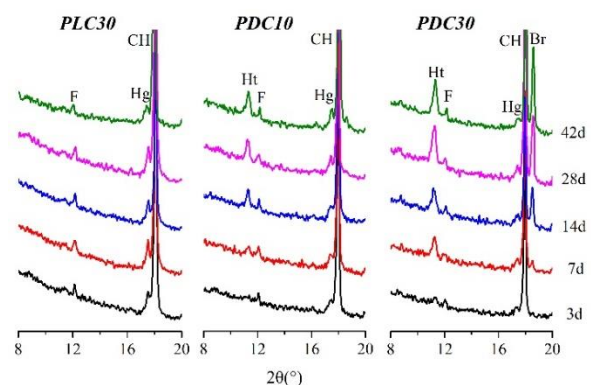


Figure 3.8: XRD patterns of paste samples cured at 80 °C in 1 mol/L NaOH. Ms: monosulfate, Ht: hydrotalcite, F: ferrite, Hg: hydrogarnet, CH: portlandite, Br: brucite.

In addition to monocarbonate, hydrotalcite and brucite, the PDC samples also presented an increased calcite content. As shown in Figure 3.9, it is found that after 180 days in water or 42 days in 1 mol/L NaOH solution, the reflection intensities of calcite significantly increase, which corresponds to the reduction of the dolomite reflections. And this phenomenon is more obvious with increasing curing temperature and alkalinity.

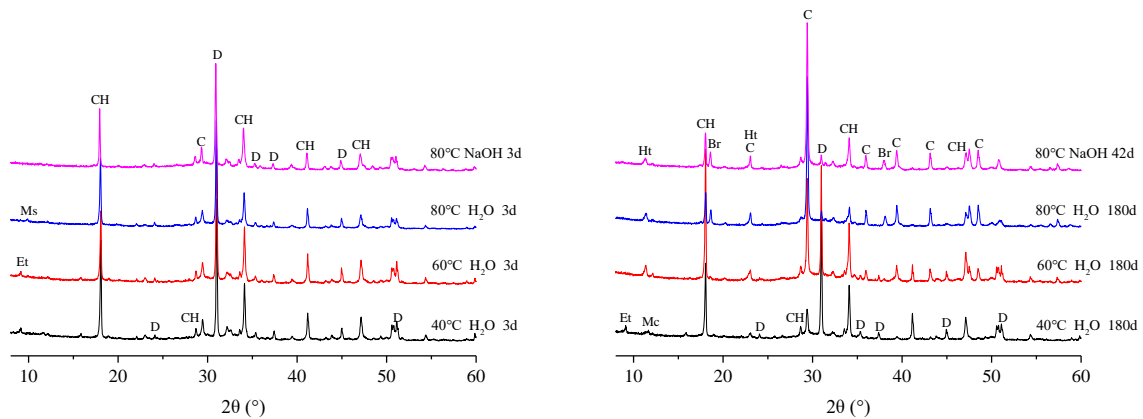


Figure 3.9: XRD patterns of PDC30 sample cured in different conditions. Et: ettringite, Ms: monosulfate, Ht: hydrotalcite, CH: portlandite, Br: brucite, D: dolomite, C: calcite.

### 3.3 Phase evolution of hydration products for PDC30 cured at 80 °C

Quantitative-XRD analysis (QXRD) was used to determine the phase evolution of hydration products of PDC30 cured at 80 °C in water and in NaOH solution, as shown in Figure 3.10. The trends for PDC30 cured in both cases are quite similar, and hence depicted together. It is clear that the dolomite content in PDC30 sharply decreases, as the hydration proceeds, whereas the amounts of calcite, hydrotalcite and brucite increase accordingly. This process is faster in alkaline solution than in water. The calcite content steadily increases with time. Hydrotalcite is always formed prior to the formation of brucite, independent of the curing media. Moreover, the amount of hydrotalcite is retained at a fairly constant level when brucite starts to form. This indicates that there is a transition in the mechanism of dolomite reaction in PDC, which inhibits the production of hydrotalcite but promotes the formation of brucite. The “ultimate” amounts of depleted dolomite are approximately 27% and 28% for PDC30 cured in water and in NaOH solution, which correspond to the reaction degree of 90% and 93% respectively, suggesting the dolomite is almost completely depleted. Accordingly, the amounts of hydrotalcite and brucite formed are about 4.0% and 5.1% in water as well as about 3.1% and 5.7% in NaOH solution.

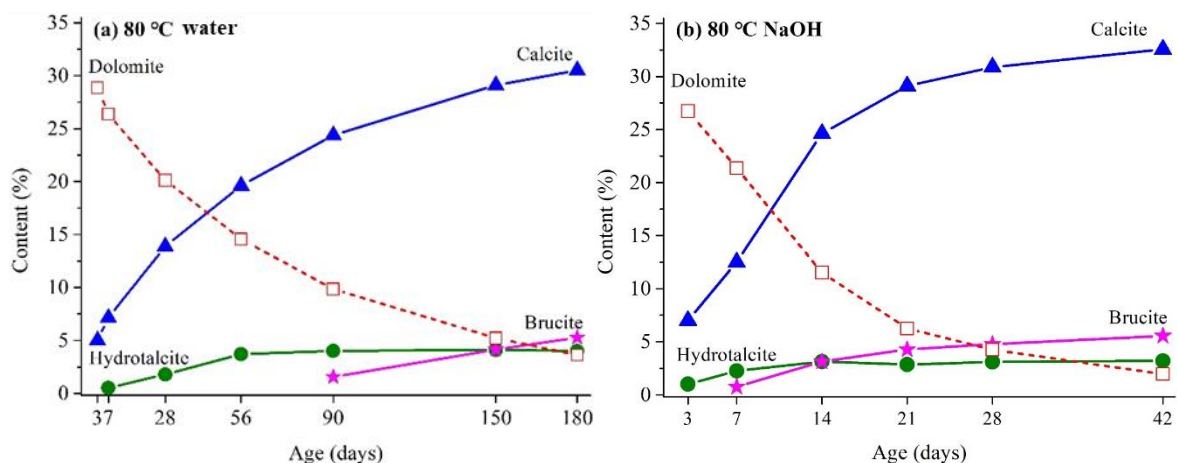


Figure 3.10: Evolution of hydration products for PDC30 cured at 80 °C in (a) water and (b) 1 mol/L NaOH.



### 3.4 Microstructure characteristics

Figure 3.11 shows the BSEM image of PDC30 cured at 80 °C in water for 180 days. The original dolomite grains can be clearly distinguished based on its angular shape and size as well as the different brightness relative to the products of cement clinker. Obviously, PDC30 shows a considerable dolomite reaction that generates many dolomite relicts, which agrees well with the QXRD results. To further understand the reaction behaviour of dolomite, elemental mapping in the Zone 1 of Figure 3.10 was performed and is shown in Figure 3.12. The resulting elemental maps show that three regions around reacted dolomite grains, including interior (A), reaction rim (B), and exterior (C), can be clearly identified. In the reaction rim (B), abundant Mg, Al and O elements are found and no Ca and Si elements present, indicating that hydrotalcite is only precipitated around the surface of dolomite grains. The interior region (A) is rich in Ca and Mg elements, which show a heterogeneous interlaced distribution. Furthermore, Mg and O elements are assembled together. Combined with XRD analysis, the phases for the enrichment of Ca and Mg are identified as calcite and brucite, respectively. In the exterior of dolomite (C), the enrichment of Ca associated with calcite is also found, while no significant amount of Mg can be detected by EDS, confirming the ease of transport of calcium ions and the low mobility of magnesium ions in high PH environment of cement paste, as reported in literature [12].

For PDC30 cured in alkaline media at 80 °C, the microstructure of paste shows a similar phenomenon (data not given).

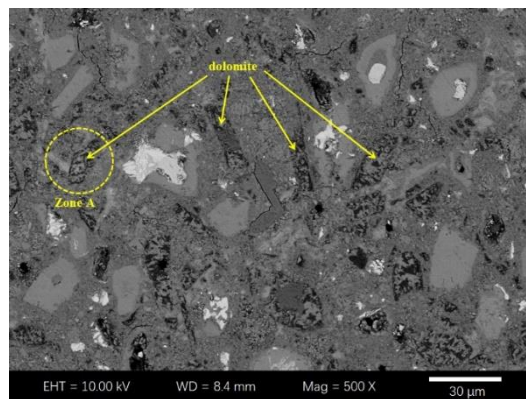


Figure 3.11: BSEM image of PDC30 cured in water at 80 °C for 180 days.

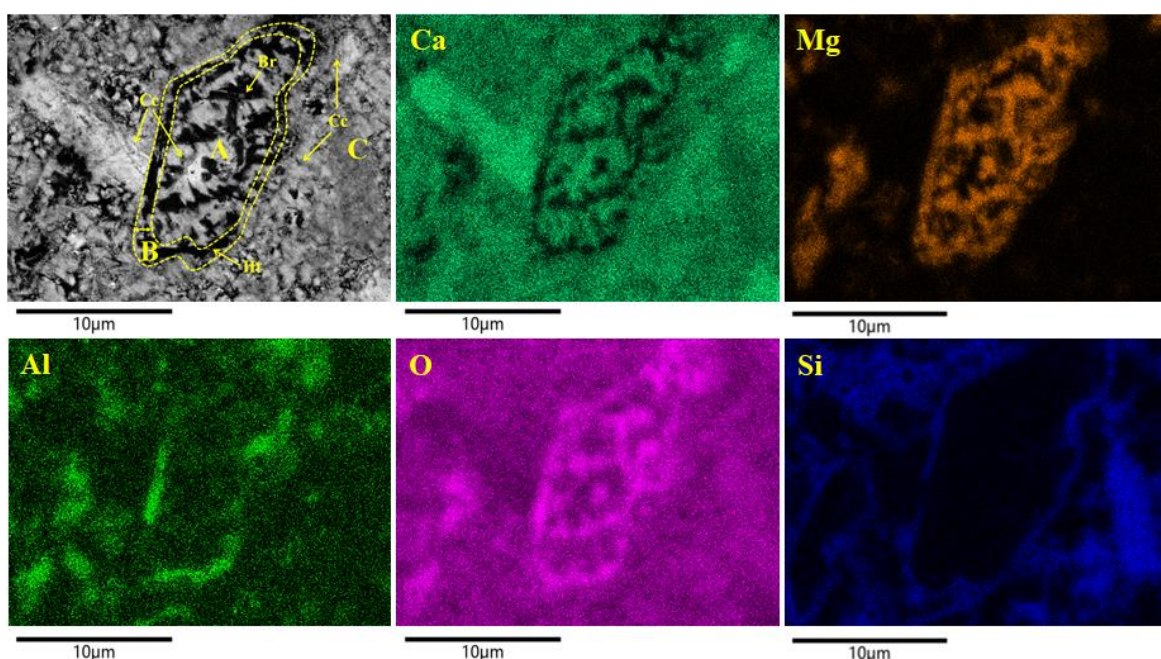


Figure 3.12: BSEM image and elemental maps of Ca, Mg, Al, O and Si for PDC30 cured in water for 180 days, as the Zone A in Fig. 10. Cc: calcite, Ht: hydrotalcite, Br: brucite.

## 4. DISCUSSIONS

### 4.1 Reaction behaviour of dolomite powder in PDC

It is well known that dolomite powder can react with portlandite to produce calcite and brucite, which is the typical dedolomitization reaction [14]. In PDC with dolomite powder, however, the dedolomitization reaction is modified, and the reaction behaviour of dolomite is strongly influenced by the dolomite dosages and curing conditions. When cured in water at 40 °C as shown in Fig. 5 and Fig.9,  $\text{Ca}^{2+}$  and  $\text{CO}_3^{2-}$  ions dissolved from dolomite contribute to the formation of carboaluminates and calcite, and  $\text{Mg}^{2+}$  ions contribute to form hydrotalcite at later age, 180 days. Brucite, as one of the typical dedolomitization products, is not identified in all examined samples throughout the testing period. The increase of curing temperature to 60 °C (Fig. 6 and Fig. 9) results in the decomposition of carboaluminates, but large amounts of hydrotalcite and calcite are formed in PDC pastes and increase with age and dolomite dosage. In PDC30, in addition to hydrotalcite,  $\text{Mg}^{2+}$  from dolomite combines to form brucite at 180 days. At 80 °C (Figs. 7-8), ettringite is unstable, and only a small amount of monosulfate is presented in PDC cured in water at early age of 3 days and subsequently transformed to other phases. Hydrotalcite is identified as the disappearing of monosulfate at 7 days, and with a continuous increase throughout the testing period. When cured in alkali solution, no monosulfate can be detected while hydrotalcite is formed as early as at 3 days.

These findings suggest that the reaction of dolomite in PDC is not the typical dedolomitization, and the availability of aluminum in PDC plays a crucial role in affecting its behaviour. At early age, ettringite and/or monosulfate are always formed owing to the quick release of aluminate and  $\text{SO}_4^{2-}$  from  $\text{C}_3\text{A}$  and gypsum in cement. Monocarbonate can also be formed at early age by the  $\text{CO}_3^{2-}$  from dolomite with  $\text{C}_3\text{A}$ , but it becomes unstable at 60 °C. Mg released by dolomite is prior to form hydrotalcite rather than brucite when free aluminum is available in PDC pastes. The formation of hydrotalcite could be facilitated by improving availability of Mg, such as elevating the curing temperature and providing the additional alkali supply. Since the stability of hydrotalcite is higher with respect to both ettringite and brucite [7], in the presence of available Mg, Al-bearing products such as monocarbonate, monosulfate and ettringite might be decomposed and transformed into hydrotalcite. Brucite is only formed in PDC with high dolomite dosages and without the availability of sufficient free aluminum.

### 4.2 Relation between dolomite reaction and expansion of PDC

The expansion patterns in Figs. 1-2 show that no significant difference can be observed between PDC and PLC cured at 40 and 60 °C, although a fair amount of hydrotalcite forms in PDC. It indicates that the formation of hydrotalcite has little influence on the volume stability of PDC samples. This finding is further supported by the deformation results of the samples cured at 80 °C, where PDC10 follows a similar expansion pattern as PLC10 throughout the testing period, and the expansions of PDC20 and PDC30 are also similar to those of PLC during the formation of hydrotalcite. However, PDC20 and PLC30 cured at 80 °C develop expansion obviously higher than PLC after 90 days of curing in water and 7 days of curing in NaOH solution. By comparing with the XRD results in Figs. 8-10, the expansion of PDC20 and PDC30 is mainly associated with the formation of brucite, and the increase in expansion is closely related with the increasing of brucite. It suggests that brucite formation caused by typical dedolomitization reaction may result in notable expansion in PDC pastes with high dolomite dosages. According to QXRD results, the amounts of brucite formed are about 5.1% and 5.7% for PDC30 cured in water and in NaOH solution at 80 °C, which are corresponding to expansion levels of 0.051% and 0.040%, respectively. Expansions at such levels are usually not harmful for cement pastes. Furthermore, the brucite formation, i.e. typical result of dedolomitization, is detected only in PDC30 cured at 80 °C and when free aluminum in cement pastes has been consumed. It is not observed in PDC pastes cured at temperatures below 60 °C. Therefore, at 10~30% dosages, dolomite reaction in PDC causes no adverse impact on the volume stability of cement-based materials.

### 4.3 Implications for the mechanism of ACR

The present results indicate that the reaction of dolomite powder in PDC is not the typical dedolomitization in alkali media to form brucite and calcite, but rather complicated. The process and products are strongly influenced by several factors, including the dosage of dolomite, curing temperature and media, etc. The typical dedolomitization is not the first process of dolomite reaction in PDC pastes, but is secondary to other processes and occurs after the free aluminum in cement pastes has been consumed. The reaction of dolomite powder in PDC and formation of products other than brucite and



calcite, will not cause harmful expansion and long-term volume stability problem of PDC pastes. However, it is interesting to note that the observed expansion of PDC pastes cured at 80 °C both in water and NaOH solution is mainly associated with the formation of brucite, and the process is promoted with additional alkalis. It is therefore confirmed that typical dedolomitization, which is theoretically a solid volume-reducing process and not supposed to be the main reason of ACR expansion, could cause expansion by forming brucite and calcite crystals.

## 5. CONCLUSIONS

1. At 40 and 60 °C, the PDC and PLC samples show similar deformation behaviours at all dosages (10-30%), with a small and steady expansion up to 180 days. When cured at 80 °C in water and 1 mol/L NaOH solution, the expansion of PDC10 is similar to that of PLC, while PDC20 and PDC30 show higher expansion than their counterparts of PLC. The difference is enlarged with the high dosages of carbonate powders.
2. At 40 and 60 °C, dolomite reaction in PDC pastes leads to the formation of hydrotalcite, which results in a reduction of aluminum bearing products such as monocarbonate and ettringite. At 80 °C in water and 1 mol/L NaOH solution, in addition to hydrotalcite which forms in priority, brucite, a typical product of dedolomitization, is formed in PDC with high dolomite dosages at later ages upon the consumption of free aluminum.
3. The availability of free aluminate in cement plays a crucial role in controlling the reaction mechanism of dolomite powder. In the presence of surplus aluminate,  $Mg^{2+}$  released from dolomite is prior to form hydrotalcite. The typical dedolomitization with the formation of brucite and calcite occurs when free aluminate is unavailable.
4. The formation of hydrotalcite has a negligible influence on the volume stability of PDC pastes. The notable expansion in PDC is mainly associated with the brucite formation caused by the typical dedolomitization, and such expansion is unarmful to the soundness of cement. Dolomite with a dosage up to 30% in PDC causes no adverse impact on the volume stability of cement-based materials.
5. It is confirmed that typical dedolomitization, a theoretically solid volume-reducing process, could cause expansion by forming brucite and calcite crystals.

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