Patent approved from the National Intellectual Property Administration, PRC
for the technique of building light footbridge

WU ZHI QIAO FOOTBRIDGE CONSTRUCTION MANUAL:

BAILEY BRIDGE

无止贝雷桥
建造手册

無止橋 慈善基金
Wu Zhi Qiao (Bridge to China) Charitable Foundation

Wu Zhi Qiao Footbridge Construction Manual

BAILEY BRIDGE

Editorial Board:
Project Committee of Wu Zhi Qiao (Bridge to China) Charitable Foundation
Tongji Wu Zhi Qiao University Team
Professor Wu Xun, Bridge Engineering Department of Tongji University
Bridge Engineering Design School of Tongji University

Editor:
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Translator:
Ms. Lilian Hiulee Sze, Mr. Zhang Zhen Yu,
Ms. Suede Kam, Ms. Harina Tang

Designer:
Ms. Bess Chow, Mr. Rio Chan

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Preface

With the establishment of Wu Zhi Qiao (Bridge to China) Charitable Foundation in 2007, I was delighted to witness every milestones and development of our projects from the application of gabion bridge to the sustainable improved versions of bailey bridge. These footbridges enable people to cross the barrier and connectivity of the villagers. Our projects also serve as a heart bridge to enhance understanding, communication and appreciation to bring forth care and love among people.

I would like to express my heartfelt gratitude to Mr. Ho Juh Kuen, the former chairperson of Wu Zhi Qiao Project Committee. Mr. Ho has supported footbridge projects from the early initiative stage. He has adopted the merits of military used bailey bridges and refined the technology for Wu Zhi Qiao footbridge project application in remote villages. Mr. Ho has joined force with his project committee team members and volunteers, which included Mr. Matthew Lee, Mr. Li Kwok Leung, Mr. Max Lee, Mr. Plato Lee, Mr. Michael Chan and Mr. Stephen Li etc., with contributions to the footbridge projects for many years. They have served as guiding force for the publication of this manual with input on knowledge of the footbridge technology and practical experiences. I would also like to thank Professor Wu Xun from Tongji University and Professor Li Nan from Kunming University of Science and Technology, for their enduring support to the Wu Zhi Qiao university teams and the lead in research and improvement on the design of Bailey bridge.

Publication of this manual was the collaborative efforts and hard work from our selfless advisors and university volunteers in Hong Kong and Mainland. We are grateful to receive patent from the National Intellectual Property Administration, P.R.C for utility model to this technique. It is a new milestone in technology development of our project. Sincerely grateful to every participated university student, volunteer, mentor, villager and strategic partners.

We wish this manual can improve living environment of villagers in the Mainland and beyond.

Miss Leonie Ki GBS, SBS, JP

Founder and Honorary President of Wu Zhi Qiao (Bridge to China) Charitable Foundation
Member of the 12th CPPCC National Committee
Member of the 10th to 12th CPPCC Yunnan Provincial Committee

Preface

Wu Zhi Qiao (Bridge to China) Charitable Foundation does not only serve the connectivity of villagers but also enhance the building of heart bridge. In the past decade, I was delighted to have the opportunities to lead student teams to serve in the remote villages for community enrichment and sharing of rural wisdom. Hong Kong and Mainland students have chance to stay under one roof together, to share simple bed and rural cuisine with memorable snapshots of life. Lots of students who have encountered the rural service experience realized that luck was not inevitable, they started to cherish life, cherish their family, and more importantly, cherish their ownself.

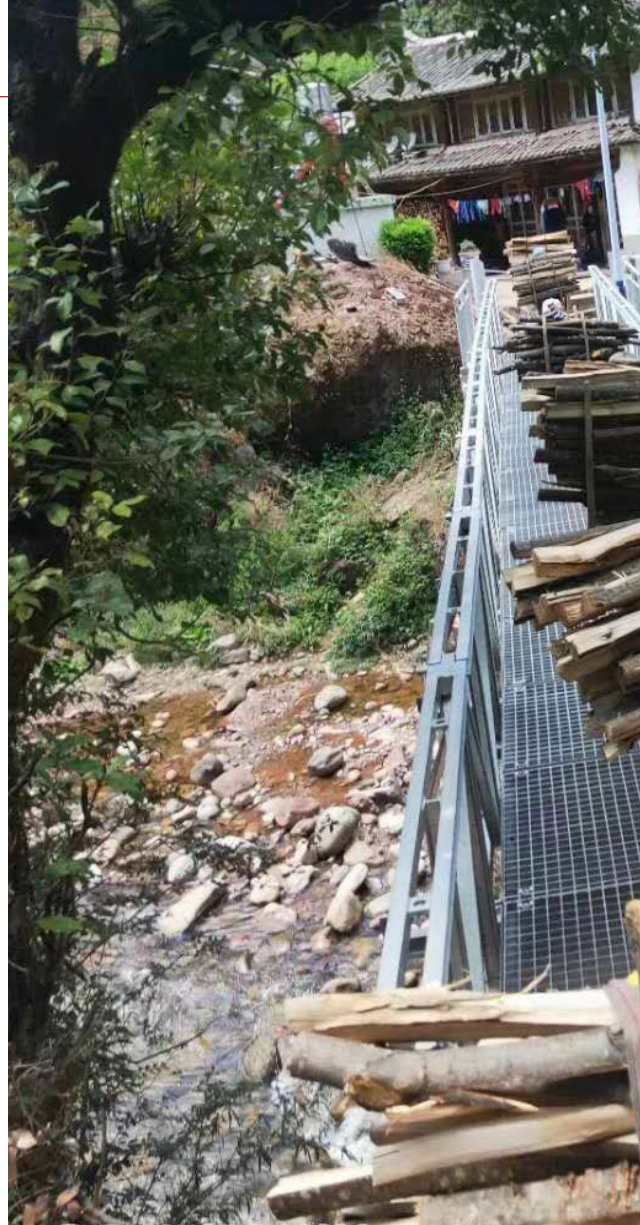
This Bailey Footbridge Construction Manual was completed with gratitude to all the student volunteers and mentors for the endure dedication and hard work for years. In particular, I would like to express sincere thanks to the Project Committee of the Foundation, students and professors, as well as all donors who have shown unfailing support. We expected that this Bailey Bridge Manual would benefit more villagers in remote areas and enhance the building of trust and heart bridge.

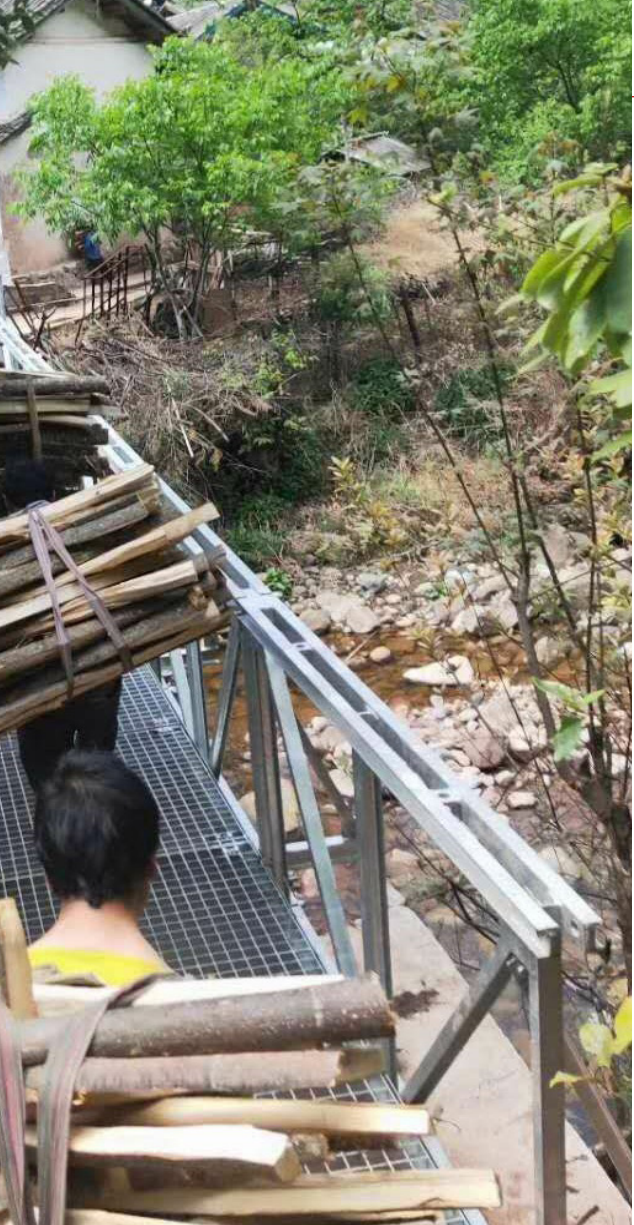
I remember profoundly that villagers have given us a farewell message upon completion of the project in Gansu province. It stated, "Not only a physical bridge has been built, but also precious friendship has reminded".

Professor Joseph Sung SBS, JP

Chairman of Wu Zhi Qiao (Bridge to China) Charitable Foundation

Content





Content

Wu Zhi Qiao
Objectives

Wu Zhi Qiao (Bridge to China) Charitable Foundation was founded in 2007 and registered as a charity in Hong Kong (no: 91/8739). Through encouraging volunteers, especially university student volunteers from Hong Kong and Mainland China, to design and build footbridges and village facilities in remote and underprivileged villages in China and beyond with green concepts, we aspire to:

1. Foster better communication, mutual understanding and integration between Hong Kong and the Mainland.
2. Improve lives of underprivileged villages in remote areas of Mainland China.
3. Inspire respect, appreciation and preservation of local culture and environment, and promulgate the concept of sustainability.
4. Provide university students a real-life experience of executing a service project which has direct impact.

Wu Zhi Qiao
Projects

The projects of Wu Zhi Qiao are accomplished by volunteer professionals and university teams from both Hong Kong, the Mainland and overseas. To the fullest extent possible, we build footbridges, eco-dwellings and small-scale facilities with locally available and sustainable materials and utilize local wisdom and green building concepts. Our volunteer teams work closely with the villagers to transfer practical building skills and knowledge of materials that will promulgate the concept of sustainability and enable the local people to maintain their footbridges and facilities in the future.

The project is also an intervarsity initiative that provides students with an opportunity to reach out to distant villages over a year. It allows our volunteers a better understanding of the life, wisdom and culture of the villagers. It also provides an opportunity to volunteers to assess, design and construct an essential infrastructure that villagers need. Most importantly, we build heart bridge of caring and friendship which truly connect people from all walks of life.

Over the past 13 years, more than 25 Wu Zhi Qiao university teams have successfully completed nearly 60 projects, including 52 footbridges, 3 village rebuild demonstration, 3 village center development and a series of community enrichment projects. The number of volunteers involved reaches 4,000 times and benefited 65,000 villagers.

1

Foreword

Wu Zhi Qiao encourage students from Hong Kong and the Mainland to design and construct footbridges as well as facilities with environmental-friendly concept in rural and remote villages in need. We provide an integrated and unique learning platform, especially for engineering student volunteers, to learn through serving and bring positive changes to the villagers. Interaction between student volunteers and villagers is formed through the cooperation in bridge building and community projects, such as design and establish earthen architecture, eco-toilets, incinerator, small-scale road paving, waste management system, electricity maintenance and other facilities. The projects allow our volunteer students to understand themselves, enrich their life and build confidence. They can also learn and experience the importance of gratitude, contentment and appreciation through humanity services.

The Origin

In the early projects of Wu Zhi Qiao, we focused on the construction of submersible bridges, which uses gabion boxes filled with rubble as pier and use bamboo board framed with steel as the deck. This kind of bridges have limited practicality as they could only be applied to flat riverbed under which river water was less than 2m in depth. The bridge was generally functional in 90% of the days in one year, while the remaining days was regarded as unsafe to cross the bridge when the river water submerged the deck.

With reference to previous years of experience and in view of the limitations of using gabion bridges in places with complicated, rugged and mountainous terrain, Wu Zhi Qiao has decided to design and modify the footbridge design with higher applicability that can benefit the underprivileged villagers in remote areas. Upon development of the Gabion bridge, we are now proceed with the publication of the construction manual of the Bailey bridge.

The Development

In 2010, Wu Zhi Qiao started the first construction of a 20-meter long steel structure bridge in Aidong Village of Lüchun County in Yunnan Province. In accordance to the statistic, it has taken reference of the bridge assistance project conducted by the United Kingdom in Sri Lanka village. However, the construction was mainly carried out by the local contractors. The bridge was weighted over 4 tons and students had limited involvement in the said process. Since then, Wu Zhi Qiao has been exploring different versions of light-weighted and assembled bridges which would allow the professional volunteers from Wu Zhi Qiao and engineering students to take up the role of main contractors. Objectives were to minimize the risk in construction and reduce the building cost with standardization of design of the Bailey bridge for the use of all student teams.

In 2015, the Chairperson of the Project Committee, Mr. Ho Juh Kuen has suggested the use of a simplified version of Bailey bridge as developed in the World War II for application in Wu Zhi Qiao projects. He has invited the student teams from Tongji University and Chongqing Jiaotong University, to take up the challenge to develop a preliminary design.

In accordance to the previous project experience, the lightest single piece of bridge component was at the project in Maosi Village. It weighed 280kg and was placed by 12-16 villagers and students. The heaviest one was at the bridge project in Sancha Village in Gansu province. The bridge weighed 900kg in total and it was eventually set up with the help from the local Rescue Team by using their crane. In view of the variation, Wu Zhi Qiao has requested that every single bridge component should be weighted less than 120kg to allow a group of 6 people to handle it easily and safely without causing bodily injury.

Apart from that, Wu Zhi Qiao has encouraged all the project design and construction should be completed without the use of heavy machinery. In doing this, it saves the use of wood in supporting platform construction and the construction cost is also reduced by around 20%. Moreover, this enhanced the safety and efficiency of construction by preventing inexperienced students from exposing to any accidents and risks of working at height when they work on the temporary working platforms.

With the accumulated experience of the footbridge construction projects in the past years, Wu Zhi Qiao's project committee members Mr. Ho Juh Kuen, Mr. Li Kwok Leung, Mr. Matthew Lee, Mr. Max Lee etc. together with Tongji University student team have modified the design of the Bailey bridge to the final version. A single span of the bridge span is set to be 16-meter long and made up by 8 pieces of 2-meter long steel panels and transoms. The heaviest piece of Bailey bridge component is around 110 kg each while the net weight of a bridge is around 2 tons. The safety factor for the pedestrian bridge is designed to be over 10. However, due to the recent conservation measures in China, lumbering is generally forbidden in mountainous area. Thus, many old wooden bridges are in a dilapidated state and the Wu Zhi Qiao Bailey bridge is just timely to fill the gap.

The first Wu Zhi Qiao Bailey bridge was constructed in Machi Village, Pengshui County, Chongqing city in 2016. Since then, the subsequent construction of Bailey bridge in Huanglonechang village in Sichuan province in 2016, Xiejia village in Guizhou province and Liuzhu village in Yunnan province in 2017, Liguang village in Lijiang city, Yunnan province in 2018, together with the two recent Bailey bridges built in Meile village in Yunnan province and Zhongting village in Guangxi province in 2019. In total, Wu Zhi Qiao have constructed 10 Bailey bridges. Hence, this version has been testified and modified for several times.

As for the design and construction of the Wu Zhi Qiao Bailey bridge, key elements included safety, manual construction, sustainability, technology innovation and the integration of advanced technology. Upon joint efforts by the Project Committee and university student teams with practical experiences and improvements, Wu Zhi Qiao has developed from the initial Gabion bridge to the current Bailey bridge. Both the practicality and efficiency have been enhanced and this demonstrates the infinite spirit of seeking continuous improvement and advancement.

Photos of Bailey Footbridge Built in 2016-2019:

1. WZQ Bailey bridge project in Machi Village, Pengshui County, Chongqing city in 2016



2. WZQ Bailey bridge project in Huanglongchang village in Sichuan province in 2016



3. 3. WZQ Bailey bridge project 1 in Xiejia village in Guizhou province in 2017



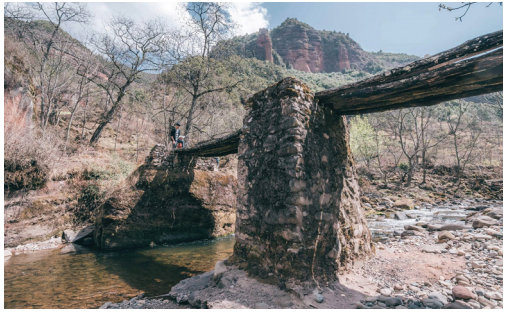
4. WZQ Bailey bridge project 2 in Xiejia village in Guizhou province in 2017



5. WZQ Bailey bridge project in Liuzhu village in Yunnan province in 2017



6. WZQ Bailey bridge project at Heshang in Liguang village, Liming township, Yunnan province in 2018

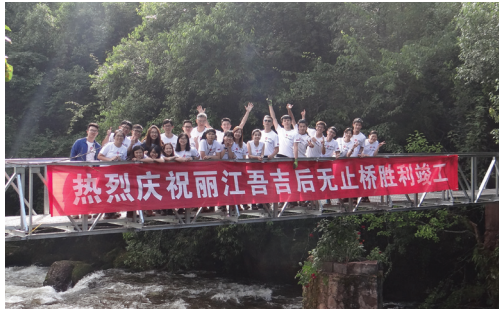


7. WZQ Bailey bridge project at Hexia in Liguang village, Liming township, Yunnan province in 2018



8. WZQ Bailey bridge project at Wujihou in Liguang village, Liming township, Yunnan province in 2018





9. WZQ Bailey bridge project in Meile village, Liming township, Yunnan province in 2019



10. WZQ Bailey bridge project in Zhongting village, Leye County, Guangxi province in 2019



2

Wu Zhi Qiao Bailey Footbridge

Overview

*

2.1 Background

The military steel Bailey bridge was initially designed by Mr. Donald Coleman Bailey (1901-1985) from the United Kingdom for application in early World War II, with the design concept of bridge construction by assembling minimum type of unit components to reach different loading and span requirements. Transportation of the components only required ordinary medium-sized truck and it can be assembled without skilled crew. During World War II, this type of military steel bridges was widely used in the European and Far East war fields.

*Photo source: The history of the Bailey bridge

https://www.strijdbewijs.nl/hinder/baileybridge.htm

2.2 The Importance of Bailey Bridge Application on Wu Zhi Qiao Project

Wu Zhi Qiao projects usually include two parts, community enrichment and footbridge construction. As compared to the general transportation and bridge construction, Wu Zhi Qiao projects have its uniqueness.

1 Construction Scale:

Wu Zhi Qiao bridges are characterized by the economical and small-scale to provide connectivity for villagers in remote rural areas. The bridges of Wu Zhi Qiao are only used as footbridge and has forbidden the use of vehicles and agricultural machinery to cross the bridge. In that respect, the design loading for Wu Zhi Qiao footbridges has usually taken as $3kN/m^2$ and is much smaller than those applied for conventional bridges.

2 Participant:

Participants are mainly students from Hong Kong and mainland universities with the support by professional technicians, social volunteers and local villagers.

3 Purpose of Bridge Building:

Wu Zhi Qiao aims to enhance communication and mutual understanding among students from Hong Kong and Mainland through the construction of bridges and eco-dwelling projects in rural and remote villages. It helps to improve the environment and quality of life of underprivileged villagers in remote areas. With the concept of sustainable development, Wu Zhi Qiao inspires the society to respect, appreciate and protect local culture, tradition and the environment. The projects also provide students with the opportunity to bring about actual changes to the villagers in humanity service and emphasize the importance of practicality and efficiency with infinite spirit of continuous improvement.

2.3 Wu Zhi Qiao Bailey Bridge

Upon years of discussion and collaboration with various universities, Wu Zhi Qiao has applied the advantages of Bailey bridge and optimal choice of material in its projects. Professors of the Tongji University in Shanghai and the Wu Zhi Qiao student team have been entrusted to develop and design a light-weighted Wu Zhi Qiao Bailey bridge. The bridge design has been given due considerations to the demand of function, natural environmental condition, technical feasibility, material transportation, cost and volunteers involvement etc. In April 2016, the first Wu Zhi Qiao Bailey bridge was constructed in Machi Village.

As the requirement on loading was smaller, the structural members of the bailey panel could be re-designed to a lighter weight, meeting its needs on economic, transportation, construction, participants' involvement and other means. With the premise of ensuring safety, Wu Zhi Qiao Bailey bridge excels the conventional Bailey bridge limitations as mentioned and it has its unique advantage of application in the Wu Zhi Qiao projects.

1 Light Structural Design:

Standard bailey panel structure is the basics of Wu Zhi Qiao Bailey bridge. A single bailey panel should have weight less than 120 kg and length 2 meters. The light-weighted design allows its application in Wu Zhi Qiao projects. It also lowers the cost and prevents excessive waste of resources, ensuring the economy and sustainability of Wu Zhi Qiao Bailey bridge construction.

2 Convenient Transportation:

Wu Zhi Qiao projects usually locate in mountainous and rugged terrain. The transportation condition is often remote and rough while manual labor are employed for conveying building materials and tools to site. The light-weighted components of Wu Zhi Qiao Bailey bridge can be easily handled manually and assembled on site.

3 Moderate Construction Difficulty:

The bridge structure and its components of Wu Zhi Qiao Bailey bridge are simplified and standardized. Only a small number of simple tools and machinery are required in its construction. As a result, the requisition of a relatively large number of skilled personnel on site is not necessary. In the circumstance, it allows a larger number of participants to involve in the project and the core values of Wu Zhi Qiao activities could be realized.

4 Good Durability:

Bailey bridge employs steel open sections, preventing the accumulation of rainwater and dust. Combined with the application of zinc galvanization on the overall structure to prevent the steel from rusting, durability can be improved. Besides, this avoids river pollution from the application of traditional anti-rust paint.

5 Long Span:

Bailey bridge has a longer span than the gabion bridge, thus, a smaller number of piers is required. Disturbance on the riverbed by excavation could be minimized and the effective flow of the river will not be hampered to a greater extent.

2.4 Summary

Wu Zhi Qiao Bailey bridge inherits the advantages of the original design of bailey bridge. However, just like any other bridge designs, it has its own limitations. In order to achieve a better result of the bridge project, it is vital in the designing stage that the environmental condition and actual requirements of the villagers are thoroughly investigated prior its commencement.

3

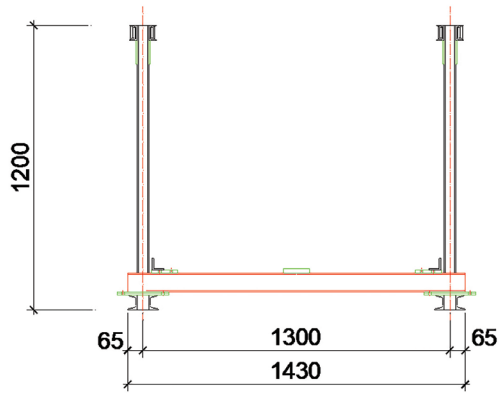
Wu Zhi Qiao Bailey bridge
General Design Information

3.1 Scope of Application

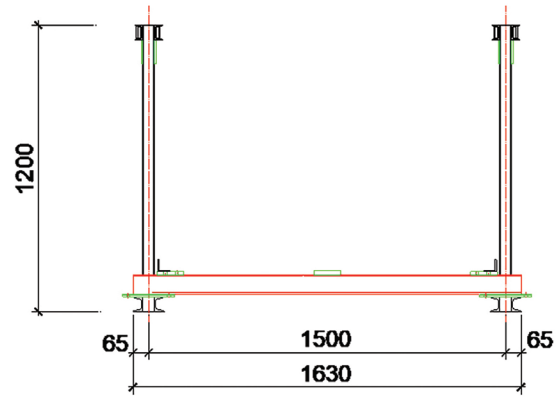
Wu Zhi Qiao Bailey bridge is a kind of light-weighted footbridge constructed from fabricated steel. It is composed of the load-bearing bailey panels, the minor load carrying transoms (floor beams), decks, other support members. The construction is simple by using standardized prefabricated components under a reasonable budget control. Moreover, the erection of the bridge could be carried out in a speedy way as only manual labor and simple machinery are required. It is a versatile design and can be used widely as a footbridge in rural and mountainous areas.

In principle, this footbridge is designed for pedestrians and livestock uses and not for vehicles or agricultural machinery. Two standards of bailey footbridge roadway width, which are 1300mm and 1500mm, measured from the two truss panel centers (also defined as clear width of 1250mm and 1450mm respectively) have built and used as shown in Figure 3.1. The 1500mm width design is more suitable to places where the need of free passage by livestock is required. The clear width of the bridge should not be larger than 1500mm and this could prevent the abused use by vehicles and agriculture machinery by overloading it.

Figure 3.1 Standards for two different widths of Wu Zhi Qiao Bailey bridge (Unit: mm):



(a) Standard for 1300mm width



(b) Standard for 1500mm width

3.2 Design Principles

3.2.1 Design Reference Period

The Wu Zhi Qiao Bailey bridge is designed and used as footbridge in villages. Under constant care and maintenance, the major structure and related components generally have a minimum service life of 10 years.

3.2.2 General requirement

The design and construction of Wu Zhi Qiao Bailey bridge should follow the requirements as stated below [Reference 1-6]:

1. Elevation of bridge bottom should be 500mm higher than the maximum water level recorded in the recent 10 to 20 years, to prevent the damage from tree trunk or rubble flowing down in the rainy season.
2. A single span of the bridge should be limited to no more than 16m (8 sections) to ensure structural stability.
3. The clear width of the footbridge should not be greater than 1500mm to ensure that the passage is only designed for pedestrian and livestock crossing.
4. In designing the deck slab, anti-skidding, convenience for conveyance and the ease of assembly should be taken into account with due consideration given to the site environment. However, the structural factors of the deck slab are not calculated in the calculation model because of certain limitations.
5. Structural design can be analyzed using the calculation model based on beam elements in which hinge joint and semi-rigidity can be ignored. To be more secure, under the condition of full dead and live loads, the maximum bending of the structure should be 1/500 of a single span.

6. As for design of buckling, the extreme load factor for live load in the first order buckling of the structure should not be smaller than 4.0.
7. The slenderness ratio of components under compression (including diagonal bracings) should not be greater than 100, while the ratio of other components should not be greater than 130.
8. The vertical vibration frequency should be greater than 3Hz to ensure the comfortability of the pedestrian.
9. The loaded components (i.e. bailey panel and transom) should adopt conventional hot-rolled steel to ensure the sectional strength, ductility and local stability.
10. The manufacturers should comply with the specifications as required. The welding process should follow the design requirements and those cut end or welded ends should be trimmed and chamfered.
11. All holes and sockets should be lubricated immediately after inspection. Bolts and screws should be painted with anti-corrosive oil while other components should be de-rusted by shot blasting. Zinc-galvanization or inorganic zinc-rich priming paint should be used at the surface to improve the resistance against rusting.
12. Each hole on the components should be welded prior to drilling and the inner face of holes should be perpendicular to the structural components. The finishing of the inner face of holes should meet the design and construction requirement and the connecting bolts, nuts, washers and screws should comply with the national standard.
13. During assembling, the sway brace should be fully tensioned by adjusting its turnbuckles.
14. Member imperfection may exist during construction due to local bending. The tolerance value should not be exceeded the followings:

(1) For loaded members (i.e. bailey truss and transom), the deviation should be within 1/1000 of the member length. For transom, the deviation should be within 2mm in both vertical and horizontal plane.

(2) For the deck, the deviation should be within 1/1000 of the length in plane and within 2mm for the elevation

(3) For the diagonal bracings and sway brace, the deviation should be within 1.5/1000 of the length.

15. The design and construction of pier foundation should follow the requirements below.

(1) The diameter of longitudinal steel rebar should not be less than 12mm. The clear distance between the rebars should not be smaller than 50mm and not larger than 350mm. The longitudinal steel ratio should not be larger than 5%.

(2) The stirrup should be designed as closed form and the diameter should not be smaller than 8mm. Angle bars should be located at the pier corner.

(3) The distance between stirrups should not be larger than 15 times of that of the longitudinal rebar and smaller than 400mm.

(4) The concrete strength should not be lower than C20.

(5) Under condition of river flow of large volume and high velocity, upstream breakwater and preventive measures should be considered appropriately.

(6) If single-directional rebars are employed, structural rebars of diameter not smaller than 12mm and spacing not larger than 250mm should be located perpendicular to the loaded single-directional rebars.

(7) The pier foundation and detailed structural design should fulfil related design standard accordingly.

For details, please refer to the Appendix B "Structure Calculation of Bailey Bridge- width 1500mm".

3.2.3 Loading

In the structural calculation of Wu Zhi Qiao Bailey bridge, the combination of vertical dead loads and live loads is the main consideration. Wind loads are lateral which are generally resisted by the sway braces. Seismic loads and wind load in vertical direction are not considered either. In the loading calculation of Bailey footbridge, only pedestrian action on deck is considered in live load. [Reference 7]

Whereas the dead loads refer to the self-weight from the structure and the deck. The self-weight of the structure can be directly considered as self-weight in the calculation model. Due to the presence of bolts, gusset plates, male and female lugs, the structural self-weight factor can be taken as 1.2 to be conservation. The self-weight of deck can be calculated according to the volume of it. The unit weight for steel is 78.5 kN/m^3. The self-weight of deck can be considered as uniform load or as a point load acting on the transom. The only pedestrian load is taken as the live load on deck. It can be taken as uniform load, $3kN/m^2$, with reference to clear width of the deck on the transom.

In the structural calculation, the double-span Bailey bridge can be calculated as a single-span with simple supported beam. Only the basic and standard loading combinations are needed for the calculation.

1. Basic Combination : 1.2×Self Weight + 1.2×Weight of Deck + 1.4× Full Pedestrian Load
2. Standard Combination : 1×Self Weight + 1×Weight of Deck + 1×Full Pedestrian Load

The basic loading combination can be used to calculate the strength and bearing capacity between overall structure and connection node, welding joint as well as structural stability. While the standard loading combination is used for calculating structural stiffness (moment). The overall structural stability is analyzed with extreme loading factor, in which the loading factor under structural buckling failure is taken as:

loading factor= (minimum pedestrian action (with deduction of dead loads))/(design value for pedestrian action).

3.3 Materials and Properties

3.3.1 Steel

The steel grade used for Bailey panel should be Q235 and Q345 and the quality should be in accordance with Carbon Structural Steels (GB/T 700) and Low Alloy Steel Covered Electrodes (GB/T 1591). The choice of grading should consider the local minimum temperature in winter. It is suggested to use grade B or above. The strength value should depend on the thickness, as shown in Table 3.1.

Table 3.1 Design Values for Steel Strength (MPa)

Steel		Tension, Compression and Bending Resistance f_d	Shearing f_{vd}	Floor Loading f_{cd}
Model	Thickness (mm)			
Steel Q235	⩽16	190	110	280
	16~40	180	105	
	40~100	170	100	
Steel Q345	⩽16	275	160	355
	16~40	270	155	
	40~63	260	150	
	63~80	250	145	
	80~100	245	140	

The zinc-rich priming paint employed should follow the Zinc-rich Priming Paint (HG/T 3668) with the application of appropriate intermediate and surface coatings that follow Epoxy Micaceous Iron Oxide Intermediate Coatings (HG/T 4340), Solvent-thinned Polyurethane Coatings (Two-component) (HG/T 2454) and other related standard. The choice of paint should provide corrosion resistance to the structure for a minimum of 10 years.

3.3.2 Connection

The connection pins for Bailey panel should be made of quality carbon structural steel or rolled steel in which the choice of material should follow the current Quality Carbon Structure Steels (GB/T 5780).

The bolts mentioned in this manual are not the main loaded components and therefore general ones can be used in line with Hexagon head bolts-Product grade (CGB/T 5780) and Hexagon head bolts (GB/T 5782). High strength bolts can also be used if needed. The dimension of the bolts should correspond with the size of openings on components.

The welding material should match to those employed main structural steel. For manual welding, the welding rod used should follow the Carbon Steel Covered Electrodes (GB/T 5117) or Low Alloy Steel Covered Electrodes (GB/T 5118). Automatic and semiautomatic welding should follow the requirements in Steel Wires for Melt Welding (GB/T 14957), Welding Electrodes and Rods for Gas Shielding Arc Welding of Carbon and Low Alloy Steel (GB/T 8110), Carbon Steel Flux Cored Wires for Arc Welding (GB/T 10045), Low Alloy Steel Flux Cored Electrodes for Arc Welding (GB/T 17493), Carbon Steel Electrodes and Fluxes for Submerged Arc Welding (GB/T 5293) or Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding (GB/T 12470). The welding procedures should fully meet the requirements stated in the Code for Welding of Steel Structures (GB50661). The welded joint should pass the visual inspection. The design value for the corresponding welding joint strength should be chosen with reference to Table 3.2.

Table 3.2 Design value for welding joint strength (MPa)

Steel		Butt weld/ welding joint			Fillet Weld f_{fd}
Model	Thickness(mm)	Compression $f_{cd,w}$	Tension $f_{td,w}$	Shearing $f_{vd,w}$	
Steel Q235	⩽16	190	160	110	140
	16~40	180	155	105	
	40~100	170	145	100	
Steel Q345	⩽16	275	235	160	175
	16~40	270	230	155	
	40~63	260	220	150	
	63~80	250	215	145	
	80~100	245	210	140	

3.4 Reference

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7. CCCC Highway Consultants Co., Ltd. General Code for Design of Highway Bridges and Culverts (JTG D60-2015) [S]. China Communications Press, 2015.

4

Wu Zhi Qiao Bailey bridge

Design

The Bailey bridge is composed of a truss system. Each section of the truss is made up of two Bailey panels and these two panels are connected by transoms and braces with diagonal supports on both outsides of these panels to increase the system's lateral stability.

4.1 Design of a Bailey Panel

The distance between the upper and lower chords of the Bailey panels is 1137mm, and each chord is made up of two C6.3 steel channels with 50mm in between. Both chords have male lugs at one end and female lugs at the other end for connecting multiple panels. In the middle, two C5 steel channels are welded together to support the chords while the C5 steel channels are slotted in the 50mm gap between each set of steel channels of the upper and lower chords. On the two ends, two C5 steel channels are welded to support both chords. Two single C5 steel channels connect the upper and lower chords by forming a V-shape. Figure 4.1.1-Figure 4.1.3 show the structure of a panel in detail, and Figure 4.1.4 is one of the completed structure of Wu Zhi Qiao Bailey bridges.

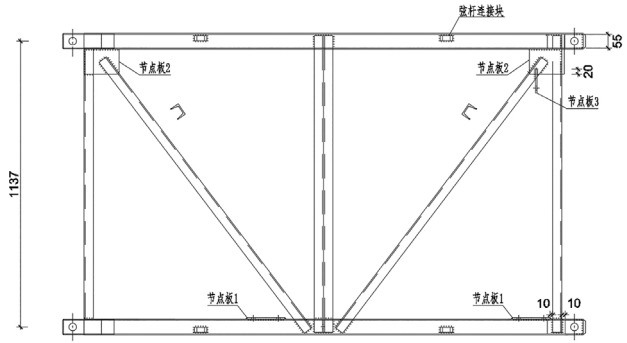

Figure 4.1.1 Bailey bridge panel (unit: mm)

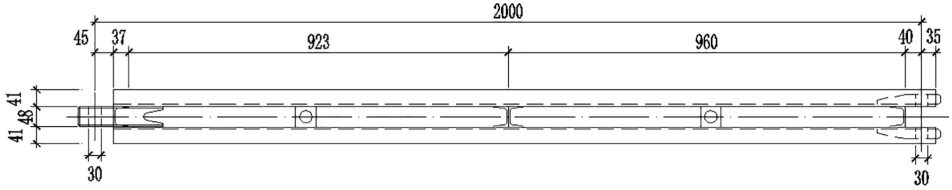

Figure 4.1.2 Horizontal member (unit: mm)

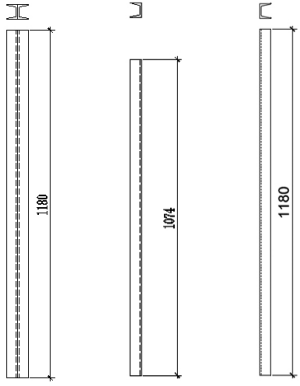

Figure 4.1.3 Vertical member (unit: mm)
(a) middle vertical member
(b) male vertical member
(c) female vertical member

Figure 4.1.4 Actual building of Bailey bridge

4.2 Design of Transom and Deck

The transom and deck are used for transferring the crowd-load to Bailey panels.

4.2.1 Design of Transom

There are two types of transom: the short and the long one. The short transom connects the lower chords of two panels through panel pins and bolts, and its length is equal to the distance between the outer edges of these two lower chords. The long transom is 620mm longer than the short transom to not only transfer load from decks to panels but also to meet the geometric requirement for connecting diagonal bracing. Long transom also connects the lower chords of two panels through panel pins and bolts. Both short and long transoms are made up of I8 I-beam which bear loads evenly. Specifically, an additional long transom is required for the first panel-pair of a Bailey bridge to fulfill the geometric requirement, as illustrated in Figure 4.2.1-4.2.4 (for a 1500mm Bailey bridge):

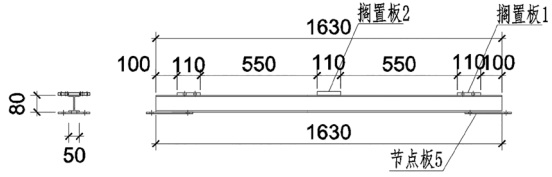

Figure 4.2.1 Short transom in elevation drawing (unit: mm)

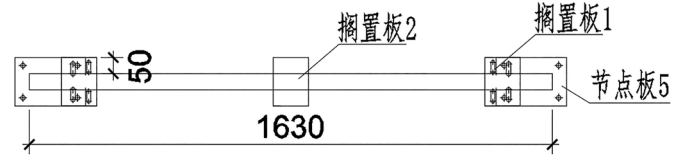

Figure 4.2.2 Short transom in a floor plan drawing (unit: mm)

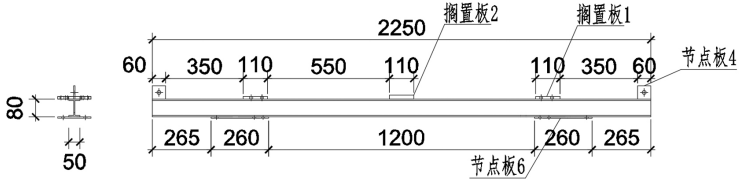

Figure 4.2.3 Long transom in elevation drawing (unit: mm)

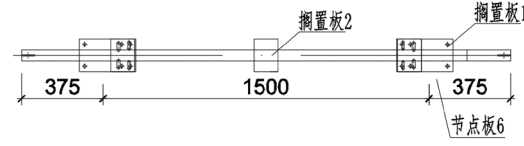

Figure 4.2.4 Long transom in a floor plan drawing (unit: mm)

4.2.2 Design of the Angle Steel Bar

Angle steel bar for deck support is used to limit lateral displacement of the deck. The angle steel bar prevents the decks from slipping, and distribute the load more evenly. The bottom of L5 angle steel bar is connected to the long and short transoms through bolts, and the decks are put on top of the angle steel bar without connection. The angle steel bar has pre-set oblong openings tailored for fastening bolts. A major dimension of angle steel bar is shown in Figure 4.2.5 (for a 1500mm Bailey bridge):

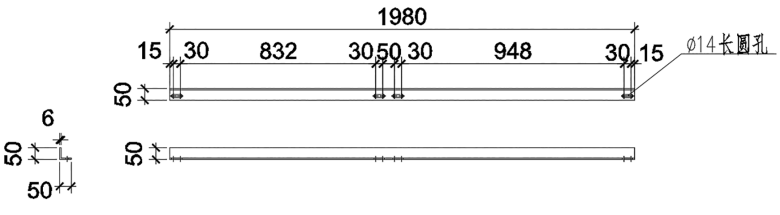

Figure 4.2.5 The dimension of angle steel bar (unit: mm)

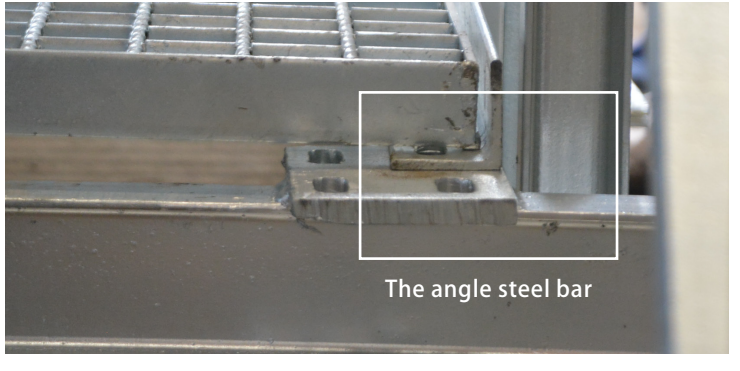

Figure 4.2.6 The angle steel bar on an actual bridge

4.2.3 Design of Decks

The deck is made of grille steel plates connected to the transoms by M-clamps. A grille steel plate is made by welding flat steel and twist steel together. Horizontal rows of the grille steel plates are made with 5mm-thick flat steel while the vertical columns are made with Φ6 twist steel, except the two ends of the vertical columns of grille steel plates that are made with 5mm-thick steel. There are two types of grille steel plates: The No. 1 plate is longer than the No. 2 plate, and details of dimensions are shown in Figure 4.2.7 and 4.2.8 (for a 1500mm Bailey bridge's deck). Figure 4.2.9 and 4.2.10 show the different views of Bailey panels:

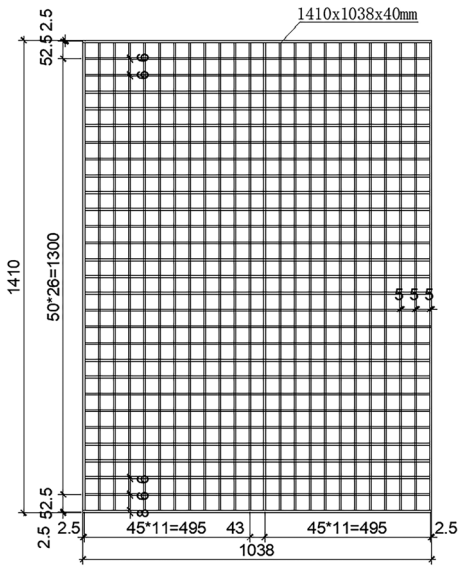

Figure 4.2.7 No. 1 grille steel plate (unit: mm)

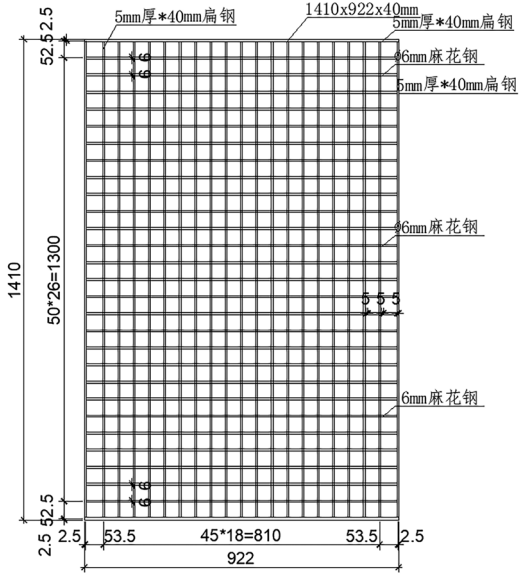

Figure 4.2.8 No. 2 grille steel plate (unit: mm)

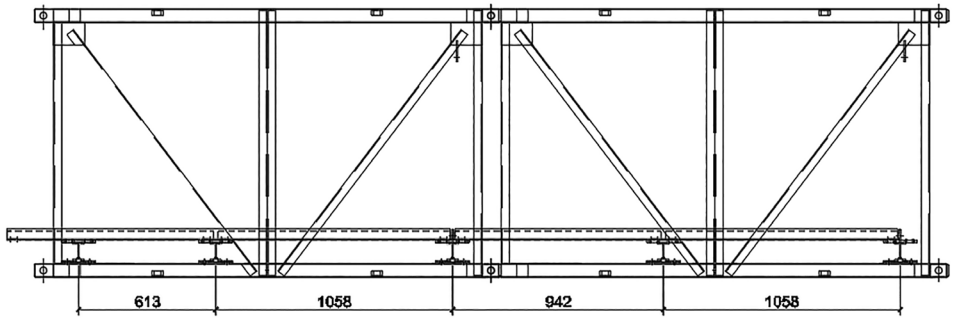

Figure 4.2.9 Elevation drawing of assembled transoms, angle steel bar and grille steel plates (1st and 2nd sections) (unit: mm)

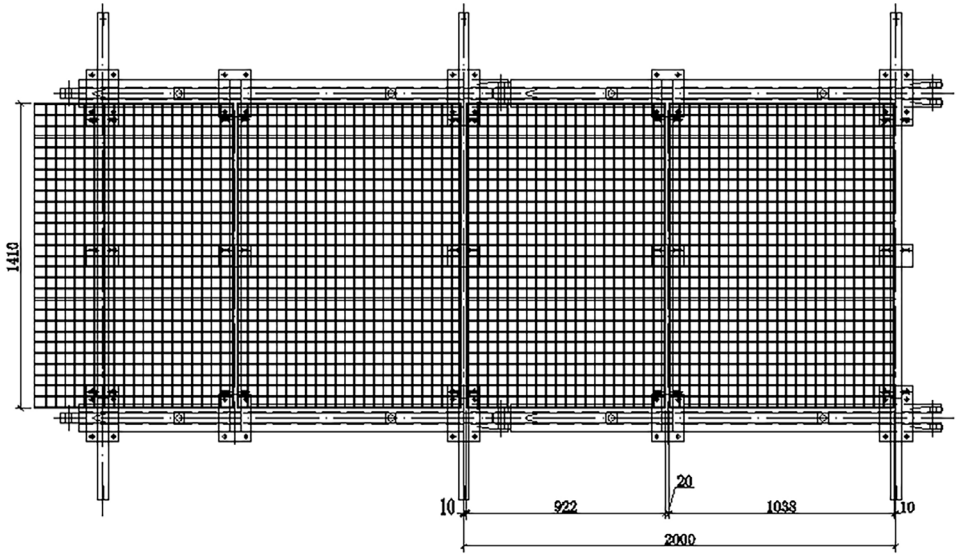

Figure 4.2.10 Floor plan drawing of assembled transoms and grille steel plate (1st and 2nd sections) (unit: mm)

For the convenience of processing and standardization, the first Bailey panel's No 2 grillage protrudes the main girder. It does not compromise or affect the structural stability and functionality.

4.3 Design of Diagonal Bracing

The diagonal bracing prevents Bailey panels from lateral torsional buckling and thus makes the Bailey bridge rigid and stable. The diagonal bracing is made of L5 angle steel and connects the bottom of the long transom to the top of each panel of the inner truss through bolts. The main dimensions are shown in Figure 4.3.1 and Figure 4.3.2 below (for a 1500mm Wu Zhi Qiao Bailey bridge):

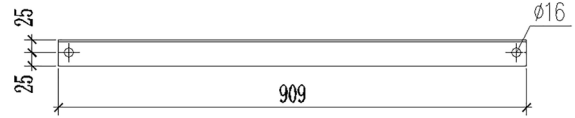

Figure 4.3.1 Dimension of diagonal bracing (unit: mm)

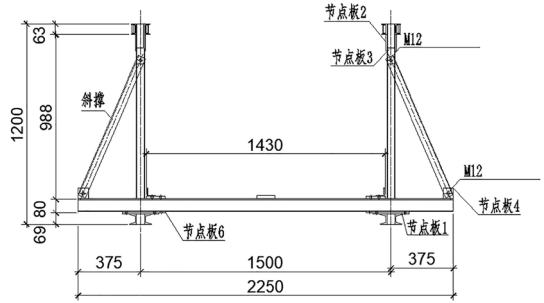

Figure 4.3.2 Sectional view of assembled diagonal bracing on the bridge (unit: mm)

4.4 Design of Sway Brace

Sway brace is used to resist lateral loads such as wind load. Sway brace is composed of two adjustable steel round rods that form an X shape with both ends hooked to the shelving plate on the long transom and the turnbuckles installed in the middle to adjust the length of sway brace. Details of the Sway Brace's dimensions are illustrated in Figure 4.4.1 and 4.4.2 (for a 1500mm Wu Zhi Qiao Bailey bridge):

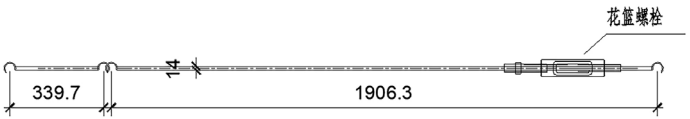

Figure 4.4.1 Dimension of Sway Brace (unit: mm)

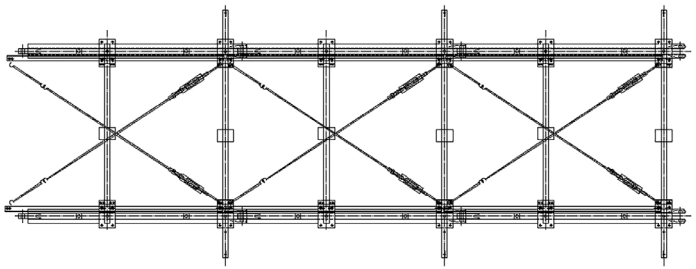

Figure 4.4.2 Floor plan drawing of Sway Brace assemble

4.5 Design Drawing of Bridge Structure and Gantry

Refer to Appendix C “Structural Design of Bailey bridge” and Appendix E “Design of the Launching Nose and Gantry” for Wu Zhi Qiao Bailey bridge structural and gantry design.

4.6 Component Processing

These aforementioned components of Bailey bridge are prefabricated with high processing precision and high welding quality. These components are processed with anticorrosive zinc coating and then preassembled to ensure the successful assembling onsite. Therefore, relevant steel processing experience and construction qualifications are looked upon favorably during vendor and contractor selection.


ARUP

5

Wu Zhi Qiao Bailey bridge

Key Points of Construction

Figure 5.1.1 Area highlighted in orange is for panels assembling and jacking

5.1 Construction Site Requirement (Site leveling for temporary approach road of a bridge)

Site selection is primarily determined by tactical requirements. It is recommended to choose a site with a stable foundation and straight riverbanks. At least one side of the banks should have a flat and spacious piece of land for assembling and jacking of bailey panels, and the arable land on both sides should be leveled for temporary approaches.

The ideal location and size of the area for assembling and jacking should be about the length of the span of the bridge (i.e., the orange boxed area) as shown in Figure 5.1.1. When there is no such ideal site, the size of the site should be at leastlarger than 4000mm (L) x 2000mm (W) and this area should be spacious enough for assembling 2 Bailey panels.

Figure 5.1.2

In designing the site for launching jacking, the width of the site must be larger than the width of the Bailey bridge, and the length of the site (from the closest end of the bridge to the end of the site) should be larger than 2/3 of the span.

6

Wu Zhi Qiao Bailey bridge

Applications (Liuzhu Village in Yunnan Province)

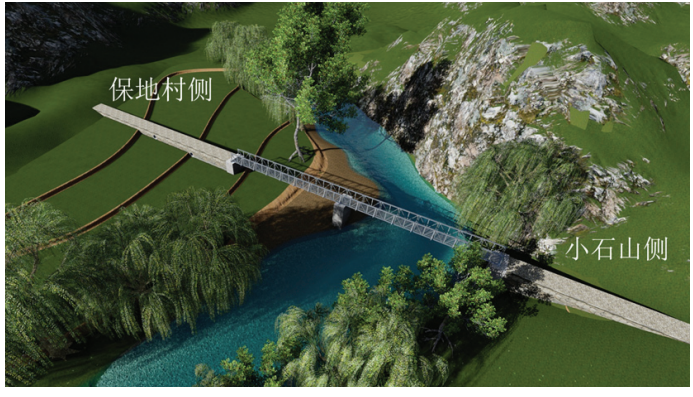

Figure 6.1.1 Design sketch of Bailey bridge project in Liuzhu village

6.1 Project Overview

The demo project is located in Liuzhu Village, Baga Township, Yanshan County, Wenshan Prefecture, Yunnan Province of China. The Bailey bridge in this project is a two-span continuous bridge with a single span of 16 meters, total length is 32 meters, the width of decks is 1430mm, the clear width of the bridge is 1250mm, and bridge height is 1200mm. The bridge weighs around 6.3 tons in total with the weight of each panel being 110kg. Web member of Bailey panels are used as handrails. The substructure of the bridge is made up of reinforced concrete. Two abutments are located at ends of the bridge, and a pier in the middle. The approach road on the ends of the bridges is around 28-meter long made of reinforced concrete, which can be used as a construction platform during the assembling of the bridge. The design sketch of the bridge is shown in Figure 6.1.1.

Figure 6.1.2 Actual building of Bailey bridge in Liuzhu village

The project commenced in February 2017 and was sponsored by the Home Affairs Bureau of the Hong Kong Special Administrative Region Government. The project received support from the Wu Zhi Qiao (Bridge to China) Charitable Foundation, the government of Yunnan province and Liuzhu Village Committee. Together with the enthusiasm and help of the villagers, more than 60 volunteers from The Chinese University of Hong Kong, The Hong Kong Polytechnic University, Tongji University, Kunming University of Science and Technology, Tsinghua University, and Education University of Hong Kong has completed the construction of a 32-meter Wu Zhi Qiao Bailey Bridge with a 28-meter approach road in August 2017 as shown in Figure 6.1.2.

6.2 Structural Design

6.2.1 Bailey Panel

The Bailey panels are the main body of the Bailey bridge. Each Bailey panel consists of the upper and lower chords, vertical and diagonal bracing, and gusset plates. In this project, each panel weighs around 110kg, and thus these panels can be manually transported for a short distance and be transported by carts for a longer distance due to the adverse transportation facilities in rural area. Bailey panels are generally stacked near the construction site for the convenience of manual transportation, as shown in Figure 6.2.1.

Figure 6.2.1 Stacking of Bailey panels

6.2.2 Transoms

Transoms are the key components of a Bailey bridge, as shown in Figure 6.2.2. Transoms can support the deck, connect Bailey panels, and stabilize the structure of the Bailey bridge. Transoms can be divided into two types, namely short and long. The long transoms connect to diagonal bracing in two ends, connect to sway brace at the bottom side, and supports deck on the top side. Transoms should be grouped in site according to their classification.

Figure 6.2.2 Transoms of Bailey bridge

6.2.3 Diagonal Bracing

Diagonal bracing is made of steel angle with openings at both ends and is used for stabilizing the structure of the bridge, as shown in Figure 6.2.3. The diameter of the openings on the supporting brace should be slightly larger than the diameter of bolts to offset the discrepancy between these openings and bolts in case there is any imprecision in processing and assembly. Based on the previous experience of Wu Zhi Qiao projects, the diameter of openings should be 4mm larger than the diameter of bolts.

Figure 6.2.3 Diagonal bracing installed on Bailey bridge

6.2.4 Sway Brace

The sway brace is one of the important components of the Bailey bridge. The sway brace can resist lateral load as well as guarantee the overall stability of the bridge. Figure 6.2.4 shows an installed sway brace. The length of a sway brace can be adjusted through the turnbuckles. Sway braces are first hooked onto the bottoms of long cross girders and then secured by tightening the turnbuckles with the use of a separate nut to prevent loosening. Sway braces are easy to assembly and can adjust the width of each section of the bridge.

Figure 6.2.4 Installed Sway Brace on the Bailey bridge

6.2.5 Deck

The project used grille plates as the deck to prevent the accumulation of mud and snow while the rain can help to clear the deck's surface. Besides, the grille plate can satisfy the requirement on the stiffness of the bridge and is a kind of ideal deck for footbridges in rural areas. Grille steel plate is connected to the cross girder using M-clamps as shown in Figure 6.2.5. The shelving plate on cross girder has oblong openings offering buffer to securely fasten the grille steel plates. Installed grille plates on Bailey bridge are shown in Figure 6.2.6. They look neat, tidy and matching with the whole bridge.

Figure 6.2.5 M-clamps

Figure 6.2.6 Grille steel plates being installed on Bailey bridge

6.3 Structural Construction

6.3.1 Installation of Gantry

Gantry is used as launching erection and safety protection equipment for constructing the bridge. The design of the gantry is dependent on the size of pier and abutments. The steps for installation of gantry is as follows, and the process is shown in Figure 6.3.1:

1. Drilling, enforcing the gantry bar on the ground/platform
2. Install the vertical bracing
3. Install the diagonal bracing
4. Install the horizontal transoms

Figure 6.3.1 Installation procedure of Gantry

6.3.2 Assembly of Bailey Panels

1. Connecting Bailey Panels:

Figure 6.3.2 Connecting Bailey panels

Figure 6.3.3 Connecting male and female lugs

2. Mounting Pins:

Figure 6.3.4 Mounting pins

3. Installing Long and Short Transoms:

Figure 6.3.5 Placing long transoms

Figure 6.3.6 Tightening the bolts

4. Installing Diagonal Bracing:

Figure 6.3.7 Installing diagonal bracing

5. Installing Sway Brace:

Figure 6.3.8 Installing sway brace

6.3.3 Launching Erection

The Wu Zhi Qiao Bailey bridge in Liuzhu Village consists of 16 modules (32 meters in total). The launching erection begins when sufficient modules have been installed. To enhance stable and overturning of the bridge into the river, the total weight of the unlaunched panels should be heavier than the total weight of those launched panels. Launching can be continued gradually upon sufficient modules are assembled.

The span of the bridge is 16 meters plus 16 meters, and the site for launching erection is on a newly built 20-meter cement path. During the inching process, the steel cable functions as a guiding and suspension cable. It also serves a safety measure for preventing the over-shooting of bridge while it is being pushed from behind.

Gantries with hoists at the piers are used for the final positioning of the bridge.

The launching nose helps to reduce the cantilever load of the Bailey bridge. It is directly installed in front of the first Bailey panels, connecting the upper and lower chords by pins and bolts, as shown in Figure 6.3.9.

Figure 6.3.9 Installation of the launching nose

Erection process in Figure 6.3.10. For details, refer to Appendix D “Construction Sequence for Launching”.

Figure 6.3.10 Process of launching and erection of Bailey bridge

As shown in Figure 6.3.11, the inching push and pull method is used in the launching process. The front section of the bridge can be moved to the pier and abutment following the gantry, hoist, and safety belts.

The Bailey bridge in the Liuzhu project has two sections (2 x 16 meters). The launching nose is relatively much lighter than a Bailey module and this helps to speed up the bridge reaching the supporting pier in the middle of river.

Figure 6.3.11 Inching push and pull method was used in the launching process

6.3.4 Bridge Deck Installation

Each deck should be conveyed by 2 people. 4 workers are recommended to carry out the installation work.

Figure 6.3.12 Installation procedure of bridge deck

6.3.5 Others

1. Bolts Check-up and Anticorrosive Coating Touch Up

Bailey panels are connected and secured by pins and bolts as shown in Figure 6.3.13. Be sure pins and bolts are tightened between Bailey panels, transoms, decks etc. Anticorrosive coatings should be applied to those non-protected parts as if necessary.

Figure 6.3.13 Inspection of bolts

Figure 6.3.14 Anticorrosive coating touch up

2. Install Support and Stabilize the Bridge Structure

Once the bridge has been hoisted, all the rollers and supporting tool could be removed. Anchoring bolts should be installed for securing the bridge structure in place from displacement.

3. Gantry Removal and Clean-Up

The erection set up such as the gantry, hoist, cable etc. are dismantled and removed. Clean up the construction area to ensure safety and usage of the bridge area.

6.3.6 Tool List

Refer to Appendix A “Tool List” for all the tools for building a Bailey bridge.

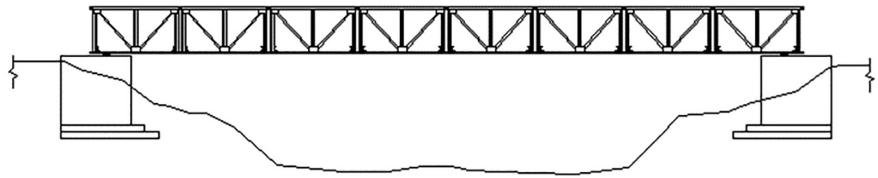

Figure 6.3.15 Final completion of Bailey bridge

6.4 Construction and Safety

6.4.1 General Safety Measures

1. Good housekeeping should be kept onsite.
2. Only authorized personnel with proper safety training should be allowed to work on site.
3. Competent site supervisors should be employed for conducting the erection with the assistance of at least 2 safely assistants.
4. All personnel working on site must be provided and equipped with proper protective gears, especially for working-at-height and high risk works.
5. Safety inspection should be made to the construction site condition, machinery and safety gear before any commencement of works.

6.4.2 Working-at-Height

All personnel must be properly trained on safety of working at height and with the wearing of proper full protection gears.

6.4.3 Cable Installation

1. The erection must be undertaken by competent personnel.
2. Safety inspection should be taken by the safety supervisor before its uses.
3. No person should be allowed to stay below the bridge when any work is carried out on it.

6.4.4 Gantry Installation

1. Upon completion, check that all bolts are securely fastened, and the whole structure is in a sound and good condition.
2. A safety system of work of installation and dismantling should be implemented.

6.4.5 Safety Supervision

1. One safety supervisor on each pier should be deployed.
2. A competent site personnel should be deployed to oversee all the construction and safety matters.

7

Wu Zhi Qiao Bailey bridge

Inspection and Maintenance

Inspection and Maintenance			
Components of bridge	Inspection items	Method of maintenance	Frequency
Abutment & Support	Examine if any cracks found on the abutments and the river embankment is in good condition	If there are small cracks found on the abutments, use cement mortar to fill the crack to prevent erosion of the reinforcing bars inside the abutments. If there is damaged of the embankment, application of a mixture of cement mortar with scribbles to fill the cracks	Once per month
	Any reshape or damage of the support	Replace the support if it is seriously damaged. (suggest Implementing by professional)	
Bailey panel	Any rusting to the steel panels	Keep the bridge dry and clean. Apply melding and anticorrosive Coating	Once per month
	Any missing parts of the bridge structure	Inform supervisor timely, and report to the local officials for the bridge status	
	Any damage or relocation of bridge components	Stop crossing the bridge and report to the immediate supervisor. Seek help from professionals	

Inspection and Maintenance			
Components of bridge	Inspection items	Method of maintenance	Frequency
Bolts	Bolts in good form and well fastened	Examine if any bolts or Bailey panels are not tightened or almost fall out. Fasten them immediately	Once per month
Deck	Any damage or missing found	Stop crossing the bridge and should restore new deck timely	All times
Approach road	Any damage or erosion found at the approach road and road foundation	Repair of approach road by village committee if small cracks and gaps are found, or contact contractor for consultation	All times

Reminders:

1. Inspection to the bridge should be carried out after each natural disasters such as flooding or earthquake so as to ensure it is safe for use.
2. If any significant damage is found, it should be reported to the related local authority immediately and the use of the bridge should be immediately banned.
3. No vehicle is allowed to cross the Bailey bridge.

8

Conclusion and Acknowledgment

Wu Zhi Qiao (Bridge to China) Charitable Foundation sincerely expresses our appreciation and gratitude to those who have contributed to the compilation of this manual. Wu Zhi Qiao Bailey bridge is the fruitful outcome of constant experimenting and modifying existing vehicle-operated Bailey bridge. It is sturdy, aesthetically pleasing, and portable-perfect for mountainous areas with adverse road conditions. Achieving matured and well-designed product is never easy. The Foundation is honored and thankful to have received generous support from industry experts, Wu Zhi Qiao Project Committee, Tongji Wu Zhi Qiao University Student Team, Zhenjiang Great Wall Heavy Industry Technology Co. Ltd. and all other volunteers and colleagues.

Firstly, the Foundation would like to thank Mr. Ho Juh Kuen, former chairperson of the Wu Zhi Qiao Project Committee. Mr. Ho is one of the founders of the Foundation, offering years of experience in pedestrian bridge projects. He has adapted and leveraged the advantages traditional military-use Bailey bridge and deployed them to the Wu Zhi Qiao projects. In 2016, Mr. Ho has invited Mr. Matthew Lee, Mr. Li Kwok Leung, Mr. Plato Lee, Mr. Max Lee, and Mr. Stephen Li to join Wu Zhi Qiao' s Chongqing Machi footbridge building project. The collaborative efforts have resulted in the success for the construction a Wu Zhi Qiao Bailey bridge for the first time. In the subsequent projects, the Project Committee has continuously optimized the design and finalized the structural design of the Wu Zhi Qiao Bailey bridge.

The Foundation is much obliged to the support from Tongji University and their technical assistance for these years. Throughout the evolution of the design of Wu Zhi Qiao Bailey bridge, the student teams had put practical research into production, testing durability and safety to enhance and confirm feasibility.

In particular, the Foundation is most grateful to Professor Wu Xun from Bridge Engineering Department of Tongji University for serving as key driver of the Tongji Wu Zhi Qiao University Student Team. Professor Wu has combined his rich industry experience and research background to make concrete suggestions to both the design of Bailey bridge and this manual. Besides, Teacher Wu Pei-feng from Bridge Engineering Department of Tongji University had created an engaging environment for students within the Institute to hone their skills with Wu Zhi Qiao projects and set a solid foundation for the growth of Tongji University Wu Zhi Qiao student team.

The Foundation is thankful to Zhenjiang Great Wall Heavy Industry Technology Co. Ltd. for their professional advice and granting access to their testing facilities. In a commercial testing environment, Wu Zhi Qiao Bailey bridge is able to make further improvement and mass-produced. Last but not least, the Foundation wishes to convey special thanks to the student team of Tongji University including Mr. Zhang Zhenyu, Ms. Liu Chang, Mr. Wang Jiaqi, Ms. Li Ang, Mr. Qiu Shuang, Mr. Chen Xianjun, Mr. Huang Liguan, Mr. Chen Zhao, Mr. Yi Daoyuan, Mr. Lao Tianpeng, Mr. Gao Zhan, Ms. Wang Cong, Mr. Ying Yufeng. They have been dedicated and involved in the first and second generation of the Wu Zhi Qiao Bailey bridge designs and associated activities visit and incorporated their valuable insights into this manual. To arrive at the final tactical requirements of the Wu Zhi Qiao Bailey bridge, the Foundation has to rely on all the Wu Zhi Qiao University Student Team who have participated in the projects and contributed their feedbacks with unfailing support in terms of effort and time.

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The Foundation wish this manual can serve as a useful reference for the future participants and students, enhancing craftsmanship with continuous modification and improvement of the techniques to benefit more villagers in the underprivileged areas with connectivity by the Bailey bridge.

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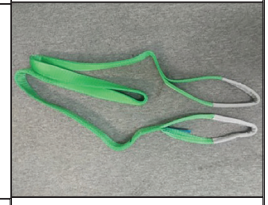
Appendices

Appendix A Tool List of Bailey Bridge Construction

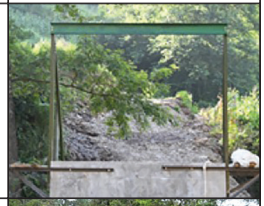
Serial Number	Tool Name	Function	Picture
1	Chain hoist	Towing Bailey panels	
2	Webbing lifting sling	Use with the Chain hoist	
3	Shackles	Towing Bailey panels	

Serial Number	Tool Name	Function	Picture
4	Protective hands gloves	For safety to every volunteer on site	
5	Socket wrench (M16/M12)	For assembling gantry, bridge structures, launching nose, M-clamps etc.	
6	Spanners	For assembling gantry, bridge structures, launching nose, M-clamps etc.	

Serial Number	Tool Name	Function	Picture
7	Anti-rust paint	Rust prevention to screws	
8	Electric drill & drill bits (M16/M20)	Install gantry	
9	Walkie-talkie	To ease communication of volunteers at the site	

Serial Number	Tool Name	Function	Picture
10	Safety belts	For safety to every volunteer on site	
11	Safety belt buckles	Use with the safety belts	
12	Safety belt pulley	Use with the safety belts	

Appendices

Serial Number	Tool Name	Function	Picture
13	Gantry	Towering Bailey panels	
14	Launching nose	Reduce the length of the cantilever of Baily bridge	
15	Hydraulic Jack	Lift up the Bailey Bridge	

Serial Number	Tool Name	Function	Picture
16	Rollers	Towing Bailey panels	
17	Pulley buckles	Connect with steel cables and hoists	
18	Tents	To store up construction utilities and components of the bridge	

Serial Number	Tool Name	Function	Picture
19	Warning tape	To set up a construction site area for safety to villagers	
20	Crowbar	To ease the installation of Bailey panels	
21	Hand hammer	Install connecting pins	

Serial Number	Tool Name	Function	Picture
22	16mm Steel cables	Towing Bailey panels and serve as protection wires to volunteers	
23	Locking buckle for pins	To buckle up steel cables	
24	Paint brushes	To paint on lubricating oil	

Appendices

Serial Number	Tool Name	Function	Picture
25	Lubricating oil	To ease the installation of connecting pins	
26	Construction warning signs	To alert safety at and around the construction site	
27	Meter ruler	Measure the construction area	

Serial Number	Tool Name	Function	Picture
28	Tape measure	For measure and inspection	
29	Safety helmets	For safety to every volunteer on site	
30	Welders	To smooth out and welding joints of the Bailey panels	

Serial Number	Tool Name	Function	Picture
31	Turnbuckles	To tighten up the sway brace, and particularly tightening the turnbuckles with the use of a separate nut to prevent loosening	
32	Flat files	To smooth out and welding the male and female lugs	
33	M20 & M16	Serve as expansion bolts	

Serial Number	Tool Name	Function	Picture
34	Socket wrench for M- clamps	To fasten the M-clamps and bolts	

Note: The above tools are only based on the previous project experience of Wu Zhi Qiao (Bridge to China) Charitable Foundation. The specific construction tools need to be selected according to the actual situation.

Appendix B Structural Calculation (width of bridge 1500m)
Appendix C Design Drawing of Bailey bridge
Appendix D Construction Sequence for Launching
Appendix E Design Drawing for the Launch Nose and Gantry

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To download the manual, please go to Wu Zhi Qiao (Bridge to China) Charitable Foundation website at https://www.bridgetochina.org.hk/
If there is any inconsistency or ambiguity between the English version and the Chinese version, the Chinese version shall prevail.
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