# ON MAGNESITE AGGREGATE REACTION AND WAYS FOR IMPROVEMENT

Ma Baoguo, Cui Kehao
Dept. of Materials, Wuhan Univ. of Technology

The paper inquires into magnesian aggregate's effect on mortar compressive strength, flexural strength and expansion value from the view point of content, size, and curing temperature. Based on experiments, mechanism and control as well as the technical method of the reduction of magnesium aggregate's reaction have been analyzed.

## INTRODUCTION

In recent years, with the increase of the building industry's interest in artificial aggregates (industrial residue) and the use of magnesian-bearing natural aggregate (Dolomite, Brueite Ankerite etc.), people are now faced with magnesian aggregate's damage to the durability of concrete. Several failures in concrete project caused by such damage have been reported in china(1, 2). Since the outside characteristic of magnesian aggregate reaction resemble to the damage of alkali-aggregate reaction, people tend to consider alkali-aggregate reaction as the cause of the damage, which led to wrong judgment and couldn't suit the remedy to the case.

For the mechanism of magnesian aggregate reaction, the existing researches (2, 3) considered that there probably exist three different reactions with the difference of initial state of magnesian aggregate.

1. Magnesium limestone's disintegration, that is:
   $CaMg(CO_3)_2 + 2MOH \rightarrow Mg(OH)_2 + CaCO_3 + M_2CO_3$
   Here M is K, Na or other alkli matal ions
2. The hydrolytic reaction of magnesia:
   $MgO + H_2O \rightarrow Mg(OH)_2$
3. Brucite's silicagel reaction:
   $6Mg(OH)_2 + 4SiO_2 \rightarrow Mg_6[(OH)_8Si_4O_{10}] + 2H_2O$

Generally speaking, as industrial residue usually has undergone high temperature process($>$1100℃) before it is used as artificial aggregate, the magnesian element in the industrial residue is existed in the form of magnesia (MgO), but to some residues which have been stored up over a long period of time, part of the magnesite element remain in the form of Brucite [$Mg(OH)_2$] as a result of magnesia hydrolytic reaction. In view of the magnesian aggregate reaction appeared in the above-mentioned mostly relates to industrial waste residue, this paper mainly studies the damage caused by magnesia hydrolytic reaction and Brucite silicagel reaction. On the basis of this, the mechanism and technical method for the control and reduction of magnesian aggregate reaction have been inquired.

## EXPERIMENT

### Materials

The cement used in this test was ordinary portland cement 525', sand used was standard specially for testing.

In order to reduce the magnesian aggregate reaction, two kind of pozzolanic materials were adopted, that is, natural pozzolanic material (Pearlite) and flyash. Their chemical composites are listed in Table 1.

Table 1. Chemical composition of pozzolanic materials

| Sample | $SiO_2$ | $Al_2O_3$ | CaO | $Fe_2O_3$ | MgO | $Na_2O$ | $K_2O$ | LOI |
|---|---|---|---|---|---|---|---|---|
| Fly ash | 50.7 | 29.3 | 2.8 | 3.9 | 1.3 | 0.4 | – | 8.1 |
| Pearlite | 68.6 | 13.4 | 1.85 | 1.04 | 0.28 | 2.33 | 4.33 | 7.55 |

In order to avoid the influence from other elements, the experiment selected chemically pure MgO and $Mg(OH)_2$ as the elements for magnesian aggregate, in which MgO was first sintered for one hour at 1100℃ and then processed into powders and particles with the diameter φ5mm and φ15mm, so as to make MgO more close to the actual state of magnesian aggregates in industrial residue.

### Method

The mortar prism of 40×40×160mm were cust, their proportional parameter were: cement/sand=1:2 water/cement=0.44 MgO [or $Mg(OH)_2$] were substituted for sand according to the designed percent by weight (MgO/cement %). The mortars were mixed by mortar mixer and vibrated by vibrator, and specimens were kept still 24hrs at 20+3℃, then demoulded and cured for 24hr at 50℃ and 80℃ separately. After steam curing for 24hr, specimen compressive strength and flexural strength were determined. When the weight of MgO was controlled as 5 percent that of cement, added MgO in sphere particles (with the diameter φ5mm and φ15mm separately) to examine the influence of the size of MgO on mortar characters.
The expansion value of magnesian aggregate was determined by relative standard. [ see(4)].

## RESULT AND ANALYSIS

### 1. The delaying hydrolization of MgO on the characterization of mortar

Table 2 shows the influence of the variation of the addition of MgO to the expansion value of cement paste. The result show that when the addition of MgO exceed 5 percent, its expansion value has gone beyond the permission of relative standard (4). As the content of MgO increased continuously, the expansion value of cement paste showed an increasing tendency.

Table 2 The variation of expansion value with content of MgO

| Sample | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| MgO% | 0 | 5 | 8 | 10 | 12 | 15 |
| △L(mm) | 3 | 5 | 5.1 | 5.2 | 5.5 | 6 |

Fig. 1 and 2 give the changing patterns of compressive strength and flexural strength of mortar under the two steam curing conditions.

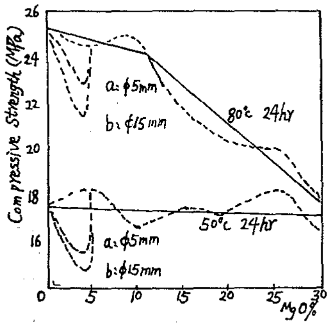



Fig. 1 Influence of MgO(%wt) on compressive strength of mortar

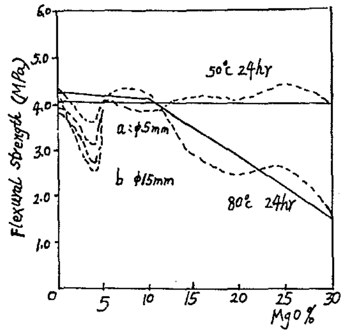



Fig. 2 Influence of MgO(%wt) on flexural strength of mortar

It can be seen from Fig. 1 that on different curing conditions, the change of powdered MgO content has different influence on the compressive strength of the mortar. The strength of mortar fluctuates by a constant value (17.4MPa) at 50℃. But when the product was cured at 80℃, MgO has an obvious effect on mortar compressive strength. The changing tendency was : when the addition of MgO was less than 10% wt, the mortar strength fell slowly, however the strength fell drastically when the addition of MgO was more than 10% wt. It is clear that the raise of curing temperature speeds up hydralytic reaction of MgO, thereby the swelling damage was aggravated. When the addition of MgO was less than 10% wt, the swelling stress was not enough to damage the binding strength produced by cement hydration in mortar, so the damage of the mortar strength was comparatively small. But if the addition of MgO was increased continuously and swelling stress surpassed binding strength, the resulting swelling damage would cause a drastic fall in the product's strength.

When the addition of MgO was 5%, as the size of MgO increased, the strength dropped obviously (a and b in Fig. 1). The reason lied in that the concentrated inside swelling stress aggravated the damaging effect to the product. It shows that the damaging effect of MgO depended not only on its relative content, but also on the size and distribution of the particle containing MgO to a great extent. Judging from MgO's effect on flexural strength (Fig. 2), its changing pattern is very similar to that in Fig. 1, this further proved the above analysis.

2. $Mg(OH)_2$ effect on mortar performance

In industrial magnesite-bearing waste, magnesite element always exists partly in the form of $Mg(OH)_2$ through hydrolization due to long-term stack. In order to study $Mg(OH)_2$ effect on the performance of mortar , the test similar to Fig. 1 and 2 was given and the result is shown in Fig 3 and 4.

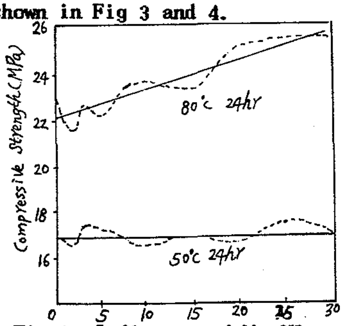


Fig. 3 Influence of Mg(OH) on compressive strength of mortar

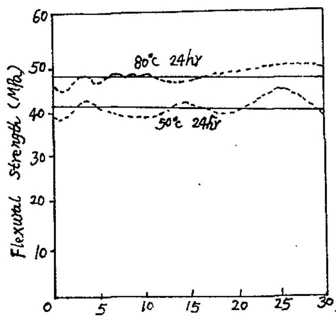
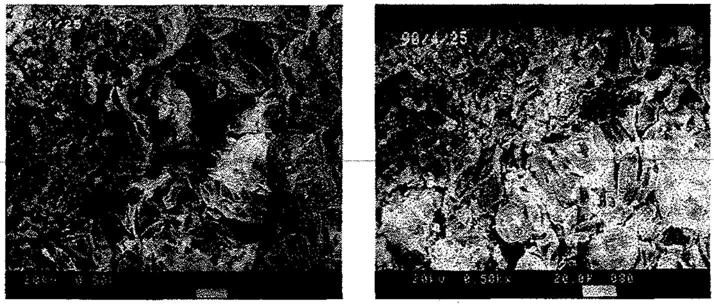


Fig. 4 Influence of Mg(OH) on flexural strength of mortar

Compare the result in Fig. 1 with that in Fig. 3, it can be seen that under 50°C curing condition, the influence of the change of $Mg(OH)_2$ content to the product is similar to Fig. 1 . It is interesting to note that when the product's curing temperature was higher (80°C), the mortar compressive strength didn't tend to drop. On the contrary, as $Mg(OH)_2$ content was increased, it went up obviously. The flexural strength also changed according to the same trend.

The above result means that when industrial magnesite-bearing waste was used as concrete aggregate, hydrolization and volume expansion of MgO in aggregate is the direct cause of concrete's durability failure (See the result of SEM in Fig. 5).



$Mg(OH)_2$ and its silicagal reation didn't destroy concrete durability. Furthermore, two effective ways were got to prevent magnesite aggregate reaction in magnesite-bearing waste. The first is to use magnesite-bearing slag after a long-time stack. The second is to use magnesite-bearing aggregate after suitable steam curing or autoclave curing. In industrial practice, we had determined the sample ( φ 20—40mm) which had been stacked for more than five years and found it had good autoclave stability.

3. Magnesite aggregate reaction's improvement

On the basis of above-mentioned experimental result and analysis, the author think that two reaction maybe exist actually for magnesite-bearing industrial residue in concrete:

1) $MgO+H_2O \rightarrow Mg(OH)_2$

2) $6Mg(OH)_2+4SiO_2 \rightarrow Mg_6[(OH)_8Si_4O_{10}]+2H_2O$

During the two reaction process, the hydrolization of MgO led to volume swelling and thus made the hardened concrete structure damage. $Mg(OH)_2$ by no means urge the damage, it could reduce or remedy the strength loss caused by structure damage to a certain extent. For this reason, when magnesian residue was used as aggregate in concrete, proper amount of pozzolanic material should be added to form $Mg_6[(OH)_8Si_4O_{10}]$. It could effectively reduce the swelling stress, improve concrete durability.

To confirm the above mentioned analysis, when the specimen containing 22% powdered sintered MgO was designed, 0~30% volcanic-ashed material was added, (fly ash, pearlite ) and then determined the expanding value and strength change of the sample. The result is shown in Fig.6 and Fig.7

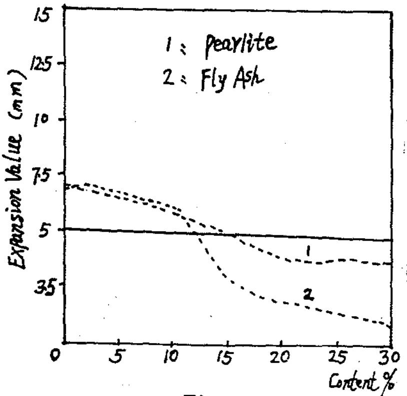



Fig.6

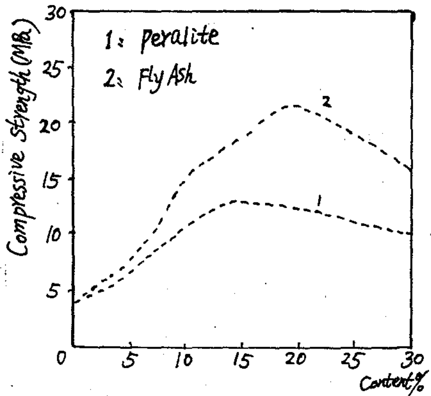



Fig.7

The result given in Fig. 6 shows that as the addition of active pozzolanic material increased, the swelling value of the sample appear to reduce gradually. When the addition is 15~20%, the swelling value is lower than that of the relevant standard. Fig. 7 shows that the addition of 10% volcanic-ash material has obvious effect to reduce the damage caused by magnesia aggregate reaction. When the addition was in the range of 15~20%, the quality of product achieved the best result. The strength of the product tends to drop as the addition exceeds 20%. The result in Fig. 7 also indicates the improving of fly ash is better than that of pearlite. The reason might lie in that pearlite has a high $K^+$, $Na^+$ content and big water requirement.

## DISCUSSTION

Considering from several engineering accidents in our country related to magnesite aggregate reaction, the period of concrete durability failure by magnesite aggregate reaction is usually 3~7 years. There exist many factors affecting magnesite aggregate reaction. But MgO's content , the size of aggregate and its distribution determine the amount of internal swelling stress. The environment temperature and humidity exert a bigger influence on the rate of magnesite aggregate reaction. By the research result on hand, when magnesian industrial waste was used as artificial concrete aggregate, to those industrial waste which MgO content might surpass 10%, its content and form of magnesite must first be distinguished. The concrete sample should be compounded according to the size and amount of aggregate required by actual proportion so as to avoid possible damage to concrete durability caused by magnesite aggregate in actual engineering.

From the previons experimental result and analysis, the author thinks that as to the artificial aggregate of magnesite-containing industrial waste, the reason of the damage to concrete durability is due to MgO delaying hydrolization which causes volume swelling and centralization stress, and forms the structure damage. However the magnesite-containing aggregate after hydrolization doesn't cause the above damage effect. And so we 've got the following technical way to reduce magnesite aggregate reaction:

(1) To avoid magnesite aggregate reaction, industrial waste should be stored for a certain period before it is used as concrete aggregate. The length of the storage period depend on magnesite content of the original waste and it's past record for high temperature. For security, the time for storage should be longer than five years. When the actual time for aggregate storage is not long enough, steam treatment can be used for the aggregate to quicken MgO hydrolytic reaction.

(2) When magnesite-containing aggregate is used for proportioning of concrete, right amount of mixed volcanic materials (The best amount of addition is about 15% wt. for this test ) was added according to actural condition. The addition of volcano can raise the reaction rate of $Mg(OH)_2$ and $SiO_2$ and reduce the stress concentration when MgO is hydrolyzed as $Mg(OH)_2$. The resultant of silicate of Brucite is helpful to raise product's strength and improve its ability to resist concrete's durabilty damage.

## CONCLUTION

1. The mechanism of magnesite-containing waste residue's damage to concrete's durability is due to MgO's slow hydration as $Mg(OH)_2$ which results in volume swelling and inside stress concentration and cause concrete's structure damaged.

2. $Mg(OH)_2$ is not the reason for magnesite aggregate reaction, on the contrary, it's helpful to improve concrete product's durability.

3. The degree and rate of magnesite aggregate reaction in concrete mainly depends on magnesite content, state, size and distribution of the original aggregate. When MgO content of magnesite aggregate surpass 10%, its content and state must be determined. Simulated accelerated damage test should be conducted according to actual practical conditions.

4. When magnesite-containing industrial waste slag is used as concrete aggregate, it must undergo an enough storage period (more than five years) to avoid magnesite aggregate reaction. In actual application, right amount of volcanic material should be added in proportioning design to reduce concrete durability damage caused by magnesite aggregate.

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