Journal of World Architecture

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Journal of World Architecture

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Renovation and Protection Project of Peking Union Medical College: Renovation and Reconstruction Design of Concealed Works

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Abstract: Peking Union Medical College (PUMC), as the representative work of Chinese modern architecture, has had a great impact on the development of Chinese modern architecture. Its advanced and complete concealed works contain great value and are valuable materials for the study of Chinese modern architecture. This paper studies the concealed works of PUMC, enriches the research data in this field, and summarizes the transformation design scheme of concealed works in the protection and repair of ancient buildings of PUMC.

Keywords: Peking Union Medical College; Concealed works; Cultural relic architecture; Renovation and protection project

Online publication: November 29, 2022

1. Introduction

Located at No. 9, Dongdan Sanjiao, Dongcheng District, Beijing, Peking Union Medical College (PUMC) is a traditional Chinese palace-style building with a Western-style interior, known as a "Western medical school in a Chinese palace" [1].

As the most important medical school established overseas by the Rockefeller Foundation, the PUMC was built using the most advanced construction technology available at the time, and the architects "did not set a budget." Therefore, the college was already equipped with very complete HVAC system, water supply and drainage systems, and electrical systems at the time, some of which are still in use today, demonstrating the high technology and quality of construction. However, since the medical school has been in use since its construction, it is difficult to conduct a detailed study of its hidden works. On the occasion of the centenary of the founding of PUMC, the historical building conservation and restoration project of the former site of PUMC was officially launched. This paper takes this opportunity to conduct a detailed study of the concealed project of the former site of PUMC, to explore its historical originality, to summarize its current problems, and to summarize and sort out this restoration and conservation project, in hopes that it can provide help and reference for the research, repair, and protection of other historical buildings of the same period [2].

2. Project overview

The former site of PUMC (Courtyard 9) mainly includes the entrance, Buildings 2, 3, and 4, connecting corridors and courtyards. The buildings in this area were the teaching areas at that time, and Buildings 2, 3 and 4 were the anatomy building, chemistry building, and physiology and pharmacology building

respectively (corresponding to Buildings B, C and D in **Figure 2**) [3]. The total construction area is 7962 m^2, including 1848 m^2 for Building 2, 3398 m^2 for Building 3, and 1844 m^2 for Building 4, which is a brick and concrete structure with one underground floor, two above-ground floors for Buildings 2 and 4, and three above-ground floors for Building 3; with two connecting corridors, one underground and one above-ground. There is also an underground equipment corridor in the courtyard. The area of Courtyard 9 is about 1800 m^2 [4]. The current situation of the project is shown in **Figure 1**

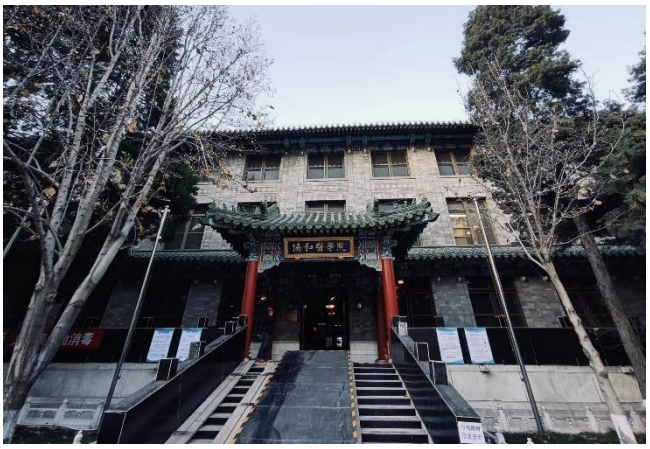

Figure 1. Project status

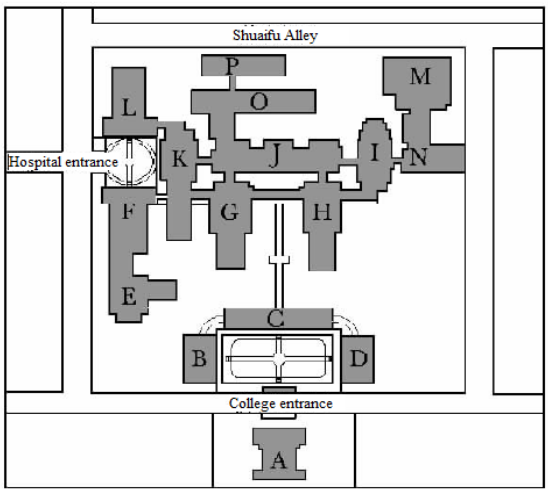

Figure 2. Project plan

3. Analysis of the value of concealed works in heritage buildings

PUMC adopted many of the world's most advanced building technologies, materials and equipment at that time. The concealed engineering of the building is well-designed, and the design of its ventilation, water supply and drainage, and electrical engineering fully takes into account the needs of building use and future development, ensuring the durability and comfort of the building. These equipment have very important historical and technological values, and are important scientific information for studying the development of building equipment, equipment processes and other building functions of the same period.

4. Restoration principles

The repair project strictly follows the relevant requirements for the repair of heritage buildings, to protect the value of cultural relics from damage, to maintain the authenticity and integrity of the heritage body and its environment, "protection-oriented, salvage first, rational use, strengthen management" is the basic policy of the repair project. In addition, the following principles should also be observed: (1) safety, (2) authenticity, (3) minimum intervention, (4) recognizability, (5) reversibility, (6) preserving architectural and cultural diversity.

5. Research on the status of concealed works

5.1. Heating and ventilation project

Most of the buildings in the late Qing and Republican periods relied on the natural environment for heating and ventilation, while a heating and ventilation system was specially designed for PUMC due to the need for a good ventilation system in hospital buildings. The important rooms in Courtyard 9 were connected by rectangular iron air ducts, and air was circulated through the vents.

In this study, we investigated and counted the historical ventilation ducts, vents, and historical equipment in Courtyard 9 of PUMC. The historical ducts in buildings 2, 3 and 4 of the Courtyard 9 are mainly ventilation ducts, which are laid inside the walls of the buildings and run from the first floor to the

top floor of the building, connecting several rooms.

Building 2 is located at the west side of the courtyard. There are three historical ventilation duct shafts on the underground floor, the incinerator air outlet on the southwest side is connected to the shaft through the horizontal duct, and the incinerator chimney leads to the ridge of the roof and discharges to the outdoors. The air in the non-invasive room in the basement on the east side is discharged to the outdoors through the duct shaft leading to the roof, and the room on the north side of the basement has air conditioning equipment to produce cold air along the duct into the large classroom on the first floor and other important rooms. There are two air inlets in the large classroom on the north side of the first floor, from which the cold air enters the classroom, and the indoor air enters the air duct shaft in the adjacent room to the outdoors through the air outlet on the southeast side, forming an air circulation. The main body of the second floor is the anatomy room, and the air in the anatomy classroom passes through two separate shafts to the top floor, and the air in the small classroom on the north side passes through a separate shaft to the top floor. The outermost week of the top floor is a duct gallery, which is connected to the outdoors through a hanging window with an opening for one person to enter for maintenance purposes, and the heating ducts are circulated through the gallery. The location of historical air ducts in Building 2 are shown in **Figure 3.**

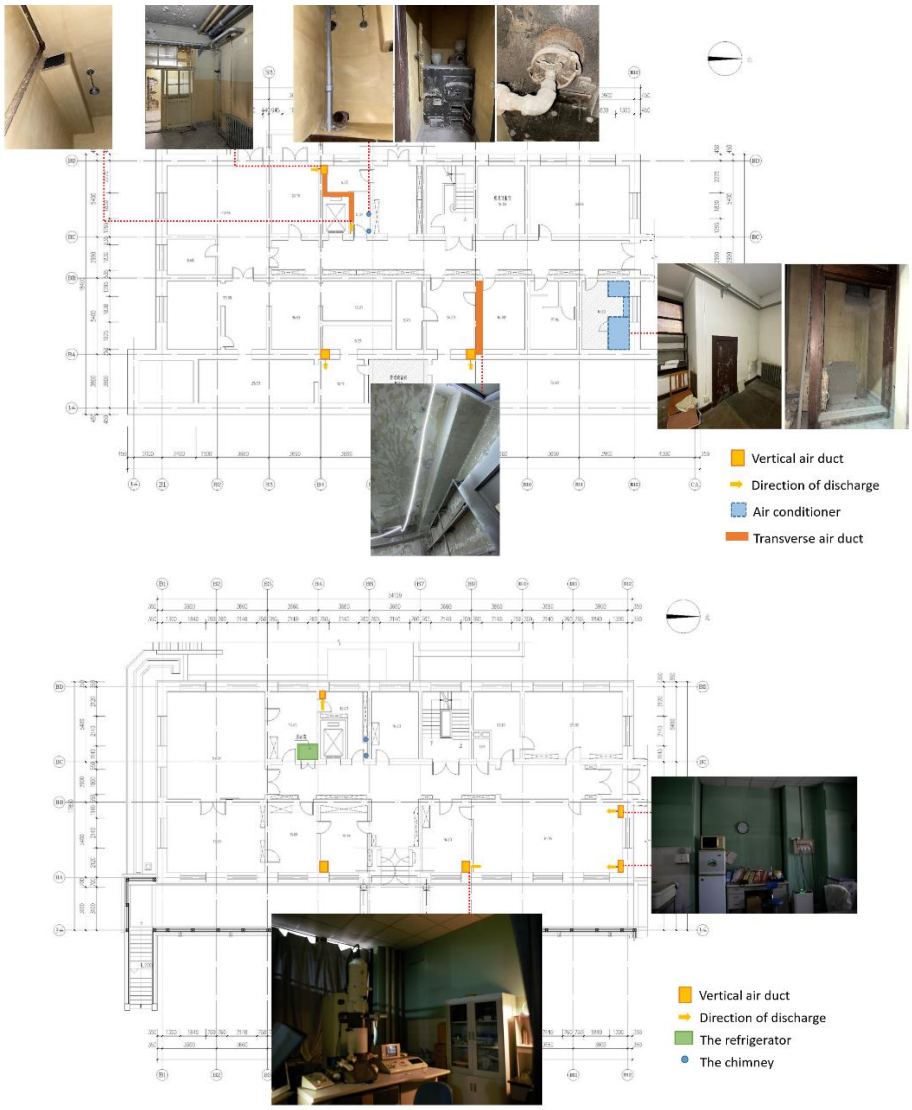

Figure 3. Schematic diagram of historical air duct in Building 2 of PUMC

Building 3 is located on the north side, the room on the southwest side of the basement is equipped

with a horizontal air duct connected to two shafts, the basement found that air conditioning equipment to produce cold air can be connected to the first-floor room along the air duct. In the room at the southwest of the first floor, cold air enters the room from the air inlet, and indoor air flows into the air duct shaft through the air outlet to the outside, forming air circulation. On the second floor, there are three air duct openings, which are connected from the ground floor to the top floor. The classroom on the northwest side has a test bench and is equipped with ducts for transporting gases and ventilation ducts for discharging harmful gases generated by experiments. The third floor to the top floor are equipped with ventilation openings at the corresponding positions of the ducts, which can prove that the ducts pass through the underground to the top floor, and finally pass through the top floor to form an air circulation outside. The location of historical air ducts in Building 3 are shown in **Figure 4.**

Figure 4. Schematic diagram of historical air duct in Building 3 of PUMC

The location of the air duct and air conditioning equipment in Building 4 is a mirror image of that of

Building 2. Cold air from the underground floor of the northwest side of the room with air conditioning can be transported to the first floor corresponding to the location of important rooms through the air ducts. More than one room on the first floor north has duct vents, three in the large classroom, presumably two duct vents on the north side are connected to the first-floor air conditioning, delivering the cold air into the rooms. Two duct shafts were found on the east side of the second-floor rooms, connected to the stuffy top floor and leading to the outdoors to form air circulation.

In addition to the original historical air ducts and equipment, there are also some additional ventilation ducts and air conditioning equipment built later. These exposed ducts and modern equipment such as outdoor air conditioners have caused serious damage to the style and features of historical buildings.

5.2. Water supply and drainage engineering

As the most advanced medical building at that time, PUMC was equipped with a relatively complete water supply and drainage system, but now most of the pipes are aging, causing many problems.

5.2.1. Water supply system status

The water supply system of PUMC has serious aging and rusting problems because they are made of galvanized steel pipes, which are now obsolete. The sanitary ware in the building also suffers from serious aging problems.

5.2.2. Drainage system status

Drainage pipes are clogged and broken, and the problem of leakage worsened due to aging of pipes. Poor local drainage of the roof drainage system causes stagnant water and increases the humidity of the building, which eventually leads to problems such as weathering of stone relics, which severely impacts the preservation of historical information of the relics and buildings. In addition, some modern drainage facilities, such as square rain grates do not match the style of the historical buildings, destroying the traditional appearance.

5.2.3. Status of fire protection system

Due to the confusion of pipeline caused by repeated transformation, it is impossible to confirm whether the hydrant pipe is correctly taken over; due to the rusting inside the pipeline and other causes of insufficient water pressure, the spraying pressure and water level of the hydrant column at the top floor does not meet the requirements; the hydrant, pipeline and tanks are rusted and aged seriously.

5.3. Electrical engineering

The original electrical wiring has been abandoned, the lines are chaotic and there is not enough space in the wiring trough to be used again, and the low-voltage distribution boxes and electrical wiring on each floor are aging. The electric wires of the security system (e.g., the circuit of smoke detector) in the office area are exposed. The pipeline layout needs to be transformed to avoid fires. The low-voltage distribution system on each floor is not standardized, and the corresponding circuit cannot be found. The air conditioner is also aging and needs to be replaced, and the electrical capacity needs to be increased. All areas of the medical school building are not energy-saving and has poor illumination. Besides, the style of lamps and lanterns is confusing and destroys the historical architectural style, so it is recommended to replace the lamps and lanterns.

6. Summary of the renovation design program

6.1. Restoration strategies

6.1.1. Repair strategy based on technological interventions to replace the old with the new

In the process of repair and renovation, we focus on the practicality and safety of the concealed works and the protection of historical buildings. Different structural safety plans are developed according to the specific conditions of the old site, and new technologies are used to repair the damaged parts, preserving the original form as much as possible, making it more recognizable in a historical sense and at the same time meeting the needs of a contemporary life. The repair technology adopted is based on the principle of reversibility, leaving room for future maintenance and conservation.

6.1.2. Diverse restoration strategies based on historical recognition

Based on the principle of minimal intervention and the principle of authenticity, its historical information is retained as much as possible, carrying historical memory and heritage. Repair work can be done according to the original information and historical information of the old site, using original materials and construction techniques as much as possible, respecting the historical value of the buildings, restoring the nostalgia, and passing on the cultural spirit.

6.2. Heating and ventilation system retrofit design

On the premise of not destroying the traditional appearance and structural safety of the historic building, the air conditioning, heating, ventilation and smoke extraction systems are upgraded to meet the comfort and usage needs of the building. Based on the analysis and research of existing problems, conservation objects and historical values, targeted conservation measures are adopted:

(1) Selecting appropriate equipment and solutions, taking into account the traditional appearance and usage needs of historical buildings.
(2) Retain the original equipment and layout as much as possible, and further enhance and utilize its usefulness.
(3) Minimal intervention to explore the value of historic buildings and further enhance their use and historical display value.

6.2.1. Air conditioning system design

(1) Fan coil system

In order to reduce the damage to the overall appearance of the historic building, fan coil air conditioning is used, the original air conditioning and outdoor units are all removed, and the air ducts, water pipes, air outlets and air conditioning ends are concealed. At present, there are no specific requirements regarding air conditioning, so we will maintain the original plan and optimize the design on this basis. The installation method of fan coil is shown in **Figure 5.**

Figure 5. Fan coil

(2) Industrial air conditioners and split-type air conditioners
In order to meet the special needs of medical buildings, we designed industrial air conditioners in special rooms such as laboratories and wall split air conditioners in equipment rooms with weak current. The existing piping and valves are old, and there are problems such as water leakage and damage, so they are replaced from scratch while maintaining their original pattern, so that they are more in line with the needs of the rebuilt building.

6.2.2. Heating system design

In terms of restoration and protection, there are no special requirements for the basement area, the original scheme of radiator heating system is maintained, and only its design is modified.

6.2.3. Ventilation system design

Through the research we sorted out the historical ventilation ducts and equipment in the building, for these valuable historical ducts and air conditioning equipment are to be preserved and protected.

(1) Protect and restore the historical ventilation ducts to their original state, and repair the visible ducts and air outlets for exhibition.
(2) The air conditioning equipment in the basement of Building 2 and Building 4 is retained and a 3D model is created to be retained and displayed as research material.
(3) A mechanical exhaust system is built in bathrooms, storage rooms, storage rooms and other rooms without external windows

Historical air duct and air conditioner can be seen in **Figure 6.**

Figure 6. Historical air duct and air conditioner

6.2.4. Anti-smoke exhaust system

In order to protect the architectural style, the project adopts the natural smoke exhaust system, and the stairwells in the building are equipped with openable exterior windows in accordance to the specifications, maintaining the original design of the building's exterior windows for smoke exhaust, and maintaining the traditional wooden exterior window style.

6.3. Water supply and drainage engineering renovation design

6.3.1. Fire fighting system

The original water source for fire fighting in this project building was supplied by PUMC, but since it was already at the end of the whole fire fighting system, the water pressure and aspects could no longer meet the fire fighting demand, so it was necessary to redesign the fire fighting system. For the protection of the overall structure of the historical building, it was decided not to introduce new water sources from other

buildings of the hospital, but to set up a 50 cubic meter water tank in the basement as the water supply for fire fighting. The original fire hydrant in Courtyard 9 was protected as a cultural relic during construction and could be displayed as an exhibit after the completion of the restoration project.

6.3.2. Drainage system

(1) The project adopts combined sewage and wastewater flow system, and the sewage and wastewater above +0.000 indoors is discharged into the outdoor sewage network by gravity.

(2) The roof adopts the gravity flow outward discharge mode, which is collected and discharged to the outdoor sewage pipe network. In this project, the waterproof characteristics of the roof will be restored and the tile surface will be partially repaired and replaced to ensure that the overall style will not be changed.

Construction status of roof waterproofing treatment is shown in **Figure 7.**

Figure 7. Roof waterproofing treatment

6.4. Electrical engineering retrofit design

6.4.1. Line laying

The original electrical system pipelines in the buildings of this project are basically laid in the walls, and the pipelines are aging and seriously damaged. In addition, the lines are chaotic and difficult to sort out, so the original lines can no longer be used. Therefore, the electrical pipelines will be rearranged in this project. To ensure that the building interior decoration is coherent with the historical style, the project has designed a connecting frame in the corridor. All lines are connected to each room through the connecting frame above the corridor. The lines in the rooms are painted with colors that are consistent with the wall, so as not to affect the overall style of the building.

There are two reasons for choosing open installation indoors. Nowadays, the number of electrical engineering lines in the building has greatly increased compared with a hundred years ago, and the original trunking space in the building wall cannot meet the current demands, so the new lines can only be installed and laid in the open. (2) The walls involved are made out of hollow bricks, these hollow bricks has a hundred years of history belongs to the category of cultural relics. If the lines were to be grooved into the walls, it will be better for the overall appearance, but it will inevitably be a great destruction of cultural relics. Hence, in order to protect the cultural relics, open installation is chosen as the method of electrical wiring. The circuit installation mode can be seen in **Figure 8.**

Figure 8. Surface mounted electrical circuit

6.4.2. Luminaire selection

The style of lamps has a great impact on the style of buildings, so careful consideration should be given to the selection of lamps in the repair and protection work. The lamps and lanterns in the buildings of this project have been replaced in the past hundred years, and their styles are no longer the original ones. Based on the purpose and principle of "repairing the old as the old" and "restoring the original style of cultural relics," the interior decoration style and lamp styles of the PUMC 100 years ago have been basically determined by referring to research literature, historical archives, and also old photos. This repair project aims to restore the original appearance of the building to the greatest extent, and chooses to use lamps with the same style as the original ones. "Qing's palace lantern" is used in the lobby, the same applies for the office area. However, in special rooms such as dissecting room and electron microscope room, professional lamps such as shadowless lamps are used. The lamp styles used can be seen in **Figure 9**

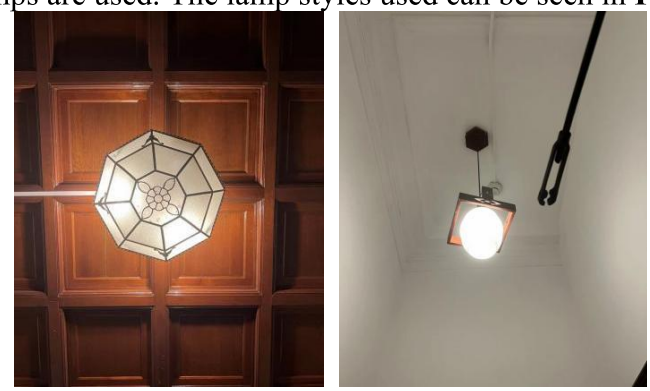

Figure 9. Lamp style

7. Conclusion

PUMC was built by Chinese traditional craftsmen under the auspices of western architects in the context of cultural exchanges between China and the West. Its special cultural background and unique construction skills have created the unique status of PUMC. As a precious architectural heritage, the historical information contained in PUMC is of great value for us to study the society, culture, economy, politics and the development of modern Chinese architecture at that time. As for the historical buildings on the old site of Peking Union Medical College, we should take protection as the first priority, study and explore their value while taking into account their use needs, and repair and transform them to meet modern needs. This paper only explores and studies the concealed works in the old site of PUMC, which also contains great value waiting for subsequent excavation.

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Disclosure statement

The authors declare no conflict of interest.

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Sequential Vision and Disorienting Experience of Garden Space in Asian Context: Comparative Analysis Based on the Residence of Ena de Silva and Xixi Villa

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Abstract: The blending of Eastern and Western cultures brought about by colonization was an important reason for the changes in Asian architecture in the 20th century. The passive input of Western design concepts into the local tradition caused a long swing in the design direction. The process of regionalism and global modernism from opposition to gradual integration can be found in the development of a series of Asian architectures. Based on the two architectural works of Geoffrey Bawa and Ge Ruliang, this paper discusses how Asian architects make in-depth regional expressions through garden space.

Keywords: Critical regionalism; Asian architecture; Garden space; Cultural comparison

Online publication: December 21, 2022

1. Introduction

Geoffrey Bawa (1919-2003), one of the most important Asian architects of the 20th century, is often characterized as a romantic vernacularist and a representative of critical regionalism due to the complex overlay of universality and locality in his works. Similarly, from the 1950s onwards, Chinese architects also began to explore regionalism. This paper compares Bawa's Ena de Silva House with Mr. Ge Ruliang's Xixi Villa to discuss the expression of profound culture and living spirit in the relationship between architecture and garden space as Asian architects.

2. A brief description of Sri Lanka and its architecture

As an island nation in the Indian Ocean a few degrees from the equator, Sri Lanka's only connection to the mainland is the Palk Strait in southeast India, and as a result, the Sinhalese make up three-quarters of the population. Despite its distance from the world's centers of power and influence, Sri Lanka has been home to immigrants from all over the world due to the Indian Ocean, allowing various architectural styles to converge here.

The island of Sri Lanka is divided into a dry zone in the northeast and a wet zone in the southwest by the action of the mountains and the Indian Ocean monsoon. With the decline of Polonnaruwa in the 13th century, the center of power gradually shifted southward and moved to the new capital of Gampola in the second half of the 14th century. The shift in the climatic zone and the mountainous terrain also forced the traditional Sinhala classical style to gradually shift to a more vernacular and adaptable architectural

vocabulary.

Sinhalese builders made a more deliberate choice between passive locations: a unique preference for mountainous sites. Mountain paths, boulders, flowing water, and buildings hidden within them have made naturalism a profound national culture and, as in many parts of Asia, they have explored the adaptive architectural elements of corridors and courtyards. Such a traditional construction idea that does not have a clear space boundary, combines natural characteristics, and follows the terrain has also been deeply demonstrated in Bawa's architecture. Local materials, such as stone, wood, brick, and clay tile, are cheap and appropriate, giving the building a unique character.

The main hall of Lankatilaka Temple, which combines Buddhist temples and Hindu temples, ranges from the thick and heavy brick arch structure of Sikhara, a typical form of the Buddhist temple in the Polonnaruwa period, to being covered with triple light tile roofs. A few kilometers away, the Gadaladeniya Temple is more influenced by Buddhism. The Pseudo stupas formed by five Buddha niches and towers are also covered with a double-pitched Kandy-style flat tile roof and supported by Portuguese Tuscan [1].

At the beginning of the 16th century, the Portuguese built forts in Colombo, the Dutch brought spacious stoep and courtyard-centered room organization (**Figure 1**), and the English kept the British Empire style in public buildings and maintained the tradition of villa design around gardens (**Figure 2**). The arrival of the invaders brought more Western classical and neo-classical architectural styles, and further fused them with the local traditional architecture.

The new Sri Lankan middle class chose to live in a smaller and more eclectic house than the houses of their colonial rulers, called "floral panel," which is a localized expression of a decorated bungalow type with stoeps.

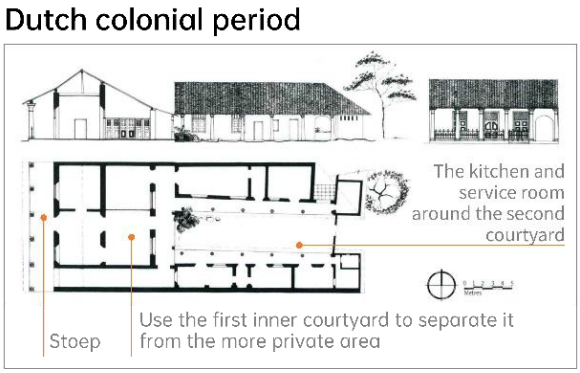

Figure 1. Plan of a typical Dutch house in Galle, redrawn by the author

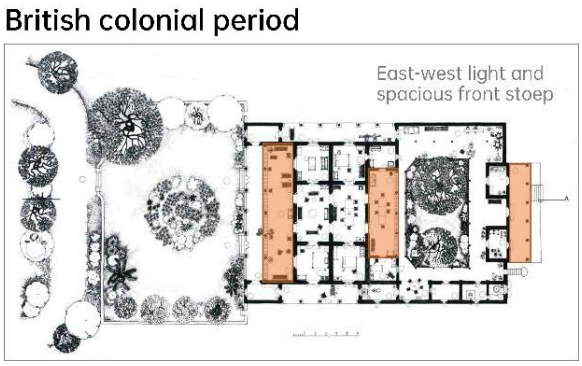

Figure 2. Plan of the main residence of Okanagoda Manor, 1992, redrawn by the author

3. Ena de Silva House

As Bawa says, "Architecture cannot be fully explained, it must be experienced." The refined design that pays attention to the scale of the body and the versatile spatial experience also contribute to the unique delicacy of Bawa's works. One of Bawa's early contemporary vernacular masterpieces, the Ena de Silva House is a rebellion against the established colonial style and a throwback to the traditional Kandy style of housing. 30 pecs (750 m²) of limited land and the owner's cherished family traditions combine to create an inward-looking architectural space, rather than an English-style villa with courtyards surrounding the building.

3.1. The courtyard: a private division and roaming experience

As an urban residence, privacy is enhanced as the space progresses from the street level to the interior of the building. The two-fold inner and outer street-level loggias progressively delineate the boundaries of the

residence while echoing to some extent the memory of the corridor of the early Dutch-style residence. The horizontal inner corridor space is strictly limited by the western wall of the first building and is only connected in front of the narrow entrance and garage. The space shrinks sharply and then opens up to a series of living scenes around a central courtyard (**Figure 3**).

In contrast to the small windows and walls of the guest room and the workshop, the living and dining spaces emphasize shared family communication and east-west penetration. The long and narrow eastern courtyard further shrinks the space, eventually leading to the memorial site of the sanctuary.

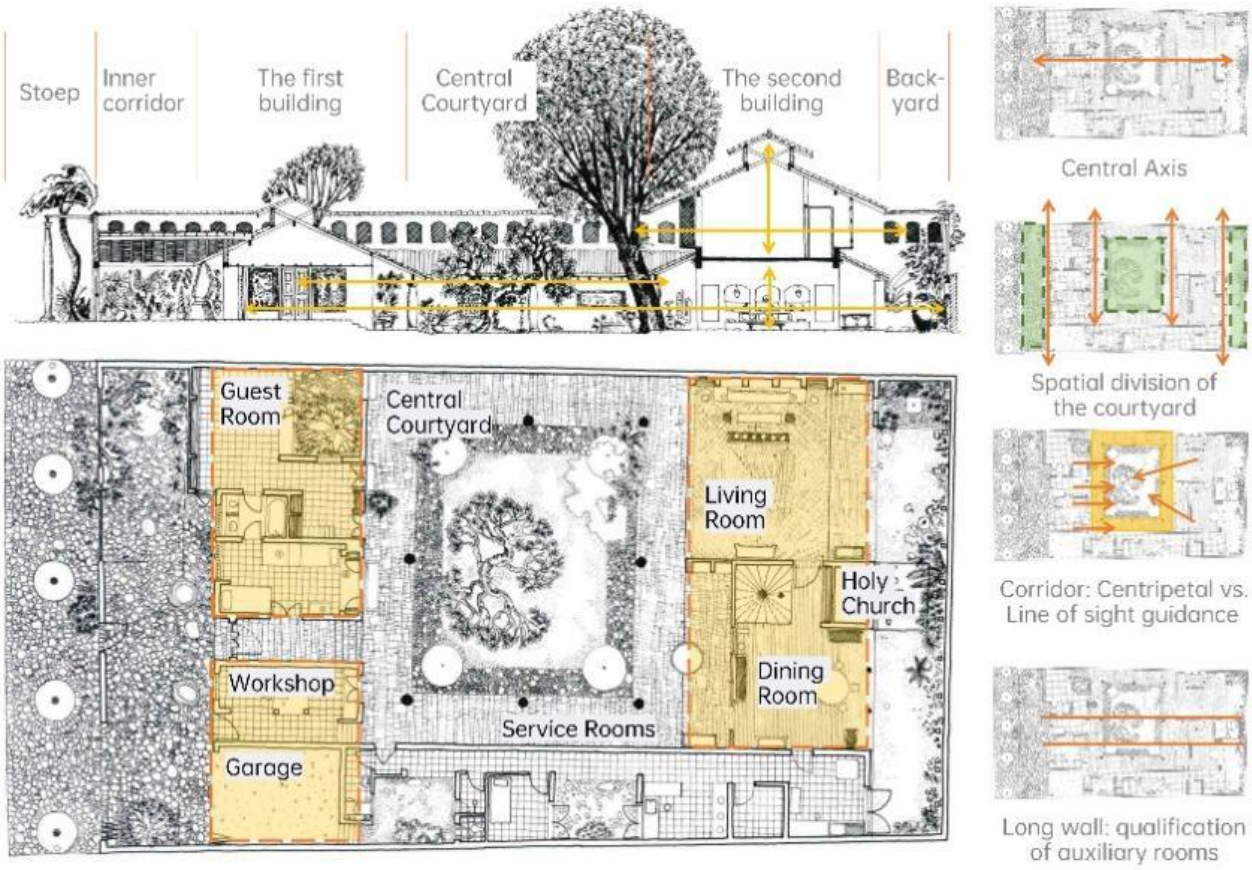

Figure 3. Section and plan of Ena de Silva House, redrawn by the author

3.2. Wrap-around corridor and deep eaves: the horizontal quality of intermediary space

In the central garden space, which is enclosed from north to south, the twisted eggplant trees are divided into separate fragments by different windows, and the trees are the undisputed visual focal point of the courtyard. Such a fragmented visual experience comes mainly from the suppression of the far-reaching gables. The heavy shadows above the deep gables almost violently enclose and cut off the outdoor landscape [2]. This treatment almost forces the people in them to sit or lie down to obtain a low viewpoint appropriate to the framed view of the courtyard.

The depressed beam treatment on the first floor of the main hall implies the perception of space on the second floor, and the bedroom space on the second floor also creates a loftier space through the erection of ventilation skylights; while the horizontal orientation of the very low sight lines forces the horizontal extension, making the limited space appear more profound and wide [3]. Although this type of sloped roof treatment was criticized by the international modernists of the time, Bawa had to admit that the sloped roof was the best strategy to adapt to the tropical climate and it gradually became one of Bawa's architectural languages. "The roof is an ever-present element, protective, prominent, and paramount, in charge of beauty

at any time and in any place" [1].

4. Critical regionalism and the exploration of Chinese architecture

Like Sri Lanka, the stylistic evolution of modern Chinese architecture was influenced by the colonial invasion of the world powers, and in the 1850s, in the face of the developing wave of modernism in the world, Chinese architectural creation was caught in the dichotomy of national form and modernism. A group of architecture scholars who returned from their studies and some foreign architects began to practice modernism on the Chinese ground, which inspired the domestic architects to reflect on the "traditional revival" movement.

The traditional revival can be broadly divided into three models: the "palace style," which is a complete imitation of antiquity; the "hybrid style," which is an eclectic approach; and the forms that highlight traditional decorative symbols [4]. Chinese architects tried to find a new path from traditional architecture to resist the flood of modernism and to continue the spirit of Chinese architecture, but the exploration always remained at the superficial level of decorative symbolism and failed to reach the spiritual level of traditional Chinese architecture.

In the 1920s, in his book *Sticks and Stones, American Architecture and Civilization*, Mumford reconstructed the concept of "regionalism" and for the first time systematically reflected on regionalism itself. Mumford went beyond the previous conflict between regionalism and globalized modernism and tried to explore the universal characteristics of regional culture under the influence of external forces on specific regions, thus eliminating the opposition between local and globalization.

The architects of Guangzhou in the 1950s practiced functionalism based on the characteristics of the subtropical regional climate [5]. They used modernism to oppose formal national styles, while at the same time modifying "international" modernism by adapting it to regional conditions. To a certain extent, these practices break away from the limitations of the decorative doctrine and are discussed from the generation logic of regional architecture.

In the 1970s, Mr. Ge Ruliang undertook a national project on "architecture and nature" and carried out a series of architectural practices in landscape areas based on the regional characteristics of the Jiangnan region. Under the framework of modernism, Mr. Ge Ruliang accomplished the architectural expression of traditional expressions such as transitions and counterpoints, the subtle interpretation of garden space, and the delicate continuation of traditional construction techniques. It can be said that Mr. Ge Ruliang, as a pioneer, broke through the limitations of China's early regionalism exploration.

5. Xixi Villa

Xixi Villa is located in Jiande City, Zhejiang Province, amid Lingqi Shengjing, which has a subtropical north-edge monsoon climate. Xixi Villa, a service building of the oriented Qingfeng Cave, is also named after the cool summer breeze of Qingfeng Cave, which is pronounced Xixi in Mandarin. The overall base is high in the north and low in the south, and the cave entrance is reached gradually by picking up steps.

5.1. Turning path: the transition of light and privacy

The short flow line from the gate of the lodge to the entrance of the cave goes through seven twists and turns. It also completes the open outdoor space of the nature trail to the semi-indoor intermediary space, and then to the fully indoor space of the artificial courtyard and indoor cave [6] (**Figure 4**).

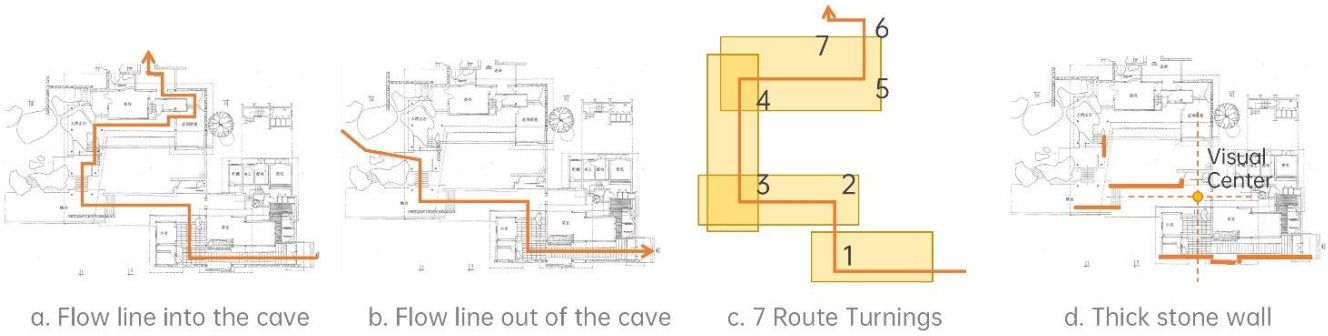

Figure 4. Schematic diagram of the 7 Route Turnings of Xixi Villa

Before the first turn, the entrance corridor is guided by a small scale of implication. The short corridor of ten meters is selectively shaded by the roof to create a three-stage vertical light space of "light-dark-light," and the slight outward thrust of the stone wall on the south side also allows light to penetrate through it, giving a richer creation in the horizontal direction (**Figure 5**).

Figure 5. Spatial changes before the first turning point

5.2. Towards the end: beyond linear guidance

In the next six transitions (**Figure 4**), the winding path is accompanied by nodes, large or small, and mostly attached to a single path itself without leading to the next space, or we call it the "end" space. In such a sequence, the viewer is located at a specific point of view above a path that leads to the site being viewed, as the viewer moves, the scene constantly changes, bringing with it the effect of a subjective reorganization of specific scenes.

These "end" spaces either point to rest, lead to a view, or simply show the opening and closing of space. But they all point to the same act: to stay. The viewer switches between different scenes, with no clear sequence or correlation between scenes. On this basis, the experience is fragmented, ultimately reaching the disorienting experience unique to Chinese gardens (**Figure 6**).

During the recent public transformation of Liuyuan Garden, the Wufeng Xianguan experienced a transformation from a nested space to open and large space as the residential function shifted to a landscape function. The original small-scale room group also constitutes many end spaces on the path side, even similar to the existence of a secret room. Compared with the spirit of place in Western gardens, a self-positioning based on the composition of the objective environment, Chinese gardens do not require the audience to be clear about their own coordinates, nor stay in the appreciation of the scenery itself, but try to find a cultural identity and natural resonance that mobilize all senses, a self-seeking introspection.

In such a path, the arrival of A→B becomes a secondary purpose instead, and staying at different nodes is the self-pleasure of leisurely strolling in the traditional living space, and the more pleasant scale brought by the small-scale space [7]. With the transformation of scenic publicness, the Five Peaks Pavilion

becomes a pause in the path and a counterpart of the large outdoor courtyard, but the mere crossing in the path makes the Five Peaks Pavilion lose its original private and centripetal hierarchy.

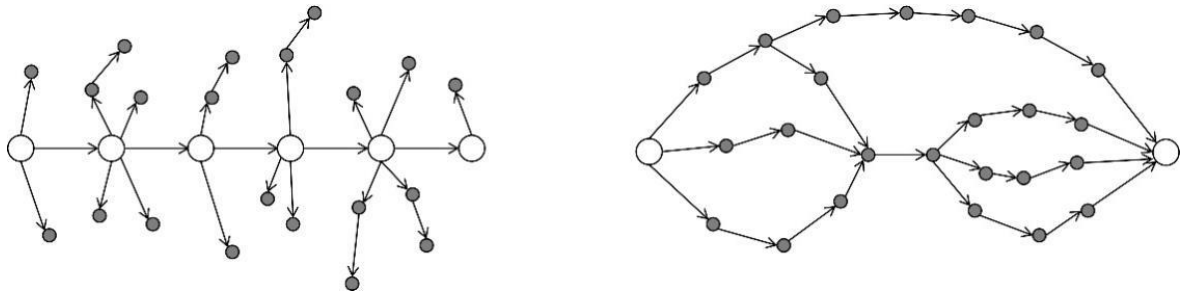

Figure 6. Narrative spatial pattern (left, vector tree; right, flow chart) [7]

The transformation of the spatial form structure also brings about a division of narrative patterns. The partitions and hoods in the garden block the visual corridor, but at the same time reduce the visual perception and lead people to a more multidimensional experience of nature. The space does not exist for the sake of practical function alone, but its spirituality becomes a more important factor. At a time when the Western spatial theory of "architectural walk" is dominant, this spatial structure of "uselessness" and "exhaustion" highlights the regional characteristics.

6. Summary

It is undeniable that both Bawa's and Ge Ruliang's works deeply reflect the control of light, visual guidance, and subtle spatial qualities in the Asian context. However, we can still experience Bawa's stronger modern spatial qualities and westernized view of the garden, as well as his realistic vision and objective representation of the site.

The presence of the central courtyard of Ena de Silva House clearly defines the place of the space, allowing all activities to happen here, under the wrap-around corridor, inducing one to roam, and allowing a clear and gradual transition between interior and exterior. The open courtyard and the airy living and dining space are ordered in pairs, partially dissolving the change of privacy in this space.

For the Chinese space represented by the Xixi Villa, the path of walking is subjected to an almost irrational zigzagging treatment. The viewer is immersed in the paths of nature, as an embellishment in the environment. In the transformation of viewpoints and coordinates, one after another unrelated scenes are transformed in front of the viewer's eyes, breaking away from the linearity of continuity. The purpose is not to lead to a specific window, but to let nature flow in between, where the visual is the medium but the purpose is to look within. The garden is no longer a clearly defined open space, but permeates every end space, interlacing and diffusing.

The main garden, the side garden, and the corridor have a similar spatial relationship explaining the different design intentions. The similarity and differences, the different colors, and such qualities show the unique charm of regionalism, and this is the fundamental point that should not be forgotten, no matter how regionalism and modernism merge and coexist.

Disclosure statement

The author declares no conflict of interest.

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Research on Highway Traffic Safety and Facility Optimization

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Abstract: Traffic safety is one of the problems that need to be addressed in the construction and development of expressway. The key content of the design of traffic safety facilities is optimizing traffic safety facilities to reduce the probability of traffic safety accidents. Based on the analysis of highway safety facilities design optimization requirements, this paper puts forward the corresponding optimization measures, and explores the innovation of safety facilities design, in hopes of providing reference for the design of highway safety facilities.

Keywords: Expressway; Traffic safety; Safety facilities optimization; Innovative design

Online publication: December 21, 2022

1. Introduction

Expressway is a bridge leading to the modernization of a country and the only way to develop modern transportation [1]. The construction of highway of our country has developed rapidly after the reform and liberation. In 1988, the first expressway was opened to traffic — Shanghai to Jiading Expressway. None of the highways in our country is historical. In order to rapidly develop our highway business and promote economic progress, the Ministry of Communications formulated the plan of "five vertical and seven horizontal" national highway main line in 1992, which laid a solid foundation for the rapid and healthy development of our highways. Now, this plan has been realized, highways have been formed from single lanes, and rapidly developed into a highway network.

In reality, the highway is not only an important way for people to travel, but also an important channel connecting various economies and promoting the social economic circulation, which means that it plays an important role in the economic development of our country. Therefore, it is very important to pay attention to highway traffic safety and optimize the design of safety facilities, which not only ensures the safety of people and property while travelling, but also brings favorable influence on the national economic circulation and development. At present, there are still problems in the design of highway safety facilities, optimizing the safety facilities, and mainly highway construction and management.

2. Optimization demand of highway safety facilities design

With the continuous progress of infrastructure construction, the highway construction develops rapidly. However, accidents happen frequently in the process of construction and development. The reason of its occurrence is because of some subjective and objective factors. The main aspect is that the traffic safety facilities of our highways are still flawed. In order to ensure traffic safety and improve transport efficiency, it is imperative to optimize the design of traffic safety infrastructure. In the optimization design of highway

safety facilities, the main focus is to provide a safe travel journey for motorists. This is mainly reflected in the traffic information, road environment, direction guidance, and full-time guarantee.

2.1. Traffic information needs

The three main traffic information needed by motorists are proper sight distance, reasonable line marking, and less interference. Sight distance refers to the distance required by motorists to avoid obstacles on the road surface and take emergency measures such as braking and overtaking. Improper sight distance will lead to misunderstanding of traffic information, leading to emotional anxiety and other problems, thus increasing the unsafe factors; Reasonable traffic signs and lines are one of the main auxiliary means for motorists to drive safely. Reasonable traffic signs and lines can help road participants to identify routes and enhance safety awareness. In the design of traffic signs and lines, the principle of visibility and legibility should be observed to ensure that these traffic signs and lines can be obtained and recognized under any circumstances. Any form of distraction should be eliminated to reduce interference information for motorists. For example, placement of other objects that are not traffic signs, such as billboards on highway should be avoided.

2.2. Road environment requirements

Visual induction, stress relief, and anti-glare are the main requirements for the road environment. Visual induction is divided into line-of-sight induction and road direction guidance, which can help motorists focus while driving. Driving for a long time will lead to fatigue and reduce of consciousness of drivers, and a good road environment and abundant road elements can avoid a monotonous driving environment, thus help in reducing fatigue. When driving at night, the interference of lights from oncoming vehicles will affect the vision of motorists, resulting in sight loss and blinding phenomenon, which easily lead to the occurrence of traffic accidents. Hence, it is a good practice to plant trees or install anti-glare materials along the road.

2.3. Active guidance and full-time support

Active guidance means providing appropriate guidance for the interaction between road participants and the road. When the vision of motorist changes due to the change of road direction, active guidance can enable road participants to obtain specific driving information from the road environment and ensure the smoothness of vehicle driving. In addition to active guidance, passive protection measures are also important to ensure safety, such as guardrails. Full-time support means that under any circumstances, no matter day or night, rain or snow, the highway needs to be safe for motorists.

3. Design of basic traffic safety facilities of expressway

It is necessary to design scientific and reasonable traffic safety facilities on the basis of meeting the basic travel safety needs of motorists, which includes following aspects.

3.1. Traffic sign design

Traffic signs are mainly installed on both sides of or above expressways in the form of graphics, symbols, numbers, and words to provide detailed and specific guidance for motorists [2]. By installing traffic signs containing various information, motorists can be provided with the specific location information, and the distance to the destination can be clearly defined, which greatly enhances the quality and efficiency of the highway [3]. In addition, warning in traffic signs can remind road participants to drive safely, enhance driving safety awareness, and achieve the purpose of improving highway driving safety and smoothness. Therefore, the size of road signs need to be reasonable according the situation of the road. Firstly, ensure

that the signs are clearly readable. Besides, the signs should be installed properly to avoid safety risks caused by improper installation. Therefore, the design of traffic signs should have a clear and concise layout, so as to facilitate the acquisition and understanding of motorists. Secondly, traffic signs should be placed in appropriate locations, which should be visible, but also cannot affect the basic driving safety.

3.2. Traffic marking design

Traffic line marking refers to all kinds of lines, guiding arrows, words, and other lines on the highway road with different roles. According to different roles and functions, traffic markings can be divided into indicators, prohibition, and warning markings [4]. The concrete forms of traffic line marking include dotted lines, solid lines, symbols, signpost, and many more, which main function is to enhance the effectiveness of highway safety facilities. In terms of traffic line marking, the driving lane is usually marked with dotted lines, the edge of the driving lane and the left side of the emergency lane are marked with solid lines, and white parallel thick solid lines are marked so that the driver can estimate the distance between the driver and the vehicle in front and so on. In addition, in order to provide clear driving directions to motorists, a number of arrow-shaped traffic markers are drawn. These markers will be placed permanently in front of the ramp exit, and corresponding text signs will indicate where the exit is leading to. In addition, there are some special markers, such as protruding road signs and reflective road signs, which helps in improving the safety of highway driving.

3.3. Safety guardrail design

Safety guardrail is the most basic and important traffic safety facilities of highway, which can provide a safe refuge area for drivers and passengers when traffic accidents occur. When the vehicle is out of control, collide with another vehicle or object, or rollover, the friction between the guardrail and the vehicle rapidly stabilizes the vehicle, avoid the progression of the accident, so as to prevent injury. The design of the guardrail should be based on the direction of the highway, location, structure, and other conditions, not only to ensure the comfort of the vehicle, but also acts as a protective measure. In addition, in order to allow the vehicle to return to a functioning state after a collision, the buffer capacity guardrail should be emphasized, so as to reduce the damage of vehicle collision.

3.4. Main design points of isolation facilities

In terms of highway isolation, corresponding isolation facilities must be set up to prevent pedestrians or animals from entering highway, thus threatening the safety of driving. Generally speaking, highway isolation facilities are mainly set up on both sides of the roadbed and around the service area. In the specific design of isolation facilities, there are mainly several types of isolation facilities, such as metal mesh, steel mesh, barbed wire, and evergreen hedge [5]. Metal mesh and steel mesh are generally set in some scenic spots and crowd gathering areas. The main consideration is the integration and aesthetics of isolation facilities and environment. However, these two kinds of isolation facilities have high cost and are not suitable for widespread promotion and application. The iron gill net is generally set in the unfrequented areas such as mountain areas and unpopulated areas. This isolation facility is cheap and has good isolation effect. It can effectively isolate wild animals and avoid traffic accidents caused by wild animals entering the highway.

In order to improve the safety and protection effect of isolation facilities, the following three aspects can also be considered. First, it is necessary to make reasonable design according to local conditions in different regions to ensure the practicability of isolation facilities. Second, the destruction of isolation facilities by force majeure should be considered, such as typhoon, mountain debris flow, wild animals bite, microbial corrosion, and so on. These factors can have a devastating impact on the performance and

longevity of the isolation facilities. Thirdly, the starting point and ending point of isolation facilities should be reasonably designed according to the construction characteristics of expressways, so as to improve the scientificity and effectiveness of isolation facilities.

3.5. Anti-glare facilities design

Anti-glare facilities are designed to prevent motorists from having accidents due to dizziness at night and improve the safety of driving at night. In reality, many vehicles do not used a standardized high beam while driving at night, which will bring adverse effects to the direction of the vehicle, causing motorists to deflect from their intended direction, bringing great night driving safety risks. The design of anti-glare facilities can improve the road environment at night, reduce the probability of dizziness, thus reducing the safety risks of driving at night [6]. There are usually two ways in designing anti-glare facilities: first, trees are planted in the middle of the road to achieve the effect of blocking lights, so as to achieve the effect of anti-glare. In the selection of trees, evergreen shrubs with heights of 1.2-1.5 m are generally selected. Second, an anti-glare board is set in the middle line of the road, which has a more significant effect. In the design of an anti-glare board, comprehensive consideration should be given to the spacing, height, width, and thickness of the anti-glare board. In addition, attention should be paid to the anti-fatigue function of the anti-glare board to avoid the visual fatigue of road participants caused by the monotonous color of the anti-glare board [7], thus leading to accidents.

4. Innovative design of highway safety facilities

With the continuous development of highway construction, more and more safety problems and challenges arise, so it is necessary to carry out a series of innovative design on the basis of traditional highway safety facilities design, to provide more security for the highway traffic.

4.1. Innovative design of traffic signs and lines

4.1.1. Set the axle load limit mark

In the innovative design of traffic signs, in addition to the conventional signs such as directions, speed limits and warnings, relevant bans can also be designed specifically, such as actively setting axle load limit signs (both in Chinese and English) [8]. For example, in the construction of the Xicheng Expressway, while laying basic signs such as minimum/maximum speed limit and tourist zone, the corresponding design and signs were also carried out in terms of axle load limit signs, and signs in both Chinese and English were used.

4.1.2. Adjusting speed limit signs

The original single-column speed limit signs can be adjusted, and the speed limit signs of different models can be redesigned into a double-column sign. For the existing double-column logo with good foundation and column condition, the logo layout can also be updated [9]. For the highway ramp, it is appropriate to choose a step by step deceleration speed limit sign, and pay attention to the ramp speed limit sign added in the deceleration lane gradual end of the starting point, if the structure is based on a single column, we should ensure that there is a 2 m gap between the lower edge of the sign board and the road, and the use of Class IV signboard reflective film.

4.1.3. Adjustment of driving signs on passenger and cargo sections

Passenger and cargo lane separation signs mainly include lane separation notice, the release of lane separation, and other contents. In the innovative design of safety facilities in the passenger and cargo sections, a single cantilever support structure can be used, with Class IV reflective film. In the specific

setting, if the road has a steep slope and the road length is more than 300 m, the passenger and cargo crossing signs should be set in the uphill section, which can well enhance the smoothness of the uphill section of traffic, reduce the probability of passenger and freight accidents due to high speed.

4.2. Innovative design of guardrail

4.2.1. Waveform beam guardrail design

The optimization of the anti-collision grade of the guardrail on both sides of the road is key to improving the safety facilities of the sections with high accident incidence, which should be strengthened on the basis of the original guardrail. Besides, guardrails with waveform beam can be added. The new guardrail should be manufactured in accordance with the SA specifications [10]. The installation spacing of the guardrail columns should be 4 m, and the new guardrail should be staggered with the original guardrail [11].

4.2.2. Design of concrete guardrail

Traffic accidents are very likely to occur at the entrance of expressway tunnels due to the influence of light and shade changes and road width changes. In view of this, the original guardrails can be replaced with F-type concrete guardrails. F-type concrete guardrails of guardrail has a high crash-avoidance rate and extends to both sides of the road of the entrance wall in the form of a parabola, which can fully meet the needs of the tunnel boundary [12]. Concrete guardrail should be designed with a steel protective layer which is 4 cm thick; C30 plain concrete is suitable for the new guardrail and tunnel limit access road.

4.3. Innovative design of other safety facilities

In the process of innovative design of safety facilities for expressway speeding sections, tunnel facade signs, contour signs, and other safety facility signs should be improved [13]. Taking the facade marking of expressway tunnel entrance/exit as an example, the line-of-sight induction is an important aspect in the innovative design. In order to improve the visual induction effect of the speeding section, red and white reflective film can be posted on the facade of the waveform guardrail in the way of up and down distribution. The lower edge of the reflective film should be 10 cm from the ground. During the posting process, the space between the reflective film and the road along the tunnel should be 8m, and the direction of the reflective film should be perpendicular to the line of sight of the driver.

5. Conclusion

In short, in the process of highway traffic safety facilities design, we should consider the motorists traffic safety needs, ensure the comprehensive setting of traffic signs and guardrail safety facilities, and the existing facilities for system optimization and improvement to ensure highway traffic safety and prevent accidents.

Disclosure statement

The author declares no conflict of interest.

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Construction Management and Installation Quality Control Strategy of Steel Bridges

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Abstract: At present, China's bridges are mostly made of concrete, which contain a large amount of cement, sand and gravel and other materials, which can easily cause environmental pollution. At the same time, China's total steel production continues to rank first in the world. The construction and development of steel bridges have sufficient basic support. At the same time, steel is more environmental-friendly than concrete, with higher strength, lower weight, and can reduce construction waste significantly, so the development of steel bridges has been on the rise. To optimize the application effect of steel structure bridges, it is necessary to analyze the construction management and installation quality control strategies of steel bridges for reference.

Keywords: Steel bridge; Construction management; Installation quality; Control strategy

Online publication: December 21, 2022

1. Introduction

Under the background of the increasing demand for transportation in China and the continuous improvement of the speed of transportation, bridge construction has received much attention, and steel structure bridges have gradually dominated the construction of long-span bridges. Compared to traditional concrete bridges, steel structure bridges are more environmental-friendly and structurally stable. At the same time, they can realize industrial production, have a short construction period, not prone to traffic jams, and can withstand large spans and loads [1]. However, in the construction of steel bridges is not managed and controlled properly, it may cause serious safety hazards and even cause accidents. Therefore, it is necessary to deeply analyze the construction management measures and installation quality control strategy of steel structure bridge.

2. Status of steel structure bridge construction

Steel bridges have been around for more than 200 years, and the application of steel bridges in China has also exceeded 100 years. In these years, the number and scale of steel structure bridges in China have continued to develop. The truss structure is currently a mixture of various forms, such as long-span suspension bridges or cable-stayed bridges with a length of more than 500 meters, in which steel box girders are mainly used as the main girder. Overall, steel structure bridges have good structural performance, low cost, short construction period, and high overall strength. However, the level of construction technology will affect the overall quality of the bridge. There is still an imperfect management system, incomplete implementation of management measures and insufficient quality control in the construction of steel structure bridge in our country, affecting the construction process, and the quality of installation. At the

same time, the use of steel structure bridges in China also has the phenomenon of reduced application rate and insufficient promotion, which cannot fully match the rapid development of the steel industry in China. Therefore, the related work of steel bridges and steel-concrete bridges still needs to be fully optimized, so as to improve the application frequency and the quality of steel bridges.

3. Construction management of steel structure bridges

(1) On- site management

The construction of steel structure bridges is easily affected by the surrounding environment, and many technologies and departments are involved in the construction process, so it is more complex than the construction of ordinary concrete bridges. Therefore, it is necessary to optimize the management of the construction environment and to ensure adequate preparation. First, the advantages and characteristics of the project should be fully understood, an appropriate construction method should be used, advanced construction technology should be applied accordingly, and all equipment needed should be readily available. Besides, it is necessary to carry out on-site survey work in advance, clarify the project plan, and formulate a traffic diversion plan to avoid situations like traffic jams. If the construction site is in a mountainous area or in the outer suburbs, attention should be paid to setting up environmental protection workers to avoid damaging the ecological environment or occupying the farming areas. At the same time, the quality of construction materials should be strictly controlled, because the amount of prefabrication of steel structure bridges is relatively large, and the degree of prefabrication is relatively high, and the quality of materials and accessories will significantly affect the service life and safety of bridges. Therefore, the construction party should conduct strict qualification review for material suppliers, and the staff involved in the procurement must complete real-name registration to ensure that the performance, quantity, specification, and appearance of the materials are up to the required standards, with certificates of qualification and relevant proof [2]. In addition, it is also necessary to predict possible emergencies and safety risks based on on-site survey results and various objective factors and propose reasonable prevention and treatment measures to ensure that the construction site environment can meet the construction needs, which allow better preparatory work [3].

(2) Progress management

Before construction, the construction progress plan should be formulated according to the overall construction period objectives and site construction conditions. Moreover, organizational, technical, and quality assurance measures should be carefully formulated. During the construction process, the construction progress should be strictly controlled, and the work should be carried out step by step according to the construction plan. After each process is completed, the staff should first conduct a self-inspection, and then the quality inspection personnel will conduct an in-depth inspection. If there are deficiencies, it should be rectified in a timely manner to ensure high quality construction. During the entire construction process, the inspection work must not be neglected just to keep up with the construction progress, so as to avoid needing huge rework, which will prolong the construction period [4].

(3) Technology management

Steel bridges are complex, thus the construction organization design and technical plan should be fully discussed and formulated before construction to ensure that the plan is reasonable and feasible. In particular, the installation of steel structure bridges is difficult, and the technical requirements are relatively high. If the construction work is not carried out in accordance to the regulations, the overall structure may be affected, which will lead to the construction quality not meeting the relevant standards. Therefore, when lifting the steel structure, not only should the quality of lifting components meet the relevant regulations, but the lifting method should also be adapted to the steel structure. Hence, it is

necessary for the staff to fully analyze the weight distribution and actual shape of the components, reasonably select the lifting method according to the hoisting equipment that can be applied on the construction site, and accurately control the lifting position and speed, and gradually complete the hoisting of the steel structure [5].

(4) Installation management

The installation effect of the steel structure base frame of the bridge should be guaranteed. The size of the foundation stone of the top support of the bridge pier needs to be compatible with the size of the backing plate, the elevation and plane position needs to comply with relevant regulations, and the horizontal deviation between the horizontal and vertical planes should be within 2 mm. The centerline of the girder on the top of the pier and the centerline of the support can be in a state of complete coincidence, and the offset error must be controlled below 2 mm [6]. At the same time, the steel structure base frame should be built in an all-round way. It is necessary to carefully inspect the steel plate unit and all parts in all aspects to confirm that they are up to standard, only then can the parts be welded. When welding the bottom plate unit, two or more base plate units are welded into a complete base plate according to the actual situation of the base frame, and then placed on the steel base frame and welded on the base frame. The welding operating procedures should be strictly followed to improve the installation quality [7].

(5) Personnel management

Construction personnel is the key to a construction process, and their professional skill level and comprehensive quality greatly affects the end product. Therefore, in personnel management, we should focus on improving their skill level and comprehensive quality. Skill trainings and education should be regularly provided to promote the continuous improvement of their professional skills and safety awareness. Especially when it comes to highly professional construction operations, it is required that the staff is officially certified to perform the required job. During the construction process, all staff should be well-behaved, and violations of regulations must be strictly prohibited to ensure the safety of the construction site [8]. At the same time, the installation of steel structure bridges requires modularization and high efficiency, which requires the coordination of multiple departments. To ensure that construction operations can be carried out in an orderly manner, especially for operations with high risks, a strict accountability system must be established to ensure their safety as much as possible. In this way, adverse situations can be dealt with effectively in a timely manner, and relevant responsible persons can be identified in time [9].

4. Quality control measures for steel structure bridge installation

The preparation stage, construction stage, and subsequent evaluation and acceptance stage of steel bridge installation all can affect overall quality of the steel bridge. Moreover, the high-altitude construction work included in the installation is more difficult and dangerous, which requires stricter quality control. Therefore, each stage contains key points of quality control, so it is necessary to carry out the discussion in stages:

(1) Preparation stage before installation

A comprehensive inspection should be carried out before installing the steel structure to ensure that the processing quality meets the relevant requirements. Therefore, in the early stage, the construction of the components should strictly adhere to the design drawings to ensure that parameters like the size, thickness, weight, and other aspects of the steel structure meet the design standards. During the construction of the structure, the components should also be measured regularly. Any deficiencies discovered should be rectified in time to provide a good basis for subsequent installation operations [10].

(2) Installation and construction stage

After the construction of the concrete pier columns, evaluation and acceptance should be carried out first, followed by the installation stage. However, if there are unqualified concrete pier columns, reasonable solutions should be designed according to the elevation, position, plane size and other aspects of the pier column foundation, so as to improve the quality of bridge construction [11].

During the installation of the steel structure, the correct installation sequence should be strictly followed. During the construction process, various operations such as arc striking, knocking, and welding must not cause damage or deformation to the beam body, so as to avoid affecting the overall stability of the beam body later. The overall stability of the body is affected by the installation of the steel structure, and based on the actual situation, the pre-camber is adjusted reasonably to ensure the safety of the overall structure [12]. Especially when piercing, because the connecting steel structure needs to be drilled on both sides, it is more likely to affect the stability of the beam body, so the control should be increased, and the use of flame reaming is strictly prohibited to avoid damage to the steel. Before installing components and steel plate units, a comprehensive inspection should be carried out before they can be built on the base frame. At the same time, appropriate welding technology should be applied, and then the welding effect should be checked to make sure that it meets the relevant standards before the next step is carried out. If it does not meet the relevant standards, it should be reworked in time. In addition, the steel should be kept in a completely clean and dry state throughout the process to reduce the possibility of rusting [13].

(3) High-altitude construction

High-altitude construction process is highly dangerous, so before entering the high-altitude construction stage, education and training must be given to the construction personnel to increase their safety awareness. Besides, before starting work, they must wear safety clothing in full compliance with relevant regulations, non-slip shoes and fasten their seat belts. Moreover, the staff should also comprehensively inspect high-altitude construction machinery and equipment and ensure that they are continuously in a safe operation state, so as to create a good working environment for high-altitude construction personnel. If bad weather occurs during high-altitude construction, the high-altitude work should be suspended, and the completed parts should be well-protected [14].

(4) Installation acceptance stage

Evaluation and acceptance should be done after the steel structure installation work is completed. During this process, the construction party needs to provide construction drawings, inspection reports, certificates of conformity, repair records, inspection records, and other materials to the acceptance party. This is to ensure that the steel bridge meet all the relevant regulations [15].

5. Conclusion

The construction of steel structure bridges is not only conducive to improving the overall quality and application effect of bridges, but also help drive the economic development. Therefore, it is necessary to strengthen construction management and quality control to ensure the safety and stability of steel structure bridges, so as to bring relevant economic, environmental, and social benefits through the construction of steel structure bridges.

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Common Problems and Maintenance Management of Highway Bridges

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Abstract: China is currently undergoing rapid urbanization, and highway and bridge construction projects are increasing in both quantity and scope. They are one of the important infrastructures in urban construction. The requirements for the construction of bridge engineering projects are relatively high, but due to the influence of various factors, problems are bound to occur, which affects the aesthetics and functionality of the bridge. Therefore, it is necessary to strengthen the analysis of common problems of highway bridges, understand the causes, and put forward corresponding countermeasures.

Keywords: Highway bridge; Disease; Maintenance management; Measures

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1. Introduction

In the process of socialist modernization, the construction urban infrastructure has been given much importance. Highway bridges are an important part of infrastructure, which directly affect people's daily travel and urban traffic. In recent years, the number and scale of highway bridges in China have been increasing, promoting economic and cultural exchanges between regions. At the same time, with the increase in vehicle ownership and the intensity of exchanges, the operating load of highway bridges has increased. This has caused issues in some highway bridges, which affect the operation safety and service life of the bridge. Therefore, it is necessary to come out with targeted solutions for these issues.

2. Necessity in addressing problems in highway bridge engineering

2.1. Improve the level of construction technology

There are many procedures and complex processes involved in the construction of highway and bridge projects, therefore needing a variety of construction techniques, and each construction method has to be in accordance to the requirements. The construction environment is relatively harsh; thus it is necessary to optimize the construction process based on the design drawings in advance. However, due to the complex geological environment of the construction site, the influence of climate, and other factors depending on the project, there will likely be deviations between the design drawings and the actual construction [1]. Hence, it is necessary for designers to utilize construction technology accordingly, improve the quality of highway bridge construction, and ensure the stability of highway bridge construction. This is because construction technology is the basis to ensure the smooth completion of construction projects. Suitable construction technology can be utilized to resolve construction problems and ensure the quality of the project.

2.2. Promote local economic growth

Highway bridges are an important part of urban infrastructure construction and urban development. Besides, it also play an important role in the construction and extension of China's highway network. Solving the problems of highway bridges can provide a basis for the smoothness of road traffic and promote the rapid development of local economy. From the analysis of the current situation of highway bridge engineering in our country, there are some deficiencies in some highway bridges. The limitations of local environment in some areas affects the exchange of foreign trade and restricts the development of local economy. Through the construction of highway bridges and rectifying the existing issues, the transportation network can be improved, which plays an important role in promoting the development of regional economy.

3. Common problems of highway bridges

3.1. Concrete cracks

From the analysis of common problems of highway bridges, concrete cracks are one of the most common problems and is most likely to cause damage to bridge structures. Therefore, it is necessary to focus on dealing with concrete cracks and strengthen the maintenance work in the later stage. When dealing with cracks in highway bridges, it is necessary to choose reasonable solution based on the causes. For example, some cracks are caused by the overloading, and some cracks are caused by the thermal expansion and contraction of concrete. Once cracks appear, the bridge structure will be prone to damage under the influence of external force. In addition, inappropriate material selection during the construction process will also cause cracks. In response to this situation, it is necessary to strengthen the monitoring of cracks and take reasonable solutions.

3.2. Bridge foundation settlement

Settlements may occur in the construction of highway bridges, and if the settlement degree is within the allowable range, it will not cause serious impacts. However, once the settlement exceeds the safe range, it will lead to potential safety hazards. Bridge settlement mainly occurs at the foundation position, especially gravity piers are most likely to cause settlement problems. Before the construction of highway bridges, calculation and evaluation will be carried out with the construction geological conditions and the bearing capacity of the foundation taken into account, and the construction plan will be designed on this basis [2]. If the calculation of foundation bearing is not accurate, it will inevitably affect the design effect of the construction scheme. In addition, subpar construction materials and disorganized construction process will also cause foundation settlement. The subsidence of the foundation will also cause cracks in the piers and abutments, and the force on the upper part of the bridge structure will be uneven, resulting in structural damage, affecting the safety of the bridge.

3.3. Damaged bridgehead

Bridgehead damage is one of the more common problems in highway bridge. It is mainly manifested in deformation and damage at the end of the bridge. If the damage is severe, the prestress of the beam-slab structure will be changed. The main reason for this situation is that the quality of the materials used in the beam-slab construction is poor, or the bridge body has been in overloaded operation for a long time. The damage of the bridgehead will significantly affect the load-bearing capacity of the bridge body. Therefore, once any damage of the bridgehead is detected, it is necessary to monitor the stability and load-bearing capacity of the bridge structure in time. If the damage is serious and cannot be repaired, it is easy to cause the bridge to collapse, causing serious accidents.

3.4. Corrosion of steel bars on highway bridges

The main body of the highway bridge is composed of reinforced concrete structure, which is also the main load-bearing structure of the bridge. If the steel bars of the bridge are corroded, the load-bearing capacity of the bridge will inevitably be reduced, causing the bridge to collapse thus lead to traffic accidents. The main reason for the corrosion of steel bars is that cracks appear in the concrete structure, and the cracks in the concrete are not repaired in time, causing external air, water, etc. to enter the interior of the concrete, and corrosion occurs after contact with the steel bars. At the same time, with the corrosion of the steel bars inside the concrete, the width of the concrete cracks will further widen, which will easily cause damage to the overall structure of the concrete.

3.5. Deck erosion

Surface erosion is also a relatively common problem in highway bridges, which mainly occurs on the supporting surface of bridges, including cap beams, abutments, and pier columns. It is manifested through defects such as honeycomb pitting or peeling on the surface (see **Figure 1**). There are many causes of surface erosion, including long-term water erosion and weathering. During the construction of highway bridges, if the construction unit fails to prevent and deal with the surface erosion problem in time, or neglect surface erosion in the later maintenance work, the stress area of the bridge support structure will be reduced under the influence of long-term erosion problems, affecting the load support of the bridge and cause problems such as the damage of the bearing position [3].

Figure 1. Denudation of the bridge surface

4. Solution and maintenance measures for highway bridge problems

4.1. Strengthen the prevention and control of crack problems

In the construction of highway bridges, under the influence of long-term high load and temperature, it is easy to cause cracks in the bridge body, which affects the operation quality and safety of the bridge body. Therefore, it is necessary to strengthen the maintenance and prevention of bridge defects [4]. Firstly, the loads of passing vehicles need to be controlled, put up maximum load bearing signs at both ends of the bridge, and ban overweight vehicles from crossing the bridge; secondly, highway bridge maintenance

departments need to regularly repair and construct the pavement of the bridge deck. The pavement layer is the direct force-bearing surface and pressure-bearing layer of the bridge body, thus it is necessary to emphasize on bridge maintenance. Even if the degree of damage is relatively small, it is necessary to deal with the cracks in time to prevent them from extending or thickening over time and causing serious damage. In addition, the treatment of cracks in highway bridges should be improved. When filling cracks, the debris in the cracks should first be removed thoroughly, and then fill in repair materials ensure proper bonding after crack treatment [5]. Finally, in the installation of contraction joints, it is necessary to ensure the stability of the expansion joint connection (see **Figure 2**) and improve the effect of resisting external impact. In addition, the construction unit needs to increase the strength of the expansion joints during construction to ensure that the expansion joints are consistent with the strength of the concrete and prevent concrete cracking caused by uneven bridge structures.

Figure 2. Bridge crack repair

4.2. Effective control of bridge foundation settlement

Among the road bridge problems, the damage caused by the settlement of the bridge foundation is relatively large, which will easily cause the bridge to collapse if not rectified in time. In bridge settlement reinforcement, the method of expanding foundation reinforcement can be adopted. This method is mainly applied when the foundation bearing capacity is insufficient or if the foundation is buried in a relatively shallow position, or if the rigidity of foundation is insufficient such as masonry. If the settlement of the structure is uneven and the soil structure of the foundation is relatively compact, this method can be used to reinforce the foundation. For foundation positions with insufficient foundation bearing capacity, pile foundations are driven in according to the bearing capacity of the foundation to increase the bearing capacity of the foundation. The parameters of pile driving need to be calculated according to the deformation of the foundation. The foundation reinforcement method is simple and convenient [6]. However, the cost of reinforcement is high to ensure the effective combination of the new and old foundations of the pile foundation and bear the load of the bridge body.

4.3. Ways to deal with bridgehead damage

High-strength concrete can be used to restore the position of the bridgehead. In the restoration process, epoxy resin is used as a curing agent to install bars on the bridge structure. During the construction, high-strength concrete needs to be added to improve the repair quality and ensure the stability of the bridge structure. Other than that, the construction personnel can fix the damaged position by binding the steel mesh on it, and at the same time using the curing agent to repair the damaged position. The curing agent is poured into the formwork, then the formwork is removed after solidification. During the restoration process, it is necessary to formulate a reasonable treatment plan based on the damage of the bridgehead, and make a technical disclosure before the construction starts, so as to ensure that the construction personnel can

thoroughly master the technical means and improve the restoration efficiency [7]. The strength of the concrete must be tested before the restoration starts to ensure that the performance of the concrete can meet the repair requirements before proceeding with construction, so as to avoid ineffective restoration of the bridgehead due to subpar concrete.

4.4. Steel bar corrosion solutions

Corrosion of steel bars is also one of the most significant problems in highway bridges. Therefore, suitable derusting measures needs to be carried out to effectively deal with the problem of steel bar corrosion, and then the cracks in the concrete need to be repaired to prevent further corrosion [8]. To treat steel bar corrosion, the surface of the rusty steel bar must first be sanded to remove the rust on the outside of the steel bar, and then the concrete cracks are repaired with epoxy resin mortar. The steel bar and the its surroundings should be isolated to prevent the air, water and other factors from coming into contact with the steel bar causing secondary corrosion, and to ensure the treatment efficiency of steel bar corrosion disease. In the corrosion treatment of steel bars, the construction unit needs to ensure the quality of epoxy resin mortar, reasonably control the proportion of filling materials, improve the bonding strength of epoxy resin, promote the recovery of the bearing capacity of engineering components, and ensure the construction treatment effect [9].

4.5. Surface erosion treatment

Although the surface erosion of highway bridges will not have much impact in the short term, if it is not controlled and treated in time, it will also cause problems in the overall quality of the bridge. In the surface erosion treatment, reinforced concrete reinforcement technology can be used to repair the eroded areas, so as to prevent the bearing capacity and service effect of the bridge from being affected [10]. In the reinforcement treatment, concrete of the same strength grade as the original construction needs to be used. After the concrete structure is completed, waterproof acrylic latex mortar with high cost performance is applied on the surface to isolate the concrete structure from the external environment and effectively prevent weathering, freeze-thaw and other factors from affecting the bridge structure [11]. If the surface erosion is serious and the steel bars are exposed, the construction unit needs derust the steel bars before using concrete for masonry. In the case of severe steel corrosion, it is necessary to repair the reinforced concrete structure first, and then take measures to improve the effect of construction technology [12].

5. Conclusion

In short, the emergence of highway bridge problems will affect the load capacity and service life of the bridge. If it cannot be maintained and strengthened in time, it will easily cause bridge safety problems. Therefore, it is necessary to analyze the common problems of highway bridges, understand the manifestations and causes of common diseases such as bridge cracks, foundation settlement, bridgehead damage, steel bar corrosion, and bridge deck erosion, and take effective reinforcement schemes based on this to improve highway bridges. In this way, the stability of bridge operation can be ensured.

Disclosure statement

The authors declare no conflict of interest.

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Application Strategy of NDT Technology in Tunnel Engineering Quality Inspection

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Abstract: Nondestructive testing (NDT) is an advanced and commonly used technique in tunnel engineering quality inspection. To achieve good application of nondestructive testing technology, its main application in tunnel engineering quality inspection strategy is analyzed, including the significance of applying nondestructive testing technology in tunnel engineering quality inspection, the main nondestructive testing technology applied in tunnel engineering quality test analysis, and the analysis of nondestructive testing technology of tunnel engineering quality inspection strategy. The analyses in this paper are done in hopes of providing scientific reference for the utilization of NDT technology and the improvement of tunnel engineering quality.

Keywords: Tunnel engineering; Nondestructive testing technology; Significance of application

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1. Introduction

To maximize the advantages of nondestructive testing technology (NDT) in the tunnel engineering quality inspection process, relevant units and technical personnel must be fully clear about this technology and the significance of applying it. At the same time, the main operation techniques should be sufficiently understood, and then reasonably apply the technology depending on the actual situation and type of project. In this way, NDT can be utilized appropriately, so as to lay a solid technical foundation for tunnel engineering quality testing.

2. NDT and its application in tunnel engineering quality testing

2.1. Overview of damage detection techniques

The purpose of NDT is to allow quality testing to be performed without changing the original state and properties of the sample [1]. In recent years, this detection technology has been widely used in many detection fields, such as aerospace, shipbuilding, customs, mechanical engineering, pressure vessels, tunnel engineering, and so on. Especially in tunnel engineering quality testing, NDT has received much attention due to its remarkable advantages [2].

2.2. The main application significance of NDT in tunnel engineering quality testing

The construction of tunnels can be affected by many factors, thus it is easy to have some problems in its structural quality. If these problems cannot be detected and resolved in time, they will not only affect the construction quality and safety of tunnel engineering, but will also pose many threats to the quality and safety of subsequent applications [3]. However, the process of quality inspection through traditional

detection technology will inevitably cause structural damage. The damages can be prevented by using NDT, and a scientific, comprehensive, and accurate testing of the engineering quality can be achieved without damaging the tunnel structure, so as to ensure the quality and safety of the tunnel engineering [4].

3. Analysis of main NDT techniques in tunnel engineering quality inspection

3.1. Ultrasonic springback detection technology

Ultrasonic springback testing is the most typical NDT in tunnel engineering quality testing. This technology can scientifically detect the strength of tunnel lining. Its working principle is to first use a rebound hammer to measure the strength of the concrete to obtain a rebound value R. The ultrasonic propagation time t is measured to calculate the ultrasonic velocity v in concrete. The rebound value R and the ultrasonic velocity value v are then used as the basis to convert the concrete strength value through the national unified strength curve or regional unified strength curve. The strength of the tunnel is then estimated with further mechanical tests.

3.2. Geological radar detection technology

Geological radar detection technology is also a very advanced NDT. Through this technology, the thickness of tunnel lining can be effectively determined. It works by transmitting electromagnetic waves through the transmitting antenna R, the waves will then be reflected into the receiving antenna R. With the help of geological radar reflection image, the reflection layer can be fully defined, and the double travel time t of its reflected wave can be measured. The detection formula is as follows:

$$z = \frac{\sqrt{t^2 v^2 - x^2}}{2}$$

where z stands for lining thickness, with the unit m; t represents the two-way travel time of the reflected wave, with the unit s; v represents the propagation speed of electromagnetic wave in the medium, with the unit m/s; and x represents the distance between the transmitting and receiving antennas, which is measured in m.

At the same time, the geological radar detection technology can also detect the tunnel lining structure. In axial detection, the right wall, left soffit, left wall, vault and right soffit measurement lines should first be arranged along the axial direction of the tunnel, and the measurements are then taken [5]. In transverse detection, it is necessary to lay a section line along the tunnel at intervals and then perform the detection. In the detection process, it is necessary to ensure that the transmitting antenna and receiving antenna are close to the tunnel lining surface so that readings can be obtained. The detection results can then be obtained after noise reduction, filtering, and equalization [6].

3.3. Infrared high temperature detection technology

Infrared high temperature detection technology is a common commonly used technology in tunnel engineering quality inspection. In this method, an infrared camera or scanner is mounted on a mobile carrier to measure lining defects, voids, and geological conditions in the tunnel. However, this technology requires a high temperature gradient, so it is best to use it under the condition of large temperature difference to ensure its detection accuracy [7].

4. Analysis on the application strategy of NDT technology in tunnel engineering quality inspection

Through the analysis above, it is clear that NDT has a very significant advantage in tunnel engineering quality inspection. In order to realize the utilization of NDT, this paper takes an actual construction quality

testing of a tunnel project as an example, and analyzes the application strategy of NDT in it. The following is the specific application of NDT in the tunnel project and.

4.1. Project overview

The total length of a tunnel is 1.275 km, most of which are Grade IV and Grade V surrounding rocks. The lining of part of the tunnel is a composite structure, and there are many safety risks on the project site. Based on this, the combination of shotcrete, system bolt, steel mesh, and section steel support is adopted in the tunnel construction to create a tunnel structural support system, so that the construction safety can be ensured. Subsequently, ultrasonic rebound testing technology and combined with geological radar detection technology was used in quality inspection. In this method, some completed sections of primary support and secondary lining were selected, and ground radar scanning was conducted to determine the thickness and detect any defects in the sampling locations. Then, the second lining of a mold was extracted, and the strength was checked by ultrasonic rebound method.

4.2. Primary support quality inspection

According to the actual characteristics of the primary support of the tunnel project, the main content of quality inspection includes three aspects: the first aspect was to detect the undercutting and overcutting in the middle of the initial support and surrounding rock; Secondly the layout and quantity of steel supports was tested [8]; Thirdly, the interference of surrounding rocks within the construction range was tested. Through geological radar scanning, three vertical strong reflection rays appeared in the detection area, which indicates that there is a cavity in the detection area. The region with the most significant distribution of reflection rays is in the annular depth of 21.5-23.5 cm, and the reflection of steel support appears at the position of 2.5 cm, indicating that there is a cavity here, and the degree of influence is relatively large. However, through the detection image of each ray position information, it is found that the reflection is relatively uniform, and the continuity of the same axis is relatively good. After further detection, it is found that the thickness of concrete injection in the initial support and the spacing of steel support are consistent with the design requirements [9].

The geological radar detection shows that there is a specific dividing line between the thickness of the initial support and the surrounding rock, but it is unclear. The reason for this situation is that each structure is complicated, and it is affected by many physical factors, thus causing irregular reflection of radar electromagnetic wave [10].

When calculating the thickness of concrete, it is necessary to define the radar electromagnetic wave transmission characteristics in the lining structure, and then calculate the thickness according to the following formula:

$$h = vt / 2$$

where, h represents the thickness of concrete, with the unit m; v represents the radar electromagnetic wave transmission speed in the lining structure, with the unit m/s. t represents the time difference between the reflected wave and the incident wave, and the unit is s.

Through testing and calculation, it is found that the primary support structure of the tunnel has under–digging phenomenon, and is partially jagged, and some areas showed sagging. All these problems will cause adverse effects on the strength and stability of the tunnel. In view of these problems, it is necessary deal with them using appropriate measures depending on their situations and locations. In this way, accidents during the tunnel construction and use can be effectively prevented, so as to achieve good control of tunnel engineering quality and safety [11].

4.3. Secondary lining quality inspection

The main contents of quality inspection of the secondary lining in this tunnel project includes the following aspects. Firstly, any defects on the secondary lining was detected; secondly, the thickness of the secondary lining was determined. Next, the degree of water seepage in the secondary lining was determined. It was found by NDT that there is a relatively obvious wedge space in the baffles of the secondary lining area [12].

The secondary lining structure of the tunnel can be calculated according to the concrete injection thickness. However, a unique method is to analyze the electromagnetic wave velocity in the secondary lining [13]. Electromagnetic wave velocity analysis can be carried out through the hole-drilling measurement method. Therefore, in the actual operation, the open hole position can be further measured, and then the dual travel time of radar image can be comprehensively considered, so as to achieve the accurate measurement of electromagnetic wave velocity [14].

In the concrete inspection, the ultrasonic rebound NDT was mainly used to detect the lining strength. In order to ensure the convenience of detection, the molding lining was regarded as a component in the detection, and ten areas was selected within each component to conduct orderly detection of each area. After the completion of springback detection, ultrasonic test was carried out, and the data was recorded in detail, which was then summarized [15]. **Table 1** is the summary of ultrasonic springback detection results of the secondary lining of a mold in a tunnel project.

Table 1. Summary of ultrasonic springback test results of secondary lining in this tunnel project

No	Item	Test result
1	Detection range	12-24m
2	Concrete design strength	C25
3	Rock type	Grade V
4	Minimum concrete strength	22.5MPa
5	Standard deviation of concrete strength	2.35MPa
6	Average concrete strength	29.4MPa
7	Concrete specified strength	25.5MPa

Based on geological radar and ultrasonic rebound testing data acquired, it was found that there are voids in the primary support and secondary lining, but the strength of the sampling position meet the design requirements, and no water seepage was found. This shows that the construction quality control of the sampling section of the tunnel project is relatively good, and there was no obvious structural safety hazard [16]. Therefore, the grouting method was used to treat the existing cavity, so as to ensure the stability and overall strength of the tunnel project to ensure its construction quality and safety while in use.

5. Conclusion

In short, NDT is significant in tunnel engineering quality testing. In the process of tunnel engineering quality testing by NDT technology, relevant units and technicians must fully understand the main types of NDT technology and their applicable conditions and apply it depending on the actual situation and type of project. In this way, the quality problems existing in the tunnel project can be found accurately in time, and the scale and severity of the problems can be determined. Reasonable measures can then be taken to deal with them, so that the construction quality and safety of the tunnel project can be well guaranteed. Besides, the quality of use can also be improved, and accidents can be prevented. Therefore, the application of NDT and the selection of optimal strategies can play a very positive role in improving the safety assurance and management of tunnel engineering during the construction and operation period.

Disclosure statement

The authors declare no conflict of interest.

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Optimization Strategy of Commercial Space in Xianyukou Hutong Based on Kernel Density and Space Syntax

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Abstract: Beijing Xianyukou Hutong (*hutong* refers to historical and cultural block in Chinese) occupies an important geographical location with unique urban fabric, and after years of renewal and protection, the commercial space of Xianyukou Street and has gained some recognition. This article Xianyukou takes commercial *hutong* in Beijing as an example, spatial analysis was carried out using methods like GIS kernel density method, space syntax after site investigation and research. Based on the street space problems found, this paper then puts forward strategies to improve and upgrade Xianyukou Street's commercial space and improve businesses in Xianyukou Street and other similar *hutong*.

Keywords: *Hutong*; Xianyukou Street; Commercial space; Space syntax; Kernel density estimation

Online publication: December 28, 2022

1. Introduction

In 1999, Beijing designated a historical protection area of the old city, and the plan clearly mentioned that the complete historical scene should be preserved or built. The 25 areas under control include Dashilan, East Liulichang Street, West Liulichang Street and Xianyukou area [1]. The traditional *hutong* in Beijing is an embodiment of the urban humanistic spirit of Beijing, while the *hutong* in the Xianyukou area mostly retains the historical traces and styles. After the protection and renovation, the Xianyukou area has developed into a traditional commercial food street.

By studying the relevant information about the renewal of commercial space in the historical district, this paper analyzes the spatial changes and development of Xianyukou Hutong and the commercial characteristics inside the *hutong*. Secondly, a survey is carried out in Xianyukou area to understand the current situation and analyze its commercial spatial form. Through field investigation, combined with point of interest (POI) data, the kernel density estimation method was used to study the degree of commercial industry clustering in Xianyukou and its surrounding areas, and Depthmap software was used to establish a space syntactics axis model to describe the regional spatial pattern, so as to obtain the characteristics of human flow [2].Finally, a comparative analysis of the spatial vitality and commercial attraction to people flow between the Xianyukou area and the surrounding traditional *hutong*, as well as the exploration of more influential factors to activate commercial space.

2. An overview of Xianyukou Hutong

In the planning of the historical and cultural Reserve of Beijing, the Xianyukou area extends to the

Damochang Street in the north, to the north of Dongzhu Shikou Road in the south, to the west of Qianmen Street, and to the east of Caochang Shi Hutong [3] , as shown in **Figure 1**. Among them, the Xianyukou Hutong with Beijing urban characteristics starts from Qianmen Street in Dongcheng District in the west and ends at Qianmen East Road in the east, facing Dashilan across the street. Xianyukou Street and Dashilan Street intersect Qianmen Street, forming the core street space node of Qianmen Street.

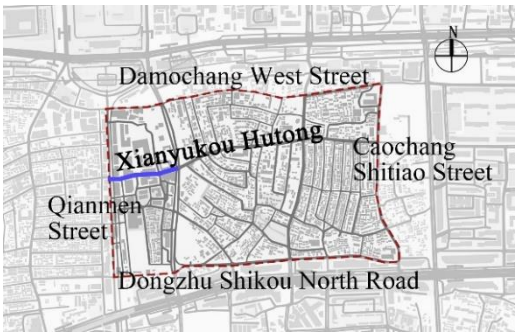
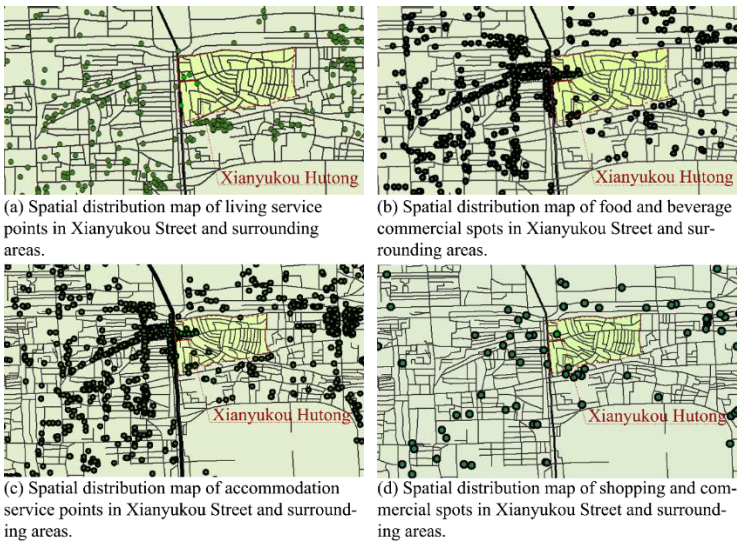


Figure 1. Range of historical and cultural blocks in Xianyukou

After rearranging the block texture, Xianyukou Street has sorted out the street pattern in three levels of historical texture, namely *hutong*, street, and courtyard, and renovated the surrounding environment and architectural features to further make Xianyukou Street more attractive. By taking advantage of its western location on Qianmen Street, it reintroduces Beijing's time-honored brand shops, unifies the commercial shops on both sides of the *hutong* for the overall appearance style, and focuses on creating the street's commercial label based on food and snacks. However, there are a series of problems in the renovation of Xianyukou Street. The value of the original building is ignored in the construction renovation, and a large scale of reconstruction and demolition are carried out [4]. Most of the streets are restored to the appearance of a certain prosperity period but fail in portraying the evolution of architectural style throughout the period, resulting in the lack of urban historical and cultural characteristics, and tend fall into the same "Internet famous antique streets" category [5]. At the same time, it overbuilds its food label and ignores the organic combination of the life mode of the people in the Xianyukou with the history and culture, and the hustle and bustle of the local people's life gradually fades.

3. Analysis on the global spatial distribution pattern of Xianyukou Street and its surrounding areas



(a) Spatial distribution map of living service points in Xianyukou Street and surrounding areas.

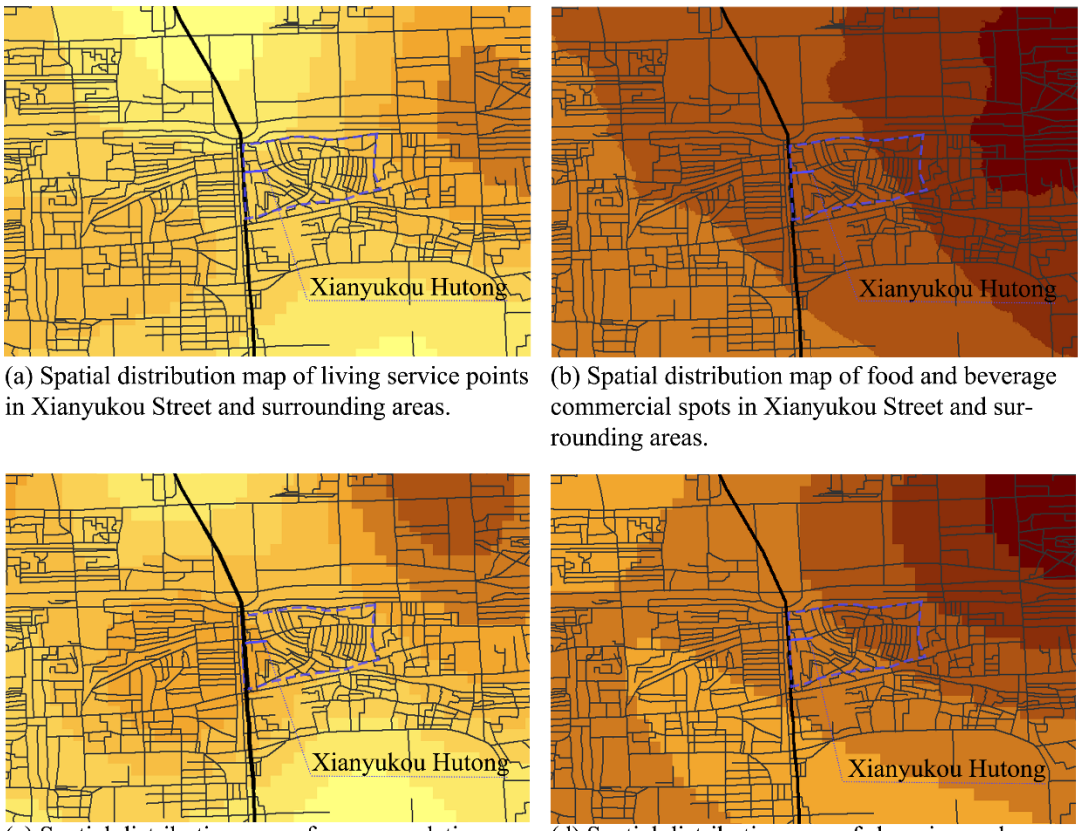
(b) Spatial distribution map of food and beverage commercial spots in Xianyukou Street and surrounding areas.

(c) Spatial distribution map of accommodation service points in Xianyukou Street and surrounding areas.

(d) Spatial distribution map of shopping and commercial spots in Xianyukou Street and surrounding areas.

Figure 2. Spatial distribution of commercial spots in Xianyukou Street

By combining POI data analysis with kernel density estimation method, the degree of industrial agglomeration in a targeted area can be visually demonstrated by graphical representation. This method is used to calculate the density of the points around the grid pixels and obtain the degree of industrial agglomeration in a certain area [5]. Then the field survey of Xianyukou Street and its surrounding areas to verify the authenticity of the information provided by the map. According to the AmAP commercial types POI classification code, the numbers of POI in the four commercial types of catering, shopping, life service, and accommodation service are 3599, 260, 1903, and 3600, respectively. In terms of the four commercial formats, although the Xianyukou area does not belong to the core area of the total density distribution of commercial POI in Dongcheng District, the locations of Xianyukou Street and Dongzhu North Road are in the core area of the total density distribution of commercial POI in Qianmen District. Based on **Figure 2**, in terms of the commercial types of catering and accommodation service points, Xianyukou Street is the same as the adjacent Qianmen Street and Dashilan Street, which have a large and dense number of POI. In particular, Xianyukou Street faces Dashilan across the street, so the positioning of Xianyukou Street needs to be more detailed and accurate, so as to highlight its *hutong* characteristics.



(a) Spatial distribution map of living service points in Xianyukou Street and surrounding areas.

(b) Spatial distribution map of food and beverage commercial spots in Xianyukou Street and surrounding areas.

(c) Spatial distribution map of accommodation service points in Xianyukou Street and surrounding areas.

(d) Spatial distribution map of shopping and commercial spots in Xianyukou Street and surrounding areas.

Figure 3. Spatial distribution of nuclear density in commercial spots of Xianyukou Street

Through the analysis of the research results by the kernel density estimation method, the four different commercial forms above have formed different spatial distribution patterns. In **Figure 3(a)**, in terms of life service commercial formats, the density of life service commercial formats in Xianyukou Street and its surrounding areas presents a spatial form of small discrete agglomeration, and the life service commercial points are relatively scattered. The northeast direction of the Xianyukou area shows a small range of hot spots, while the Xianyukou Street is located in the sparse periphery of the two small range of hot spots, and

the density of life service points is low. As shown in **Figure 3(b)**, in terms of catering commercial formats, the density characteristics of commercial formats in this area show that Beijing Workers' Stadium in the northeast direction of Xianyukou Street is located in the central area, while Xianyukou Street is located in the peripheral area of the commercial core. **Figure 3(c)** shows that in terms of commercial forms of accommodation services, the density of commercial forms of accommodation services in this region also presents a spatial form of small discrete clusters, and the commercial points of accommodation services are mainly scattered around small hot spots in the Forbidden City and Tian'anmen Square. Xianyukou Street is located around the core of accommodation services centered on Meishi Street and Dashilan Street. It is in the transition area between the commercial activity intensive area and the residential area. In Figure 3 (d), in terms of commercial forms of shopping, this area shows a spatial form spreading outward from the central area. The core of commercial forms of shopping is still the core of Beijing Workers' Stadium in the northeast direction, and Xianyukou Street is in the central area, which is in the transitional zone of the integration of the eastern and western commercial cores.

Among them, the distribution characteristics of food and beverage commercial spots in Xianyukou Street and its surrounding areas are consistent with the overall distribution of shopping commercial spots, and the distribution mode is regional intensive distribution, mainly concentrated in Beijing Workers' Stadium. The distribution density of Xianyukou Street is very similar to that of Qianmen Street and Dashilan Street. The distribution characteristics of living service commercial points are unified with the overall distribution of accommodation service commercial points, showing a small range of hot spots, and the distribution of commercial service points in Meishi Street and Dashilan street is more dense than that in Xianyukou Street, especially the distribution of residential service commercial points with Meishi Street as the center of the small range of hot spots. Based on the distribution characteristics of the four commercial service points, Xianyukou Street has not formed a self-centered service radiation hotspot and competitive strength.

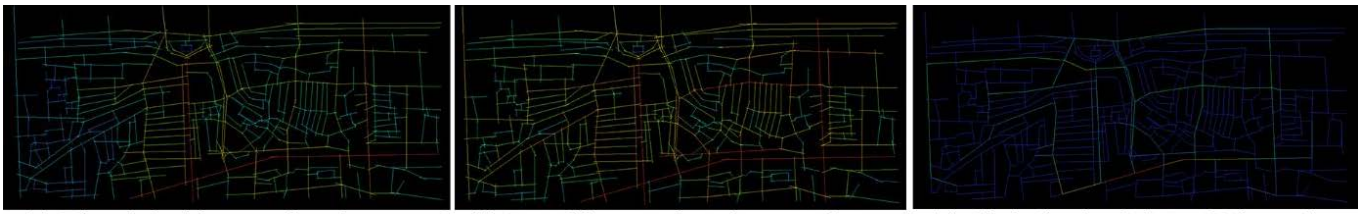
4. Spatial syntax interpretation of Xianyukou Street and its surrounding areas

4.1. Space syntax

Space syntax is mainly used for analyzing the integration degree and selection degree of the target space. The degree of integration mainly represents the accessibility of a certain space in the city. The higher the degree of integration, the stronger the accessibility of the region. The degree of integration can be divided into the overall degree of integration and the local degree of integration [6]. The degree of choice represents the aggregation attraction of a certain space to the flow of people. In the research method of historical and cultural blocks, the most appropriate local integration degree is the topological radius distance of R = 3, because R = 3 is the closest scale value similar to human walking in the space [7].

4.2. Spatial syntax analysis of Xianyukou Street

Xianyukou Historical District is closely connected with Qianmen, Dashilan, and Caochang areas in many aspects, such as geographical location, culture, history, and economy, but there are also a series of differences [8]. Therefore, in the space syntax analysis of Xianyukou Street, Qianmen, Dashilan, and Caochang areas are also included in the research scope to explore the similarities and differences of the designated areas. DepthmapX software was used for this analysis, and the research object was first transformed into an identifiable axis map [9]. Then, the axis map of Xianyukou Street and its surrounding areas is studied and analyzed with relevant analytical means, and the spatial structure features presented are further interpreted.



(a) The global integration degree of Xianyukou and its surrounding area. (R=11)

(b) Local integration degree of Xianyukou and surrounding area. (R=3)

(c) Global selectivity of Xianyukou and its surrounding areas.

Figure 4. Spatial Syntax analysis of Xianyukou and surrounding areas

4.2.1. Analysis of block integration degree in Xianyukou District

DepthmapX software was used to analyze the global integration degree of this area and the local integration degree of the three topological distances (R = 3), as shown in **Figures 4(a)** and **(b)**. The axes with the highest global integration degree values of Xianyukou Street and its surrounding areas are Qianmen Street, Jewelshi Street, Dongzhu Shikou Street and Caochang 10 respectively. The local integration values of these four streets were 1.659, 1.611, 1.767 and 1.558, respectively [10]. **Figure 4** shows that local integration of other streets was lower than 1.500. When the topological distance is equal to 3, the axes with the highest local integration value in the Xianyukou area are 3.076 in Qianmen Street, 3.009 in Caochang Shitiao Street, 2.922 in Xianyukou Street and 2.716 in Jewelshi Street. In addition, the local integration value of Xianyukou Street is 2.363, lower than that of Dashilan (2.520). Thus, we can judge that the main commercial centers of Xianyukou and its vicinity are located in Qianmen Street and Xianyukou Street. In the area of Xianyukou and its surrounding area, other streets showed low accessibility.

4.2.2. Analysis of block selection in Xianyukou district

From the global perspective of Xianyukou and its nearby areas, Figure 4(c) shows that the axes with the highest global selection degree Rn are Dongzhu shikou Street, Qianmen Street, Meishi Street, Qianmen East Road and Xianyukou Street, with the global selection degrees of 128112, 66044, 72593, 51798, and 52082 respectively. In addition to the above streets and alleys, the selection degree of regional streets and lanes is obviously lower (**Figure 4**). By comparing the choice degree of Dashilan Street and Xianyukou Street, the choice degree of Dashilan Street is 4512, while that of Xianyukou Street is 2427. The former is significantly higher than the latter, indicating that Dashilan Street is significantly more attractive to citizens and tourists than Xianyukou Street, which is consistent with the actual situation obtained from the field survey.

5. Summary of commercial space problems in Xianyukou Street

5.1. The degree of regional integration is low

The accessibility of Xianyukou Street is low, which fails to form a complete walking tour streamline system with the secondary streets in the surrounding area. In the investigation, it was found that the flow of people centered on Xianyukou Street radiated to the surrounding secondary *hutong*s in a fishbone shape, connecting the surrounding six hutongs in series, without forming a commercial walking circuit. Although Xianyukou Street and its surrounding areas have rich commercial forms, and the street scale has a hierarchical walking system, the utilization rate of shops in secondary *hutongs* such as the surrounding Dajiang Hutong is low, and some secondary *hutong* are impassable with fences, which further makes the walking system of Xianyukou block unable to be closed.

5.2. The selection of blocks is low

Xianyukou block lacks core attraction, it is difficult to attract more tourists continuously. On one hand, the characteristic commercial value of the traditional *hutong* is not reflected in the design and layout of its commercial space. Xianyukou Street and Dashilan Hutong have the same commercial positioning, and it is located at the opposite of Dashilan, while Dashilan already has a greater visibility. On the other hand, most of the new Xianyukou Street is transformed to introduce time-brand gourmet shops, and the translation of "old Beijing flavor" is superficial, and the buildings are mostly newly built, with low openness. As a representation Beijing cuisine, the symbol of "fish" has not been organically translated, such as on manhole covers, streetlamps, pavement, building walls and other details. Secondly, the entrance of Xianyukou Street lacks the reuse and creation of the historical and cultural characteristics of *hutong*, and fails to make full use of the intersection space between Qianmen Street and Xianyukou Street. Besides, the driving force of people flow are the Pianyifang, Tianleyun Theatre, which are at the easternmost exit. Moreover, there is a lack of resting places like seats for tourists. Most of the shops only set up the sales window, and tourists can only sit on the floor in front of the store or go into the store to have a rest. In addition, the commercial utilization rate of Xianyukou Street is high, only a few trees are planted, and there is little greenery in the courtyards of the surrounding secondary *hutong*, but these courtyards do not play the function of staying and resting.

5.3. Lack of linkage with the surrounding core area

Xianyukou Street is located in the transition zone between Dashilan and Beijing Workers' Stadium. However, it failed to closely connect with Dashilan by using the surrounding stream of people to form its own competitiveness and commercial radiation. There are few shopping and commercial spots in Xianyukou Street, and the catering and accommodation commercial spots are not dense enough. Besides, the major theaters, the art galleries, the Taiwan Guild Hall, and other passenger flow driving forces are on the east side, and the secondary main stores in the middle are not closely related to the main commercial stores at both ends.

5.4. Xianyukou Street commercial space renewal and improvement strategy

Table 1. Current situation and renewal strategy of commercial space in Xianyu Street

Status quo problem	Status quo node space	Status node space diagram	Upgrade and improvement strategy	Strategy schematic
The degree of regional integration is low	Flow of people (flow line is fishbone shape)		Set the main tour route to guide the flow of people. Set it as the circular streamline with the core of Xianyukou Street	

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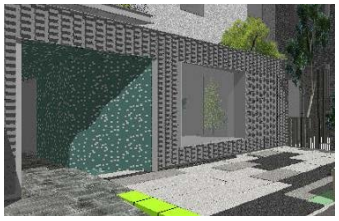
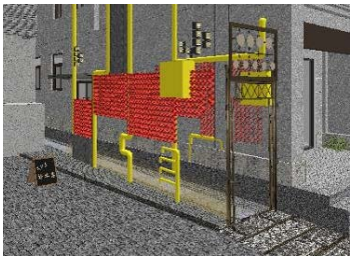
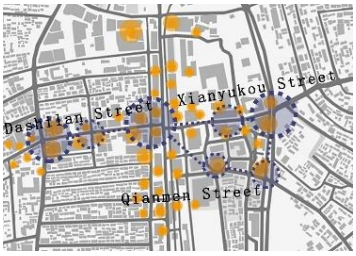
Status quo problem	Status quo node space	Status node space diagram	Upgrade and improvement strategy	Strategy schematic
The selection of blocks is low	Characteristic commercial space		Into the store culture	
	Entrance (Intersection of Xianyukou Street and Qianmen Street)		(1) Multi-level display entrance space (2) Add an entrance signature	
	Public facilities, greening		Increase greenery and rest areas	
Lack of linkage with the surrounding core area	Layout of commercial points		Form commercial system with Dashilan and Qianmen Street	

First of all, through strengthening the commercial and green space inside the block, the single building shops, *hutong*s and blocks are connected to form a series. Based on the current commercial walking system, it will further integrate and activate the surrounding secondary *hutong*s, make the shops more accessible and welcoming and increase the attraction of Xianyukou Street and its surrounding areas. Moreover, strengthen the spatial permeability between streets will increase the connectivity between street areas in the line of sight, increase the tour route indication chart, make the surrounding secondary hutong and Xianyukou Street businesses into a "ring system"; tourists can return to Qianmen Street after visiting the Xianyukou area. Secondary *hutong*s should serve to enrich the tourists' senses in various forms, they can be transformed into commercial space such as creating photography walk space, Virtual Reality (VR) experience hall, stages, and so on, or create an area for Beijing cuisine and cultural experience.

Secondly, core appeal needs to be built. Further emphasize on what Xianyukou street is known for, which is a place for Beijing cuisine. Besides, cultural and folk cultural activities of "old Beijing flavor"

food needs to be developed from multiple angles and avoid blindly building monotonous antique buildings. Instead, design commercial space combined with the unique food culture of shops, such as shop signs, exhibition area of the founding story of the time-brand, characteristic black brick wall, and so on. In this way, it makes rational use of the entrance space to enrich the facade display form and spatial level change of the entrance space, further open the west entrance interface, and increase the entrance interesting facilities with bright colors to activate its vitality. At the same time the overall cultural connotation of the block and the original street architectural characteristics should be considered, so as to ensure an authentic display of architectural characteristics of various shops and color coordination, to avoid the highly unified facade of street shops, single way of cultural display and monotonous commercial space. Green plants should be planted in the *hutong* to support commercial development and break the pattern of single function within the area. At the same time, some small-scale public cultural space or resting spots should be added in the street node space, and at the same time meet the needs of the market, food display and other activities in a specific season, to increase the sense of participation and identity of citizens.

The linkage with Dashilan Hutong should be strengthened and form its own commercial characteristics. Commercial anchor stores and secondary anchor stores for shopping and catering should be introduced to attract the flow of people from the two surrounding core business districts. At the entrance of Xianyukou Street, the central and eastern exits should be arranged to form a commercial gathering point with the surrounding retail merchants. At the central part of Dajiang Hutong and the intersection of Dajiang Hutong and Nan Xiaoshun Hutong, a commercial gathering point is formed with the art and culture center and the surrounding commercial points, so as to link with Dashilan in terms of distance and commercial points (**Table 1.)**

6. Conclusion

Xianyukou Historic District is closely related to the social life and historical style of Beijing, and also reflects the historical precipitation of the civilization in this area. Focusing on the commercial buildings and surrounding public space in Xianyukou Street, this study analyzed the shortage of commercial space in Xianyukou Street, and finally put forward the improvement strategy reflecting the cultural value of the old city. While continuing its precious historical context and regional connotation, this study adds new functions to activate the vitality of the region and make it integrate with modern life. Only through the reuse and creation of history and culture can people experience the real historical and cultural value of the city.

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Disclosure statement

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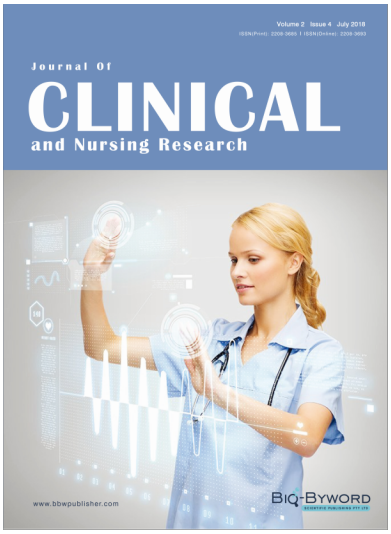

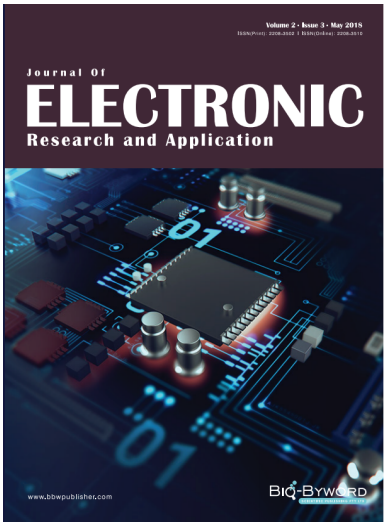

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