Optimal selection on water-supply pipe of building based on analytic hierarchy process

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Abstract: The main problem of pipes used in water-supply system was analyzed, and the commonly used pipe and their main features were introduced in this paper. The principles that the selection on water-supply pipes should follow were pointed out. Analytic Hierarchy Process (AHP) using 9 scaling was applied to optimize water-supply pipes quantitatively. The optimal water-supply pipes were determined according to the sorting result of comprehensive evaluation index. It could provide the reference to select the reasonable water-supply pipes for the engineers.

1 Introduction
Water-supply network has played a key role on people's life and work, which constitutes the main part of urban water-supply system and becomes an integral part of urban infrastructure construction. The construction of water-supply pipe network can reflect a country's economic development level in a certain extent. Pipe is an important part of the water-supply network construction, which costs more than a third of the total cost of pipe network construction, so how to choose pipe in water-supply pipe network engineering construction holds the important status. Pipe is the important restricting factor on the water-supply pipe network. At present, the outstanding problems existing in urban water-supply pipe network is as follows: corrosion is serious, the phenomenon such as pipeline dirt and aged, secondary pollution of water quality is more serious. The operation energy consumption due to leakage is larger, which must be pay enough attention[1]. From what has been discussed above, water-supply pipe must be choose reasonably in order to achieve water pipe network reliable operation, economic and reasonable cost, convenient maintenance, no secondary pollution.

2 The main problems existing in the water-supply pipe
In recent years, the development trend of water-supply pipes are diversified with the rapid development of building residential water-supply system, and requirements for the performance of the water-supply pipe is becoming more and more high. At present, urban water-supply network in China still has some problems, such as the leakage of pipe, blasting rate being higher, and pipeline corrosion, aging, and serious dirt, making water produce secondary pollution. The problem cause water quality reduce, water energy consumption increase, seriously affect the economic benefits of water-supply enterprises and water security of users. In view of the city water-supply pipe network construction being not perfect and exiting some problems, in the future city pipe network
transformation process, the selection of water-supply pipe should be paid more attention to reliable quality, reasonable economic indicators, in order to reduce the operating cost, save investment, ensure water-supply safely and efficiently\textsuperscript{[2-4]}.

3 Commonly used pipe and its features

In the water distribution system, pipe plays an important role, the factors to consider when choosing pipe have the following several aspects: the first is feed water flow and pressure of water-supply pipe, secondary water quality problems, finally, factors such as pipe installation, and ease of maintenance must be given attention, according to different pipe, the different principle must be followed\textsuperscript{[5]}.

3.1 Metal Pipe

When metal pipes such as thin-walled stainless steel pipe and copper pipe were in use process, corrosion phenomena can also appear, which was mainly chloride and sulfide deposit. In the surface oxidation protective film inhibits corrosion, which can maintain and repair for a long time. The copper pipes are influenced easily with the pH of water. If high acidity, corrosion phenomenon will appear. At the same time, high dissolved oxygen and demineralized water, could also result in corrosion of copper, so on these occasions, the brass try not to be used. If the chloride ions in the water content were higher, which will also cause corrosion of austenitic stainless steel pipes, in this kind of circumstance, thin-walled stainless steel pipes is unfavorable choose. Metal pipe connection has a variety of ways, each has advantages and disadvantages. Material, wall thickness and the use occasions must be considered comprehensively to determine pipes. If different metal tube or pipe is connected, the electrochemical corrosion of the pipeline should be pay sufficient attention.

3.2 Plastic Pipe

In general, for the linear expansion coefficient, plastic pipe's was more than metal pipe's, which is also an important difference between plastic pipe and metal pipe. The deformation of plastic pipe occurs in the shaft up generally. The common deformation is bending mainly in the horizontal direction, and the degree of deformation is directly proportional to temperature difference. As a result, the problem must be taken into account in design and construction of installation, the slip joint or angle natural compensation method can be choose. When choosing plastic pipe fittings, adhesive containing benzene class organic solvent should be avoided to choose, so as not to make water quality secondary pollution. The detection qualified tubing must be choose according to the quality supervision and inspection authorities.

3.3 Composite Pipe

The welding aluminum alloy and polyethylene were adhesive by the glue to produce aluminous model multiple tube, whose characteristic was both the advantages of plastic pipe and metal pipe, namely corrosion resistance and resistance to high pressure. According to different uses of hot and cold water, aluminous model multiple tube can be divided into high density polyethylene and crosslinked polyethylene aluminous model multiple tube. Adding a layer of UPVC in the galvanized tube constitutes the plastics-steel multiple tube, which also combines the advantages of steel pipe and plastic steel pipe. The plastics-steel multiple tube commonly was used as a cold water pipe, whose cost is higher. Steel skeleton PE pipe is a new kind of pipeline, which has the advantages of double-sided anti-corrosion pressure. PE pipe has been widely applied in municipal water-supply engineering, but its cost is higher. The plastic coated pipe was produced with polyethylene (PE) resin or non-toxic polypropylene and other organic matter deposited on the inner wall of the steel tube, which is characterized by high strength, water resistance, corrosion resistance, not easy fouling, long service life.

4 The principles to be followed when choosing water-supply pipes material

Water-supply pipe plays an important role in supplying the user with clean water. Water quality are greatly influenced by the feed water pipe. Currently, metal pipe, plastic pipe, composite pipe are three
main water-supply pipeline, each has advantages and disadvantages, and the accurate choice must be based on the principles of weighing the pros and cons to make\textsuperscript{[6]}.

4.1 Clean Sanitation
Water from the water plant generally go through a long pipeline to reach the user, during this time, chlorine that tap water contains may produce a new physical and chemical reaction with the pipe wall, water quality reaching users was affected, and the inner wall of the pipe was corroded. Therefore, health performance testing qualified pipe must be chosen according to the authority supervision departments of the state.

4.2 Safe and Reliable
Water-supply pipe in the process of water distribution and supply must bear a certain amount of water pressure, meet the mechanical strength grade to prevent rupture, and whose sealing must be better to prevent leakage phenomenon. At the same time, the pipe can resist the influence of vibration, water hammer and heat bilges cold shrink, all of these in pipe network design must be considered.

4.3 Conducive to Environmental Protection
Feed water pipe can be recycled use and have no pollution to the environment, which has become an important factor when choosing pipe for technical personnel, especially country issued a series of policies to protect earth's environment. Galvanized pipe is easy to rust, which has been basically eliminated. Copper pipe with good anticorrosion performance and pressure performance, has become an important material of high-grade decoration. Most plastic pipes can be recycled, which are now also widely used.

4.4 Saving Energy
Any pipe material in the production process and installation process must consume energy. In general, the thin-wall pipe production more efficient than thick wall pipe production. Steel-plastic compound pipe, metal pipe, plastic pipe, their production energy consumption gradually reduce. According to the construction perspective, using besmear brush twisted tooth is more energy-saving than hot melt connection, electric welding and gas welding. If a second pressure was needed in the process of water distribution, the more local head loss of the pipeline, the more energy consumption.

4.5 Saving Investment
Under the condition of meeting health and safety, technical and economic analysis must be conducted from the aspects of pipe material price, construction installation cost, to choose appropriate pipes to save the cost of network construction.

5 Using AHP to select construction water-supply pipe
In order better to unify the qualitative analysis and quantitative analysis for decision making problem which is influenced by many factors, the analytic hierarchy process (AHP) occurs. AHP was brought up firstly by the T· L· Saaty, which was suitable for problem sorted sequence according to the advantages and disadvantages\textsuperscript{[7–9]}. The influence factors of building water-supply pipe are more, so it is suitable for using AHP to optimize choice.

5.1 Setting the Structure Model among Levels
Building water-supply pipe model mainly consists of three layers, namely the target layer, rule layer and solutions. The target layer is the building water-supply pipe. Rule layer according to the survey mainly includes health clean, safety and reliability, and cost, whose importance was based on the opinions of the experts and customers to order. 5 kinds of pipes such as thin-walled copper pipes, thin-walled stainless steel pipes, PVC - U pipes, PP-R pipes, the lining of PVC galvanized pipes were choose as the research object. Building water-supply pipe hierarchical model is shown in Fig.1.
5.2 Construction of Judgment Matrix
According to the experience of the engineers and expert advice, 9 scaling method is used to determine the element size values of judgment matrix, as shown in table 1 to table 4.

TABLE 1. Building water-supply pipe decision-making target table

|   | A   | B1 | B2 | B3 |
|---|-----|----|----|----|
| B1 | 1   | 3  | 5  |
| B2 | 1/3 | 1  | 3  |
| B3 | 1/5 | 1/3| 1  |

TABLE 2. Building water-supply pipe clean sanitation indicators table

|   | B1 |   | C1 | C2 | C3 | C4 | C5 |
|---|----|---|----|----|----|----|----|
|   |    |   | 1  | 1/3| 1/5| 1/3|
| C1 | 1  | 1 | 1  | 1/3| 1/5| 1/3|
| C2 | 1  | 1 | 1  | 1/3| 1/5| 1/3|
| C3 | 3  | 3 | 1  | 1  | 1/3| 1  |
| C4 | 5  | 5 | 3  | 1  | 1  | 3  |
| C5 | 3  | 3 | 1  | 1/3| 1  | 1  |

TABLE 3. Building water-supply pipe safety and reliability index table

|   | B2 |   | C1 | C2 | C3 | C4 | C5 |
|---|----|---|----|----|----|----|----|
|   |    |   | 1  | 5  | 5  | 3  |
| C1 | 1  | 1 | 5  | 7  | 7  | 5  |
| C2 | 1  | 1 | 7  | 1  | 1  | 1/3|
| C3 | 1/5| 1/7| 1  | 1  | 1  | 1/3|
| C4 | 1/3| 1/5| 3  | 3  | 1  |    |
| C5 | 1/3| 1/5| 3  | 3  | 1  |    |

TABLE 4. Building water-supply pipe construction cost index table

|   | B3 |   | C1 | C2 | C3 | C4 | C5 |
|---|----|---|----|----|----|----|----|
|   |    |   | 1  | 3  | 5  | 3  | 3  |
| C1 | 1  | 3 | 5  | 3  | 3  | 1  |    |
| C2 | 1/3| 1 | 3  | 3  | 3  | 1  |    |
| C3 | 1/5| 1/3| 1  | 1  | 1  | 1/3|

FIGURE 1. Building water-supply pipe structure model figure
5.3 Consistency Check

The eigenvalue method is used to judge the consistency of matrix:

\[ CI = \frac{\lambda_{\text{max}} - n}{n - 1} \]

1) The formula of the \( CI \) shows consistency index, \( \lambda_{\text{max}} \) for the largest eigenvalue, \( n \) shows the number of factors, namely the order number.

The mean random consistency index \( RI \) can look up to the table 5, the consistency ratio \( CR \):

\[ CR = \frac{CI}{RI} \]

2) When \( CR < 0.1 \), hierarchical sorting result consistency can be accepted.

| TABLE 5. The relations between the mean random consistency index and matrix order |
|-----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Matrix Order    | 1      | 2      | 3      | 4      | 5      | 6      | 7      | 8      | 9      | 10     | 11     | 12     |
| \( RI \)        | 0      | 0      | 0.52   | 0.89   | 1.12   | 1.26   | 1.36   | 1.41   | 1.46   | 1.49   | 1.52   | 1.54   |

Total sorts consistency check:

\[ CI_T = \sum_{j=1}^{5} a_j CI_j \]

3)

\[ RI_T = \sum_{j=1}^{5} a_j RI_j \]

4)

\[ CR_T = \frac{CI_T}{RI_T} \]

5)

5.4 The Calculation Results and Analysis

AHP software yaahp v. 9.1 was used to solve the calculation, the main results as shown in table 6. The biggest characteristic value \( \lambda_{\text{max}} \) was obtained by the software yaahp a. v. 9.1. Consistency index (\( CI \)) was obtained according to the formula (1), \( RI \) value can be checked by the table 5, consistency ratio (\( CR \)) was calculated by the formula (2), total sorts consistency check according to the formula (5), \( CR_T = 0.0184 < 0.1 \), shows the total sequencing result also has the satisfactory consistency.

| TABLE 6. Building water-supply pipe weight calculation table |
|-----------------|--------|--------|--------|--------|--------|--------|
|                | B1     | B2     | B3     | Results Total Sorts |
| C1              | 0.6333 | 0.2605 | 0.1062 |                   |
| C2              | 0.0737 | 0.3333 | 0.4285 | 0.3168          |
| C3              | 0.1952 | 0.2618 | 0.2297 | 0.1809          |
| C4              | 0.0737 | 0.4218 | 0.0747 | 0.1790          |
| C5              | 0.4624 | 0.0566 | 0.0868 | 0.1771          |
| \( \lambda_{\text{max}} \) | 5.0555 | 5.0955 | 5.1973 |                 |
| \( CI \)        | 0.0124 | 0.0213 | 0.0440 |                 |
| \( RI \)        | 1.41   | 1.41   | 1.41   |                 |
| \( CR \)        | 0.0088 | 0.0151 | 0.0312 |                 |

It can be seen from table 6, when considering health clean, PP-R pipe is the best, when considering
safety and reliability, thin-walled stainless steel pipe is the best, when considering the cost, PVC - U pipe is the best.

It a word, methods 1 comprehensive weight (0.3168) is the biggest, namely the comprehensive performance of the thin-wall copper pipe is the best, which can be applied to the high standard residential water-supply pipeline installation. The second is the PP-R pipe, whose comprehensive performance is higher, plus the price and the advantages of convenient installation, which is suitable for ordinary residential decoration water-supply pipe.

6 Conclusions
(1) It should master the commonly used pipe and its main features, follow the principle of the pipe selection, consider various factors, and do specific analysis, to select the best pipe for exerting its maximum efficiency.

(2) Using 9 scale AHP to optimize building water-supply pipe material, it is concluded that comprehensive weight (0.3168) of thin-wall copper pipe is the biggest, which can be as a priority for building water-supply pipe. Application of AHP can break the limitations of traditional methods and more comprehensively consider various influencing factors, the evaluation results more reliable.

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