Assessing the efficiency level of ground basalt stone and fine sand in compressive strength of portland cement

Vu Dinh Dau
Department of Building Materials, University of Civil Engineering (NUCE), 55 Giai phong Road, Hai Ba Trung District, Hanoi, Vietnam

Abstract. Compressive strength of a portland cement were effected by natural mineral admixtures (PGKTN) such as basalt stone and fine sand. In general, a higher content of natural mineral admixture, a lower compressive strength of blended portland cement. Influence level depended on such as the kind and content, the fineness of natural mineral admixture.

In this paper, study results on the efficiency level of ground basalt stone and fine sand on the compressive strength in mortar PCB was introduced. Investigation results show that the higher content of ground basalt stone and fine sand in blended portland cements, the lower compressive strength were investigated. Efficiency level of natural mineral admixture in the compressive strength of blended portland cement is different for mortar and paste cement. Study data show efficiency levels of the chemical and physical effect by the active and inert components in these admixtures on compressive strength of blended portland cement. It confirmed that the efficiency level of these natural mineral admixtures in the compressive strength is increased with the increasing of the content and grinding of a basalt stone and fine sand.

1. Introduction
Mineral admixtures (PGK) have been used to produce blended portland cement for increasing productivity and economic efficiency. With the outstanding advantages of economic and technical efficiency, the PGK using in cement and concrete is widely used in the world and will become an indispensable material in the future.

Natural mineral admixtures (PGKTN) are available materials with very large reserves and stable quality in Vietnam country. Although having lower activity than artificially mineral admixtures, due to its low cost and availability in all regions, it is often used widely. Depending on the purpose and specific technical requirements, use mineral admixtures accordingly.

The role and influence of PGK in cement and concrete technology have been studied by many domestic and foreign scientists [1-10]. Different types of PGK have different levels of influence on the properties of cement and concrete. Therefore, the use of appropriate types and contents of PGKTN to achieve high technical and economic requirements should be studied in detail.

According to some research results, fine PGK have two effects: chemical and physical effects that have a favorable effect on the properties of cement and concrete. PGKTN used in cement in our country have differences in origin, chemical composition and activity. Depending on the type of PGKTN and manufacturing technology that has different levels of influence. The chemical effect of PGKTN is mainly related to the chemical reaction of the active ingredient with Ca (OH)₂ due to hydration of cement minerals, while the physical effect is mainly due to inert part of PGK. Physical effects increase the dispersion ability of cement particles, improve the structure of cement stone and...
concrete. Depending on the type and fineness of mineral admixtures used that have different influence levels on the physical and mechanical properties of cement and concrete [1-3,6,7]. This study investigates the effects of two types of PGKTN in our country as ground basalt and fine sand with different fineness to the most basic characteristic is the compressive strength of PCB cement. Based on the influence of used PGK and the inert BaSO$_4$ component to the compressive strength of the cement mortar, it is possible to evaluate the efficiency level due to the chemical and physical effects when using these two types of PGK in the compressive strength of portland cement. This helps to better understand the role of chemical and physical effects of PGK when choosing the type and manufacturing technology.

2. Materials used and research methods

2.1. Materials used
But Son portland cement (PC40) was used in the study. The properties of cement are determined by TCVN in accordance with PC40.

Natural mineral admixtures used are fine sand (C) and basalt (BZ). Basalt stone from Ha Nam was ground in a ball mill to achieve the fineness designated as BZ1 and BZ2. The fine sand used is the fine sand of Red river which is dried and ground in a ball mill to meet the fineness requirements of C1 and C2. Barite (BaSO$_4$) with the low fineness barite (Ba1) and the high fineness barite (Ba2), are used as inert materials to study the physical efficiency of the PGK types used. The test to determine the specifications of ground basalt, fine sand and BaSO$_4$ is given in Table 1.

| No. | Characteristics                       | Test method         | Unit | BZ1 | BZ2 | C1  | C2  | Ba1 | Ba2 |
|-----|--------------------------------------|---------------------|------|-----|-----|-----|-----|-----|-----|
| 1   | Residual amount on sieve 0.09mm       | TCVN 4030:2003     | %    | 7.0 | 1.8 | 6.6 | 1.5 | 5.35| 1.76|
| 2   | Specific gravity                      | TCVN 4030:2003     | (g/cm$^3$) | 2.79 | 2.79 | 2.63 | 2.63 | 3.78 | 3.78 |
| 3   | Bulk density                          | TCVN 4030:2003     | (kg/m$^3$) | 924  | 851  | 806  | 778  | 1750 | 1580 |
| 4   | Index of activity with PC             | TCVN 6882:2001     | %    | 78.4 | 83.2 | 76.5 | 81.1 | 73.8 | 76.5 |

The fine aggregate used in the study was Song Lo yellow sand which removed particles $>5$mm and particles $<0.14mm$ meeting the technical requirements of Vietnamese standard TCVN 6227: 1996. The water used meets the Vietnamese standards TCVN 4506: 2012 for water mixed with mortar and concrete.

2.2. Research methods
Determining the properties of the materials used and the compressive strength of cement are carried out according to Vietnamese standard methods (TCVN). In this topic, the non-standard method is also used to determine the efficiency level in the compressive strength of the cement mortar due to the active and inert components by following steps:
- Determining the overall efficiency of used PGK in mortar.
- Determining the efficiency level due to physical effect (VL) in compressive strength due to inert component by using BaSO$_4$ instead of portland cement.
- Determining the efficiency level due to chemical effect (HH) in the compressive strength due to the chemical active components of PGK.
3. Research results
The mixtures using ground PGK such as basalt (BZ1 and BZ2), sand (C1 and C2) and Barite (Ba1 and Ba2 play the role of inert components) with the percentage of PC replacement by mass is 10, 20, 30 and 40% are denoted as in Table 2.

| No. | PGK% | Grinding Basalt | Grinding sand | BaSO4 |
|-----|------|-----------------|---------------|-------|
| 1   | 0    | PC              | PC            | PC    |
| 2   | 10   | PBZ1-10         | PC1-10        | PBa1-10 |
| 3   | 20   | PBZ1-20         | PC1-20        | PBa1-20 |
| 4   | 30   | PBZ1-30         | PC1-30        | PBa1-30 |
| 5   | 40   | PBZ1-40         | PC1-40        | PBa1-40 |
| 6   | 10   | PBZ2-10         | PC2-10        | PBa2-10 |
| 7   | 20   | PBZ2-20         | PC2-20        | PBa2-20 |
| 8   | 30   | PBZ2-30         | PC2-30        | PBa2-30 |
| 9   | 40   | PBZ2-40         | PC2-40        | PBa2-40 |

3.1. Study on compressive strength of cement mortar using natural mineral admixtures
Results of determining the compressive strength of mortars using finely ground basalt, sand and barite according to TCVN 6016-2011 at ages 3, 7 and 28 days are shown in Table 3-5 and illustrated in Figure 1-3.

| No. | Sample symbol | Compressive strength (N/mm²) |
|-----|---------------|------------------------------|
| 1   | PC            | 24,7                        |
|     | PC1-10        | 21,8                        |
|     | PC1-20        | 19,2                        |
|     | PC1-30        | 17,6                        |
|     | PC1-40        | 14,6                        |
|     | PC2-10        | 23,1                        |
|     | PC2-20        | 20,4                        |
|     | PC2-30        | 18,6                        |
|     | PC2-40        | 15,4                        |
| 2   | PC            | 31,3                        |
|     | PC1-10        | 28,3                        |
|     | PC1-20        | 23,7                        |
|     | PC1-30        | 22,2                        |
|     | PC1-40        | 19,9                        |
|     | PC2-10        | 29,1                        |
|     | PC2-20        | 23,8                        |
|     | PC2-30        | 22,7                        |
|     | PC2-40        | 20,8                        |
|     |               | 43,5                        |
|     |               | 39,8                        |
|     |               | 33,2                        |
|     |               | 31,2                        |
|     |               | 27,4                        |
|     |               | 40,5                        |
|     |               | 35,1                        |
|     |               | 32,0                        |
|     |               | 29,8                        |
Figure 1. Relationship between compressive strength and content of C1 and C2

Table 4. Compressive strength of cement mortar with ground basalt (BZ1 and BZ2)

| No. | Sample symbol | 3 days (N/mm²) | 7 days (N/mm²) | 28 days (N/mm²) |
|-----|---------------|----------------|----------------|-----------------|
| 1   | PC            | 24,7           | 31,3           | 43,5            |
|     | PBZ₁-10       | 21,7           | 28,3           | 39,8            |
|     | PBZ₁-20       | 19,0           | 24,2           | 33,5            |
|     | PBZ₁-30       | 17,4           | 22,5           | 30,9            |
|     | PBZ₁-40       | 15,3           | 20,2           | 27,4            |
| 2   | PBZ₂-10       | 23,0           | 30,1           | 40,5            |
|     | PBZ₂-20       | 20,2           | 25,3           | 34,7            |
|     | PBZ₂-30       | 18,1           | 23,0           | 32,4            |
|     | PBZ₂-40       | 16,5           | 20,7           | 28,0            |

Figure 2. Relationship between compressive strength and content of BZ1 và BZ2.
Table 5. Compressive strength of cement mortar with Ba1 and Ba2

| STT | KÍ HIỆU MÅU | 3    | 7    | 28   |
|-----|-------------|------|------|------|
| 1   | PC          | 24,7 | 31,3 | 43,5 |
|     | PBa1-1      | 21,4 | 27,8 | 39,1 |
|     | PBa1-2      | 18,2 | 22,1 | 31,5 |
|     | PBa1-3      | 16,1 | 20,5 | 28,7 |
|     | PBa1-4      | 13,5 | 18,5 | 25,1 |
|     | PBa2-1      | 22,4 | 28,2 | 39,8 |
|     | PBa2-2      | 19,2 | 23,0 | 32,3 |
|     | PBa2-3      | 16,7 | 21,4 | 30,0 |
|     | PBa2-4      | 14,2 | 19,1 | 26,2 |

Figure 3. Relationship between compressive strength and content of Ba1 và Ba2.

Research results of replacing 10-40% PC with PGK show that:
- Ground basalt and ground fine sand reduce the compressive strength of cement mortar. The decreasing in compressive strength at early age of mortar tends to be greater than at long age.
- When increasing the content of used PGK, the level of reduction in compressive strength increases, but 10% of PGK has the least reduction in compressive strength.
- Increasing hardened time, the development of compressive strength of cement mortar increases depending on the type and content of PGK used. As the fineness of these PGK increases, the level of compressive strength attenuation decreases at all PC replacement levels.
- The reduction of compressive strength of Ba is larger than that of BZ and C with the same level of PC replacement.

3.2. Evaluate the efficiency level of PGK in compressive strength of PC mortar.

The effect due to chemical effect (HH) and physical effect (VL) (dispersion and filling) of used PGK in compressive strength is determined by the level of compressive strength change due to PGK and BaSO₄ at each level of coordinate. Based on the results of the compressive strength of mortar used ground BZ and C, finely barite at ages 3, 28 days can calculate the level of efficiency in the compressive strength by used PGK, by HH and VL of each type PGK used.

3.2.1. The efficiency level of ground basalt in compressive strength of PC mortar.

The results of calculation of the efficiency level in the compressive strength of the used mixtures are given in Table 6-7 and illustrated in Figures 4-5.
Table 6. Efficiency level in compressive strength of BZ mortar at 3 days of age

| No. | Symbol sample | Compressive strength level of mortar at 3 days (%) | Efficiency in Compressive strength compared to 100% PC sample (%) | Efficiency in Compressive strength compared to % PC mortar (%) |
|-----|---------------|----------------------------------------------------|----------------------------------------------------------------|---------------------------------------------------------------|
|     |               | By BZ | By Ba | By BZ | By VL | By HH | By BZ | By VL | By HH |
| 1   | PC            | 100   |       |       |       |       |       |       |       |
| 2   | PBZ₁-10      | 87.86 | 86.64 | -12.14 | -13.36 | 1.22 | -2.38 | -3.73 | 1.35 |
| 3   | PBZ₁-20      | 76.92 | 73.68 | -23.08 | -26.32 | 3.24 | -3.85 | -7.89 | 4.04 |
| 4   | PBZ₁-30      | 70.45 | 65.18 | -29.55 | -34.82 | 5.27 | 6.36 | -6.88 | 13.24 |
| 5   | PBZ₁-40      | 61.94 | 54.66 | -38.06 | -45.34 | 7.28 | 3.24 | 8.91 | 12.15 |
| 6   | PBZ₂-10      | 93.12 | 90.69 | -6.88  | -9.31  | 2.43 | 3.46 | 0.76 | 2.70 |
| 7   | PBZ₂-20      | 81.78 | 77.73 | -18.22 | -22.27 | 4.05 | 2.23 | -2.83 | 5.06 |
| 8   | PBZ₂-30      | 73.28 | 67.61 | -26.72 | -32.39 | 5.67 | 4.68 | -3.41 | 8.09 |
| 9   | PBZ₂-40      | 66.80 | 57.49 | -33.20 | -42.51 | 9.31 | 11.34 | -4.18 | 15.52 |

Figure 4. The efficiency level due to VL and HH of BZ at 3 days of age.

Table 7. Efficiency level in compressive strength of mortar at 28 days of age

| No. | Symbol sample | Compressive strength level of mortar at 28 days (%) | Efficiency in Compressive strength compared to 100% PC sample (%) | Efficiency in Compressive strength compared to % PC mortar (%) |
|-----|---------------|----------------------------------------------------|----------------------------------------------------------------|---------------------------------------------------------------|
|     |               | By BZ | By Ba | By BZ | By VL | By HH | By BZ | By VL | By HH |
| 1   | VPC           | 100   |       |       |       |       |       |       |       |
| 2   | PBZ₁-10      | 91.50 | 89.89 | -8.50  | -10.11 | 1.61 | 1.66 | -0.13 | 1.79 |
| 3   | PBZ₁-20      | 76.99 | 72.46 | -23.01 | -27.54 | 4.53 | -3.73 | -9.48 | 5.75 |
| 4   | PBZ₁-30      | 71.02 | 65.98 | -28.98 | -34.02 | 5.04 | 1.48 | -2.46 | 3.94 |
| 5   | PBZ₁-40      | 62.99 | 57.70 | -37.01 | -42.30 | 5.29 | 4.98 | -1.53 | 6.51 |
| 6   | PBZ₂-10      | 93.11 | 91.49 | -6.89  | -8.51  | 1.62 | 3.45 | 1.66 | 1.79 |
| 7   | PBZ₂-20      | 79.77 | 74.25 | -20.23 | -25.75 | 5.52 | -0.29 | -2.59 | 2.30 |
| 8   | PBZ₂-30      | 72.26 | 68.97 | -27.74 | -31.03 | 3.29 | 6.40 | -1.48 | 7.88 |
| 9   | PBZ₂-40      | 64.37 | 60.23 | -35.63 | -39.77 | 4.14 | 7.28 | 0.38 | 6.90 |
Figure 5. The efficiency level due to VL and HH of BZ at 28 days of age.

The results of determining the efficiency level of BZ in the strength of mortar with 2 different fineness when the rate of PC replacement from 10 to 40% at the ages showed:

- **At the age of 3 days**
  + When replacing PC with BZ, due to an efficiency level of HH and VL, the compressive strength of mortars will be reduced as compared with the compressive strength of PC mortar with all replacement rates. Increasing the BZ content, the efficiency level due to both HH and VL tends to decrease: with BZ1 is -12.13 to -38.06 and BZ2 is -6.88 to -33.20 when the content changes of PC replacement increases from 10 to 40%. Increasing the fineness of BZ, the efficiency level due to HH and VL in the compressive strength of mortar increased.
  + Evaluating the efficiency level according to the actual PC content in the mixtures shows: The BZ content increases, the overall efficiency level in the compressive strength increases: with BZ1 from -2.38 to 6.36 and with BZ2 is 2.23 to 11.34 when replacing PC from 10 to 40%. The fineness of BZ increases, the efficiency level due to HH and VL are increased. The efficiency level of BZ due to VL is almost negative, and the efficiency level due to HH is positive with the efficiency level from 1.35 to 15.52 when BZ replaced PC from 10- 40%.
  + At the age of 3 days, the efficiency level of BZ is low due to VL and HH, so the strength of mortar is strongly reduced with all replacement rates. As the BZ content increases, the level of negative influence tends to decrease, possibly because BZ increases the dispersion ability, which increases the hydration of portland cement. Increasing the fineness of basalt, the reduction level on the compressive strength of mortar decreases.

- **At the age of 28 days**
  + With the mortar system when replacing PC with BZ from 10 to 40%, the efficiency level due to HH and VL of BZ in the system is still low, so reducing the compressive strength of the mortar with all replacement rates. The level of reduction is from 8.5% to 37.5%. The amount of BZ increases, the level of negative influence tends to increase. Increasing the fineness of BZ, the level of efficiency in the compressive strength of BZ replacing PC increases. The efficiency level in the compressive strength of mortar due to BZ1 and BZ2 is much different from the age of 3 days with the content of replacing PC from 10 to 40%.
  + Evaluating the efficiency level according to the actual PC content in the mixture, it is shown that: The BZ content increases, the efficiency level increases: with an increase of -3.73% to 7.28% when replacing PC from 10 to 40%. The fineness of BZ increases, the efficiency level due to HH and VL are increased. The efficiency level of BZ due to VL is still negative, while the efficiency level due to HH is positive and reaches values from 1.79% to 7.88%. Increasing the content of BZ, the efficiency level of HH tends to increase more strongly.
3.2.2. The efficiency level of ground sand in the compressive strength of portland cement mortar

The results of calculating the efficiency level in the compressive strength due to VL and HH of C in mortar grades studied at ages 3 and 28 days are shown in Table 8-9. Comparison of the efficiency level in compressive strength by VL, HH of C at the age given in Figure 6-7.

Table 8. Efficiency level in compressive strength of mortar with C at 3 days of age

| No. | Symbol sample | Compressive strength level of mortar at 3 days (%) | Efficiency in Compressive strength compared to 100% PC sample (%) | Efficiency in Compressive strength compared to % PC in mortar (%) |
|-----|----------------|--------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|
|     |                | By C | By Ba | By C | By VL | By HH | By C | By VL | By HH |
| 1   | PC             | 100  |       |       |       |       |       |       |       |
| 2   | PC<sub>10</sub> | 88.26| 86.64 | -11.74| -13.36| 1.62  | -1.93| -3.73 | 1.80  |
| 3   | PC<sub>20</sub> | 77.73| 73.68 | -22.27| -26.32| 4.05  | -2.82| -7.89 | 5.07  |
| 4   | PC<sub>30</sub> | 71.26| 65.18 | -28.74| -34.82| 6.08  | 1.79 | -6.88 | 8.67  |
| 5   | PC<sub>40</sub> | 59.11| 54.66 | -40.89| -45.34| 4.45  | -1.48| -8.91 | 7.43  |
| 6   | PC<sub>C-10</sub> | 93.53| 90.69 | -6.47 | -9.31 | 2.84  | 3.91 | 0.76  | 3.15  |
| 7   | PC<sub>C-20</sub> | 82.59| 77.73 | -17.41| -22.27| 4.86  | 3.24 | -2.83 | 6.07  |
| 8   | PC<sub>C-30</sub> | 75.30| 67.61 | -24.70| -32.39| 7.69  | 7.58 | -3.41 | 10.99 |
| 9   | PC<sub>C-40</sub> | 62.35| 57.49 | -37.65| -42.51| 4.86  | 3.91 | -4.18 | 8.09  |

Figure 6. The efficiency level due to VL, HH of C in compressive strength (%) at 3 days of age.

Table 9. Efficiency level in mortar compressive strength of C at 28 days of age

| No. | Symbol sample | Compressive strength level of mortar at 28 days (%) | Efficiency in Compressive strength compared to 100% PC sample (%) | Efficiency in Compressive strength compared to % PC in mortar (%) |
|-----|----------------|--------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|
|     |                | By C | By Ba | By C | By VL | By HH | By C | By VL | By HH |
| 1   | VPC            | 100  |       |       |       |       |       |       |       |
| 2   | PC<sub>10</sub> | 91.49| 89.89 | -8.51 | -10.11| 1.60  | 1.66 | -0.13 | 1.79  |
| 3   | PC<sub>20</sub> | 76.32| 72.46 | -23.68| -27.54| 3.86  | -4.59| -9.48 | 4.89  |
| 4   | PC<sub>30</sub> | 71.73| 68.18 | -28.27| -31.82| 3.55  | 2.46 | -2.46 | 4.92  |
| 5   | PC<sub>40</sub> | 62.99| 59.08 | -37.01| -40.92| 3.91  | 4.98 | -1.53 | 6.51  |
| 6   | PC<sub>C-10</sub> | 93.11| 91.49 | -6.89 | -8.51 | 1.62  | 3.45 | 1.66  | 1.79  |
| 7   | PC<sub>C-20</sub> | 80.69| 77.94 | -19.31| -22.06| 2.75  | 0.86 | -2.59 | 3.45  |
| 8   | PC<sub>C-30</sub> | 73.56| 68.97 | -26.44| -31.03| 4.59  | 5.09 | -1.48 | 6.57  |
| 9   | PC<sub>C-40</sub> | 68.51| 62.30 | -31.49| -37.70| 6.21  | 14.18| 0.38  | 13.80 |
Figure 7. The efficiency level due to VL, HH of C in compressive strength (%) at 28 days of age.

The results of evaluating the efficiency level of ground sand when the PC replacement rate from 10 to 40% at the hardened age in the mixtures showed:

- **At the age of 3 days**
  + C1 and C2 reduce the compressive strength of mortar with all levels of PC replacement rates due to the low level of efficiency. The content of C increases, the level of negative effect increases so it reduces the compressive strength of mortar from 11.74 to 40.89% corresponding to PC replacement content from 10% to 40%. Increasing the fineness of C, the level of compressive strength reduction of the PC replacement rates is reduced.
  + Evaluation of the efficiency level of C1 and C2 according to the actual PC content in the mixtures shows: Content of C increases, the level of efficiency in compressive strength increases to 1.79% (with C1) and to 7.58% (with C2) when replacing PC up to 40%. The fineness C increases, the level of efficiency due to both VL and HH increases. The level of efficiency of C due to HH of all C ratios is positive and reaches from 1.80 to 10.99%.

- **At the age of 28 days**
  + The efficiency level in the compressive strength of the mortar due to C1 and C2 replaced up to 40% PC is higher from the age of 3 days. The compressive strength of C (due to both VL and HH) in the strength of the mortar with all replacement rates has a negative value. Increased content of C: the efficiency level of C in compressive strength decreases from 8.51% to 37.01% when replacing from 10% to 40% PC in mortar. Increasing the fineness of C, the efficiency level of C due to VL and HH increases not much.
  + Evaluating the efficiency level according to the actual PC content in the mixture, it is shown that: The efficiency level of C is positive, so it increases the compressive strength of mortar. The C content increased, the efficiency level increased with the increase of 4.98% (with C1) and 14.18% (with C2) with the C content of 40%. The efficiency level of C due to VL is almost negative and the largest is -9.48%, while the efficiency level due to HH is positive and reaches the largest value to 13.80%. Increasing the fineness of C increases the efficiency level both due to VL and HH.

4. **Conclusion**

Survey results on the efficiency level of ground sand and basalt replacing up to 40% PC in the mortar compressive strength can be reached as follows:

- Using ground basalt and fine sand to replace PC from 10-40% reduced the compressive strength of PC mortar.
- Reducing the compressive strength of PC mortar with the reduced level at an early age greater than the long-term age.
- The reduction level in compressive strength of mortar depends on the type, content and fineness of the PGK used. The higher the C and BZ content, the greater reduction level in the compressive
strength of the mortar. Increasing the grinding fineness of C and BZ, the reduction level of compressive strength decreases.
+ Each type of PGK used has a reasonable PC replacement content for the lowest level of compressive strength reduction.
- Evaluation of the efficiency level of BZ and C in the compressive strength of the mortar according to the actual PC content in the mixture showed:
+ When replacing PC to 40%, C and BZ have effectively increased the compressive strength of PC mortar. As the used content and the hardened time increased, the efficiency levels of ground BZ and C increased.
+ The efficiency level in the compressive strength of C and BZ is due to the effect of VL and HH can be determined through the use of BaSO$_4$ plays an inert role and depends on the type, content and fineness of PGK used.
+ The efficiency level of BZ and C due to VL and HH increases with increasing PC replacement content. The level of efficiency due to HH is much greater due to VL with the same content replacing PC for this study.
+ The efficiency level of BZ is larger than that of finely ground C.

The results of this study indicate that the efficiency level due to physical effect is negative, but in fact this value is positive. The reason for this is that we assume that by reducing the percentage of PC the reduction in the compressive strength of this mortar mixture will decrease accordingly. In order to increase the rationality of the research results, it is necessary to consider more about this hypothesis. In order to evaluate the effect of PGK on compressive strength, it is so necessary to further study the effect of inert PGK type, PGK types with higher fineness to the strength properties of mortar and concrete.

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