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Comparing the Impact and Requirements of Terrain and Landform on Building Materials in China

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Abstract: Based on China's current policies for the development of the western region, infrastructure is the top priority. However, the geological structure of the western region of China is very complex and lacks experience. Therefore, the core of this paper is to study the demand for building materials and structures under different geological conditions. This article explores the construction materials and methods in specific terrains and landforms in China, including alluvial plains, plateaus, and hills, through literature analysis and specific data analysis. Through case analysis, including the building materials and methods of Shanghai Tower, the building materials and methods of residential buildings on the Qinghai Tibet Plateau and the Qinghai Tibet Railway, and the building materials and methods of traditional buildings and reconstructed buildings in southwest mountainous areas of China, specific conclusions are drawn and their data are compared. There are also applications of some new building materials in specific regions. This provides a certain reference value for the renovation of traditional residential buildings in some special terrain and landforms.

Keywords: Buildings on alluvial plain, building material, Buildings on plateau, Buildings on hills.

1. Introduction

To begin with, this paper would like to talk about the building materials, i.e. stone, concrete, and steel. Stone is a material with excellent durability. The history of humans using natural stone as building materials can be traced back thousands of years. During the ancient Greek civilization, stone pillars and lintel techniques were used in the construction of many temples. In ancient Rome, architects used stone as a material to build waterways and introduced mountain springs into towns to solve the problem of insufficient water supply. During this period, the most innovative use of stone was as a coating material for concrete. The ancient Romans also developed a system of combining beams, columns, and arches with the use of stone. However, due to the emergence of new materials such as concrete, steel, and glass, new structural systems with efficient and lightweight characteristics have replaced the original heavy-stone structural systems [1]. Due to the advantages of high strength, good durability, strong seismic and impact resistance, excellent plasticity, and strong waterproof performance, concrete has become the most critical building material in construction engineering. However, due to the direct relationship between the construction quality of concrete and the safety, usability, seismic performance, and durability of building structures, there are certain unstable factors. Concrete material still replaced stone in the 19th century due to the development of economic and living requirements in urban cities and stone can not bear the weight brought by tall buildings [2]. Steel structure systems are superior to reinforced concrete structures in terms of strength, self-weight, and application type, and mixing with concrete can greatly reduce restrictions on terrain and topography. It still has some questions, such as fireproofing and whether steel will be corroded [3].

There are many kinds of special terrain, like the Qinghai-Tibet Plateau, some alluvial plain Qinghai-Tibet Plateau and some hills and valleys. First, for example, from the geotechnical characteristics of the subsoil of the deltaic alluvial plains of Bangladesh. The subsoil is generally composed of sandy material. Due to unstable subsoil, significant changes may occur in the short distance horizontally, and the bearing capacity of the soil is extremely low in the upper six to ten meters. So that area must consider a special material to build infrastructure [4]. And in plateaus, especially the Qinghai-Tibet Plateau, most high-altitude areas are located in remote areas with harsh environments and almost no government energy supply. Once disasters occur, such as fires, earthquakes, avalanches, epidemics, etc., transportation difficulties, long construction periods, and energy shortages may occur. Prefabricated lightweight components, on-site assembly, solar energy supply, and energy-self-sufficient prefabricated net zero energy buildings have become feasible ways to solve this problem [5].

2. Results

This part analyzes the requirements of architectural buildings in alluvial plains, plateaus, and hills.

2.1. Alluvial plain architecture

Shanghai is located in the southeastern front of the Yangtze River Delta. During the Quaternary geological period, the global climate alternated between cold and warm, leading to multiple fluctuations in sea level. At the same time, under the control of tectonic movements, the sedimentary cover layer in this area reached 150-400 meters, which is the main characteristic of the foundation soil composition in the Shanghai area. In the Shanghai area, the groundwater level is affected by factors such as surface water, surface evaporation, and precipitation, with an overall annual variation range of about 1m. In this project, pressurized water is mainly contained in sandy soil layers and sandy silt layers, mostly around 3i. e. 12m underground, and exhibits periodic changes with the seasons. According to the survey results, the foundation soil exposed within a depth range of 100.0m below the ground belongs to the Quaternary Holocene (Q4) coastal to estuarine, shallow sea, and swamp facies, as well as the Upper Pleistocene (Q3) estuarine to coastal, coastal to shallow sea facies sedimentary layers and the middle Pleistocene (Q2) estuarine to lacustrine facies sedimentary layers. Mainly composed of cohesive soil, silty soil, and sandy soil. According to its geological age, genetic type, soil properties, and differences in physical and mechanical properties, it can be divided into 9 layers and sub-layers belonging to different levels. The plane shape of the foundation pit of Shanghai Tower is an irregular quadrilateral. The deepest excavation depth of the foundation pit is about 11.45m, and the safety level of the foundation pit engineering is level 2. On the west side of the site is a municipal confluence box culvert, with a complex surrounding environment. Based on the current experience in similar foundation pit design and enclosure, there are 2-3 layers of gray clayey silt mixed with powdery clay on this site, which have good permeability. Therefore, the foundation pit of this project can be surrounded by bored piles and cement soil water barriers. For areas with complex surrounding environments, underground continuous walls can be used for enclosure, and internal support should be provided [6]. The data analysis of pile driving depth is provided in Table 1.

Table 1: Building data for different soil structure.

Soil layer name	General bottom burial depth /m	Average value of general resistance P/MPa	Pull-out coefficient
Grey clay silt	12	1.97	0.6
Grey powdery clay	26	1.06	0.7
Dark green powdery clay	31	2.36	0.75
Grass yellow powdery clay and clayey silt	41	3.36	0.7
Grey sandy silt	67	7.28	/

2.2. Plateau architecture

The Qinghai Tibet Railway (Xining Lhasa) has a total length of 1956 km and passes through multiple climatic and geological zones, with complex terrain and landform, the Golmud Lhasa section is 1142 km long, with approximately 960 km of the line reaching an altitude of over 4000 m, crossing a continuous permafrost area of approximately 550 km [7]. The long-term stability of permafrost subgrade engineering is the key to the safe operation of the Qinghai Tibet Railway. Unlike nonpermafrost roadbeds, constructing roadbeds in permafrost areas causes thermal disturbance to the underlying permafrost, leading to a decrease in the upper limit of permafrost, an increase in permafrost temperature, and a series of adverse geological problems such as thermal melting lakes and ponds, resulting in uneven deformation, cracking, and other diseases of the roadbed, threatening its stability. The instability of the Qinghai Tibet Railway is due to the infiltration process of accumulated water, which on the one hand increases the moisture content of the foundation soil, softens the soil, and reduces its strength, leading to a decrease in the stability of the roadbed. On the other hand, accumulated water can cause serious hydrothermal erosion on permafrost roadbeds, leading to degradation of permafrost and inducing problems such as thermal thawing settlement and cracking of permafrost roadbeds. In response to the problems of settlement and cracking in permafrost roadbeds, comprehensive reinforcement measures such as raising road shoulders with rubble, adding soil protection roads, rubble slope protection, hot rods, and drainage blind ditches have been taken. Through comprehensive treatment of areas with severe roadbed settlement, the stability of the roadbed has been significantly improved. For example, from 2007 to 2010, the annual settlement of the K1496+750 section of the Qinghai Tibet Railway was greater than 5 cm.

For frame structures without basements in mountainous areas, to prevent the torsional effect caused by the horizontal thrust of the soil on the building body when adjacent to the mountain, retaining walls are used to separate the soil on the mountainside from the main body of the building structure at a certain safe distance, so that the main structure is not affected by the horizontal thrust of the soil. Due to the weak lateral stiffness of the frame structure itself [8]. Here are several solutions for building materials.

Option 1: A reinforced concrete cantilever retaining wall is erected on the foundation, with a 100mm gap left with the main body and filled with polystyrene board. The top of the wall is lifted out using floor panels to prevent rainwater from entering the inside of the retaining wall.

Option 2: Install an independent gravity retaining wall outside the foundation of the main side column. The ground beam of the main building is lifted out of the lifting column and combined with the extended beam of the frame column to form a closed frame, which is used to deal with the problem of excessive overhang at the unloading platform.

Option 3: Similar to Option 2, an independent retaining wall is set up outside the main body, but a column is used on the foundation. One end of the platform beam is supported on the platform column, and the other end is lying on the top surface of the retaining wall. A 100mm deformation joint shall be left horizontally between the platform beam and the top surface of the retaining wall.

Option 4: Similar to Option 3, only the top platform beam support method will be changed to set sliding bearings on the left side and the top of the platform column, and no deformation joints will be left between the right side and the retaining wall. Limiting measures will be set up [9]. For permafrost areas where the site elevation is higher than the designed indoor ground, the base elevation should be determined first based on the outdoor ground design elevation and considering the depth of soil freezing on the site. If the outdoor ground elevation is -0.3m, the current site elevation is 1.0m, and the freezing depth is 1.6m, the minimum design elevation of the foundation should be -1.9m [10].

2.3. Hills architecture

In the mountain area, the vast majority of residential buildings in the Mabian area were built in the 1960s to 1980s using wooden structures with a construction period of 30-50 years. Due to the relatively backward economy and lack of earthquake resistance and disaster prevention knowledge in mountainous areas, existing buildings currently have earthquake resistance defects , as shown in Figure 1.

Figure 1: Traditional residential buildings in mountainous areas.

Traditional houses of the Yi ethnic group are generally built with wooden structures. Wooden structures have many advantages: Wooden buildings have the characteristics of green and environmental protection, and wooden materials are renewable and biodegradable materials; Lightweight wood has good seismic performance, and flexible design, and is suitable for building low-rise houses; In traditional Yi ethnic houses, wooden mortise and tenon components are often used as decorations under the eaves, which are beautiful and elegant, and have a national flavor [20]. However, wooden structures also have some drawbacks: poor corrosion resistance and susceptibility to insect infestation in mountainous areas; The climate in mountainous areas is humid, and the wood in old residential areas is heavily corroded by rainwater and insect infestations; Wooden structures have poor fire resistance and are prone to fire; short service life [11].

3. Discussion

3.1. Comparison

A preliminary understanding of the required foundation depth for different soil conditions is based on Table 1. In the following discussion, the necessary conditions for building under different terrain conditions are also mentioned, such as considering the influence of permafrost on plateaus, the impact on natural disasters, and the limitations of transportation of building materials in mountainous areas. Therefore, the main building materials in mountainous areas are sourced locally.

For the planning of future alluvial plain buildings, the main factor is the influence of foundation depth in different soils rather than the influence of building materials. However, high-strength lightweight materials should be selected as much as possible for building materials.

There are also many requirements for foundation depth in mountainous soil conditions, but the foundation depth is much shallower than in alluvial plains, as shown in Table 2.

Table 2: Comparison of Foundation Depth Requirements for Different Soils.

Soil layer name	fak	Introduction
Miscellaneous Fill		Recently, artificial filling mainly consists of cohesive soil with a high content of bricks, concrete blocks, plant roots, etc. The thickness is 0.5-6.4m. Foundation treatment is required to serve as the foundation bearing layer
fine sand	100kPa	A thickness of 0.5-3.3m can be used as the foundation bearing layer
Medium sand	160kPa	A thickness of 1.3-2.6m can be used as the foundation bearing layer
Silty clay with sand	150kPa	A thickness of 0.7-3.4m can be used as the foundation bearing layer
gravels	240kPa	A thickness of 0.8-4.1m can be used as the foundation bearing layer
basalt	500kPa	Strongly weathered rock can serve as the foundation bearing layer

Traditional wooden structures have poor performance in corrosion resistance, fire prevention, and service life, so new buildings are mainly considered to use brick and concrete structures or steel structures. The steel structure adopts a cold-formed thin-walled light steel structure, which is a new type of material. Compared with ordinary brick concrete and masonry structures, it has significant advantages in earthquake resistance, thermal insulation, saving construction land, and ecological protection [12], but the cost of using steel structures alone is higher. Taking into account the comprehensive cost and construction difficulty, the ethnic characteristics of the Yi ethnic group in the Mabian Mountains and their impoverished economic situation are analogous to the reconstruction of buildings in most poverty-stricken counties in China.

3.2. Future plans

However, the permafrost situation in high-altitude areas is very unstable, so there is no usual requirement for different regions. This mainly includes air-cooled roadbeds, gravel (gravel) protective roads (slope), hot rod roadbeds, and their different forms of combinations [13]. Among them, gravel air-cooled+gravel slope protection, and gravel protective road - gravel slope protection can adapt to the impact of future climate warming of 1.0 ℃.

In the future, because transportation in the Xizang Plateau is very inconvenient, the Tibetan stone masonry structure will be a widely used structural form on the Tibetan Plateau because it is easy to use local materials and can better withstand the cold climate in the plateau. But its load-bearing walls are made of rubble and clay, with high stiffness and weak seismic energy consumption, and have suffered significant damage in previous earthquakes. Modular steel structure buildings are lightweight and have good seismic performance, which can greatly reduce casualties in earthquakes. At the same time, steel has recycling value and huge advantages in post-disaster repair, demolition, and reconstruction. There is still a certain gap between the economic development of Xizang and that of developed provinces on the mainland. At present, traditional modular buildings consume a large amount of steel and cost a lot of construction. Therefore, the material selection of the new modular structural system must take into account the characteristics of "lightweight" and "high-strength", not only having strong seismic performance but also having certain economic performance. Based on these two aspects, cold-formed steel, as an economical lightweight thin-walled steel, has the advantages of reasonable cross-section, material saving, diverse variety, and high utilization rate, and can also be combined with punching and other processes in production. It is an economical section of steel. It has great research value and development and application prospects in the research of new modular structure systems suitable for the Xizang plateau area [14].

4. Conclusion

In summary, the data for this study comes from numerous research papers as well as data from CNKI, including the selection of building materials and differences in construction methods under various terrains, landforms, and soil conditions. In addition, this article integrates a large number of theories from other scholars, mainly using case analysis and paper research to understand the specific influencing factors on the selection of building materials, as well as the characteristics of traditional dwellings in various regions and the selection of building materials. This method has resulted in effective research on the application of new building materials and methods in specific regions, thus providing more research options to a certain extent.

From the analysis of the paper on Shanghai Tower, the depth of 100.0m below the ground in Shanghai is mainly composed of cohesive soil, silty soil, and sand. According to its geological age, genetic type, soil properties, and differences in physical and mechanical properties, it can be divided into 9 layers and sub-layers belonging to different levels. This indicates that the terrain in most areas of Shanghai is very complex, making it difficult to choose building materials. The selection of building materials is closely related to the construction method, so for example, in alluvial plains such as the Yangtze River Delta, bored piles can be used as the pile type. The bored piles are easy to form and have little impact on the surrounding environment; Take appropriate measures to prevent hole collapse and drilling in sandy and silty soil; If necessary, pile end grouting measures can be taken to improve the bearing capacity of the pile end. The foundation pit can be surrounded by drilled cast-in-place piles and cement soil waterproofing. For areas with complex surrounding environments, continuous high-pressure rotary jet grouting can be used to adjust the curvature, horizontal displacement, and ring deformation of the tunnel, ensuring the safe operation of the combined box culvert.

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