Development of regionally specific green building design & assessment standards for the Qinghai-Tibet plateau region of China

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Abstract. Establishment of regionally specific green building (GB) standards has been proved to be an effective way to promote GB development in different regions. China released its first national Evaluation Standard for Green Building (GB 50378) in 2006. Since then, regionally specific GB standards have quickly been established in its different provinces/cities. However, such standards were not established in the Qinghai-Tibet plateau region until about ten years later, which made it the last region in the country to possess its own regionally specific GB standards. Supported by research funds from the Ministry of Housing and Urban-rural Development of Qinghai province and Tibet autonomous region respectively, the research group of this paper studied on how to develop regionally specific GB design and assessment standards for the Qinghai-Tibet plateau region. Literature review, field investigations, questionnaire surveys, group interviews and case studies were conducted to clarify regionally specific conditions and needs, based on comprehensive analysis of which, sub-zones were established and specific provisions were established or customized to suit regionally specific conditions. Main results, experiences and lessons learnt from the research are introduced and discussed, further researches in the relevant field are also recommended.

1. Introduction
While green building (GB) becomes more and more emphasized in the building sector in many countries of the world, establishment of regionally specific green building (GB) standards has been proved to be an effective way to promote GB development in different regions. To promoted GB development, China formally released its first national Evaluation Standard for Green Building (GB 50378) in 2006 and since then has updated it twice[1-3], following which a number of different GB related standards/codes, such as Code for Green Design of Civil Building (JGJ T229)[4], have been established at national level and they together have played important roles in leading and driving GB development in the country.

Being a country with vast territory, its natural, economic and cultural conditions vary greatly from place to place. Unified standards and or codes cannot fully suit different conditions and needs of different places; therefor, “how to construct GB design/assessment standards suitable for different regions based on the existing national standards/codes had been researched, based on which a series of
regionally specific GB design and assessment standards at provincial and city level. However, regionally specific GB standards were not established in the Qinghai-Tibet plateau region, which possesses harsh natural environment, unique cultural features and economic conditions, until about ten years later after the release of the first national GB evaluation standard (Fig.1). This made it the last region in China to possess its own regionally specific GB standard.

![Figure 1 The Qinghai-Tibet plateau region in China](image)

Entrusted by the Department of Housing and Urban-rural Development of Qinghai province and the Department of Housing and Urban-rural Development of Tibet Autonomous Region respectively, the research group of this paper undertook researches on the establishment of some GB design & assessment standards for the Qinghai-Tibet plateau region of China, which include the Design Standard for Green Building in Qinghai (DB63/T 1340)[6, 7], the Evaluation Standard for Green Building in the Tibet Autonomous Region (DBJ540002) [8]and the Design Standard for Green Building in the Tibet Autonomous Region (DBJ540001)[9].

Content of the research is related to four of the UN sustainable development goals (SDGs): No.11 sustainable cities and communities, No.3 good health and wellbeing, No. 6 clean water and sanitation, and N.7 affordable and clean energy. Literature review, field investigation, questionnaire survey, group interview and case study methods were applied in the research with an objective to identify regionally specific characteristics of the Qinghai-Tibet plateau region, so as to develop GB standards with clear regional suitability.

2. Literature research on the regional characteristics
Literature research was conducted to identify regional climate, resource, economic and cultural characteristics, main results of which are listed as the following:

2.1. Regional natural climate and resource characteristics
Qinghai-Tibet plateau is the largest plateau in China and the highest in the world. It is also called the "roof of the world" and the "third pole". It is located in the northwest of China, It is about 2,800 kilometers long from east to west, 300 to 1,500 kilometers wide from north to south, and generally between 3,000–5,000 meters above sea level, with an average elevation of more than 4,000 meters[10]. Its natural climate and resource characteristics are as the following:
2.1.1. Climatic and geographical characteristics. It belongs to the cold and severely cold climate zone, with high altitude, low average annual temperature, short cool summer, long cold winter. It is regard as the initiator and regulator of climate change in the northern hemisphere. The geographical and seasonal distribution of precipitation is extremely uneven in this area. Annual precipitation vary between 20 ~ 4000 mm in different areas of the region.[11] It has an annual sunshine duration of 2500 ~ 3650h and a total solar radiation of 4800–6400MJ/m², which makes it a typical solar energy enrichment area. [4] It is also rich in wind resources. The available time of annual wind speed is more than 5000h.[5][12] Climate change in this region not only directly drives the climate change in eastern and southwestern China area, but also has a huge impact on the northern hemisphere, even possesses sensitivity, forethought and regulation to global climate change.

2.1.2. Land resources characteristics. Its average altitude is far higher than the surrounding areas at the same latitude. The areas above 4,000 meters account for 60.93% of the total area of Qinghai province and 86.1% of the total area of Tibet Autonomous Region. With large area, diverse land types and obvious vertical distribution, land resources in this region are distributed unevenly and their quantity is extremely unbalanced. The land suitable for grazing accounted for 53.9% of the total land area, the land suitable for agriculture accounted for 0.9%, the land not suitable for any use accounted for 34.5%. Cultivated land is mainly concentrated in its eastern loess hill and gully region.[10]

2.1.3. Vegetation resources characteristics. With wide variety of plant species, staggered plant geographical components, complex vegetation types and abundant plant resources, the vegetation resources in this region presents significant regional differences. The number of plant species in the whole plateau region is more in the southeast and less in the northwest. Affected by adverse geographical climate, such as severe cold, high altitude and low precipitation, plant species in this region are relatively few with obvious ecological vulnerability.[10] Most existing plants in this region are small trees, shrubs and grasses, while tall trees are scarce and grow slowly. With global climate change and the impact of human activities, there is a trend of further degradation of local plants.[13]

2.2. Regional economic and cultural characteristics
Located in China's agricultural culture and nomadic culture interlaced areas, its economic income mainly come from agriculture and graziery, industry is relatively backward. Its population is mainly concentrated in a few more developed cities. It is an area where the central plain’s culture, Islamic culture and Tibetan Buddhist culture coexist. It is also an area where the different nationalities, such as Han, Tibetan, Turkish, Salar and Mongolian, live together.[14] Religious beliefs and lifestyles of different ethnic groups constitute a rich and colorful cultural environment in the region. Under long term effects from special geographical, climate and cultural environment, different kinds of vernacular dwellings, such as Zhuangkuo, tents, bleaching room, adobe house, etc., have been developed with distinct regional characteristics (Fig. 2-4).[15]
3. Investigations regarding effects of regional characteristics on GB design

In order to more comprehensive intuitive understanding of the geographic conditions of the researched region, a series of field investigation were conducted in the Qinghai province and the Tibet Autonomous region, supported by the Departments of the two places respectively, details are the follows:

3.1. Questionnaire survey

Based on the existing national code and standards for GB design and assessment, also refer to the standards of Jiangsu, Shaanxi, Guangxi, Zhejiang provinces and Beijing, Shenzhen, Chongqing, Wuhan cities, as well as related literature. A questionnaire with a set of questions regarding local general conditions in building design practice were proposed and presented in the form of an excel document. Those questions involved 7 professional areas, which are planning, architecture design, structure engineering, heating, ventilation and air conditioning engineering, water supply and drainage engineering, electrical engineering, and landscape design. Examples of the questions are listed in Table 1.

Table 1. Examples of questions listed in the questionnaire

| Professional areas                        | Examples of questions regarding local building design conditions                                                      |
|-------------------------------------------|------------------------------------------------------------------------------------------------------------------------|
| Planning                                  | Which are the ecologically sensitive areas in your region?                                                              |
| Architecture design                       | What kind of simulation software is commonly used in local building design?                                              |
| Structure engineering                     | What are the locally special energy-saving design methods?                                                              |
| Heating, ventilation and air conditioning | What are the special requirements for foundation treatment in the local seismic fortification zone?                   |
| Water supply and drainage engineering     | Which precast structural elements are advocated locally?                                                               |
| Electrical engineering                    | Which building materials are promoted locally?                                                                         |
| Landscape design                          | What is situation of local solar, geothermal and wind energy utilization?                                               |
|                                           | What is the overall utilization rate of non-traditional water in the region?                                            |
|                                           | What do you think is the feasibility of integrating energy consumption monitoring systems into local buildings?       |
|                                           | What are the approximate species and number of native plants?                                                           |

A set of questionnaires were then sent to representative planning and or design institutes/companies with the help of regional Departments of Housing and Urban-rural Development. All the questionnaires were filled and sent back, the information in which were collected and analyzed systematically to identify the main concerns, requirements, expectations and problems in term of GB development in the research region.

3.2. Group interview

For the main problem, especially the differences or vague points that had been identified from the questionnaire survey, a set of group interview were then conducted targeting technical directors as well as project leaders in representative planning or design institutes /companies. The causes and background of the questions in the questionnaire were deeply discussed, and the implementation of GB in the researched region, especially their views on specific problems encountered in GB design, construction and operation were fully exchanged.

3.3. Case study
Field investigation was conducted on constructed GB projects in the researched region, including star labeled projects. Construction drawings of the projects were reviewed and specific problems encountered in the projects’ construction were investigated in detail, based on which suggestions were collected. They mainly relate to the regional climate condition, such as severe cold, windy, high altitude and low rainfall; the diverse and complicated geological conditions, scarce plant resources and other regional and natural characteristics; the backward technical, economic and infrastructure conditions in some areas; and the insufficient local building materials resources; as well as the impact of such natural features and regional conditions on the site selection, building design, material selection and landscape design.

4. Development of regionally specific GB design/assessment standards

4.1. Comprehensive zoning of regional environmental features

Literature research and field research show that different areas in the Qinghai-Tibet region possess complex and diverse regional characteristics, and the differences between different areas are very obvious. Therefore, it is necessary to establish a green building design standard for the province.

To reflect the diverse and complex regional characteristics of the research region, the natural differences and sub-areas of local climate, resources, economy, culture, geology, geomorphology, plants and dwellings, as well as the administrative divisions of the region were first analyzed, based on which, five zones were established for the Qinghai province: I Eastern loess hilly-gully area; II Qilian mountain area; III Upstream area of the Yellow River; IV Qaidam area, V Qingnan plateau area (Fig.5); and two zones were established for the Tibet autonomous region: I Lhasa, Shigatse, Nyingchi, and Qamdo city areas; II other areas (Fig.6).

4.2. Provision adapted to regional climate and resource characteristics

(1) Provisions adapted to regional climate resource characteristics

- With many mountainous areas as well as long wintertime with heavy snow and strong wind, it is basically not suitable for bicycle travel in the Qinghai-Tibet region (only except a few city areas, such as Xining, Haidong and Lhasa). Therefore, in the "site planning and outdoor environment" section, provisions regarding bicycle travel are either deleted or revised.
- Locates in the cold and sever cold climate zone, most landscape plants can hardly survive on the roofs or external walls of buildings. Therefore, in the "architectural design and indoor environment" section, provisions regarding roof & vertical greening are deleted.
Locates in the cold and sever cold climate zone, heat island effects are considered having positive effect for the region (e.g. it helps to raise outdoor environmental temperature in wintertime, shorten melting time of snow on the road surface, etc.); therefore, provisions regarding "control of heat island effect" are deleted.

With long and short summer, local experiences show that even a small amount of shade blocking sunlight from the south façade of buildings can cause significant resentment among local users. Therefore, provisions for avoiding blocking sunlight are added. For example, "in front of the south window of low-rise buildings, small deciduous trees or shrubs are recommended, while large evergreen trees should be avoided to prevent adverse effects on people’s access to natural sunlight from indoor spaces".

With cool and pleasant summertime, cooling demand is very low in the Qinghai-Tibet region. Air conditioning is only used in buildings with special indoor environmental requirements, such as hotels and hospitals. Therefore, provisions regarding shading, cooling as well as use of refrigeration systems are deleted or revised.

Rainy season in the Qinghai-Tibet region is highly concentrated and the spatial and temporal distribution of precipitation is uneven. Therefore, provisions regarding the utilization of rainwater are verified as for example "drought areas like Qaidam basin area are not subject to the articles on rainwater infiltration measures" and "rainwater is preferentially to be disposed by discharging to green land through natural slopes".

(2) Provisions adapted to regional energy resource characteristics

Renewable resources such as solar energy and wind energy in the Qinghai-Tibet region are abundant, therefore:

Provisions regarding “comprehensive analysis of renewable energy resources available on the project site” and some specific requirements for the “utilization of solar energy” are added. For example "solar hot water system shall be installed in the newly built residential buildings which are no more than 18 floors high. If a building is more than 18 floors high, the system shall be installed for residents in the top 12 floors". If the installation of solar hot water system is not possible, this should be evaluated by qualified evaluation agencies". "New public buildings with an area of more than 5,000 square meters should use at least one renewable energy source".

Provisions regarding the use of solar energy and wind power are added. For example, “solar energy should be reasonably used for environmental lighting; wind-powered hybrid street lamps can be considered in areas that are rich in wind resources; small solar street lamps and solar hybrid street lamps and other renewable energy facilities are encouraged to be used for landscape lighting, normal education, display or other purposes where wiring is difficult, based on economic and technical feasibility analysis”, “when utilizing photovoltaic power generation scheme, give priority to the grid-connected power generation system".

(3) Provisions adapted to regional vegetation resource characteristics

Due to high altitude, cold climate and large variety of geological types, the species, distribution and growth of native vegetation in the Qinghai-Tibet region are largely different from those in other areas in China. Therefore, an appendix with a table of normal urban plants both added to the design standard to facilitate the selection of native vegetation in different zones.

In most areas of Qinghai-Tibet region, the plant species are mainly shrubs and grasses. In the Qaidam and Qingnan plateau areas, there are basically no tall trees. Therefore, provisions regarding greening design (especially those refer to the number of trees) are revised. For example, it states that "Qaidam area and Qingnan plateau areas are not subject to the restriction for the number of afforest and trees".

In the Qinghai-Tibet region, the number of local plant species is not large, while the survival rate of exotic plants is low; besides, plants in this region growth slow and there is a trend of degradation. Therefore, provisions regarding protection of existing plants are added. For example, "before landscape design, the status of plants on site should be investigated and all the existing
plants on site should be carefully protected and or utilized”; "the plant configuration should reflect the characteristics of the resources and characteristic of natural landscape in the Qinghai-Tibet region, different plants should be configured according to their ecological habits”.

(4) Provisions adapted to the characteristics of regional land resources
✧ There are collapsible loess areas in the northeast part of Qinghai-Tibet region, where rainwater infiltration may has adverse effects on buildings if it is not properly treated. Therefore, provisions regarding rainwater infiltration treatment are added for such areas. For example, "for collapsible loess areas, specific soil geological conditions shall be taken into consideration", "appropriate rainwater infiltration measures should be taken in combination with the site topography, geomorphology and geological conditions".

(5) Provisions adapted to the stage of regional economic development and requirements of construction management
✧ The production and supply capacity of building materials in the high altitude and desert areas of Qinghai-Tibet region is backward, and basic conditions for the use of local building materials are often lacking. Therefore, provisions regarding the use of local materials are revised. For example, A list of regional GB materials is provided in the appendix of design standard to facilitate the need of material selection in GB design process; however, "Qaidam and Qingnan plateau area are not subject to the requirements for the use of local building materials". Possible incentives for using local materials were discussed in the group interviews; however, consensus was not reached so no specific provision is added.
✧ To meet the latest requirements of local government for strengthening the management of GB design process, a provision regarding " GB design documentation" is added to the standards.
✧ To reflect relevant requirements in the "GB action plan" of the Qinghai-Tibet region, a section of “decoration and renovation design” is added to the design standard.

5. Conclusions
Development of regional GB design and assessment standards is an important and effective way to promote GB development in different regions. This paper reviews and summarizes the process and outcome for the development of regional suitable GB design and assessment standards in the Qinghai-Tibet region of China.

Typical regional natural, economic and cultural characteristics were summarized and their effects on GB design were investigated, based on which comprehensive zoning were established and provisions adapted to regional characteristics were revised and or established.

There are still some questions of regional suitability that have not been fully answered in this study, such as how to balance the contradiction between solar energy utilization (which requires a large building spacing) and land saving in the high latitude regions, how to fully reflect the complexity and diversity of topography of the researched region and how to reflect the complex and diverse national cultural characteristics of the researched region. Further researches still need to be conducted to explore answers to such questions.

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