Study on the correlation of key indicators of P.O42.5 cement

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Abstract—The development history and social contribution of cement were briefly described. The physical and chemical indexes of P.O42.5 cement were tested according to GB 175-2007 standard. The correlation of coagulation time, strength and chemical index was analyzed. The results showed that the final coagulation time was closely and positively correlated with the initial coagulation time, and the correlation coefficient was 0.9572. The 28-day compressive strength doesn’t have obvious correlation with final setting time, loss on ignition, MgO content and SO3 content.

1. INTRODUCTION
In 1796, British J Parker made the first modern cement from marl. In 1824, British Joseph asprin invented Portland cement for the first time and obtained the patent right. In 1889, a "fine loam" factory was set up near Kaiping coal mine in Tangshan, Hebei province, China [1-4]. With the emergence of cement, the continuous maturity of production technology and the increasing of product category, the human society has developed greatly. The emergence of cement has changed the building structure. The civil structure, stone-wood structure and brick-wood structure have gradually been replaced. With the participation of steel and sand, cement is widely used in high-rise buildings, roads and bridges, water conservancy facilities and so on, solving many difficult problems in the history of construction [5].
Cement industry is an important basic industry for China's national economic development and an important symbol of the national economic level and comprehensive strength. Since 1985, China's cement output has consistently ranked first in the world, which provides strong industrial support for China's economic construction and social development [6].

The standard number GB 175-2007 classifies general portland cement into portland cement, ordinary portland cement, slag silicate cement, portland-pozzolan cement, fly ash cement and composite portland cement according to the variety and content of materials mixed with cement[7]. The ordinary portland cement is composed of a hydraulic cementing material made by grinding gypsum, portland cement clinker and 6%-15% mixed material. It is referred to as“ordinary cement”, code name P.O.

2. PHYSICAL AND CHEMICAL INDEX DETECTION
Based on the extensive market of P.O42.5 cement, the test samples are selected from qualified P.O42.5 cement produced by different manufacturers in Chongqing at different times. The detection method adopts the method specified in the standard of GB 175-2007“General Purpose Portland Cement”. The detection method of loss on ignition, MgO, SO3 and cl- adopts the standard of GB/T 176-2017 “Cement
Chemical Analysis Method”. The setting time (T1-initial setting time, T2-final setting time) is detected in the method of GB/T 1346-2011 “Testing Method for Water Requirement of Normal Consistency, Setting Time and Soundness of Portland Cement”. Strength (Z3-flexural strength of 3 days, Z28-flexural strength of 28 days, Y3-compressive strength of 3 days, Y28-compressive strength of 28 days) is detected in the method of GB/T 17671-1999 “Testing Method for Strength of Cement Mortar (ISO Method)”. The detection equipment includes the Vicat apparatus, electronic balance, cement mortar mixer, vibrating table, microcomputer-controlled full-automatic pressure testing machine, atomic absorption spectrophoto-meter, chloride ion detector, experimental resistance furnace, etc.

3. CORRELATION ANALYSIS

This paper makes a correlation analysis on the key indexes of P.O42.5 cement, which has a high market share in Chongqing, in order to determine the correlation between the indexes and provide guidance and reference for the research on the quality improvement of such products. The correlation coefficient is calculated by Formula 1. The \( R_{xy} \) represents the sample correlation coefficient. The \( S_{xy} \) represents the sample covariance. The \( S_x \) and \( S_y \) represents the sample standard deviation of X and Y.

\[
R_{xy} = \frac{S_{xy}}{S_x S_y}
\] (1)

3.1 Correlation between Final Setting Time and Initial Setting Time

The test results of initial setting time T1 and final setting time T2 of the sample group are shown in table 1. The corresponding correlation curve is shown in fig 1. The correlation coefficient \( r=0.9572 \) and the univariate regression equation \( T_2=0.9593T_1+65.935 \) are obtained by computing and data processing in excel. Through correlation analysis, it can be seen that the final setting time of P.O42.5 cement produced in our city is closely and positively correlated with its initial setting time.

Table 1 T2-T1 test results

| NO | 1   | 2   | 3   | 4   | 5   | 6   | 7   |
|----|-----|-----|-----|-----|-----|-----|-----|
| T1 | 104 | 114 | 128 | 130 | 130 | 130 | 141 |
| T2 | 151 | 174 | 185 | 190 | 201 | 193 | 236 |
| NO | 8   | 9   | 10  | 11  | 12  | 13  | 14  |
| T1 | 148 | 151 | 157 | 158 | 160 | 164 | 171 |
| T2 | 213 | 210 | 210 | 208 | 207 | 223 | 242 |
| NO | 15  | 16  | 17  | 18  | 19  | 20  | 21  |
| T1 | 178 | 181 | 190 | 210 | 214 | 216 | 252 |
| T2 | 230 | 239 | 240 | 255 | 279 | 273 | 313 |

![Fig. 1 Correlation curve between T2 and T1](image-url)
3.2 Correlation of flexural strength between 28-day and 3-day
The 28-day flexural strength and 3-day flexural strength test results of the sample group are shown in table 2. The corresponding correlation curve is shown in fig 2. The correlation coefficient $r=0.2528$ is obtained by computing and data processing in excel. The correlation analysis shows that the 28-day flexural strength of P.O42.5 cement produced in ChongQing is positively correlated with the 3-day flexural strength, but the correlation is weak.

| NO | 1  | 2  | 3  | 4  | 5  | 6  | 7  |
|----|----|----|----|----|----|----|----|
| Z3 | 5.1| 5.2| 5.2| 5.3| 5.3| 5.3| 5.3|
| Z28| 8.3| 7.9| 8.5| 7.3| 7.9| 7.9| 7.5|
| NO | 8  | 9  | 10 | 11 | 12 | 13 | 14 |
| Z3 | 5.3| 5.5| 5.6| 5.6| 5.6| 5.6| 5.6|
| Z28| 7.8| 8.2| 8.5| 8.0| 7.6| 8.2| 7.8|
| NO | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| Z3 | 5.6| 5.9| 6.0| 6.0| 6.2| 6.5|    |
| Z28| 8.0| 8.6| 7.9| 8.3| 8.2| 7.8| 8.3|

Fig. 2 Correlation curve between Z28 and Z3

3.3 Correlation of compressive strength between 28-day and 3-day
The 28-day compressive strength and 3-day compressive strength test results of the sample group are shown in table 3. The corresponding correlation curve is shown in fig 3. The correlation coefficient $r=0.5862$ is obtained by computing and data processing in excel. Through the correlation analysis, it can be seen that the 28-day compressive strength of P.O42.5 cement produced in ChongQing province is positively correlated with the 3-day compressive strength, and it is a moderate correlation between them.

| NO | 1  | 2  | 3  | 4  | 5  | 6  | 7  |
|----|----|----|----|----|----|----|----|
| Y3 | 25.5| 28.0| 28.2| 29.4| 29.5| 29.6| 29.7|
| Y28| 49.2| 48.3| 48.4| 49.8| 52.0| 45.3| 50.4|
| NO | 8  | 9  | 10 | 11 | 12 | 13 | 14 |
| Y3 | 29.7| 30.1| 30.3| 30.4| 30.7| 31.0| 31.2|
| Y28| 48.2| 50.7| 54.8| 52.9| 46.0| 56.0| 48.4|
3.4 Correlation between flexural strength and final setting time of 28-day
The 28-day flexural strength and final setting time test results of the sample group are shown in table 4. The corresponding correlation curve is shown in fig 4. The correlation coefficient $r=0.1980$ is obtained by computing and data processing in excel. Through correlation analysis, it can be seen that the 28-day flexural strength of P.O42.5 cement produced in ChongQing province is positively correlated with the final setting time, but the correlation is weak.

Table. 4  Z28-T2 test results

| NO  | 1   | 2   | 3   | 4   | 5   | 6   | 7   |
|-----|-----|-----|-----|-----|-----|-----|-----|
| T2  | 151 | 174 | 185 | 190 | 193 | 201 | 207 |
| Z28 | 7.3 | 7.9 | 7.9 | 8.5 | 8.3 | 8.0 | 8.3 |
| NO  | 8   | 9   | 10  | 11  | 12  | 13  | 14  |
| T2  | 208 | 210 | 210 | 213 | 223 | 230 | 236 |
| Z28 | 8.2 | 7.9 | 8.2 | 7.6 | 7.9 | 7.8 | 8.2 |
| NO  | 15  | 16  | 17  | 18  | 19  | 20  | 21  |
| T2  | 239 | 240 | 242 | 255 | 273 | 279 | 313 |
| Z28 | 7.5 | 7.8 | 8.3 | 8.6 | 8.5 | 8.0 | 7.8 |
3.5 Correlation between compressive strength and final setting time of 28-day

The 28-day compressive strength and final setting time test results of the sample group are shown in table 5. The corresponding correlation curve is shown in fig 5. The correlation coefficient $r=0.0648$ is obtained by computing and data processing in excel. According to the correlation analysis, the 28-day compressive strength of P.O 42.5 cement produced in ChongQing province has no correlation with the final setting time.

| NO | 1    | 2    | 3    | 4    | 5    | 6    | 7    |
|----|------|------|------|------|------|------|------|
| T2 | 151  | 174  | 185  | 190  | 193  | 201  | 207  |
| Y28| 49.8 | 50.4 | 53.8 | 52.0 | 48.4 | 55.1 | 51.6 |
| NO | 8    | 9    | 10   | 11   | 12   | 13   | 14   |
| T2 | 208  | 210  | 210  | 213  | 223  | 230  | 236  |
| Y28| 53.9 | 56.0 | 56.4 | 45.3 | 48.4 | 46.0 | 55.8 |
| NO | 15   | 16   | 17   | 18   | 19   | 20   | 21   |
| T2 | 239  | 240  | 242  | 255  | 273  | 279  | 313  |
| Y28| 50.7 | 48.2 | 54.8 | 52.9 | 55.0 | 48.3 | 49.2 |

Fig. 5 Correlation curve between Y28 and T2
3.6 Correlation between compressive strength and flexural strength of 28-day
The 28-day compressive strength and 28-day flexural strength test results of the sample group are shown in table 6. The corresponding correlation curves are shown in fig 6. The correlation coefficient r=0.4889 is obtained by computing and data processing in excel. Through correlation analysis, it can be seen that the 28-day compressive strength and 28-day flexural strength of P.O 42.5 cement produced in ChongQing province are positively correlated, is a moderate correlation between them.

Table 6 Y28-Z28 test results

| NO  | 1  | 2  | 3  | 4  | 5  | 6  | 7  |
|-----|----|----|----|----|----|----|----|
| Z28 | 7.3| 7.5| 7.6| 7.8| 7.8| 7.8| 7.9|
| Y28 | 49.8| 50.7| 45.3| 46.0| 48.2| 49.2| 50.4|
| NO  | 8  | 9  | 10 | 11 | 12 | 13 | 14 |
| Z28 | 7.9| 7.9| 7.9| 8.0| 8.0| 8.2| 8.2|
| Y28 | 53.8| 56.0| 48.4| 55.1| 48.3| 53.9| 56.4|
| NO  | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| Z28 | 8.2| 8.3| 8.3| 8.3| 8.5| 8.5| 8.6|
| Y28 | 55.8| 48.4| 51.6| 54.8| 52.0| 55.0| 52.9|

Fig. 6 Correlation curve between Y28 and Z28

3.7 Correlation between chemical index and compressive strength of 28-day
The correlation distribution and correlation coefficient square of compressive strength, loss on ignition, MgO content, SO₃ content and cl- content of 28-day are shown in Fig 7. It can be seen that 28-day the compressive strength has no obvious correlation with loss on ignition, MgO content and SO₃ content. It is only weakly negatively correlated with cl- content, and the correlation coefficient is -0.3629. This shows that the 28-day compressive strength of the qualified P.O 42.5 cement is almost unaffected by the loss on ignition, MgO content and SO₃ content, but the strength increases slightly with the decrease of cl-. 
4. CONCLUSION

Through the research on the correlation of various physical and chemical indexes of P.O 42.5, the results show that the final setting time is closely and positively correlated with the initial setting time, and the correlation coefficient is 0.9572. There is a moderate correlation between the 28-day compressive strength and the 3-day compressive strength and the correlation coefficient is 0.5862. The correlation between the 28-day compressive strength and 28-day flexural strength is also moderate and the correlation coefficient is 0.4889. The 28-day flexural strength is positively correlated with the 3-day flexural strength and the final setting time, but the correlations are weak. The correlation coefficients are 0.2528 and 0.1980 respectively. The 28-day compressive strength has a negative and weak correlation with cl', and the correlation coefficient is -0.3629. The 28-day compressive strength has no obvious correlation with final setting time, loss on ignition, MgO content and SO₃ content.

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