Construction Characteristics and Quality Control Measures Under High Altitude and Cold Conditions

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Abstract. Restricted by the natural environment factors, the high altitude and cold regions have low air pressure, low air density, large temperature difference between day and night, and long freezing and cold time. During the construction, strict requirements are put forward for the material preparation, material transportation, construction machinery, construction technology, workers' personal safety and other aspects. Based on the engineering construction in Tibet, this paper studies the optimization scheme of concrete mix proportion and the systematic insulation measures of concrete construction in high altitude and cold regions. The influence of ultra-low temperature on metal welding process is studied. The effects of welding wire selection, welding environment guarantee and worker training on welding quality assurance are studied. The calculation method of mechanical efficiency reduction and the influence of altitude on environmental factors and quota adjustment coefficient are studied. The results of this study provide reference and technical support for the construction in high altitude and cold areas.

1. Introduction

The Qinghai Tibet Plateau, known as the "roof of the world" and "the third pole of the earth", has the latest uplift, the largest area and the highest altitude in the world. Due to the influence of topography, geomorphology and atmospheric circulation, the climate in Tibet is unique and complex, with large temperature difference between day and night, and a long period of freezing and high cold in a year. Especially with the increase of altitude, the decrease of air pressure and air density, the oxygen content per cubic meter of air gradually decreases. When the altitude is 3000 meters, it is equivalent to 73% of the sea level, about 62% - 65.4% when the altitude is 4000 meters, about 59% when the altitude is 5000 meters, and less than 52% when the altitude is more than 6000 meters. As a result, the efficiency of construction machinery and construction personnel is seriously reduced. Therefore, the material preparation, material transportation, construction machinery, construction technology, workers and so on are put forward severe challenges.

R He et.al. investigated the permafrost and cold regions environmental problems and the mitigation methods of the oil product pipeline, located on the Qinghai-Tibet Plateau [1]. S Wang et.al. provided a calculation method for ground ice volumes estimation of permafrost layers in north-eastern Qinghai-Tibet Plateau, considering landform types, borehole data and measured water content [2]. W Yu et.al. reviewed the engineering risk assessment methods for permafrost in Tibet Plateau and the arctic regions and risk evaluation of constructions (tunnel, bridge, roadbed etc.) [3]. Through field investigation, data analysis, AHP and regression analysis modelling, the fitting curve and formula that accurately reflect
the efficiency reduction of construction machinery in alpine area are obtained [4]. X Liu et.al studies the thermal insulation measures of construction machinery, construction water supply, concrete pouring process, etc. during construction in Tibet alpine region, which provides a reference for winter construction in Alpine Region [5]. Y Li et.al studies the technical requirements and countermeasures of the rotary drilling construction scheme in the gravel geological environment of high altitude and cold area, optimizes and compares the construction scheme, and provides technical support for the application of rotary drilling pile technology in the field of Highway Engineering in high altitude and cold area [6].

Taking Tibet as an example, this paper analyses the key links of building construction design under the conditions of high altitude and cold, studies the optimization scheme of concrete mix proportion under the environment of high altitude and cold, and studies the specific control measures to reduce the temperature stress and dry shrinkage of concrete and provide the construction quality under the conditions of high altitude and cold in winter. The adverse effect of high cold conditions on metal welding process is studied, and the improvement measures are put forward. This paper combs the influence law and characterization method of special climate conditions such as high cold, low pressure and hypoxia on the efficiency of construction machinery, and studies the influence of high cold and altitude conditions on construction personnel. The conclusions of this paper lay a foundation for Tibet to scientifically cope with the challenges of high altitude and cold, ensure the construction quality and efficiency, and ensure the safety of personnel, and also provide an important reference for the construction of other areas with similar conditions.

2. Concrete construction

Concrete is one of the main building materials used in the construction industry. Due to the dry climate in Tibet, the surface water evaporates quickly and the temperature difference between day and night changes greatly (may exceed 40 °C), how to control the temperature stress and shrinkage deformation of concrete in a reasonable range through quality control is the primary problem to be solved in concrete construction.

2.1. Concrete mix design

In order to reduce the temperature stress of concrete and prevent the shrinkage cracks on the concrete surface, the concrete mix proportion should meet the following conditions,

1) Cement with low hydration heat should be selected as far as possible, and alternative cementitious materials such as fly ash can be selected if conditions permit.

2) Selecting appropriate concrete admixtures, such as superplasticizer, air entraining superplasticizer, pumping agent, etc., can effectively reduce the water consumption of concrete mixing and the corresponding cement consumption, reduce the hydration heat and ensure the good performance of concrete.

The engineering practice shows that the anti-crack performance of concrete will be significantly improved after adopting the optimized mix proportion design compared with the engineering without adopting the optimized scheme. In addition, in addition to the normal quality control measures of concrete construction, the control of concrete temperature stress and shrinkage is also the content of plateau concrete quality control. According to the information provided by engineering practice and relevant references, the following measures are proved to be effective and reliable,

1) Reasonable control of concrete layers, joints and blocks.

2) Control the temperature of concrete warehouse.

3) For large open-air warehouse, plastic woven tarpaulin shall be timely covered after concrete pouring to prevent concrete shrinkage caused by evaporation of surface water, reduce temperature difference between inside and outside of concrete and reduce concrete stress.

4) to control the time of concrete pouring, especially in the season with large temperature difference, it should be poured at night or at noon according to the size of concrete block number.
2.2. Concrete construction in winter
Before concrete construction in winter, sufficient preparations should be taken, including:

(1) calculation and selection of concrete layers and blocks, thermal calculation of concrete, calculation of sand aggregate reserve, selection and economic comparison of concrete insulation measures, and selection of concrete pouring time;

(2) Preparation of thermal insulation materials for concrete warehouse surface, storage of sand and gravel, thermal insulation of concrete mixing equipment, preparation of hot water mixing equipment and implementation of thermal insulation measures for water source.

In the construction organization stage, the key raw materials, warehouses, mechanical equipment and construction environment shall be systematically designed according to the overall construction schedule of the project. The specific measures are shown in figure 1.

![Figure 1. Thermal insulation measures for winter construction](image)

As shown in figure 1, during concrete construction in winter, exposed pipes shall be avoided as far as possible, and the exposed pipes near the mixing system and warehouse surface shall be insulated to ensure water consumption for concrete construction. The mixing plant is placed in the semi-permanent house, and the electric heater is properly set in the house to improve the temperature in the house. The aggregate conveying system shall be closed and the aggregate bin shall be covered with tarpaulin. The enclosed concrete transport vehicle is used and wrapped with thermal insulation quilt for thermal insulation. The concrete storehouse surface is insulated by warm shed method. Seal the cement warehouse window and hang cloth curtain on the door. Use electric heating boiler to heat the mixing water. Through comprehensive measures, the temperature of each link of construction is guaranteed and the construction quality is guaranteed.

Although the concrete construction can be carried out in winter through technical measures and generation process control, considering the harsh winter climate and severe hypoxia in Tibet Plateau, which threaten the safety of construction personnel and the high cost of concrete construction in winter, winter construction should be avoided as far as possible.
3. Quality management and control of welding construction in winter

In winter, the welding of steel structure is carried out at extremely low temperature. Among them, low temperature welding refers to that the ambient temperature within 0.5 m around the weld is lower than the minimum welding construction temperature specified in the specification, while ultra-low temperature refers to more than the minimum value specified in the specification, which makes the welding quality control more difficult. The Chinese national standard JGJ81-2002 "Technical Specification for Welding of Building Steel Structure" stipulates that the minimum temperature of low temperature welding is 0 °C, and the ambient temperature in winter in Tibet is often lower than -10 °C, which belongs to ultra-low temperature environment.

In the welding process, high temperature and low ambient temperature have a serious adverse effect on the welding quality, which is shown in the following aspects: the quality of low temperature welding seam cannot be guaranteed, and the sudden cooling of welding seam is easy to produce cracks; too low ambient temperature will not only increase the hardness of welding seam, but also change the microstructure of welding seam, at the same time, it also has a great impact on the impact toughness of welding seam, which is easy to appear undercut, slag and other phenomena; Too low ambient temperature reduces the preheating effect of weld, which makes it difficult to maintain the stability of interlayer temperature of weld; too low ambient temperature will increase the difficulty of welder operation, and also affect the qualified rate of weld. Therefore, how to ensure the construction quality of ultra-low temperature welding of steel structure through welding quality control technology and measures is a major technical challenge in high altitude and cold regions.

The technical measures of ultra-low temperature welding quality control include: (1) reducing the influence of material by controlling the welding temperature and the temperature drop rate after welding. It is suggested to use the material with low temperature impact toughness. (2) Low hydrogen type welding wire is selected to reduce the time-lapse cracks caused by hydrogen element not precipitated in time due to too fast temperature drop. (3) The symmetrical welding of each joint form shall be designed and strictly implemented; (4) at the same time, the ambient temperature and the cooling rate of the weld shall be strictly controlled, the closed operation platform shall be set up before welding, and the heating measures such as small sun fan shall be adopted to make the ambient temperature of welding at 0-- Stop welding when the ambient temperature is less than -15 °C, and stop welding in rainy and snowy days to reduce the occurrence of stress concentration and hot cracks. (5) The welder entering the site shall be trained, and the examination and screening shall be strict [7]. The welder with good technology, strong ability and serious responsibility shall be selected for welding operation, and the unqualified welder shall be eliminated.

4. Mechanical efficiency reduction

4.1. Influencing factors of mechanical efficiency reduction

Mechanical efficiency reduction refers to the objective phenomenon of reducing the efficiency of mechanical operation because the machinery cannot perform the normal quota in the plateau, high altitude and complex working environment. The vast majority of Tibet Plateau is over 3000m above sea level, with thin air, low air pressure, large temperature difference between day and night, and obvious efficiency reduction of various types of machinery, which is quite different from that in plain areas. The specific performance is as follows,

(1) For fuel oil construction machinery, due to the reduction of oxygen content in the air, insufficient fuel combustion and poor heat dissipation performance, the operation efficiency of machinery decreases and the fuel consumption increases. Due to the thin air, the normal oil-gas mixture ratio cannot be guaranteed, and the incomplete combustion results in the carbon deposition and glue formation at the cylinder, piston and valve, which increases the wear of these parts. Because of the low pressure on the plateau, the boiling point of water will decrease, so the consumption of engine cooling water will increase. This kind of machinery includes excavator, diesel engine and loader.
(2) For electric mechanical equipment, because it is sensitive to heat, humidity and atmospheric environment (such as dust and gas pollution), the reduction of atmospheric pressure and air density will reduce the heat dissipation capacity, resulting in the rise of temperature and the decrease of motor power. This kind of main mechanical equipment includes: concrete mixer, welding machine, electric welding machine.

4.2. Mechanical and manual adjustment coefficient
According to the above analysis, the mechanical efficiency reduction is mainly controlled by the changes of environmental factors, including air pressure, temperature and relative humidity. The variation of main environmental parameters with altitude is shown in table 1 [8].

| Altitude (m) | Atmospheric Pressure (kPa) | Temperature (℃) | Relative Humidity (%) |
|--------------|-----------------------------|------------------|-----------------------|
| 2000         | 79.97                       | 35.3             | 85                    |
| 3000         | 70.64                       | 25.3             | 72                    |
| 4000         | 61.30                       | 19.3             | 50                    |
| 5000         | 53.98                       | 13.2             | 30                    |
| 6000         | 47.31                       | 7.2              | 5                     |

Affected by the efficiency reduction of machinery and the working efficiency of personnel, the altitude of the construction project should be taken into account in the design budget compilation of plateau area, and the construction labour and machinery consumption of the budget quota should be multiplied by the corresponding adjustment coefficient. In reference [8], according to the budget quota of water conservancy construction engineering, the manual and mechanical adjustment coefficients of water conservancy construction engineering at different altitudes are given, as shown in figure 2.

Figure 2. Variation of plateau construction quota adjustment coefficient with altitude

4.3. Calculation method of effective power of internal combustion engine
For power correction and verification of internal combustion engines in high altitude areas, the standards used in China are GB 1105.1 Correction of effective power of internal combustion engines and GB 1105.1-87 Calibration of environmental conditions and power, fuel consumption and oil consumption
of internal combustion engine bench performance test methods. It can be divided into adjustable oil quantity method and equal oil quantity method.

The adjustable oil quantity method is suitable for the calibration of the effective power under the calibration condition and the overload power condition, and the equal oil quantity method is suitable for the conversion of the calibration condition or the overload power condition. Due to the low atmospheric pressure and low temperature in plateau area, the power of test site environmental condition in plain area should be converted to the power of standard environmental condition by equal oil method, and then adjusted to the power of use site environmental condition by adjustable oil method. The correction calculation method of effective power of internal combustion engine based on adjustable fuel method is corrected according to the field environmental data in table 1.

4.3.1. Equal oil method

The conversion of effective power for non-supercharged and supercharged gasoline engine are expressed as (1),

\[ P_0 = \alpha_a \cdot P \]  \hspace{1cm} (1)

\[ \alpha_a = \left( \frac{99}{P_s} \right)^{1.2} \left( \frac{T}{298} \right)^{0.6} \]  \hspace{1cm} (2)

For diesel engines

\[ \alpha_d = f_a^{m_f} \]

For non-supercharged or supercharged equipment,

\[ f_a = \left( \frac{99}{P_s} \right)^{0.7} \left( \frac{T}{298} \right) \]  \hspace{1cm} (3)

\[ f_a = \left( \frac{99}{P_s} \right)^{0.7} \left( \frac{T}{298} \right)^{1.5} \]  \hspace{1cm} (4)

For turbocharged equipment,

\[ f_m = 0.036 \frac{q_e}{\pi_k} - 1.14 \]  \hspace{1cm} (5)

Where \( P \) is effective power under site environmental conditions (KW), \( \alpha_d \) is lower conversion coefficient of diesel engine with equal fuel method, \( f_a \) is atmospheric factors, \( f_m \) is characteristic index of diesel engine, \( P_s \) is the dry air pressure under site environmental conditions (KPa), \( T \) the temperature in field environment (K), \( q_e \) is the specific displacement cycle diesel supply (mg/L.C), and \( \pi_k \) is boost ratio.

4.3.2. Adjustable oil method

This method can be used to calibrate the effective power under the calibration condition and the overload condition. Effective power of field condition can be expressed as (6),

\[ P = \alpha \cdot P_0 \]  \hspace{1cm} (6)

\[ \alpha = k + 0.7(k - 1) \left( \frac{1}{\delta m} - 1 \right) \]  \hspace{1cm} (7)

\[ k = \left( \frac{p - a\varphi p_{sw}}{p_0 - a\varphi_0 p_{sw_0}} \right) m \left( \frac{T_0}{T} \right) n \left( \frac{T_{ce}}{T_c} \right) q \]  \hspace{1cm} (8)

\( P_0 \) is effective power under standard environmental conditions (KW), \( k \) is indicated power ratio, \( \delta m \) is mechanical efficiency, \( p \) and \( p_0 \) are atmospheric pressure at site and standard ambient conditions (KPa), \( T \) and \( T_0 \) are temperature at site and standard environmental conditions (K), \( T_c \) is inlet temperature of cooling medium of intercooler (K), \( \alpha_d \) is power conversion coefficient of diesel engine with equal fuel method, \( \varphi \) is relative humidity, and \( a, m, n, q \) are power correction factors.

Through the above theoretical formula, the internal combustion engine power without altitude can be calculated, so as to determine the efficiency reduction coefficient of construction machinery in high altitude and cold areas.

5. Conclusions

Based on the engineering construction in Tibet, this paper analyses the characteristics of environment and climate in high altitude and cold regions. In high altitude and cold regions, the negative impact on engineering construction mainly comes from objective factors such as low air pressure, low air density,
large temperature difference between day and night, long freezing time, etc. Therefore, it puts forward severe challenges to material preparation, material transportation, construction machinery, construction technology, worker protection, etc. This paper puts forward the optimization scheme of concrete mix proportion and the systematic insulation measures of concrete construction, obtains the influence law of ultra-low temperature and high cold conditions on the metal welding process, and puts forward the specific methods and measures to ensure the welding quality from the selection of welding wire, the guarantee of welding environment and the training of workers. This paper combs the expression method of mechanical efficiency reduction under the condition of high altitude and cold, and summarizes the influence law of altitude on environmental factors and quota adjustment coefficient. The results of this study provide a reference for the construction in high altitude areas, and provide technical support for the construction quality assurance and efficiency improvement.

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