Method of rock mass quality classification in ancient underground engineering based on three-parameter interval grey number

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Abstract. Rock mass quality classification is an important basis for long-term protection and tourism development of ancient underground engineering, however, the existing rock mass quality classification methods are difficult to apply to the special project of ancient underground engineering. Based on the in-depth analysis of the characteristics of ancient underground engineering and the influencing factors of rock mass quality, an evaluation index system for rock mass quality classification of ancient underground engineering is established by taking the long-term tensile strength of rock and the weathering velocity of rock mass as indicators. Secondly, for the evaluation index value has the character of bounded-but-unknown uncertainty, and in order to avoid information loss in interval numbers, the three-parameter interval grey number theory is introduced, based on the concept of three-parameter interval grey number distance measure, a rock mass quality classification calculation model for ancient underground engineering is established. Then, because of the complexity of ancient underground engineering, the idea of group decision-making is introduced, and based on the variation coefficient method, the weight calculation method of evaluation index is established to improve the reliability of weight calculation. Finally, a rock mass quality classification method for ancient underground engineering based on three-parameter interval grey number is established. The method is used to analysis the practical engineering, it shows that the method proposed here is feasible and reasonable.

1. Research Background
There are a large number of large-scale ancient underground projects in China. In Zhejiang Province, more than 10 have been discovered, such as the Longyou Grottoes in Quzhou, the large-scale ancient underground engineering quarries in the Snake Island in Taizhou, and the Jin Grottoes in the Tang and Ming Dynasties in Suichang. The scale of these large-scale ancient underground projects is huge. Taking the Snake Island as an example, there are more than 1,000 large and small caverns. These ancient underground projects have a history of hundreds of years and thousands of years at least, showing the excellent engineering and technical ability of the ancient people. Therefore, they contain high cultural relic value and scientific and artistic value [1-2]. And with the rapid development of China's economy, many ancient underground projects have been developed into important tourist resorts. Six of them in Zhejiang Province have become national 4A-level scenic spots, receiving a large number of tourists every year. The quality condition of engineering rock mass is an important factor affecting the stability of ancient underground engineering. Rock mass quality classification is a
necessary prerequisite for long-term protection of ancient underground engineering and ensuring the safety of tourists. However, there is no specific method for rock mass quality classification of ancient underground engineering.

So far, scholars at home and abroad have proposed many rock mass quality classification methods, but most of them are proposed for the stability classification of tunnel surrounding rock[3-6], which is not applicable to some special rock engineering. For this reason, some scholars have carried out targeted research, among which He Guangliang et al.[7] and Qi Shengwen et al.[8] In view of the fact that TBM construction tunnels not only need to consider stability but also drivability, a rock mass quality classification method suitable for TBM construction conditions is proposed. Ji Huibin and others[9] put forward a rock mass quality classification method based on UWCQ system, which is suitable for underground water-sealed caverns, an underground oil storage project. Wu Aiqing et al [10] put forward an improved classification method of BQ engineering rock mass according to the characteristic that dam foundation engineering pays more attention to the influence of structural plane occurrence on dam foundation anti-sliding stability.

Ancient underground engineering is also a special underground engineering, which has its own characteristics. Since most of them belong to the national protected cultural relics, the protection of ancient underground projects pays more attention to long-term stability. Through years of research, Yang Zhifa and others have found that it is more reasonable to use the long-term strength of rock mass to evaluate the long-term stability of ancient underground projects [11]; Moreover, because the ancient underground engineering has existed for a long time and the seemingly slow weathering rate of rocks has a noticeable influence on the ancient underground engineering through long-term accumulation[12], the ancient underground engineering has more strict requirements on the influencing factors. Although the evaluation index system of the existing engineering rock mass classification method can provide a good reference for the selection of evaluation indexes of the ancient underground engineering, it cannot be completely copied, and evaluation indexes that can reflect the characteristics of the ancient underground engineering need to be introduced to make the established rock mass quality classification evaluation index system applicable to the ancient underground engineering.

Moreover, for ancient underground engineering, due to the inhomogeneity of the rock mass itself, the incompleteness of the acquired information, and the dynamic change of parameters over time, the rock mass quality evaluation index or parameter has obvious interval uncertainty characteristics. Therefore, the use of interval numbers to characterize the evaluation index values is in line with the engineering practice. In fact, the current national standards and industry standards for rock mass quality classification are treated according to this [13], i.e. each rock mass quality grade corresponds to an interval value. However, the traditional two-parameter interval method may still have shortcomings, namely, engineers are often conservative in practical engineering, sometimes setting the upper and lower limits of interval numbers too large, which may lead to a certain degree of distortion of information; And when people get parameter information, sometimes they can get the most possible value point besides knowing the upper and lower limit values of the value interval. The existing traditional two-parameter interval number value method fails to reflect this problem, thus causing some effective information to be lost and increasing the uncertainty of evaluation results. In addition, the weight analysis of evaluation index is an important part of rock mass quality classification. The existing research mainly uses hierarchical analysis and other methods to calculate the weight, which provides a feasible way for multi-factor weight calculation. However, because rock mass quality classification is a multi-factor complex system, it is difficult for a single expert to be competent. It is necessary to use the experience and wisdom of expert groups to make group decisions on the weight of evaluation index, so as to improve the reliability and scientficity of weight determination. At present, there is no literature on the use of group decision advantages in the weight calculation of rock mass quality classification.

To sum up, the existing rock mass quality classification method has achieved many achievements, but its direct application in ancient underground engineering still has some deficiencies. Therefore, it
is necessary to improve the existing achievements and propose a new rock mass quality classification method in order to reflect the engineering characteristics of the above-mentioned ancient underground engineering rock mass quality classification. Therefore, this paper will establish a rock mass quality grading evaluation index system according to the characteristics of ancient underground engineering. According to the problem of information loss in interval numbers, a three-parameter interval grey number theory is introduced to establish a classification calculation method for rock mass quality of ancient underground engineering, so as to reflect the characteristic of interval uncertainty in the value of evaluation indexes. In addition, considering the advantages of group decision-making, it is introduced and combined with the idea of coefficient of variation method to establish the evaluation index weight calculation method, thus establishing the ancient underground engineering rock mass quality classification method based on three-parameter interval grey number, so as to make the ancient underground engineering rock mass quality classification more reasonable and operable.

2. Ancient underground engineering rock mass quality evaluation index system
In order to establish a rock mass quality classification method for ancient underground engineering based on three-parameter interval grey number, the evaluation index system of rock mass quality classification for ancient underground engineering must be established first. At present, the research on the main influencing factors of engineering rock mass quality is very mature, while the ancient underground engineering pays more attention to long-term protection, and its strength evaluation index takes the long-term strength as more reasonable (usually when the roof is pulled and broken), and the influence of rock weathering cannot be ignored. Therefore, based on the existing research results[1-2,12,14-19] , this paper selects five factors as evaluation indexes: long-term tensile strength \( f_t^* \), rock mass integrity coefficient \( K_i \), structural plane state \( J_c \), groundwater inflow \( A \) and rock weathering speed \( v \). The rock mass quality and evaluation index are divided into five grades according to the traditional classification thought, as shown in Table 1. The evaluation index system can better reflect the influence of various factors on ancient underground engineering.

| Rock mass quality grade | \( f_t^* \) (MPa) | \( K_i \) | \( J_c \) | \( A \) (L/min/10m) | \( V \) (mm/y) | Standardized score values | \( k_r \) (max) |
|-------------------------|-----------------|------|------|----------------|------|-----------------|------|
| grade 1                 | >1.00           | 0.85~1.0 | The structural plane is small and discontinuity, and the structural plane is rough and hard. | 0~2 | <0.05 | 80~100 | [80,90,100] |
| grade 2                 | 0.65~1.00       | 0.75~0.85 | The extension of the structural plane is short, without mud, and the structural plane is rough and hard. | 2~5 | 0.05~0.1 | 60~80 | [60,70,80] |
| grade 3                 | 0.30~0.65       | 0.65~0.75 | The structural plane extension length is more than ten meters to tens of meters, and some structural plane have mud film. | 5~10 | 0.10~0.3 | 40~60 | [40,50,60] |
| grade 4                 | 0.15~0.30       | 0.45~0.65 | The scale of the structural plane is large, the extension length is hundreds to thousands of meters, and most of the structural plane are soft. | 10~25 | 0.30~0.5 | 20~40 | [20,30,40] |
| grade 5                 | <0.15           | <0.45 | The structural plane extension length is more than thousands of meters, and most of the structural plane are soft. | >25 | >0.5 | 0~20 | [0,10,20] |

3. Three-parameter interval grey number classification method for rock mass quality of ancient underground engineering
In this paper, the established rock mass quality classification method for ancient underground engineering mainly includes the calculation model of rock mass quality classification for ancient underground engineering based on three-parameter interval grey number and the weight determination method based on group decision, which will be introduced respectively below.
3.1. Definition of Three-parameter Interval Grey Number and Brief Introduction of Operation Rules

In order to introduce the three-parameter interval grey number theory into the method of this paper, we need to know its relevant concepts and operation rules, which are limited in length. This paper will only make a brief introduction, as follows.

(1) Grey number of traditional interval number[20]. The grey numbers with both upper limits $a^+$ and lower limits $a^-$ are called interval grey numbers and are recorded as:
\[ a(\otimes) = [a^-, a^+] \]
(1)
When the parameter itself has fluctuation and the information is not completely obtained, that is, when the parameter has interval uncertainty, the interval grey number has good applicability. However, it still fails to make full use of relevant information, resulting in information loss. In practical engineering, it is often difficult to obtain the exact values of parameters, but it is much easier to give their approximate intervals, and sometimes the most possible values of parameters can also be obtained. At this time, the interval grey number of formula (1) will cause information loss. Therefore, some scholars have proposed the concept of three-parameter interval grey number.

(2) Three-parameter interval grey number[20]. For the interval grey number $a(\otimes) = [a^-, a^+]$, if the number with the greatest possibility to take $a^+$ its value is known, the interval grey number can be recorded as:
\[ a(\otimes) = [a^-, a^*, a^+] \]
(2)

The interval grey number represented by equation (2) is called the three-parameter interval grey number, which contains more information.

(3) Three-parameter interval number addition and number multiplication[21]. For three-parameter interval grey numbers, there are
\[ a(\otimes) + b(\otimes) = [a^- + b^-, a^* + b^*, a^+ + b^+] \]
(3)
\[ \lambda a(\otimes) = [\lambda a^-, \lambda a^*, \lambda a^+] \quad \lambda > 0 \]
(4)

(4) Three-parameter interval number distance[20]. For the three-parameter interval grey number $a(\otimes) = [a^-, a^*, a^+]$, $b(\otimes) = [b^-, b^*, b^+]$, it is called
\[ d(a(\otimes), b(\otimes)) = \frac{2}{3} |a^* - b^*| + \frac{1}{3} (\alpha |a^- - b^-| + (1 - \alpha) |a^+ - b^+|) \]
(5)
The distance of $a(\otimes)$ and $b(\otimes)$ is sum, which $\alpha$ is the risk preference coefficient, and its value is generally 0.5. When the grey number in one interval degenerates to real number, the distance measurement formula is still applicable.

The distance between the three-parameter interval grey numbers can be used to judge the proximity between the two grey numbers. The smaller the distance, the closer the two grey numbers are. Therefore, the rock mass quality grade can be judged according to the principle of minimum distance. The three-parameter interval grey numbers well represent the interval uncertainty of evaluation indexes. Therefore, it is reasonable and feasible to apply the theory to the rock mass quality grade of ancient underground engineering.

3.2. Rock Mass Quality Classification Calculation Model for Ancient Underground Engineering Based on Three-parameter Interval Grey Number

According to the interval uncertainty theory and the aforementioned evaluation index system of ancient underground engineering rock mass quality classification, the calculation model of ancient underground engineering rock mass quality classification is established by introducing the concept of three-parameter interval grey number.
Among them, 

\[
\sum_{i=1}^{5} w_i = 1 \quad (7)
\]

In the formula, \( \mathbf{R} \) is an evaluation value vector composed of three-parameter interval grey numbers of five evaluation indexes \( p_i (i=1, 2, \ldots, 5) \); \( [r_i^{-}, r_i^{*}, r_i^{+}] \) is the value of the grey number in the three-parameter interval of the first evaluation index; “\( \cdot \)“ is a matrix multiplication operation; \( \mathbf{W} \) is the weight vector corresponding to five evaluation indexes \( p_i \); \( w_i \) is the weight value of 5 evaluation indexes \( p_i \) respectively; For the evaluation results of rock mass quality classification is \( n(\otimes) \), it is a three-parameter interval grey number \( [n^{-}, n^{*}, n^{+}] \), and then calculate its distance from five rock mass quality grades, and record it as follows:

\[
d_j\left(n(\otimes), k_j(\otimes)\right) = \frac{2}{3} \left| n^{*} - k_j^{*}\right| + \frac{1}{6} \left( \left| n^{-} - k_j^{-}\right| + \left| n^{+} - k_j^{+}\right| \right) \quad (8)
\]

Among them, the standard value \( k_j(\otimes) \) corresponding to the \( j \)-th rock mass quality grade can be divided, and then the rock mass quality grade of ancient underground engineering can be determined according to the principle of minimum distance of ash number. For example, when the distance from the standard value \( n(\otimes) \) with rock mass quality grade of grade 3 is the smallest, the rock mass quality grade is determined to be grade 3.

In order to use this calculation model to classify the quality of ancient underground engineering rock mass, it is necessary to establish a standardized method for evaluating index values to make them comparable, and also to establish a calculation method for evaluating index weights.

### 3.3. Standardization Method of Evaluation Index Value

The above-mentioned used rock mass quality grading evaluation indexes for ancient underground engineering can be divided into two categories: qualitative indexes and quantitative indexes, in which the structural plane state is a qualitative index. The local water inflow can also be determined according to the qualitative description when it is difficult to measure. Moreover, the physical meaning and dimension of different evaluation indexes are not the same. For example, the unit of long-term tensile strength of rock is MPa, the higher the value, the better the quality of rock mass, while the unit of weathering speed of rock is mm/year. The higher the value, the worse the quality of rock mass. These problems make it impossible to directly calculate each evaluation index by using Equations (6) to (8). All evaluation indexes need to be standardized to make the dimension of each evaluation index uniform and comparable. For this reason, the index value of each evaluation index is converted into a score value in the range of 0~100. Without losing generality, 0 ~ 100 is equally divided into five grades corresponding to rock mass quality classification in five intervals. The specific standardization method is shown in Table 1. And in order to be able to use equation (8) to calculate the distance and then judge the surrounding rock grade, it is necessary to give the standard values corresponding to the division of each rock quality grade. According to the interval of rock quality grade, it is determined as the three-parameter interval grey number \( k_j(\otimes) \), as shown in Table 1. Therefore, on the basis of the above, according to the characteristics of the evaluation index value, it can be specifically divided into the following three situations for standardization.

(1) For quantitative evaluation indexes, when the rock mass quality grade at which the evaluation index value is located has clear upper and lower limits, and is positively correlated with rock mass quality, the linear interpolation method can be adopted for standardization. The gray value of the
three-parameter interval set in the actual project to obtain the evaluation index is \([r_i^-\), \(r_i^*, r_i^+\)], where the most probable value \(r_i^*\) can be standardized according to the following formula:

\[
\tilde{r}_i = k_j + \frac{20(r_i^* - b_j^+)}{b_j^+ - b_j^-}
\]  

(9)

In the formula, \(\tilde{r}_i\) is the evaluation value after standardization of the most probable value of the \(i\)-th evaluation index; When \(r_i^*\) is in the \(j\)-th rock mass quality grade, the upper limit \(b_j^+\) and lower limit \(b_j^-\) of the intermediate classification standard corresponding to the evaluation index are set as the lower limit of the first rock mass quality grade after standardization treatment as shown in table 1. Similarly, the sum can be standardized for \(r_i^-\) and \(r_i^+\) according to the above formula.

From Table 1, it can be seen that the long-term tensile strength of rock has no upper limit value in Grade I, so an equivalent upper limit value can be determined, and the upper limit value is 2 MPa in this article. Similarly, the lower limit value of the fifth grade of rock weathering speed is 10mm/ year.

(2) For the quantitative evaluation index, when the rock mass quality grade at which the evaluation index value is located has clear upper and lower limits and is negatively correlated with rock mass quality, the following formula can also be used for standardization based on linear interpolation:

\[
\tilde{r}_i = k_j + \frac{20(r_i^* - b_j^+)}{b_j^+ - b_j^-}
\]  

(10)

In the formula, the symbolic meaning is the same as before.

(3) For the qualitative evaluation index, firstly make qualitative evaluation according to the field data and then give a score of 0~100 according to the corresponding relation in Table 1.

3.4. Method for Determining Weight of Rock Mass Quality Grading Evaluation Index Value

At present, the weight of evaluation index is mainly determined by using experts' engineering experience and based on analytic hierarchy process. However, different experts have different engineering experience and areas of expertise, so the weight results are often different. Therefore, group decision-making thought can be introduced to make full use of the collective wisdom of expert groups, so as to improve the credibility and scientificity of weight calculation. However, due to different engineering experiences and familiar fields, different experts often get different weight results, i.e. different experts have different decision-making levels. Therefore, experts should be given a weight to reflect their decision-making level. For this reason, this paper will invite multiple experts to give weight values to the evaluation index based on the idea of group decision-making, then use the idea of coefficient of variation for reference to calculate the weight of experts themselves, and finally determine the weight of the evaluation index, as follows.

(1) Invite experts to use AHP to determine the weight of 5 evaluation indexes. That is, the judgment matrix is first constructed by comparing each evaluation index in pairs based on the scale of 1 ~ 9, and then the weight sum of each evaluation index is obtained. Due to the limitation of space, the analytic hierarchy process is not introduced in this paper, and the reference [22] can be consulted to indicate the weight given by the S-th expert to the I-th evaluation index. We can form a matrix of the weight values given by different experts, and record them as follows \(W_s = (w_{si})_{5\times 5}\). Then the weight values given by the expert S to the five evaluation indexes can be expressed by weight vectors and recorded as:

\[
W_s = \begin{pmatrix} w_{s1} & w_{s2} & \cdots & w_{s5} \end{pmatrix}
\]  

(11)

(2) Calculate the weight of experts themselves. By introducing the method of reference [23], based on the idea of coefficient of variation and following the principle that the minority is subordinate to the majority, the difference between the information given by experts and other experts is analyzed. The difference between expert S and expert K is calculated by the following formula:
The degree of difference between expert \( S \) and all other experts can be calculated, and the total degree of difference can be obtained, namely:

\[
A_k = \sum_{k=1}^{v} |W_s - W_k|
\]

And order

\[
\tilde{W} = \left( \frac{1}{A_1}, \frac{1}{A_2}, \ldots, \frac{1}{A_v} \right)
\]

Will be normalized \( \tilde{W} \)

\[
W' = (w_1, w_2, \ldots, w_v)
\]

In the formula, \( w_v \) is the weight of the fifth expert.

(3) The final weight of each evaluation index can then be calculated according to the following formula.

\[
W = W' \cdot W_\theta
\]

Furthermore, it can be substituted into equation (6) for calculation.

So far, a rock mass quality classification method for ancient underground engineering based on three-parameter interval grey number has been established, and its application in engineering analysis will have better applicability and operability.

4. Engineering Case Analysis

In order to verify the rationality of this method, it is applied to the rock mass quality classification of Qingfengdong ancient caverns in shepan island [2].

4.1. general situation of the project

Qingfengdong Ancient Cavern Group is located in the low hills in the north-central part of shepan island. According to historical data, it is estimated that excavation began during the Eastern Han Dynasty, with a history of more than 1,000 years. Each cavern of Qingfengdong ancient cavern group is above the local erosion datum level. The cavern group consists of 9 caverns, mainly pyroclastic rocks, of which tuff, rhyolite, rhyolite porphyry, etc. account for a considerable proportion. Relevant investigations show that there are no major regional faults passing through shepan island, and there are 7 influential faults at the location of Qingfeng Cave's ancient caverns. According to Sun Guangzhong's structural plane classification method [24], these faults are mainly Class III and Class IV structural planes. Among them, Fault F15 is located at the slope section outside the cave, with a length of more than 110 meters and passes through the northwest sidewall of Cave 5. Fault F7 has a visible length of more than 80 meters, and the local fracture zone is 0.1~0.3 meters, which is opposite to the No.7 cave area. Fault F20 is about 20m in length and has scratches on the fault plane, which affects the dangerous blocks near No.7 cave. Fault F16 has a visible length of about 70m, passes through hole 1, and there is siliceous vein invasion in the fault, which has certain influence on holes 1, 5 and 4, and may produce unstable blocks and dangerous rocks. Faults F17, F18 and F19 are between 20 meters and 50 meters in length, and are all filled with siliceous dikes. Some Shi Ying crystals occur, so the friction coefficient is usually high. Faults mainly affect holes 2, 3, 4 and 5. Most of the joint surfaces in the evaluation area are flat, closed and free of fillers. A few of them have slight alteration such as chloritization. The joint length is generally 4 to 10 meters, and the joint spacing is relatively large, generally 5 to 10 meters. The joints are mainly thick and medium-thick rock masses, and the phenomenon of joint cross-cutting and dislocation is relatively rare. Generally speaking, the wind tunnel area is clear of fracture and poor joint development, and the rock block is good. Only due to weathering and excavation, some joints have undergone tensile cracking, and the rock mass integrity coefficient is about 0.87 to 0.97. In terms of hydrogeological conditions, the groundwater in this area
is relatively poor, and a small amount of fissure water seeps out or drips out from some sections of the roof of a few caverns. Laboratory tests show that the uniaxial saturated compressive strength of the rock is about 66.7MPa and the tensile strength is about 6.92MPa. Yang Zhifa and others obtained the long-term tensile strength of the rock is about 0.39 MPa to 0.47 MPa through back analysis. Through the measurement and analysis of 12 points, it is shown that the weathering speed of rock mass is 0.015~0.12mm/ year.

4.2. Analysis Process and Results
The rock mass quality of the ancient underground project is classified by the method in this paper. The specific process is as follows:

(1) Each evaluation index value is determined according to engineering geological data and expert discussions, and converted into standardized score values according to Equations (9) and (10), as shown in Table 2.

| evaluation index  | $f^*$                     | $K_v$                      | $J_c$                      | index value          | standardized score values |
|-------------------|---------------------------|----------------------------|----------------------------|-----------------------|----------------------------|
|                   | $[0.39,0.43,0.47]$        | $[0.87,0.93,0.97]$         |                           | grad 2~grad 3         |                             |
| evaluation indexe | standardized score values |                           | $A$                       | $[45,47,50]$          | $[83,91,96]$               |
|                   |                           | index value                | $v$                       | $[2,4,8]$             | $[0.015,0.09,0.12]$         |
|                   |                           | standardized score values  |                           | $[48,67,80]$          | $[58,64,94]$               |

(2) Invite 3 experts to determine the weight of each evaluation index according to AHP as shown in Table 3, and then calculate the weight of each expert = (0.371, 0.365, 0.264) based on the idea of coefficient of variation method, and then calculate the final weight of each evaluation index as $W = (0.305, 0.231, 0.160, 0.15)$.

| evaluation index | $f^*$ | $K_v$ | $J_c$ | $A$ | $v$ |
|------------------|-------|-------|-------|-----|-----|
| expert1          | 0.323 | 0.234 | 0.163 | 0.163 | 0.117 |
| weight           | expert2 | 0.281 | 0.235 | 0.191 | 0.158 | 0.135 |
|                  | expert3 | 0.314 | 0.223 | 0.113 | 0.127 | 0.223 |

(3) Calculate the rock mass quality grading evaluation result as $=[55.4, 62.9, 74.3]$ according to Formula (6).

(4) accord to that formula (8), the distances of the standard value corresponding to the division of each rock mass quality grade are respectively 26.4, 6.4, 13.5, 33.5 and 53.5, wherein the minimum distance is 6.2, and the corresponding rock mass quality grade is level 2; The second is 13.5, which corresponds to grade 3. Therefore, according to the principle of minimum distance, the rock mass quality grade of the ancient underground project can be rated as second-class deviation.

4.3. Discussion
(1) The rock mass quality of the ancient underground project is classified by the method in this paper, and the classification result is secondary deviation, i.e. the rock mass quality at the site is better, but it is inclined to grade 3, i.e. the overall stability is better, but there may be risks in some sections. In fact, during the period from 210 to 2011, 4 of the 9 caverns of the ancient caverns group once experienced 1.8 kg to 8.5 kg of rock falling events, thus it can be seen that the calculation results of this method are
consistent with the actual project, which shows that the analysis results of this method can better reflect the actual project.

(2) In order to further illustrate the rationality and operability of this method, the "Engineering Rock Mass Classification Standard" is adopted to classify the ancient underground engineering rock mass quality, and the revised \[BQ\]=512 is obtained. According to the "Engineering Rock Mass Classification Standard", the classification can determine that it is a second-class preference, and the results are both second-class compared with the results of this method. However, the conclusion preference of BQ method and the conclusion deviation of this method are better. According to the comparison of actual engineering data, this method is more in line with the engineering practice, which also proves to some extent that the factors such as long-term tensile strength of rocks and weathering speed of rocks selected in this paper as evaluation indexes can better reflect the ancient underground engineering.

(3) From Table 3, it can be found that Expert 1 and Expert 2 have basically the same order of importance for the five evaluation indexes. Both agree that the weight of rock weathering speed is the smallest, but Expert 3 is completely different. The weight of rock weathering speed given is 0.223, which is only inferior to 0.314 of long-term tensile strength of rock. Therefore, the author of this article specially consulted Expert 3. Expert 3 believes that long-term stabilization is of course very important. However, the long-term protection of ancient underground works should not only focus on this, but also on the long-term protection of the original appearance of ancient underground caverns. This is because there are many ancient carved patterns and murals on the surrounding rocks of ancient underground works. However, the weathering of rocks will cause these patterns to be destroyed before the instability of ancient underground caverns. The weathering resistance of rocks is actually a manifestation of the good and poor quality of rock mass. Thus, it can also be explained that ancient underground works do have their particularity and need special research.

5. Conclusion
In this paper, aiming at ancient underground engineering, a special rock engineering, three-parameter interval grey number theory and group decision are introduced to deeply discuss the classification of rock mass quality, and the following conclusions can be obtained.

(1) The long-term tensile strength and weathering speed of rocks are taken as indexes for evaluating the quality of rock mass in ancient underground engineering, so that the established evaluation index system can better meet the requirements of long-term protection of ancient underground engineering.

(2) Using three-parameter interval grey number to describe the evaluation index of ancient underground engineering rock mass quality classification can not only reflect the interval uncertainty of evaluation index values, but also provide more effective information than the two-parameter interval grey number, thus increasing the reliability of evaluation results.

(3) A method for determining the weight of evaluation indexes based on group decision-making is established, which makes full use of the wisdom and experience of expert groups, avoids the shortage of individual expert experience, measures the credibility of individual experts by using the idea of coefficient of variation, and then synthesizes the weight information on this basis, thus making the weight calculation reasonable and reliable.

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