The Hong Kong Polytechnic University

TECHNICAL REPORT NO.24

Erection of Bamboo Scaffolds

K F Chung and Y C Siu

INBAR

INTERNATIONAL NETWORK FOR BAMBOO AND RATTAN

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INBAR publishes an ongoing series of Working Papers, Proceedings and Technical Reports, occasional mongraphs, reference materials and the INBAR Newsmagazine. It also provides an on-line library featuring relational databases on bamboo and rattan products, organizations, projects, experts and scientific information.

Financial support for INBAR's programs is provided by the Governments of China and the Netherlands, the International Development Research Center (IDRC) of Canada, and the United National International Fund for Agricultural Development (IFAD).

Address:
Anyuan Building No. 10, Anhui Beili, Asian Games Village
Chaoyang District, Beijing 100101, People's Republic of China
Tel: +86 (10) 64956961, 64956978, 64956982
Fax: +86 (10) 64956983
E-mail: info@inbar.int
Website: http://www.inbar.int/

Mailing Address:
Beijing 100101-80, People's Republic of China

The Research Centre of Advanced Technology in Structural Engineering (RCATISE) of the Hong Kong Polytechnic University was established in 1999 to provide a focused platform for research and development of advanced technologies in structural engineering in the South East Asia.

Further information about the **RCATISE** may be obtained at the RCATISE web address: *http://www.cse.polyu.edu.hk/research/rcatise/home.htm*

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Printed by : Colour Max Commercial Printing Company Limited.

ISBN : 962-367-366-3

Foreword

Bamboo scaffolds have been widely used in construction applications in South East Asia, in particular, Hong Kong for many years. Because of their high adaptability and low construction cost, bamboo scaffolds can be constructed in different shapes to follow any irregular architectural features of a building within a comparatively short period of time. In general, bamboo scaffolds are mainly used to provide access of workers to different exposed locations to facilitate various construction and maintenance process. Besides widely erected on construction sites, bamboo scaffolds are also used in signage erection, decoration work, demolition work and civil work.

In 1999, a research and development project titled '*Bamboo Scaffolds in Building Construction*' was undertaken at the Research Center For Advanced Technology in Structural Engineering (*RCATISE*) of the Hong Kong Polytechnic University with the support of the International Network of Bamboo and Rattan (*INBAR*). A Steering Committee was set up as follows:

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- Mr Y.S. So, Wui Loong Scaffolding Works Co. Ltd., Hong Kong
- Dr S.P. Chiew, Nanyang Technological University, Singapore

The major objectives of the project are to promote the effective use of bamboo scaffolding in building construction through advancement and dissemination of structural bamboo technology. Both the established knowledge and the proven practice of bamboo scaffolding in Hong Kong are formalized and documented as follows:

a. *Erection of Bamboo Scaffolds* covering material selection, typical configurations with details, and erection procedures for builders and scaffolding practitioners.

b. *Design of Bamboo Scaffolds* covering material requirements, typical applications, structural principles and safety requirements for structural engineers.

Other activities include the investigation on modularization of bamboo scaffolds, and the search for improved structural forms using the integrated analysis and design software *NAF-*

NIDA (which is developed specifically for stability analysis of slender skeletal structures). Moreover, engineered connections are also developed for improved buildability and rational data for design.

This document *Erection of Bamboo Scaffolds* presents the basic features of bamboo scaffolds and the respective practical applications in building construction, and it has been presented to the following organizations for reviews and comments:

- Architectural Services Department, Government of the Hong Kong Special Administrative Region (HKAR)
- Buildings Department, Government of the HKSAR
- Housing Department, Government of the HKSAR
- Hong Kong Association of Contractors
- Hong Kong Association of Bamboo Scaffolding

Technical support from the Construction Industry Training Authority (CITA) of the Government of HKSAR, in particular, Ir Albert Y.C. Tong, Executive Director of CITA, is gratefully acknowledged.

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1. Introduction

Bamboo scaffolding is an ancient structural system used in China over a few thousand years. It is believed among Chinese scaffolding practitioners that the first tree house built by 'Yau Chau Sze' some 5000 years ago used bamboo extensively. In Hong Kong, it is one of the few traditional building systems which survives by self-improvement through practical experiences of scaffolding practitioners over the last 50 years. In spite of open competition with many metal scaffolding systems imported all over the world, bamboo scaffolding remains to be one of the most preferred systems for access in building construction.

Bamboo scaffolds are mainly used to provide workers access for execution of various construction and maintenance activities. Besides widely used on construction sites, bamboo scaffolds are also used in decoration work, demolition work, signage erection and slope work.

This document is compiled together with another complementary document titled *Design of Bamboo Scaffolds* to promote the effective use of bamboo as a construction material. Both documents will enable engineers and builders to take full advantages offered by bamboo scaffolding to facilitate building construction, leading improved overall construction economy. A number of references on the material aspect of structural bamboo and the structural behaviour and design of bamboo scaffolds are included in the Bibliography for further information.

In order to facilitate the readers in going through the document, an overall view on the main features of the document is presented as follows:

a) The advantages of bamboo scaffolds in building construction is highlighted in Chapter 1, and a number of practical issues such as site tests and loading requirements are also presented.

b) In Chapter 2, a basic understanding on the structural forms of bamboo scaffolds is introduced together with relevant requirements on supports against overall equilibrium and stability.

c) A number of common applications of bamboo scaffolds are described in Chapter 3 and illustrated with photographs in Chapter 4.

d) The structural forms and the erection sequences of the following bamboo scaffolds are fully presented with illustrations in Chapter 5:

- Single layered scaffolds
- Double layered scaffolds
- Cantilever scaffolds
- Foot-bridge scaffolds
- Platform scaffolds

e) In Chapter 6, basic forms of fastenings with plastic strips between bamboo members are introduced and tightening sequences of knots for members in practical orientations are also illustrated with photographs.

1.1 Advantages of bamboo scaffolds

In general, the use of bamboo has the advantages over other types of scaffolds in terms of low material cost, simple erection, and adaptability to site conditions.

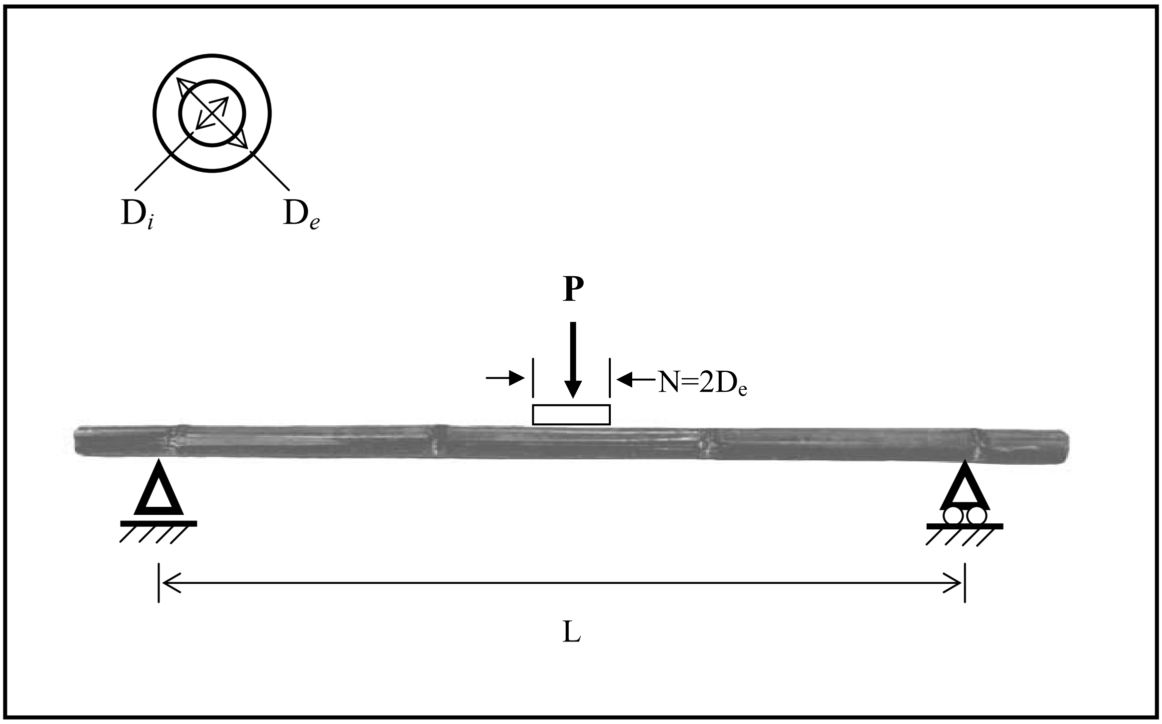
Bamboo is light-weighted material which may easily be handled manually, and the erection of bamboo scaffolds require no machinery nor sophisticated hand tools. They may be cut and tailor-made easily to suit any contour of a construction structure, and thus bamboo scaffolds may be erected much quicker than conventional metal scaffolds. Moreover, bamboo scaffolds may be securely erected at any level of a building stretching a few storeys high. This flexibility of bamboo scaffolds is particularly advantageous in urban areas where buildings are tall and crowded, leaving limited space for construction or maintenance activities.

In Hong Kong, it is estimated that erection of bamboo scaffolds is about 6 times faster, and dismantling of bamboo scaffolds about 12 times faster than metal scaffolds, when compared with same number of workers. The speed of construction is often the overwhelming factor enabling its continual use in Hong Kong.

1.2 Field tests

In order to ensure the quality of bamboo on site is sufficient for structural applications, a simple bending test is devised and illustrated in Figure 1.

Figure 1 One point load test for selection of bamboo members on site.



The field test may be executed on site as follows:

a. Measure the external and the internal diameters of the bamboo member, i.e. D_e and D_i.

b. Place the bamboo member over two supports of L m apart.

c. A load is applied at mid-span of the bamboo member over a bearing length of at least 2 times D_e . The applied load is increased gradually until the bamboo member is failed, and the maximum applied load, P , is recorded.

d. Evaluate the ultimate bending strength of the bamboo member, f_{yb} , which is given by: or

$$M = \frac{P \times L}{4} = f_{yb} \times Z \quad \text{where} \quad Z = \frac{\pi (D_e^4 - D_i^4)}{32\, D_e}$$

e. Based on three tests, the design strength of the bamboo member, f_y , is given by:

$$f_y = \frac{f_{yb,a}}{\gamma_M}$$

where

$f_{yb,a}$ is the average value of f_{yb} from three tests, and

γ_M is a material factor of 1.5.

Based on typical test set-up, the ultimate bending strength of bamboo members may be obtained from Table 1. For practical reasons, the supported span of the bamboo members is limited to a minimum of 0.5 m to a maximum of 6.0 m. Tables 1A, 1B and 1C present the ultimate bending strength of bamboo members with a thickness of 5 mm, 7.5 mm and 10 mm respectively. Linear interpolation on data is permitted. For details on the measurement of the physical and the mechanical properties of bamboo, refer to the INBAR Standard given in the list of references.

<u>Example 1 A simple bending test on bamboo member</u>

D_e = 40 mm
D_i = 30 mm
L = 1.20 m
P = 80 kg

From Table 1, f_{yb} = 50 N/mm^2 for L = 1.09 m, and
f_{yb} = 60 N/mm^2 for L = 1.31 m,

Thus, f_{yb} = 55.0 N/mm^2 by linear interpolation for L = 1.20 m

and f_{yb} / γ_M = 55.0 / 1.5
= 36.7 N/mm^2

Example 2   A bamboo member with two tests of different supported spans

Test 1

D_e	=	90 mm
D_i	=	80 mm
L	=	5.50 m
P	=	80 kg

From Table 1, f_{yb} = 40 N/mm^2 for L = 5.48 m

Thus f_{yb} = 40 N/mm^2 for L = 5.50 m conservatively.

Test 2

D_e	=	90 mm
D_i	=	80 mm
L	=	2.80 m
P	=	160 kg

From Table 1, f_{yb} = 40 N/mm^2 for L = 2.74 m

Thus f_{yb} = 40 N/mm^2 for L = 2.80 m conservatively.

In both tests, the ultimate bending strength of the bamboo member is found to be 40 N/mm^2. With a material factor of 1.5, the design strength of the bamboo member is estimated as 26.7 N/mm^2.

1.3 Common bamboo members in bamboo scaffolds

- Kao Jue
  They are structural members with a typical external diameter ranging from about 50 mm at the bottom to 30 mm at the top of a member. The wall thickness may range from 5 mm in low quality Kao Jue to 10 mm in high quality Kao Jue. They are used extensively as vertical and horizontal members in bamboo scaffolds.

- Mao Jue
  They are primary structural members in bamboo scaffolds with a typical external diameter ranging from about 80 mm to 100 mm at the bottom to about 50 mm to 70 mm at the top of a member. The wall thickness may range from 6 mm to 10 mm. They are used extensively as vertical and diagonal members in bamboo scaffolds.

- Fir
  They are heavy duty members in bamboo scaffolds and used extensively as vertical members.

1.4 Loading requirements

The loading requirements for general construction activities are given in Table 2 which is derived directly from the same requirements associated with metal scaffolds as given in BS5973. The construction loads and also the self-weight acting on bamboo scaffolds should not exceed the allowable loads permitted by the corresponding design. Moreover, wind effects on the scaffolds should be considered as appropriate.

1.5 Safety and inspection

It is important to ensure the structural integrity of bamboo scaffolds and thus safety to both workers and the public. It is the usual practice that bamboo scaffolds should be erected by a 'qualified' scaffolding practitioner who possesses sufficient knowledge on both the erection procedure and the structural behaviour of bamboo scaffolds. Furthermore, it is necessary to inspect bamboo scaffolds regularly, and any damage or deterioration to bamboo scaffolds should be repaired immediately. Supports and restraints to the bamboo scaffolds for overall stability should not be modified at any time. For details of codes of practice on safety and inspection of bamboo scaffolds, refer to the list of references.

Table 1a Selection table for single point load field test of bamboo members with 5 mm wall thickness

P (kg)	Bending strength		Maximum span (m)								
			B40/30	B50/40	B60/50	B70/60	B80/70	B90/80	B100/90	B110/100	B120/110
		D_e (mm)	40	50	60	70	80	90	100	110	120
		D_i (mm)	30	40	50	60	70	80	90	100	110
		Z (mm^3)	4295	7245	10979	15498	20801	26889	33762	41421	49865
80	f_{yb}	20		0.74	1.12	1.58	2.12	2.74	3.44	4.22	5.08
	(N/mm^2)	30	0.66	1.11	1.68	2.37	3.18	4.11	5.16		
		40	0.88	1.48	2.24	3.16	4.24	5.48			
		50	1.09	1.85	2.80	3.95	5.30				
		60	1.31	2.22	3.36	4.74					
		70	1.53	2.58	3.92	5.53					
		80	1.75	2.95	4.48						
120	f_{yb}	20			0.75	1.05	1.41	1.83	2.29	2.81	3.39
	(N/mm^2)	30		0.74	1.12	1.58	2.12	2.74	3.44	4.22	5.08
		40	0.58	0.98	1.49	2.11	2.83	3.65	4.59	5.63	
		50	0.73	1.23	1.87	2.63	3.53	4.57	5.74		
		60	0.88	1.48	2.24	3.16	4.24	5.48			
		70	1.02	1.72	2.61	3.69	4.95				
		80	1.17	1.97	2.98	4.21	5.65				
160	f_{yb}	20			0.56	0.79	1.06	1.37	1.72	2.11	2.54
	(N/mm^2)	30		0.55	0.84	1.18	1.59	2.06	2.58	3.17	3.81
		40		0.74	1.12	1.58	2.12	2.74	3.44	4.22	5.08
		50	0.55	0.92	1.40	1.97	2.65	3.43	4.30	5.28	
		60	0.66	1.11	1.68	2.37	3.18	4.11	5.16		
		70	0.77	1.29	1.96	2.76	3.71	4.80			
		80	0.88	1.48	2.24	3.16	4.24	5.48			
200	f_{yb}	20				0.63	0.85	1.10	1.38	1.69	2.03
	(N/mm^2)	30			0.67	0.95	1.27	1.64	2.06	2.53	3.05
		40		0.59	0.90	1.26	1.70	2.19	2.75	3.38	4.07
		50		0.74	1.12	1.58	2.12	2.74	3.44	4.22	5.08
		60	0.53	0.89	1.34	1.90	2.54	3.29	4.13	5.07	
		70	0.61	1.03	1.57	2.21	2.97	3.84	4.82	5.91	
		80	0.70	1.18	1.79	2.53	3.39	4.39	5.51		

Table 1b Selection table for single point load field test of bamboo members with 7.5 mm wall thickness

P (kg)	Bending strength		Maximum span (m)								
			B40/25	B50/35	B60/45	B70/55	B80/65	B90/75	B100/85	B110/195	B120/105
		D_e (mm)	40	50	60	70	80	90	100	110	120
		D_i (mm)	25	35	45	55	65	75	85	95	105
		Z (mm^3)	5324	9325	14496	20840	28360	37055	46927	57976	70203
80	f_{yb} (N/mm^2)	20	0.54	0.95	1.48	2.12	2.89	3.78	4.78	5.91	
		30	0.81	1.43	2.22	3.19	4.34	5.67			
		40	1.09	1.90	2.96	4.25	5.78				
		50	1.36	2.38	3.69	5.31					
		60	1.63	2.85	4.43						
		70	1.90	3.33	5.17						
		80	2.17	3.80	5.91						
120	f_{yb} (N/mm^2)	20		0.63	0.99	1.42	1.93	2.52	3.19	3.94	4.77
		30	0.54	0.95	1.48	2.12	2.89	3.78	4.78	5.91	
		40	0.72	1.27	1.97	2.83	3.85	5.04			
		50	0.90	1.58	2.46	3.54	4.82				
		60	1.09	1.90	2.96	4.25	5.78				
		70	1.27	2.22	3.45	4.96					
		80	1.45	2.53	3.94	5.67					
160	f_{yb} (N/mm^2)	20			0.74	1.06	1.45	1.89	2.39	2.95	3.58
		30		0.71	1.11	1.59	2.17	2.83	3.59	4.43	5.37
		40	0.54	0.95	1.48	2.12	2.89	3.78	4.78	5.91	
		50	0.68	1.19	1.85	2.66	3.61	4.72	5.98		
		60	0.81	1.43	2.22	3.19	4.34	5.67			
		70	0.95	1.66	2.59	3.72	5.06				
200	f_{yb} (N/mm^2)	20			0.59	0.85	1.16	1.51	1.91	2.36	2.86
		30		0.57	0.89	1.27	1.73	2.27	2.87	3.55	4.29
		40		0.76	1.18	1.70	2.31	3.02	3.83	4.73	5.72
		50	0.54	0.95	1.48	2.12	2.89	3.78	4.78	5.91	
		60	0.65	1.14	1.77	2.55	3.47	4.53	5.74		
		70	0.76	1.33	2.07	2.97	4.05	5.29			
		80	0.87	1.52	2.36	3.40	4.63				

Table 1c Selection table for single point load field test of bamboo members with 10 mm wall thickness

P (kg)	Bending strength		Maximum span (m)								
			B40/25	B50/35	B60/45	B70/55	B80/65	B90/75	B100/85	B110/195	B120/105
		D_e (mm)	40	50	60	70	80	90	100	110	120
		D_i (mm)	20	30	40	50	60	70	80	90	100
		Z (mm^3)	5891	10681	17017	24908	34361	45379	57963	72114	87834
80	f_{yb} (N/mm^2)	20	0.60	1.09	1.73	2.54	3.50	4.63	5.91		
		30	0.90	1.63	2.60	3.81	5.25				
		40	1.20	2.18	3.47	5.08					
		50	1.50	2.72	4.34						
		60	1.80	3.27	5.20						
		70	2.10	3.81							
		80	2.40	4.36							
120	f_{yb} (N/mm^2)	20		0.73	1.16	1.69	2.34	3.08	3.94	4.90	5.97
		30	0.60	1.09	1.73	2.54	3.50	4.63	5.91		
		40	0.80	1.45	2.31	3.39	4.67				
		50	1.00	1.81	2.89	4.23	5.84				
		60	1.20	2.18	3.47	5.08					
		70	1.40	2.54	4.05	5.92					
		80	1.60	2.90	4.63						
160	f_{yb} (N/mm^2)	20		0.54	0.87	1.27	1.75	2.31	2.95	3.68	4.48
		30		0.82	1.30	1.90	2.63	3.47	4.43	5.51	
		40	0.60	1.09	1.73	2.54	3.50	4.63	5.91		
		50	0.75	1.36	2.17	3.17	4.38	5.78			
		60	0.90	1.63	2.60	3.81	5.25				
		70	1.05	1.91	3.04	4.44					
200	f_{yb} (N/mm^2)	20			0.69	1.02	1.40	1.85	2.36	2.94	3.58
		30		0.65	1.04	1.52	2.10	2.78	3.55	4.41	5.37
		40		0.87	1.39	2.03	2.80	3.70	4.73	5.88	
		50	0.60	1.09	1.73	2.54	3.50	4.63	5.91		
		60	0.72	1.31	2.08	3.05	4.20	5.55			
		70	0.84	1.52	2.43	3.55	4.90				
		80	0.96	1.74	2.78	4.06	5.60				

Table 2 General load requirements for bamboo scaffolds

BS 5973: 1993: Table 1 Access and working scaffolds					
Duty	Use of platform	Distributed load on platforms (kN/m^2)	Maximum number of platforms	Commonly used widths using 225mm boards	Maximum bay length (m)
Inspection and very light duty	Inspection, painting, stone cleaning, light cleaning and access	0.75	1 working platform	3 boards	2.7
Light duty	Plastering, painting, stone cleaning, glazing and pointing	1.50	2 working platforms	4 boards	2.4
General purpose	General building work including brickwork, window and mullion fixing, rendering, plastering	2.00	2 working platforms + 1 at very light duty	5 boards or 4 boards + 1 inside	2.1
Heavy duty	Blockwork, brickwork, heavy cladding	2.50	2 working platforms + 1 at very light duty	5 boards or 5 boards + 1 inside or 4 boards + 1 inside	2.0
Masonry or special duty	Masonry work, concrete blockwork, and very heavy cladding	3.00	1 working platform + 1 at very light duty	6 to 8 boards	1.8

BS5973: 1993: Code of practice for assess and working scaffolds and special scaffold structures in steel, the British Standards Institution.

2 Basic members in bamboo scaffolds

Bamboo scaffolds are structural systems made up of bamboo members and plastic strips. They are tubular skeletal frameworks using bamboo members in the forms of vertical members such as posts and standards, horizontal members such as base ledgers and ledgers, and also inclined structural members such as bracings. Each of the members is described as follows:

a. Posts
   They are the vertical members which rest on the ground or steel brackets as the primary load-bearing members. They support all the loadings in the scaffolding systems such as the self-weight of bamboo members and the construction loads. Usually, they are strong and good quality bamboo members like Mao Jue or Fir poles.

b. Standards
   They are the vertical members which do not rest on the ground or steel brackets, and instead, they are attached to the base ledger as secondary members with little load-bearing capacity. The standards are provided mainly as safety measures of preventing workers falling off the platforms accidentally. Some standards may be used to support ledgers with the help of bracings, depending on the overall member configurations. Both Mao Jue and Kao Jue may be used.

c. Ledgers
   They are the primary horizontal members which are supported by posts and standards. For ledgers supporting working platforms, all the construction loads are assumed to act onto the ledgers and thus they are load-bearing. For ledgers erected at levels between working platforms, they are mainly used as safety measures, similar to standards, or simply as ladders for workers to climb on. In general, Mao Jue is used as the primary or base ledgers while Kao Jue is used in all the other ledgers.

d. Bracings
   They are pairs of diagonal members connected to posts and standards in order to form triangulated frameworks. They are very effective in providing rigidity against side movements due to lateral or wind loads, and Mao Jue is commonly used. In scaffolds with heavy bracings, the primary load paths may be modified in such a way that some of the gravity loads may be taken by bracings through standards.

e. Transoms
   They are short members connected orthogonal to ledgers in order to support working platforms. In general, Kao Jue is always used as transoms.

Working platforms are provided with timber planks to allow access for workers, and also a level and safe working area for workers to carry out various construction work such as plastering and painting. Side toe boards and end toe boards are also suitably fixed to all working platforms where a worker may potentially fall from a height of more than 2 m. The boards are arranged in such a way that the gap between the top of toe boards and guard rails does not exceed 700 mm but with a minimum height of 200 mm.

2.1 Supports

It is very important to provide adequate vertical and lateral supports to a scaffolding structure to ensure overall equilibrium and stability. They should be provided at regular intervals along the height and the length of the scaffolds as follows:

a. Vertical supports
   They are key structural elements in scaffolds as all the gravity loads such as the construction load and the self-weight of the scaffolds have to be supported properly in order to enable overall equilibrium of the scaffolds. As the gravity loads go through the posts, supports to the posts are essential. The posts may be supported by direct bearing against the ground or resting on steel brackets which are anchored onto building walls. The supports should be firm and rigid, otherwise, significant settlements in heavily loaded supports may have adverse effects on the overall behaviour of the scaffolds.

b. Lateral supports
   Lateral supports from building walls are important to scaffolds as they restrict any inward or outward movement of the scaffolds. Several types of lateral supports may be found while the most commonly used one is the 'push and pull' support which consists of a 6 mm diameter mild steel bar as a 'putlog', and a short piece of bamboo as a 'prop'.

   In general, it is required for each of the posts of the bamboo scaffolds to be tied up at regular intervals by the putlogs which are firmly fixed to the building wall, and then next to each putlog, a prop is installed between the post and the building wall. The putlogs may thus prevent the scaffold expelling away from the building, and at the same time the props may prevent the scaffold leaning towards the building.

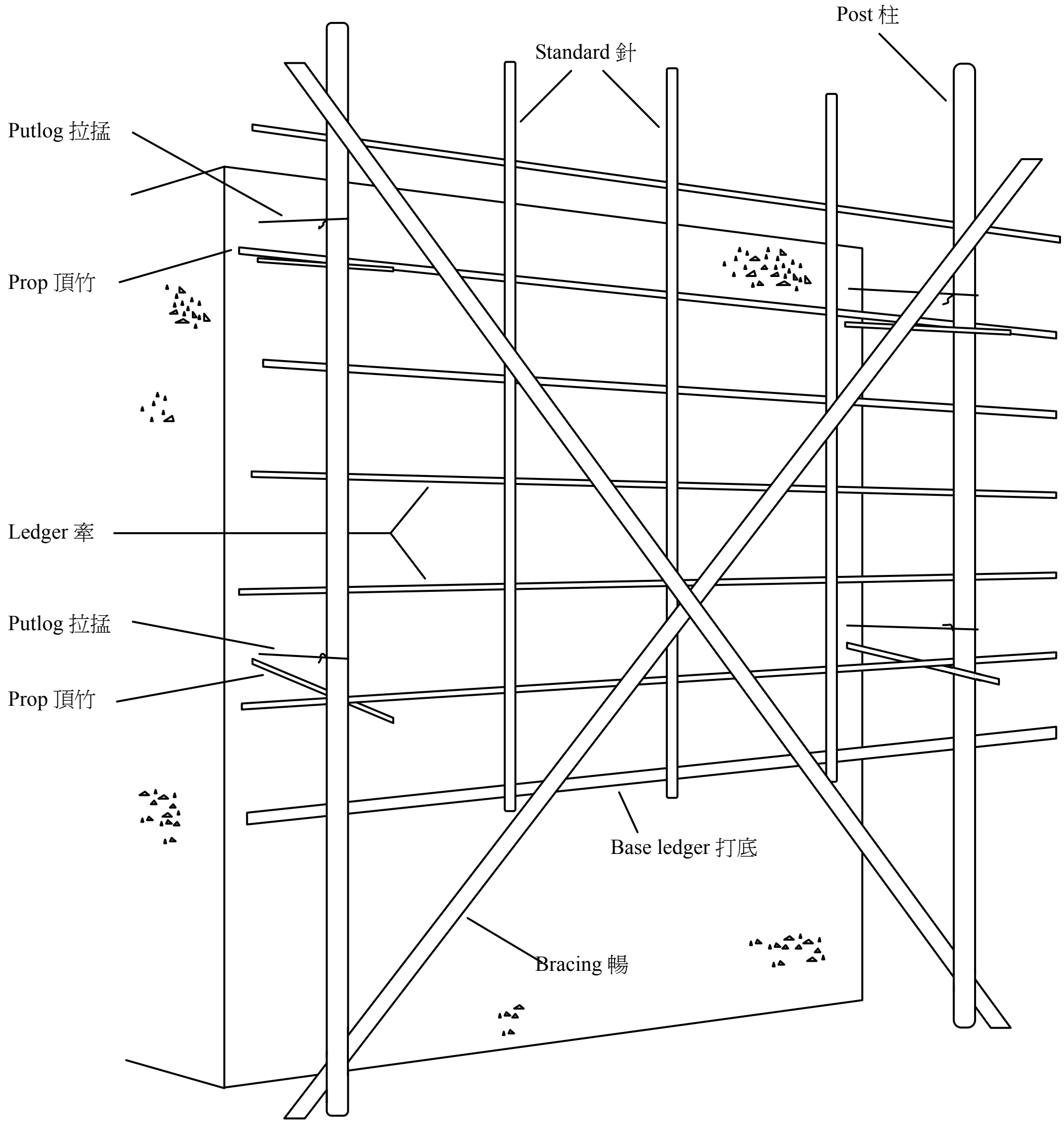
   In erecting a scaffold next to an existing building, a bunch of wires may be used as putlogs, instead of steel bars. For example, in truss-out scaffolds with large projections extended from building walls, wires may be used as cross-bracings to provide lateral supports to the projected portion of the scaffolds. In such case, the wires are firmly anchored onto the wall of the buildings with appropriate fixings.

3 Types of bamboo scaffolds

Bamboo scaffolds are classified by their applications. Some of these applications widely adopted in Hong Kong are briefly described:

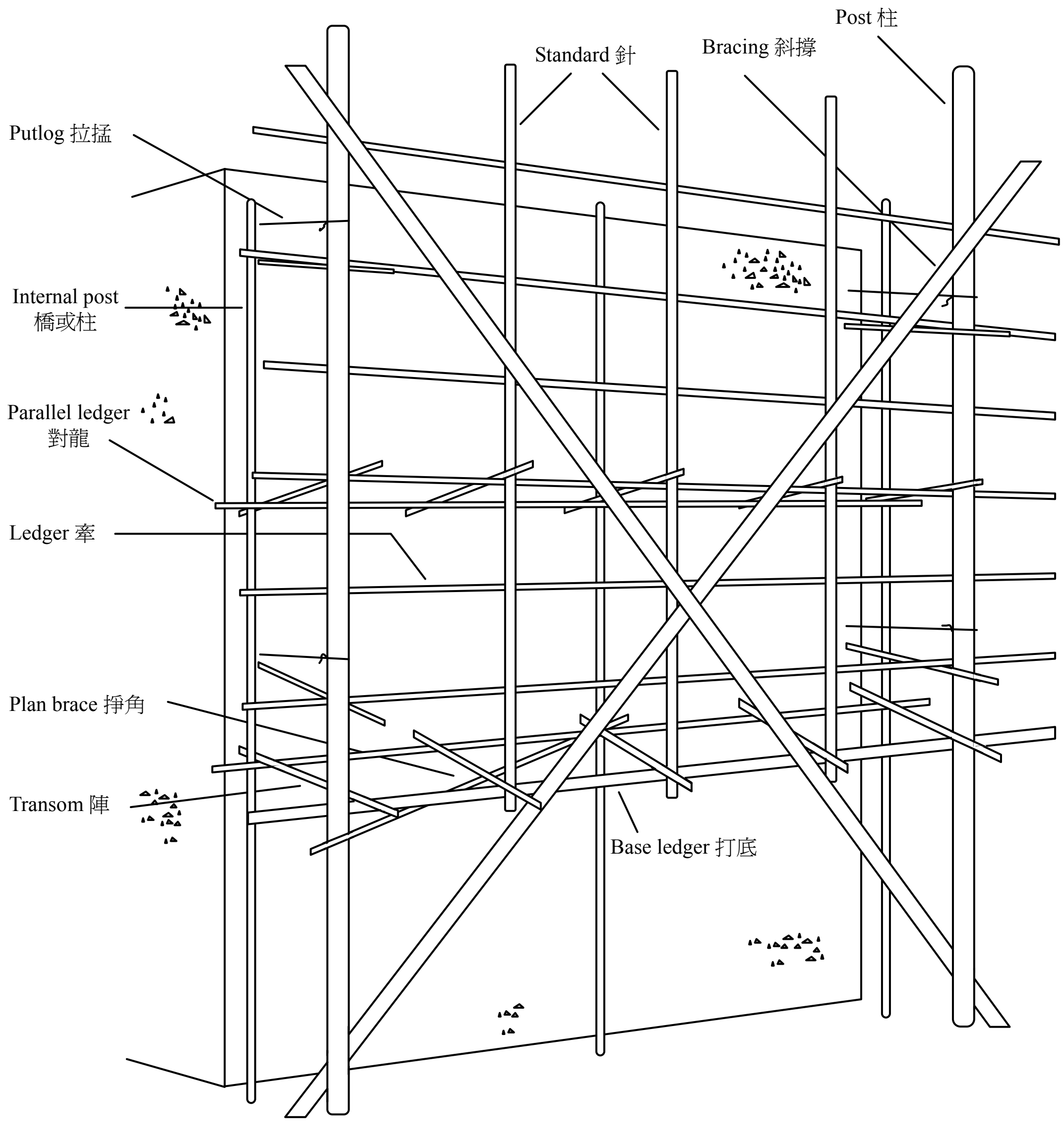
3.1 Single layered scaffolds

They are the basic structural units of scaffolds consisting of posts, standards, ledgers and bracings. They are mainly used for the provision of access, or for the provision of supporting frame structures for screen mesh or advertisement signage.



3.2 Double layered scaffolds

They consist of two layers: an outer single layered scaffold and an inner layer of posts and ledgers erected inside. Between the two layers, short poles or transoms are connected to both the outer posts and the outer standards to the inner posts. The transoms are used to support timber planks which form working platforms. They are used for provision of access and also working platforms for various construction activities in building construction.

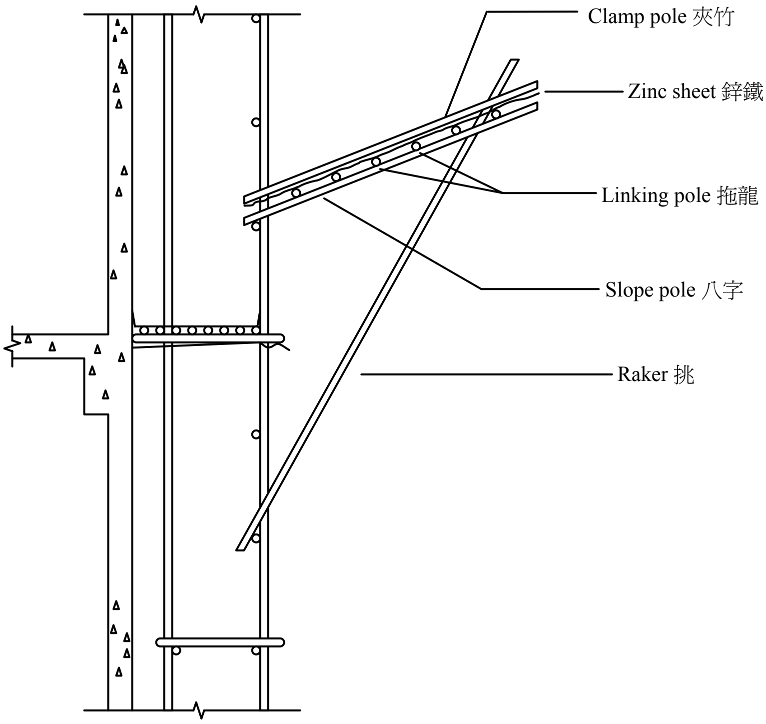


3.2.1 Catch fans

In double layered scaffolds, catch fans and obstruct plates are always necessary for protection to the public.

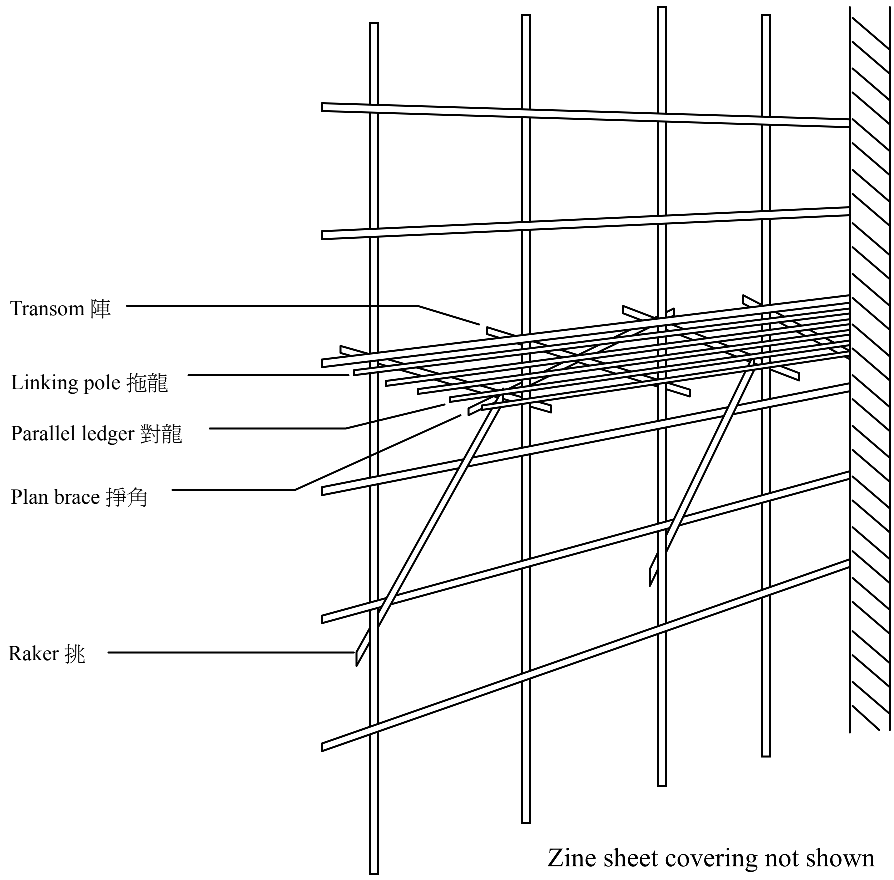
Catch fans are used to prevent debris falling from height, which may endanger the public. They are typically erected at an interval of five storeys and attached to the outer layer of the scaffolds. Nylon or galvanized zinc sheets will be laid on the catch fans to collect falling objects.

The size and the inclination of catch fans are usually determined according to actual site conditions. If a catch fan is too large, additional members such as hang poles and rakers are required.



3.2.2 Obstruct plates

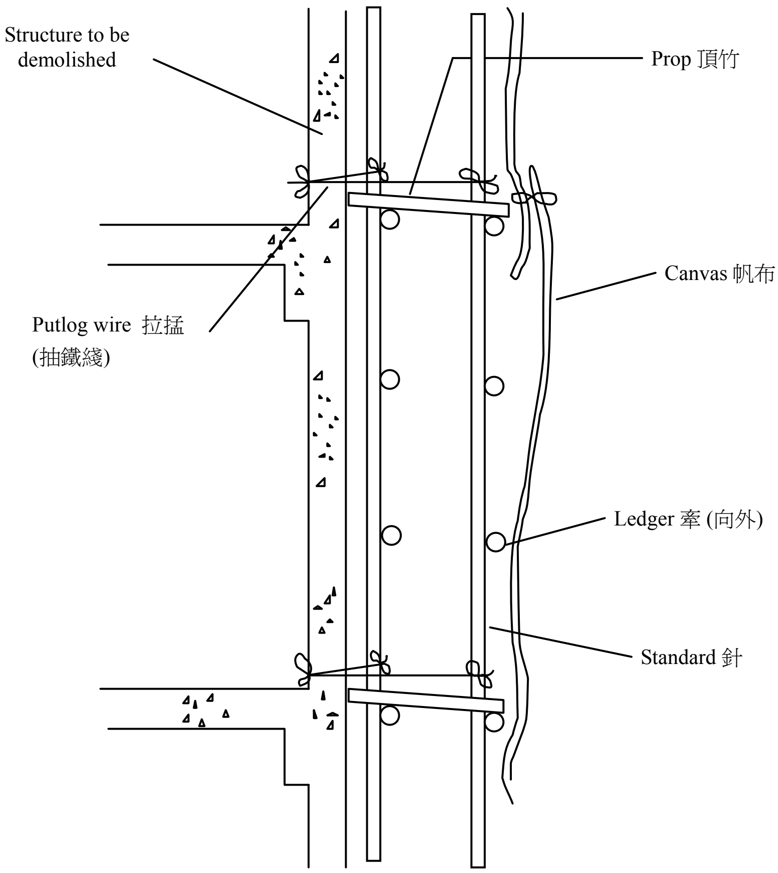
They are safety barriers closely covered with bamboo members and galvanized zinc sheets. For a building under construction, they are often erected around the building between the outer layer of the bamboo scaffolds and the external surface of the building in order to provide protection for workers below the obstruct plates.



3.3 Demolition scaffolds

Bamboo scaffolds are also used in building demolition work. The whole scaffolds are covered by canvas in order to collect dust and debris. A heavy duty net should also be required for protection to the public. However, with the canvas covering, the whole scaffolds may not survive heavy wind condition, and thus it is recommended to remove the canvas portion by portion immediately after the building demolition.

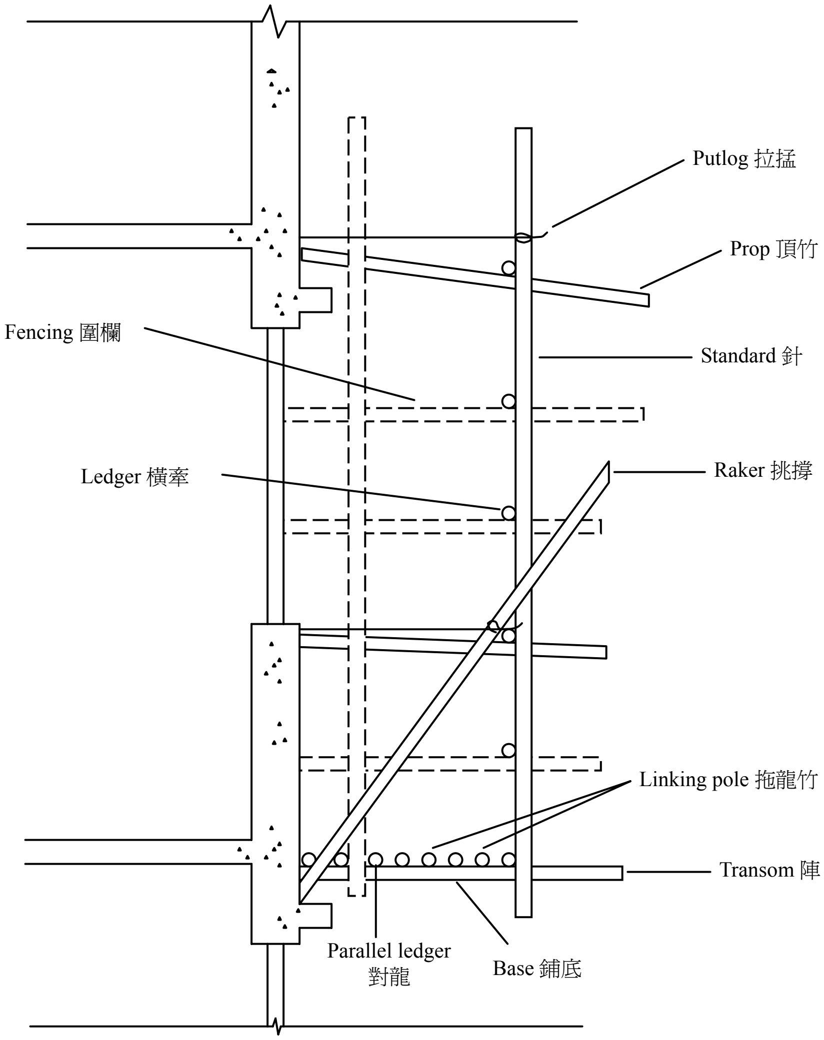
During erection of demolition scaffolds, steel wires will be installed firmly onto existing buildings to serve as lateral restraints to the scaffolds. It should also be noted that the ledgers are fixed at the outside elevation of the scaffolds, which is the reverse in bamboo scaffolds for construction work. With the ledgers outside, canvas may be easily tied onto the ledgers and the workers can climb onto the scaffolds from inside.



3.4 Truss-out scaffolds

They are used in locations where it is not practical to erect scaffolds from the ground, for examples, for repairs of external drainpipes, and partial repairs to external facades. Since these are light duty scaffolds, Kao Jue may be used instead of Mao Jue. The rakers or hang poles should also be supported by permanent structures of the building.

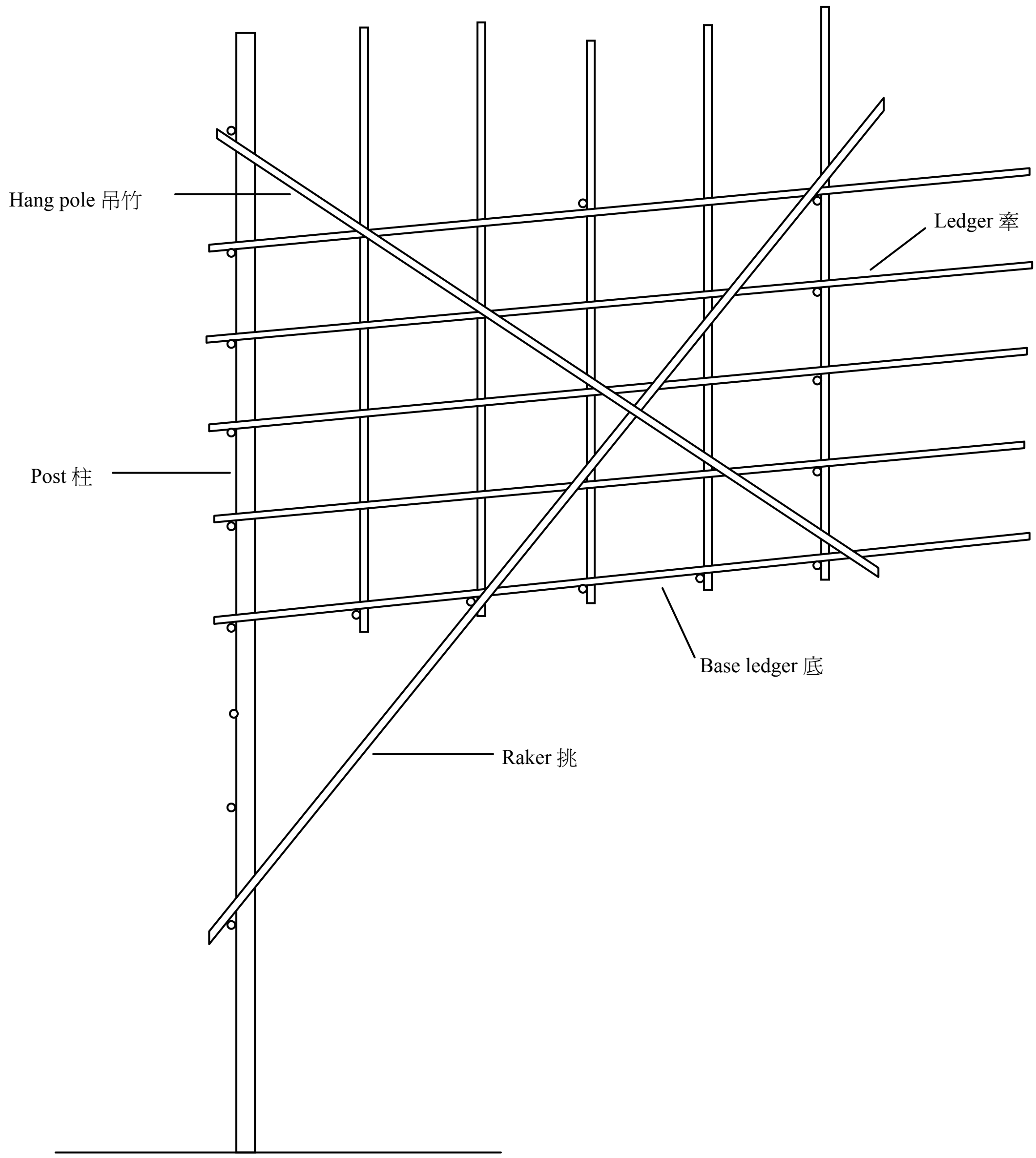
It is important to ensure that during execution of the construction work, the loading including the construction load, the self-weight of equipment, and the storage, if any, should not affect the stability of the scaffolds.



3.5 Signage scaffolds

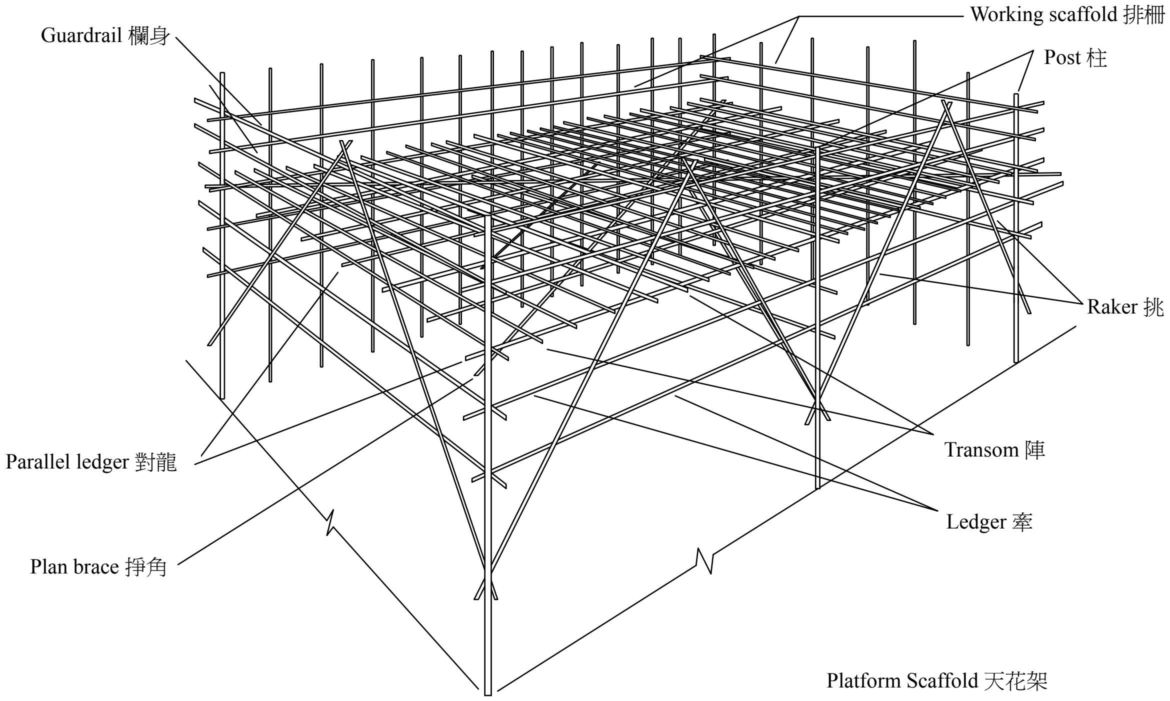
Signage scaffolds are usually cantilever structures with direct supports from permanent structures at only one end of the scaffolds. The other end of the scaffolds are supported by steel wires or hang poles which are in terms anchored properly to other permanent structures. Timber boards are commonly used to provide working platforms for construction activities. Moreover, it is important to provide a minimum clearance from the bottom of the scaffolds to the street level or the road surface in order to maintain unhindered passage of vehicles.

It is the trade practice to fix the cantilever length and height of the scaffold to a ratio of 4 to 3, i.e. if the cantilever length is 8m, then the height of the scaffold is 6m.



3.6 Platform scaffolds

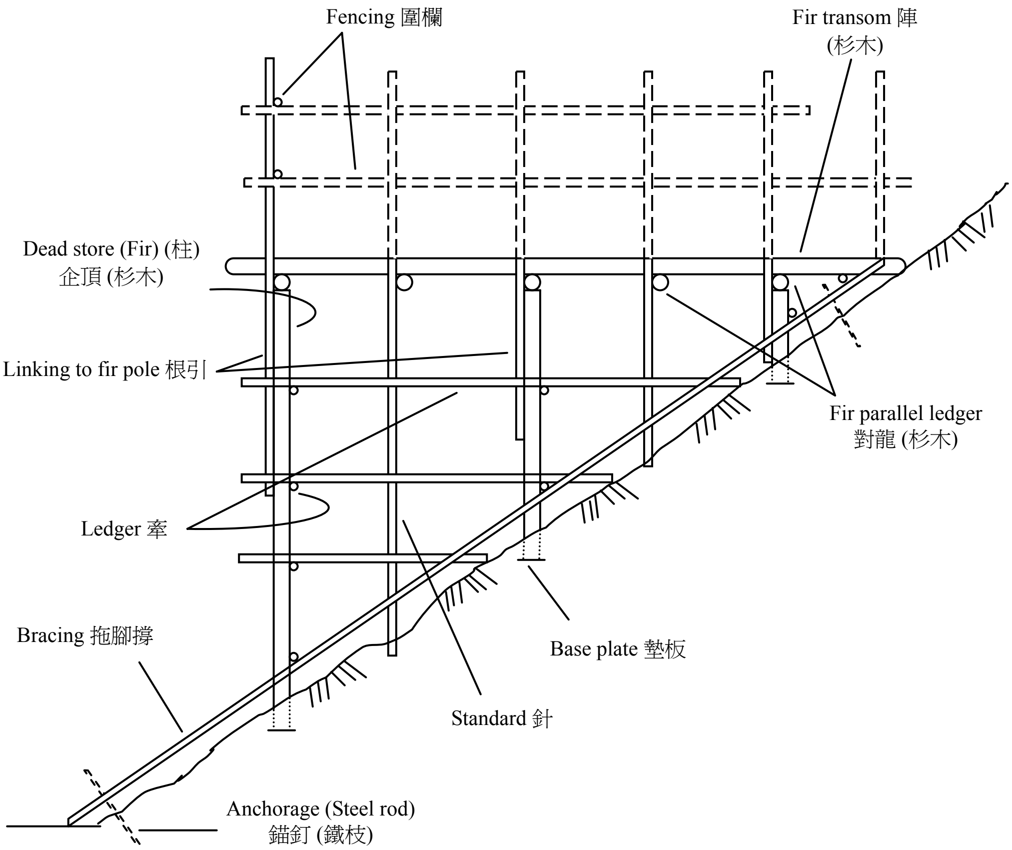
They are large working platforms covered with closely spaced horizontal bamboo poles for provision of working spaces for construction activities. The actual layout of the posts depends on site conditions. Rakers are commonly used to minimize the number of posts and to increase the plan area of the platforms with little obstruction to pedestrians and vehicles underneath.



Platform Scaffold 天花架

3.7 Civil work scaffolds

They are usually single layered scaffolds with large working platforms for construction activities. The single layered scaffolds merely provide access of workers and supervisors to specific locations and all construction activities should only be carried out on the working platforms, for example, site investigation. Timber planks are usually put on the ledgers of the scaffolds and also directly on the slope surface. If heavy construction work is required, a double layered scaffold may be used. In general, large diameter fir poles are normally used to support the platform, and attention against settlement may be required.



4 Illustrations of bamboo scaffolds in building construction

Various bamboo scaffolds in building construction are presented as follows:

Figure 4.1 Single layered scaffold

Figure 4.2 Double layered scaffold

Figure 4.3 Catch fan in double layered scaffold

Figure 4.4 Obstruct plate in double layered scaffold

Figure 4.5 Cantilever scaffold for signage work

Figure 4.6 Truss-out scaffold for repair of external walls

Figure 4.7 Civil work scaffold on slope

Figure 4.8 Scaffold for renovation work

Figure 4.9 Single layered scaffold around a circular tower for access

5 Structural forms and erection sequences of bamboo scaffolds

5.1 Single layered scaffolds

Single layered scaffolds are commonly known as the working scaffolds which are erected at about 750 mm to 900 mm from the building face of a building. It is the basic unit of bamboo scaffolds.

The erection of a single layered scaffold is summarized as follows:

a. Two Mao Jue are first erected as the main posts which may rest on the ground or onto steel brackets which are anchored firmly from building walls. A primary ledger or base ledger of either Mao Jue or Kao Jue is then connected with the posts. Two ledgers are then erected onto the posts.

b. Three Kao Jue are then erected in between the two Mao Jue as standards which overhung from the ledgers and do not rest on the ground or steel brackets. A pair of bracings is then provided at an inclination between 30° to 45° from the vertical.

c. Once the skeleton of the scaffolding is completed, putlogs and props are then attached to the posts for lateral restraints.

Typically, a total of five bamboo members are used over a horizontal distance of about 1.5 m to 2.4 m. The horizontal distance between two adjacent standards is about 600 to 750 mm while the vertical distance between two ledgers is about 600 to 750 mm.

The erection sequence of a single layered scaffold is presented in Figure 5.1.

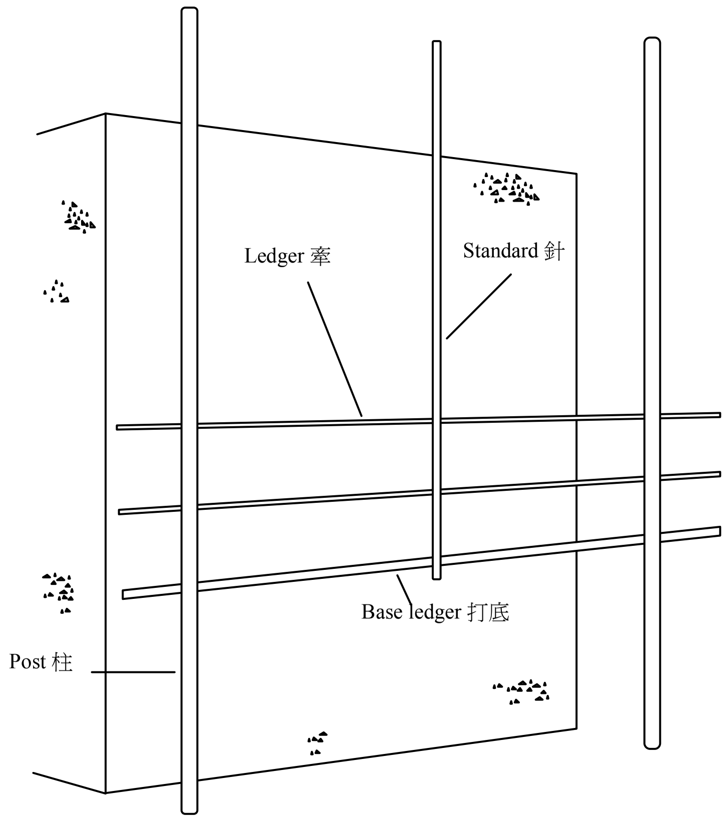


Figure 5.1a Stage 1/3

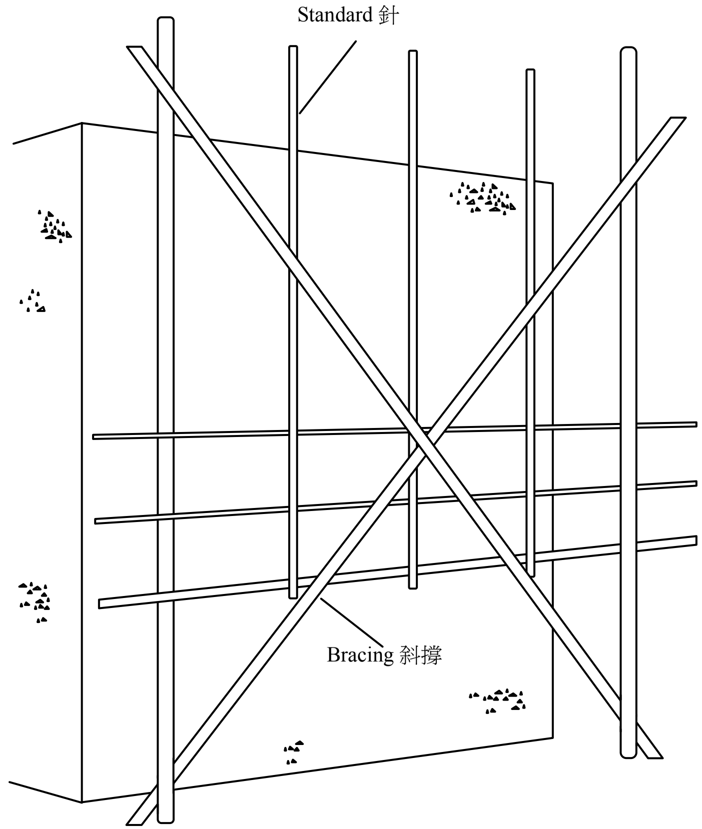


Figure 5.1b Stage 2/3

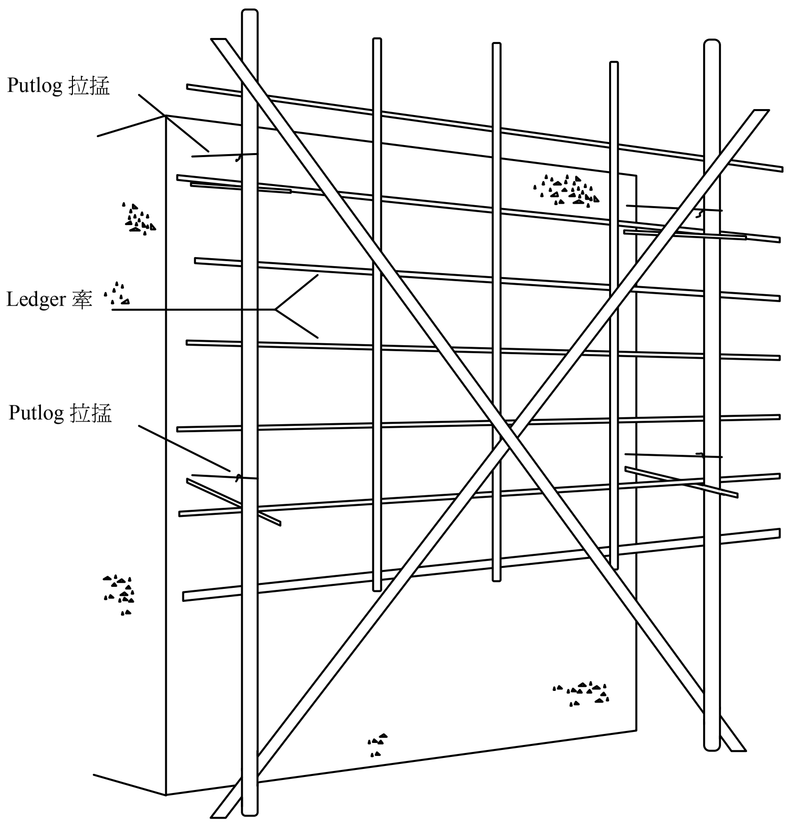


Figure 5.1c Stage 3/3

5.2 Double layered scaffolds

The double layered bamboo scaffolds consist of two layers. The inner layer is also known as the finishing scaffold which is usually erected at about 150 mm to 300 mm from the building face of a building. The outer layer is known as the working scaffold, and is erected at about 600 to 700 mm from the inner layer.

The erection of a double layered bamboo scaffold may be summarized as follows:

Outer layers

a. Two Mao Jue are first erected as the main posts which may rest on the ground or onto steel brackets which are anchored firmly from building walls. A primary ledger or base ledger of either Mao Jue or Kao Jue is then connected with the posts. Two ledgers are then erected onto the posts.

b. Three Kao Jue are then erected in between the two Mao Jue as standards which overhung from the ledgers and do not rest on the ground or steel brackets. A pair of bracings is then provided at an inclination between 30° to 45° from the vertical.

c. Once the skeleton of the scaffold is completed, putlogs and props are then attached to the posts for lateral restraints.

Inner layers

d. Three Mao Jue or Kao Jue are first erected as the inner posts at about 300 mm from the building face. Parallel ledgers of Kao Jue are then attached onto the inner posts.

e. Transoms are then erected to connect the ledgers of the outer layer onto the parallel ledgers of the inner layers. The spacing of the transoms follows that of the posts and the standards of the outer layers.

f. Timber planks are then placed over the transoms between the inner and the outer layers to form working platforms.

Typically, a total of eight bamboo members are used over a horizontal distance of about 1.5 m to 2.4 m. The horizontal distance between two adjacent standards is about 600 mm to 750 mm while the vertical distance between two ledgers is about 600 to 750 mm.

The erection sequence of a double layered scaffold is presented in Figure 5.2. Both the catch fans and the obstruct plates may be erected according to the basic erection sequence of the double layered scaffolds.

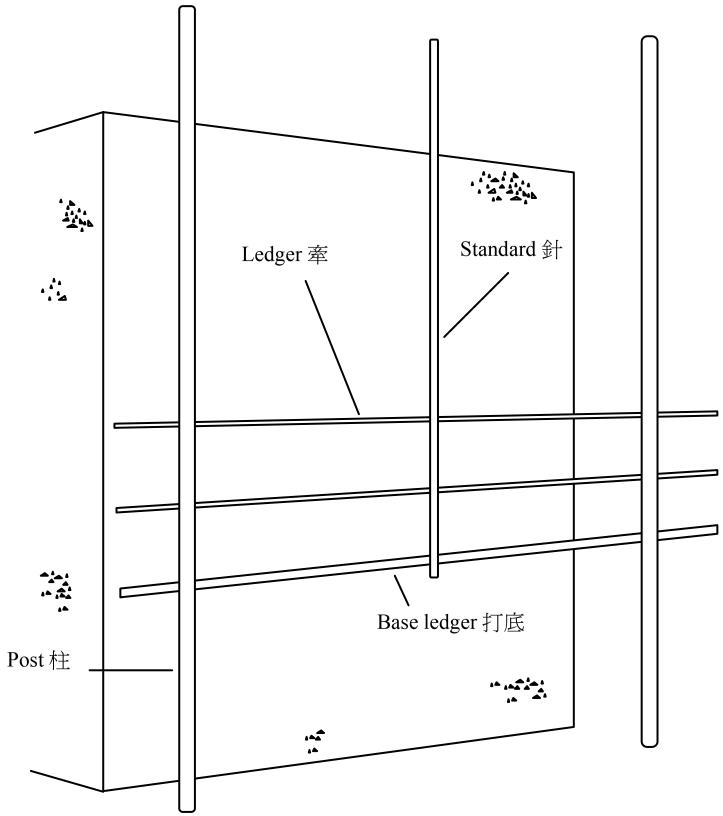


Figure 5.2a Stage 1/6

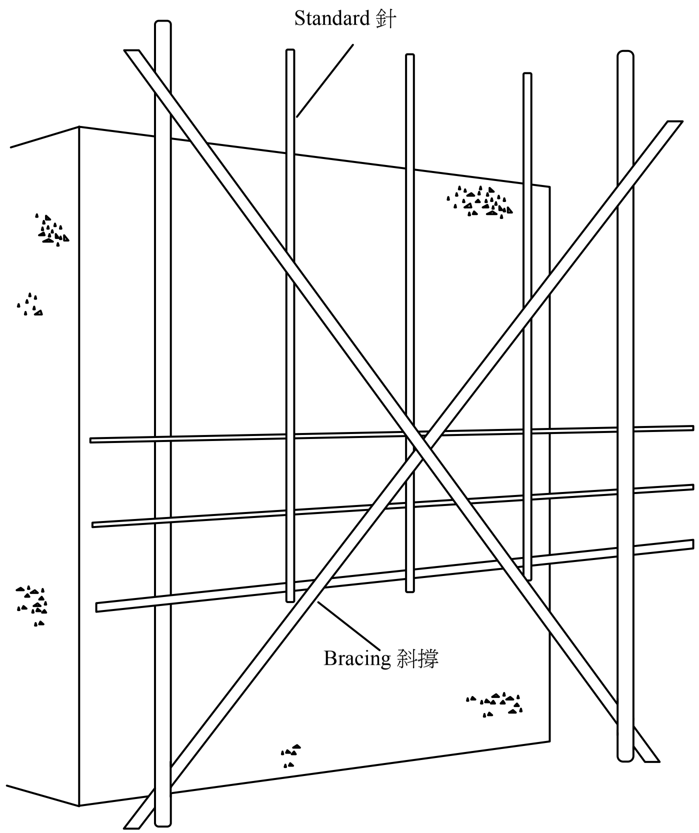


Figure 5.2b Stage 2/6

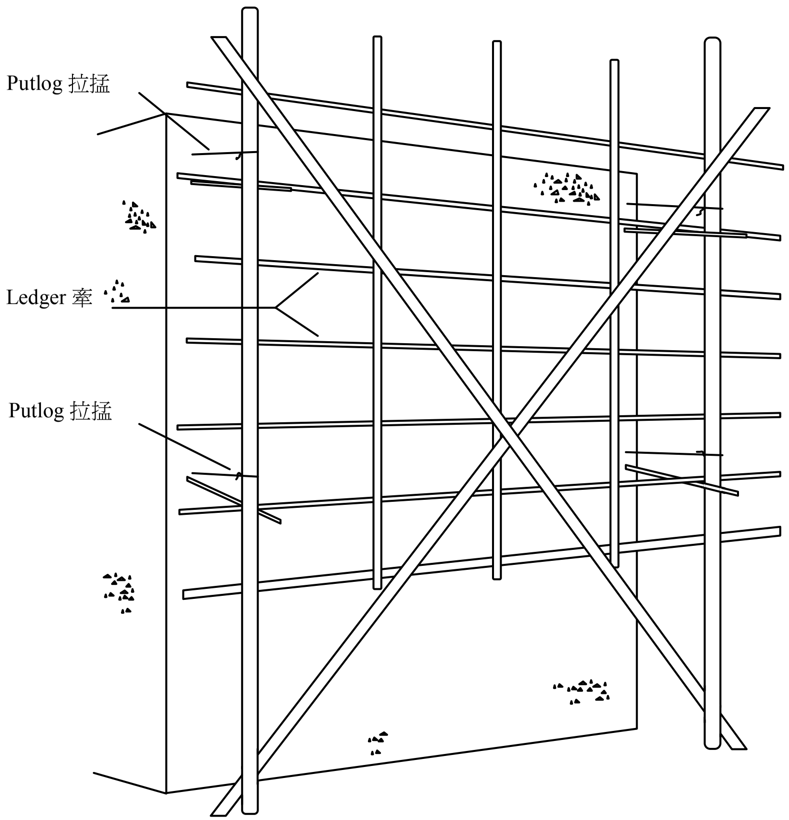


Figure 5.2c Stage 3/6

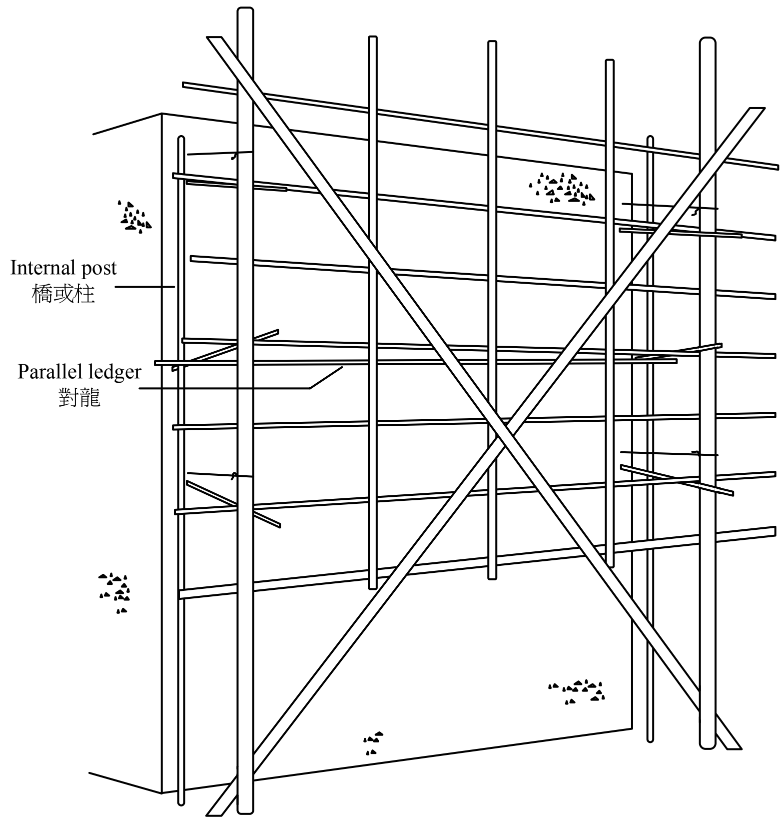


Figure 5.2d Stage 4/6

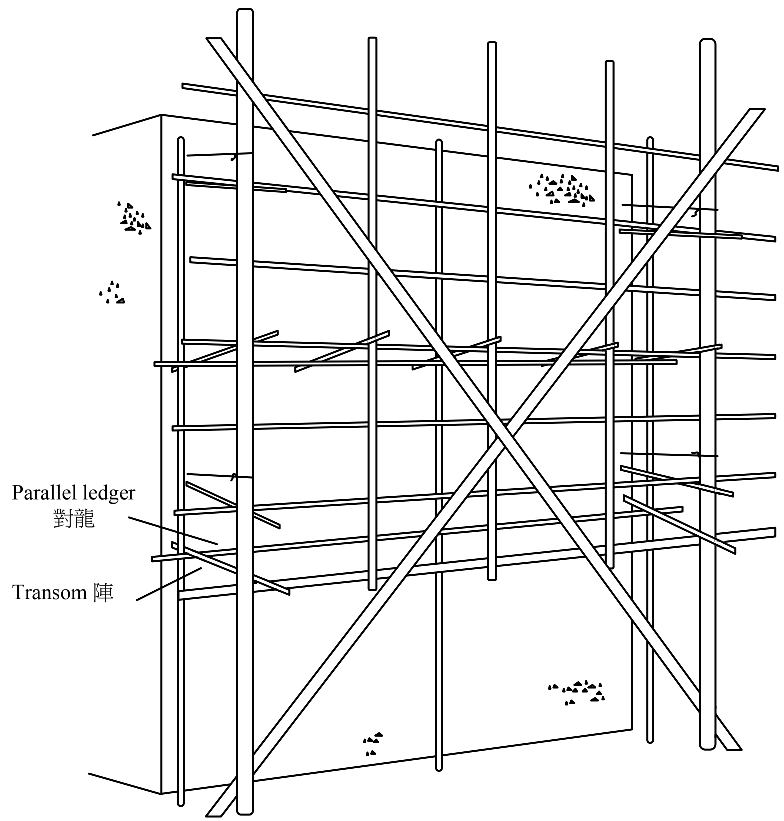


Figure 5.2e Stage 5/6

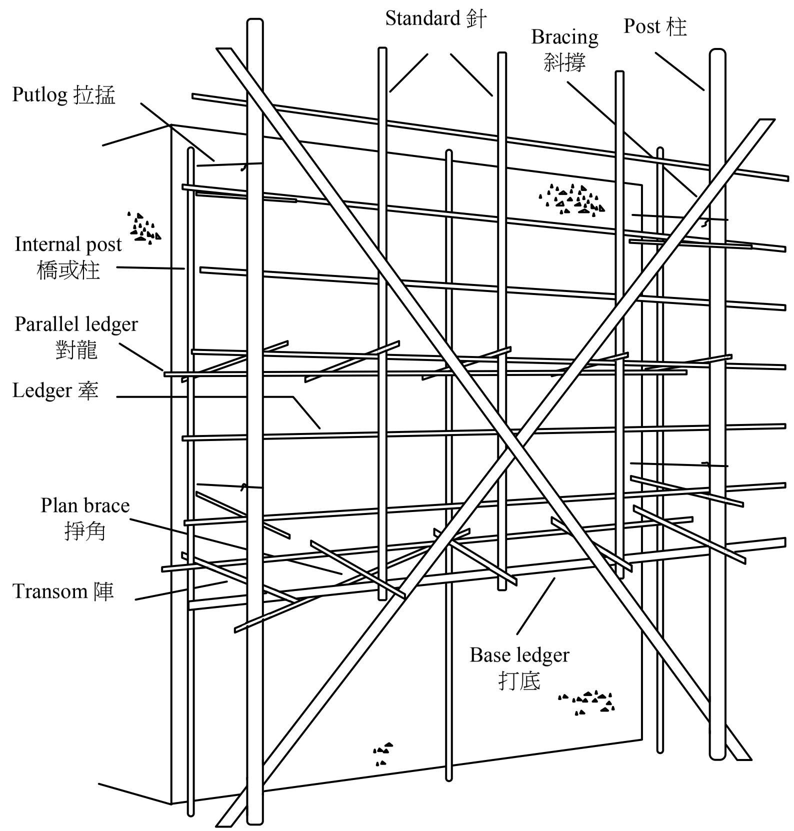


Figure 5.2f Stage 6/6

5.3 Cantilever scaffolds

Cantilever scaffolds are assemblies of skeletal frameworks erected to provide access or working platforms at elevation. They are used in situations where supports to both ends of a scaffold being not possible due to restricted access or absence of suitable supports. In general, single layered scaffolds are erected orthogonal to supporting building structures, and only one end of the scaffolds is directly supported by the building structures. Steel wires are commonly used as cross-bracings in attaching the other end of the scaffolds in order to restrain lateral movements against wind loads.

The erection of a cantilever scaffold next to an existing building is summarized as follows:

a. A single layered scaffold is first erected along the building wall with proper vertical and lateral supports. Two posts are also erected as the primary load-bearing members of the cantilever scaffolding.

b. Both rakers and ledgers are then erected orthogonal to the building wall, forming triangulated frameworks with the posts.

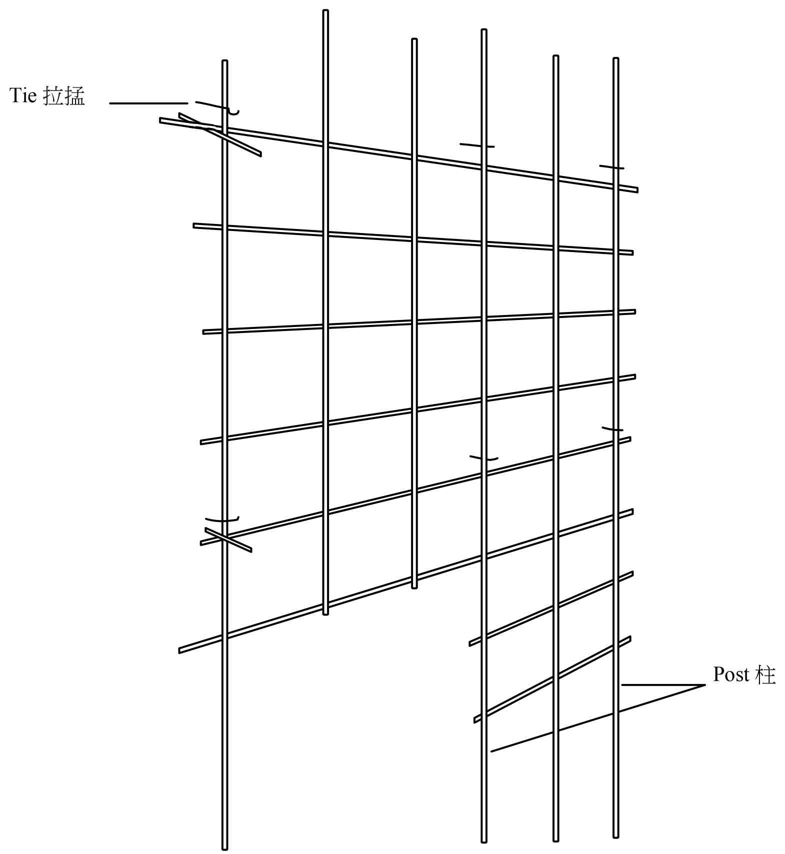
c. Standards are then erected to form a single layer scaffolding projecting from the building wall.

d. Projected ties are also erected as lateral restraints to the projecting scaffold. Moreover, hang poles are also erected and together with the rakers to form effective bracings to the projected scaffoldings.

e. Another projecting single layered scaffold is then erected as in Sequences a to d.

f. Bear poles are then used to connect the top ledgers of the two projecting scaffolds while transoms are used to connect the bottom ledgers. Closely spaced linking poles are then installed to cover the transoms to provide a working platform for construction activities. Horizontal short poles are then connected to the outermost standards as guardrails.

The erection sequence of a cantilever scaffold is presented in Figure 5.3.



Bracing not shown.

Figure 5.3a Stage 1/6

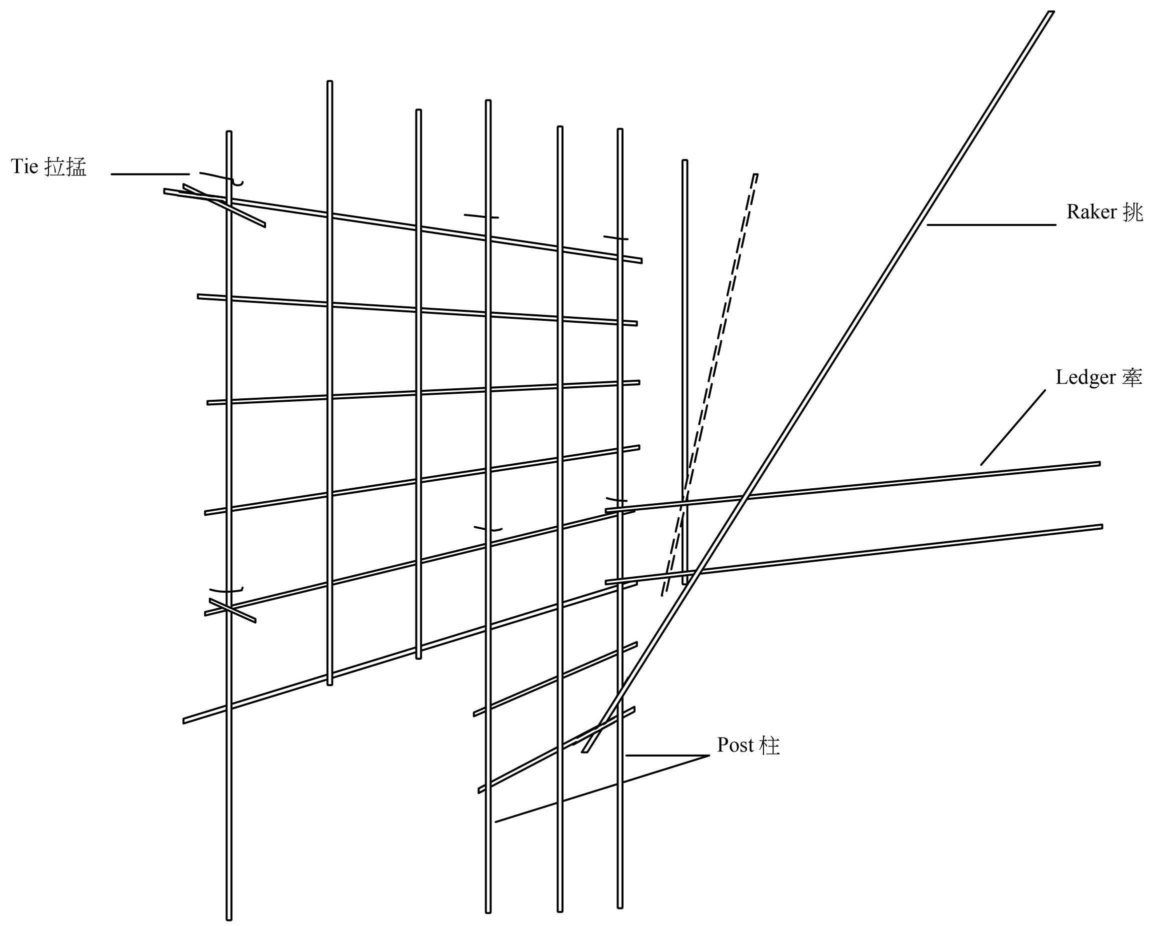


Figure 5.3b Stage 2/6

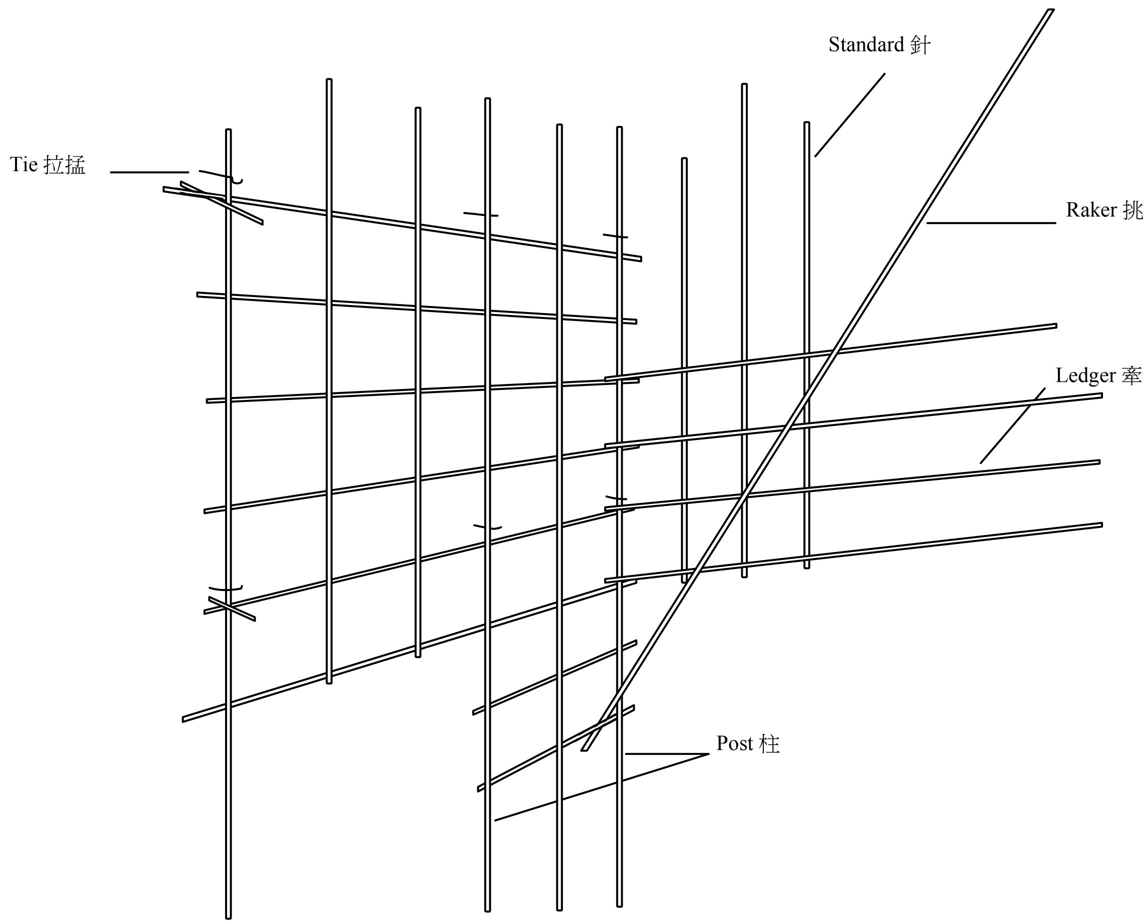


Figure 5.3c Stage 3/6

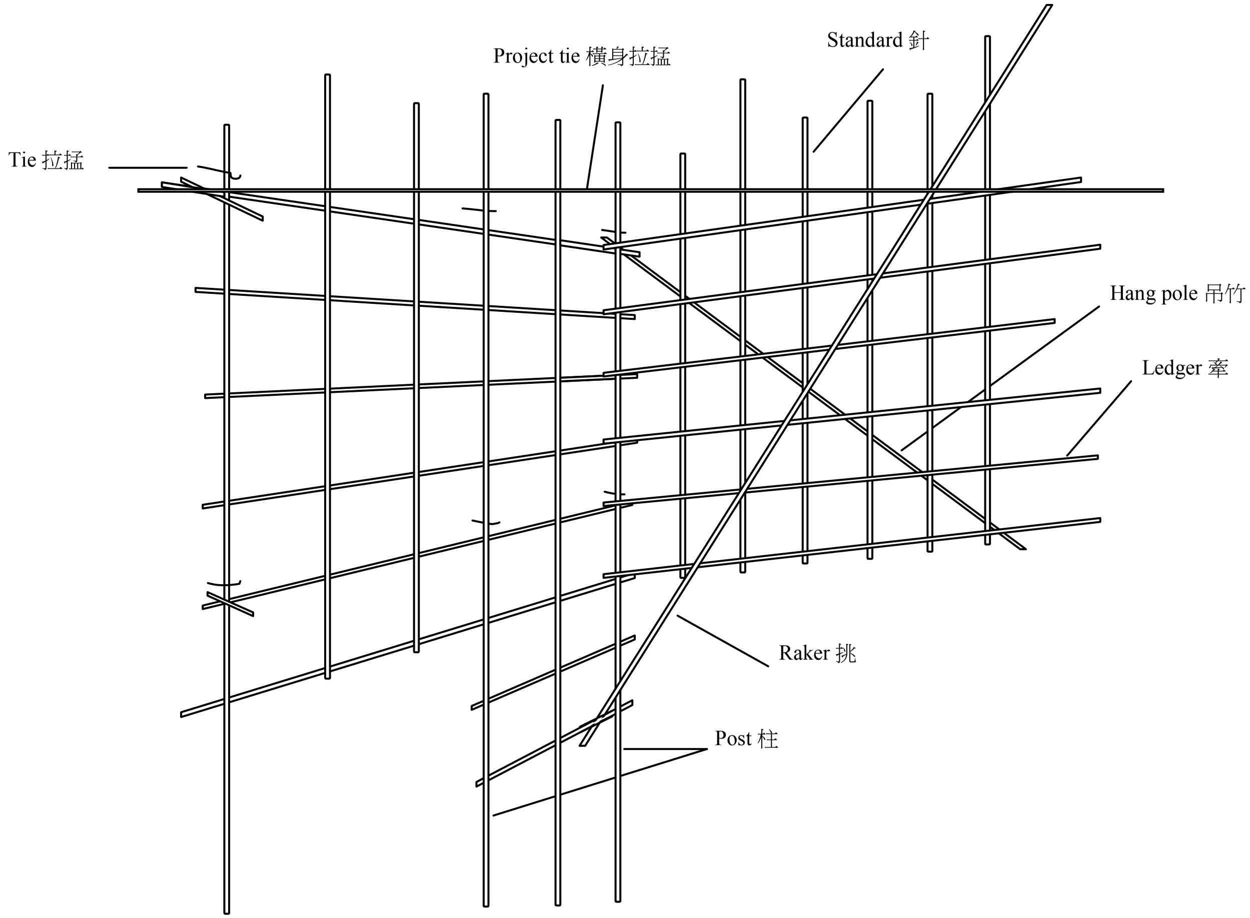


Figure 5.3d Stage 4/6

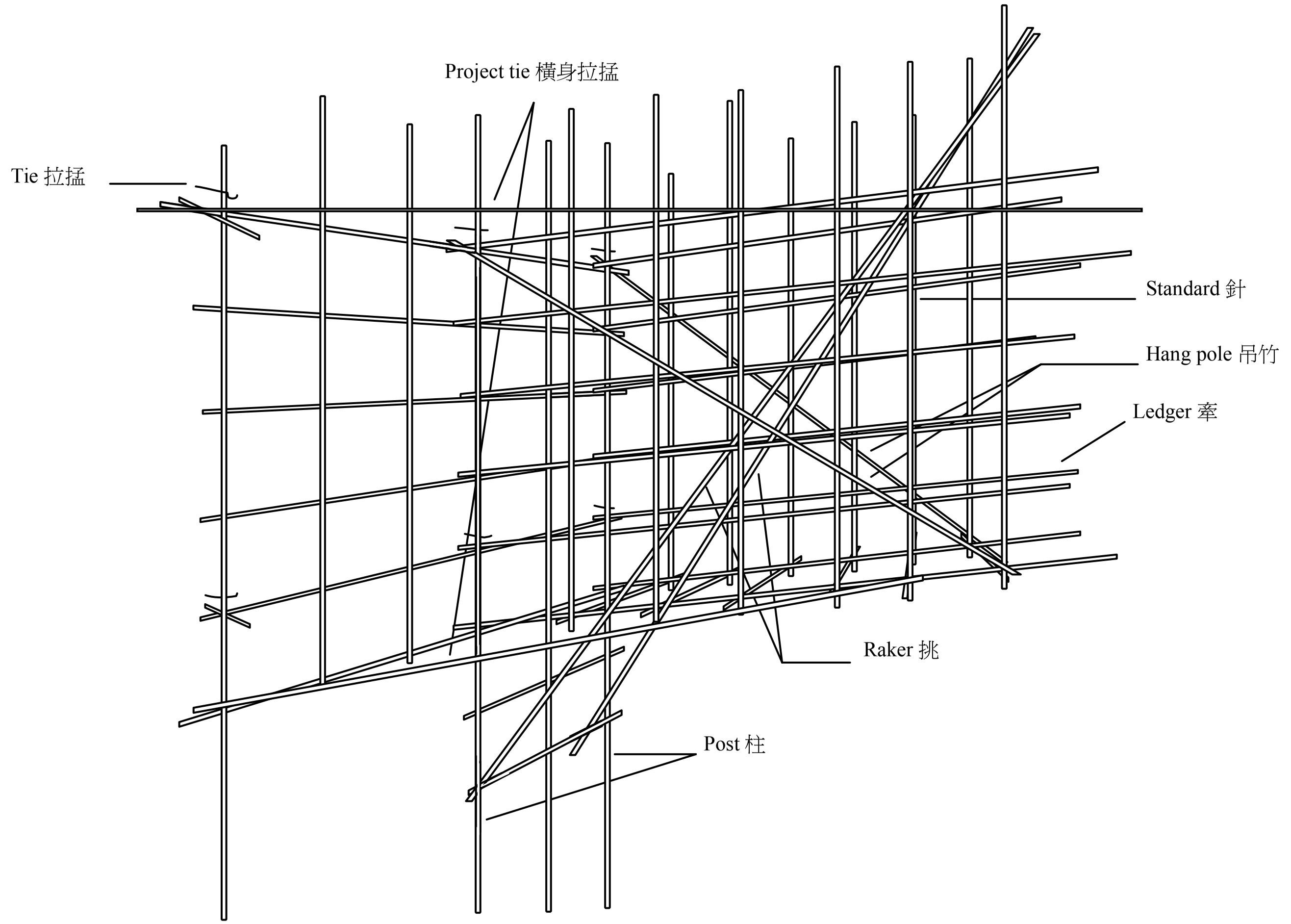


Figure 5.3e Stage 5/6

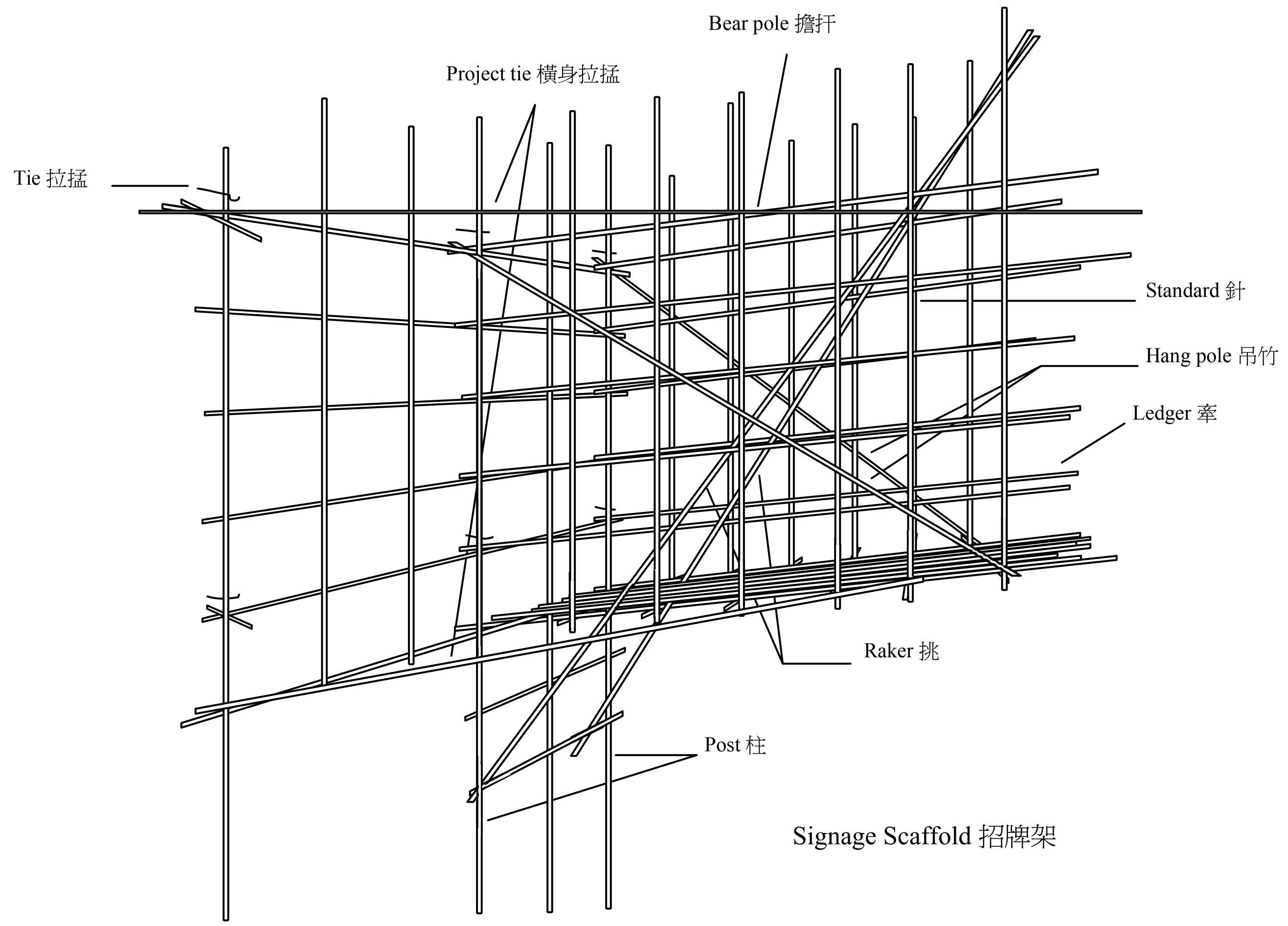


Figure 5.3f Stage 6/6

5.4 Foot-bridge scaffolds

Foot-bridge scaffolds are assemblies of skeletal frameworks to provide passage at elevation. In general, two single layered scaffolds are erected apart as piers and triangulated frameworks are then erected to span between the scaffolds as a footbridge.

The erection of a foot-bridge scaffold is summarized as follows:

a. Two single layered scaffolds are first erected with proper vertical and lateral supports. The posts are the primary load-bearing members of the foot-bridge scaffold.

b. A pair of parallel ledgers is then erected across the scaffold.

c. Rakers are then erected to form a triangulated framework together with standards and ledgers. Bamboo members are erected as guardrails for safety.

d. Another triangulated framework with rakers, standards and ledgers are then erected.

e. Transoms are erected along the base ledgers of the two triangulated frameworks to form the foot-bridge, and closely spaced bamboo members are then used to cover the transoms to form platform for passage.

The erection sequence of a foot-bridge scaffold is presented in Figure 5.4.

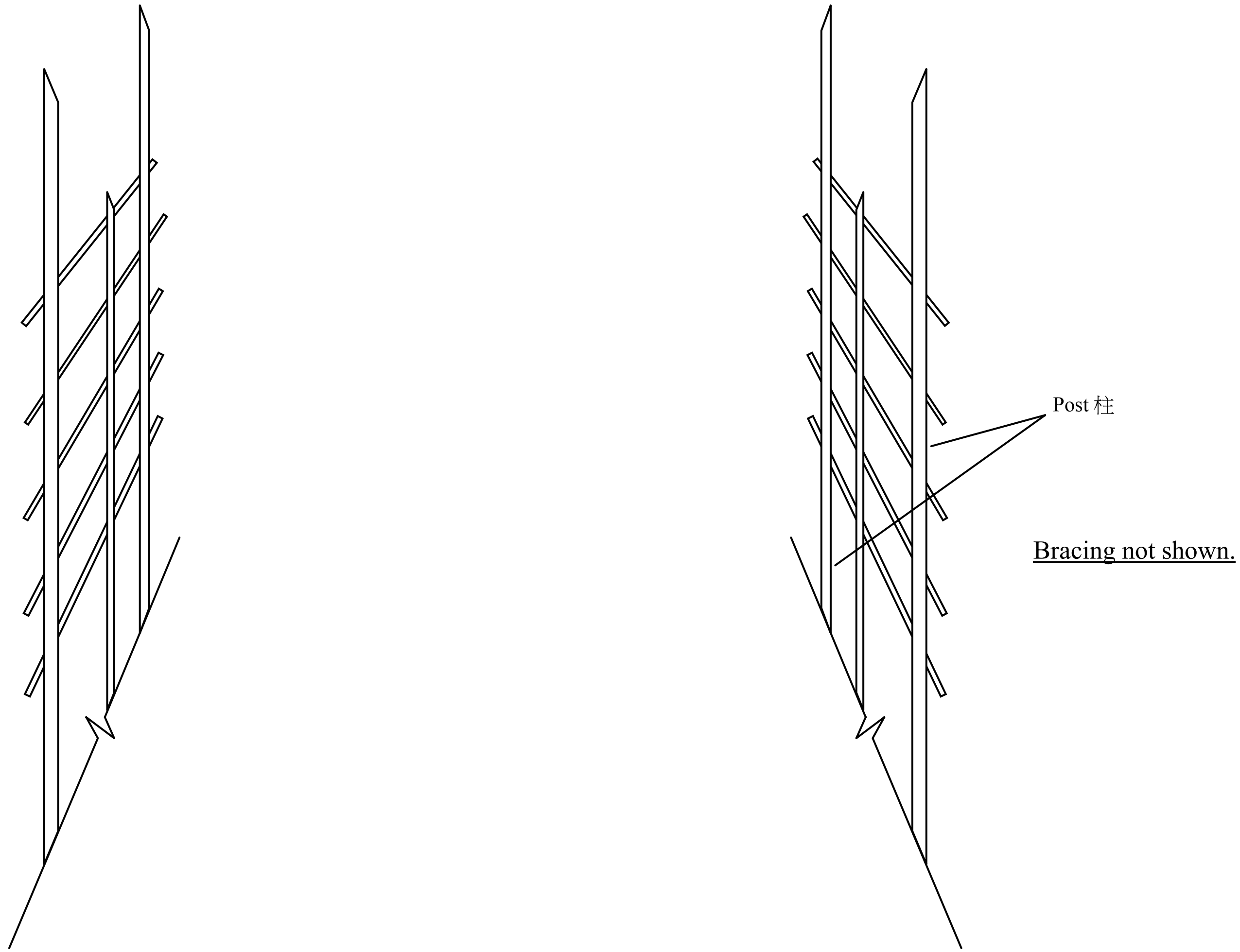


Figure 5.4a Stage 1/5

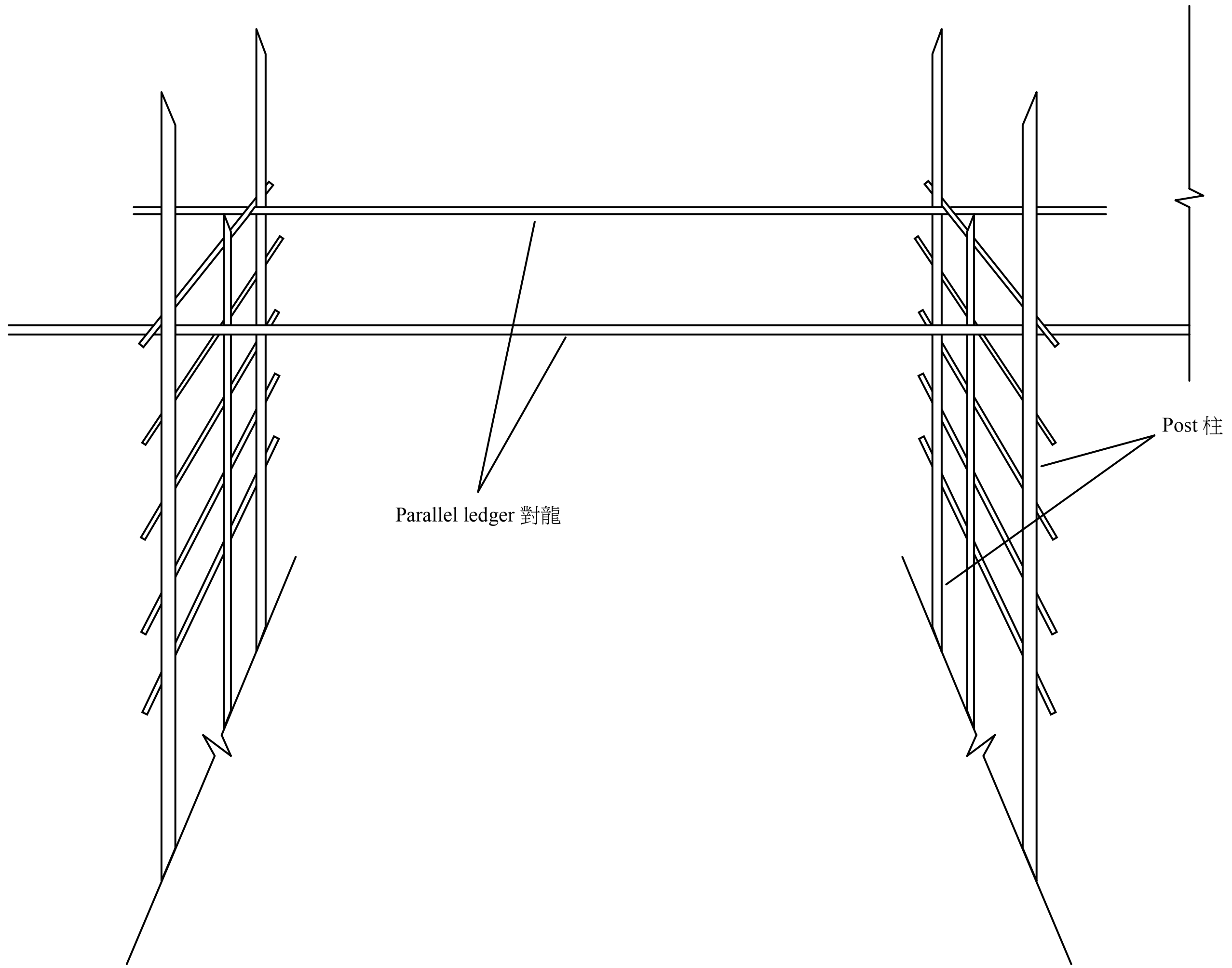


Figure 5.4b Stage 2/5

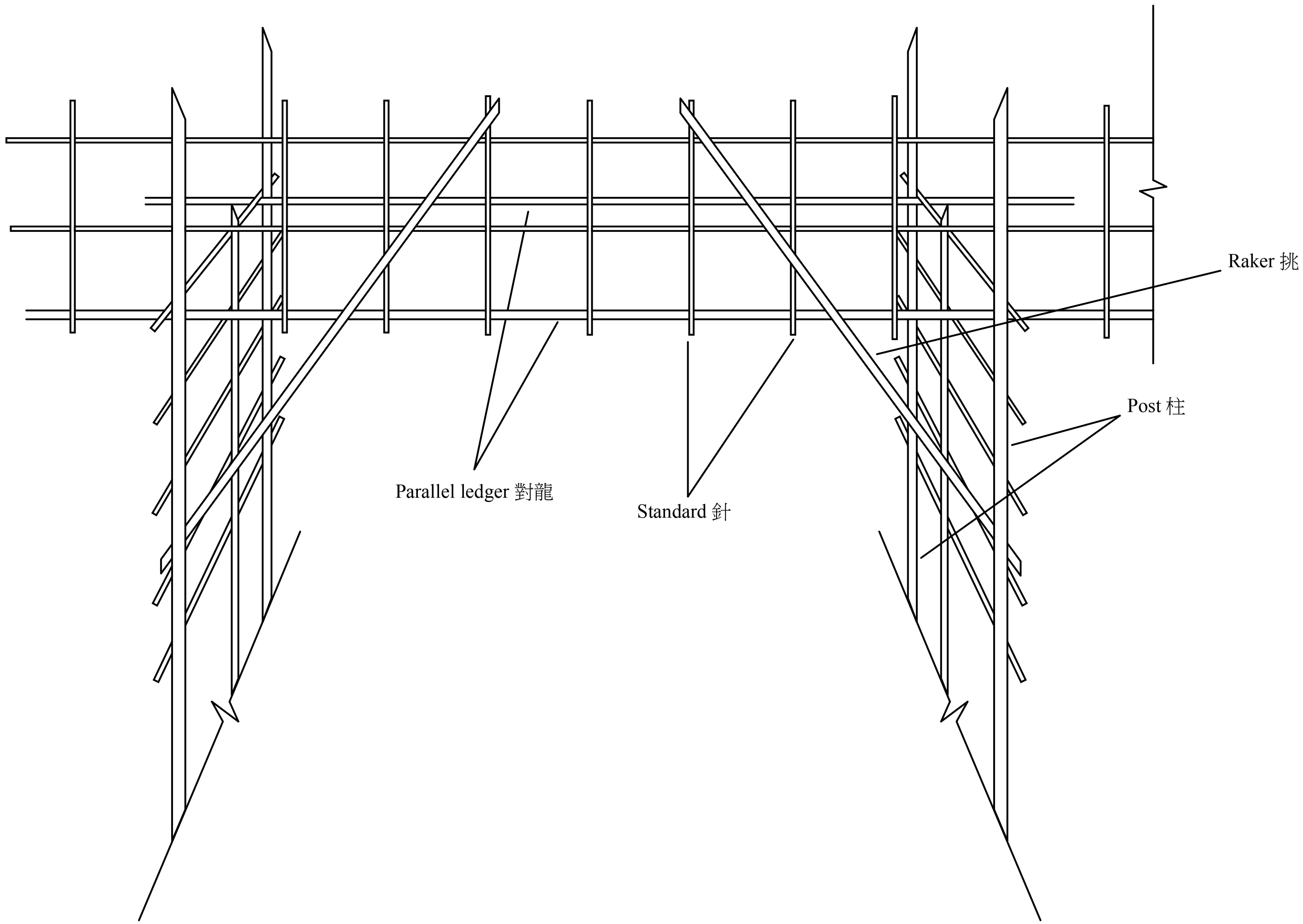


Figure 5.4c Stage 3/5

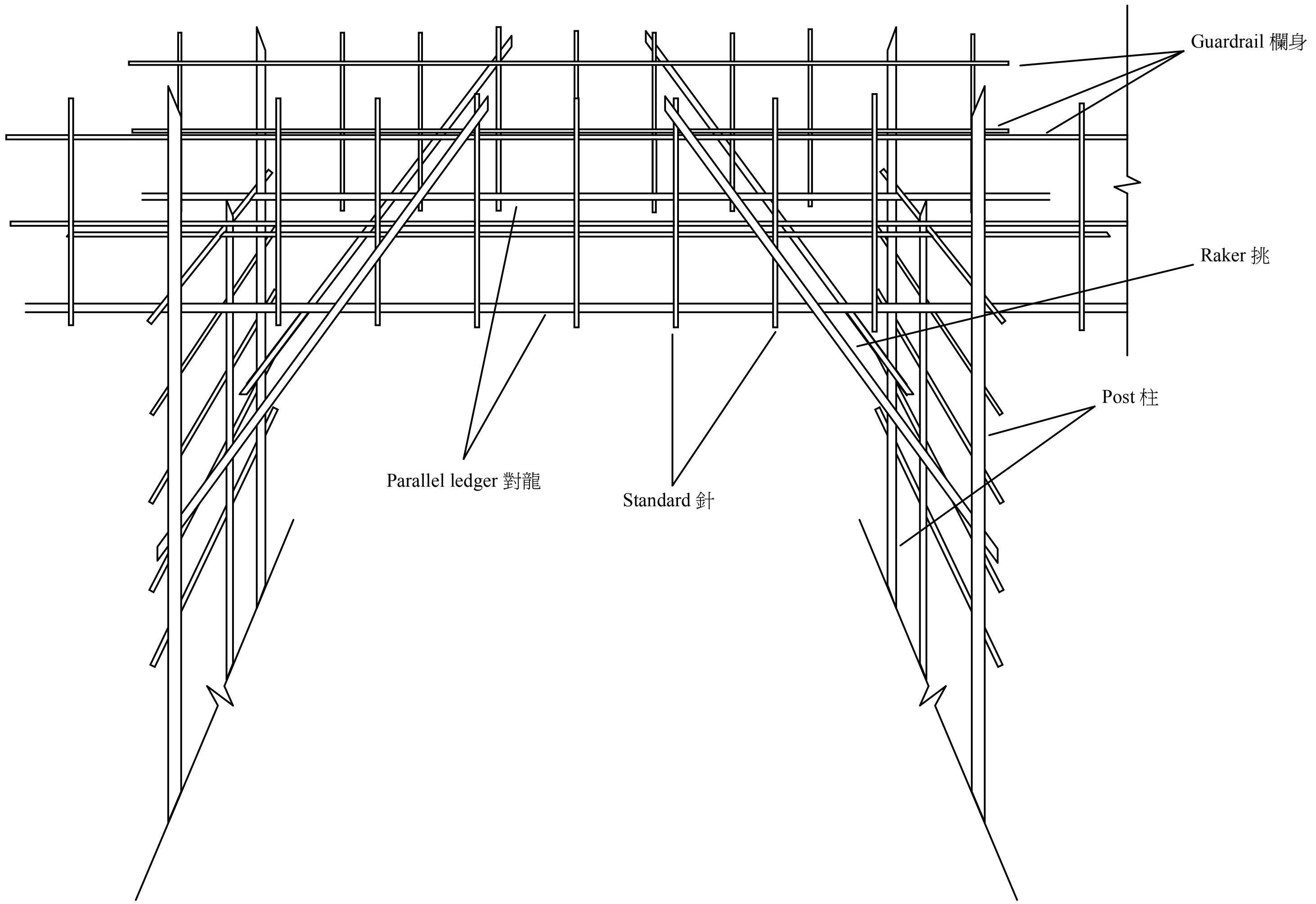


Figure 5.4d Stage 4/5

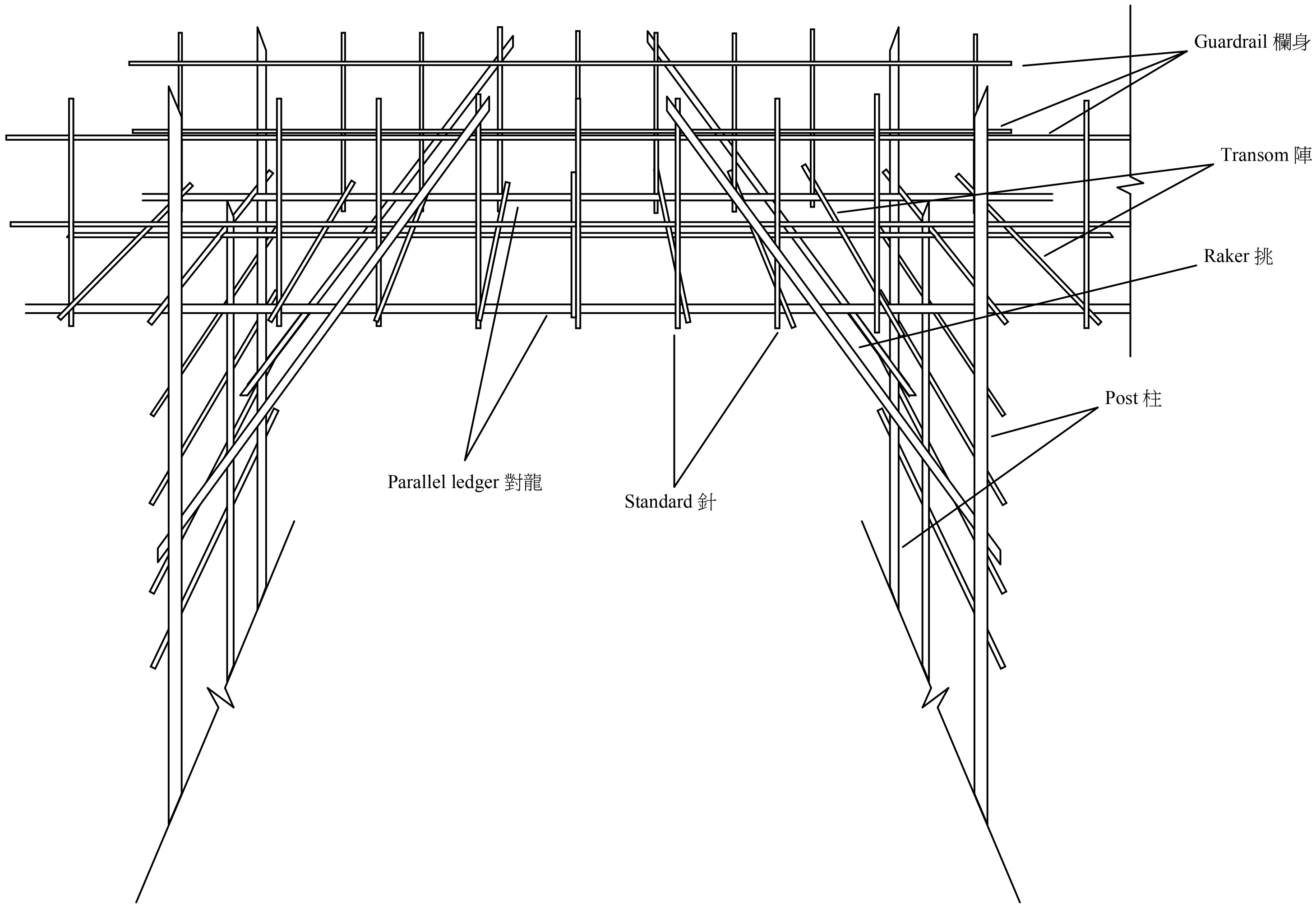


Figure 5.4e Stage 5/5

5.5 Platform scaffolds

Platform scaffolds are assemblies of skeletal frameworks to provide large working spaces at elevation for various construction activities. A large platform is supported at four sides by triangulated frameworks which provide overall stability and lateral restraints to the structures. The load-carrying capacity of the platform depends on the layout of the scaffolds and also the sizes and strengths of the bamboo members.

The erection of a platform scaffold is summarized as follows:

a. Two single layered scaffolds are first erected orthogonal to each other as the first two sides of the scaffolds, and they provide lateral rigidity to the structure during erection. The single layered scaffolds also provide access to the platform.

b. Posts are then erected at regular intervals together with ledgers to form the basic skeleton of the other two sides.

c. Rakers are then erected to the skeleton of the latter two sides to form triangulated frameworks.

d. Transoms are then placed to form a grid over the top ledgers of each of the four frameworks. A pair of plan braces is also erected as diagonals below the transom grid.

e. Guardrails are then erected as safety measures to the platform.

The erection sequence of a platform scaffold is presented in Figure 5.5.

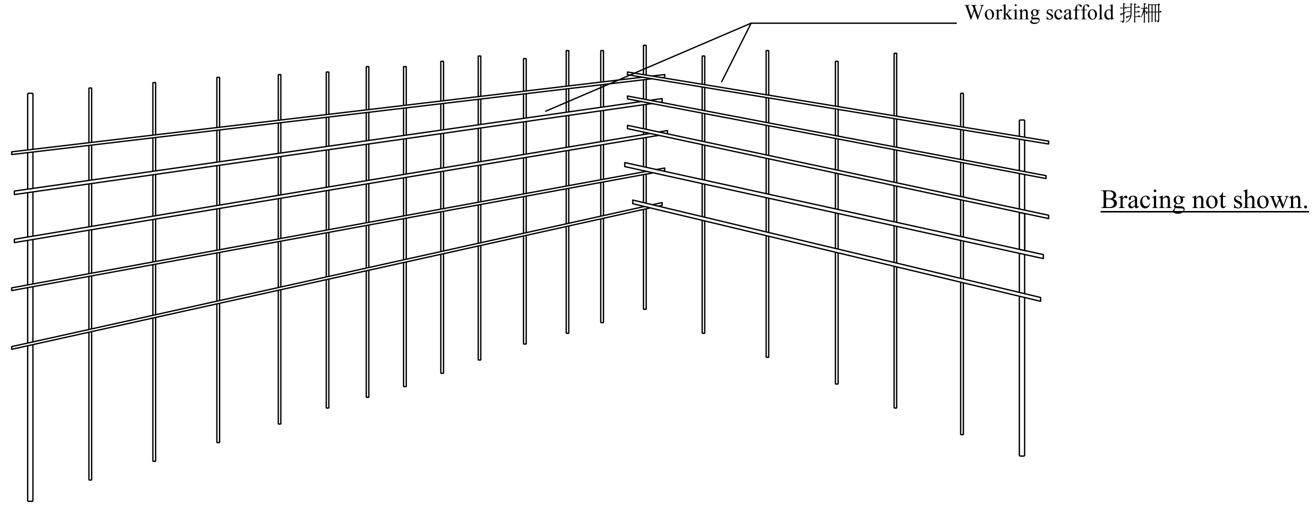


Figure 5.5a Stage 1/5

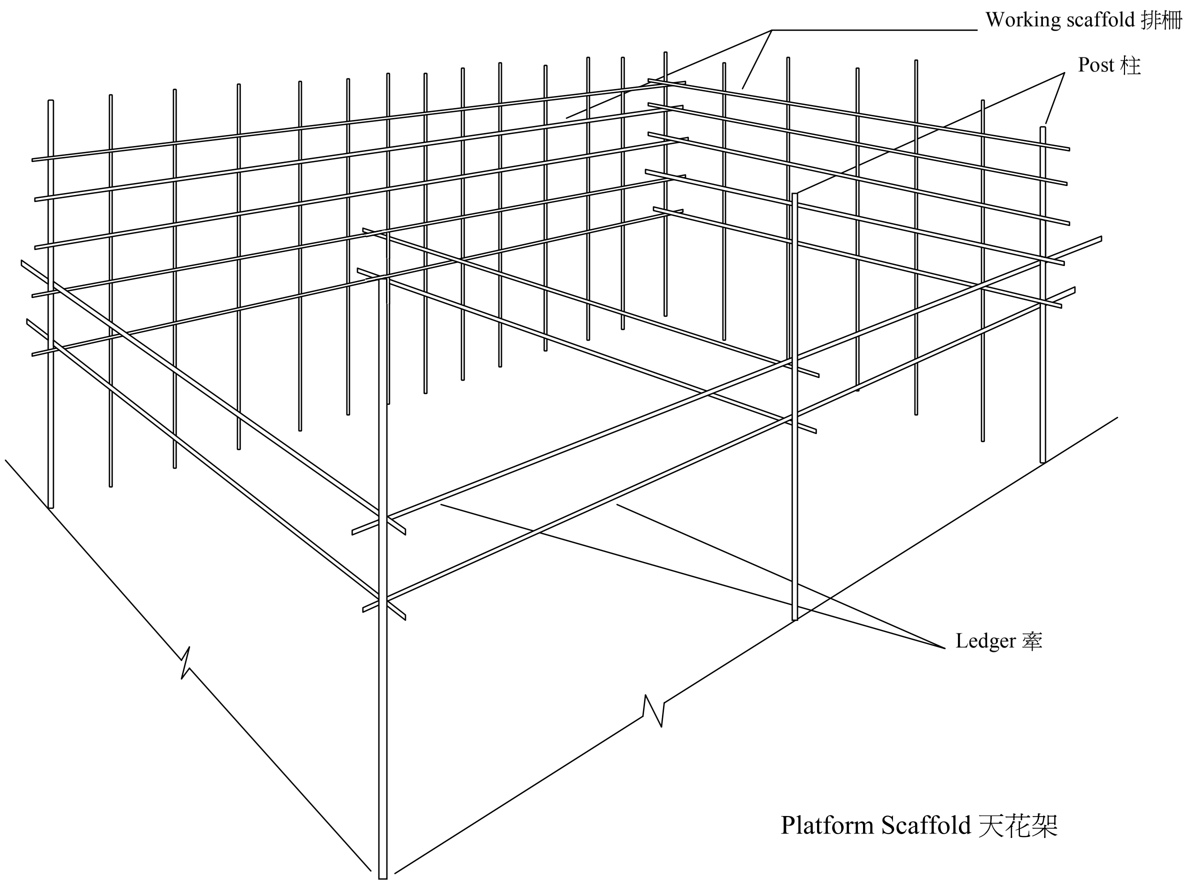


Figure 5.5b Stage 2/5

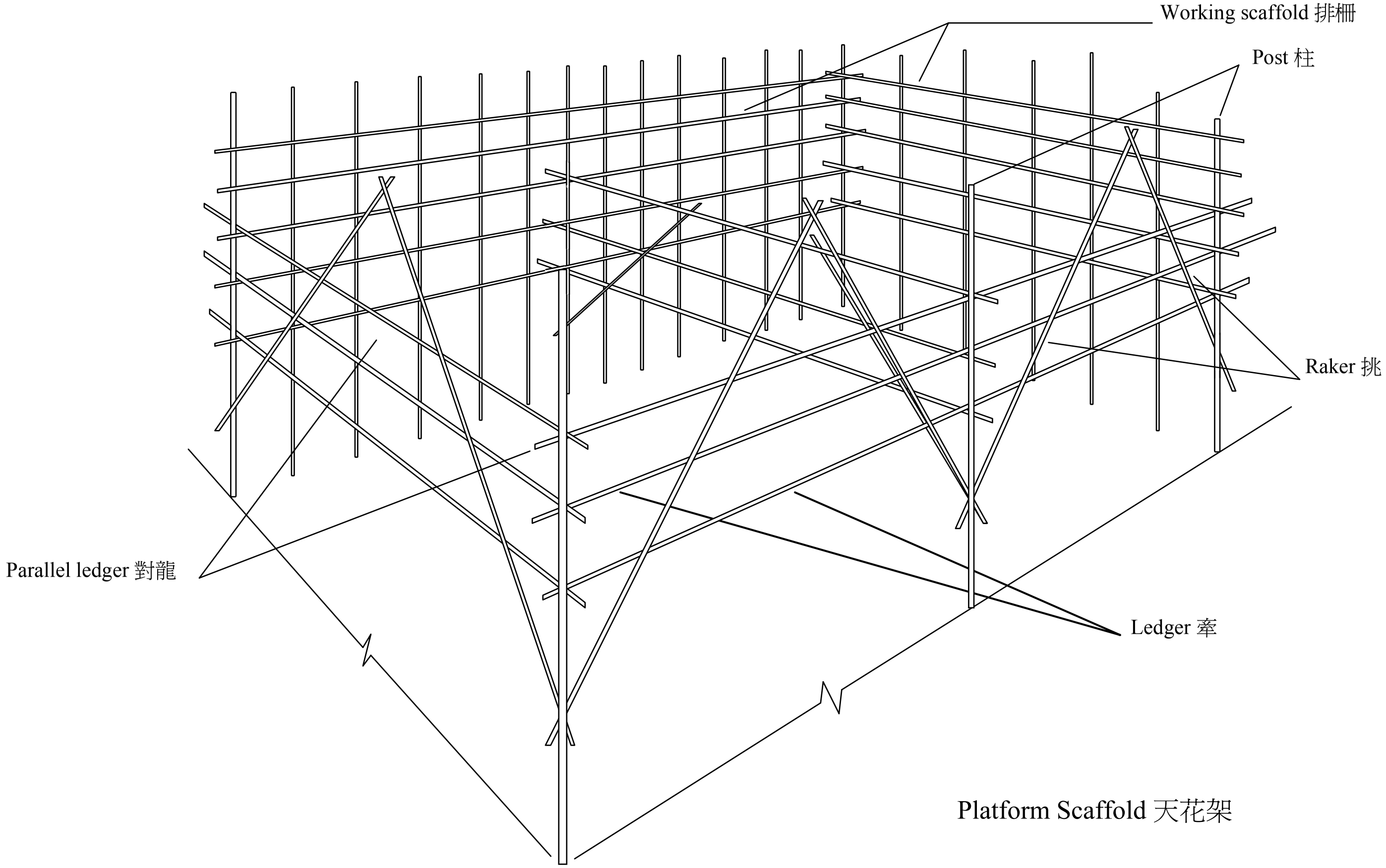


Figure 5.5c Stage 3/5

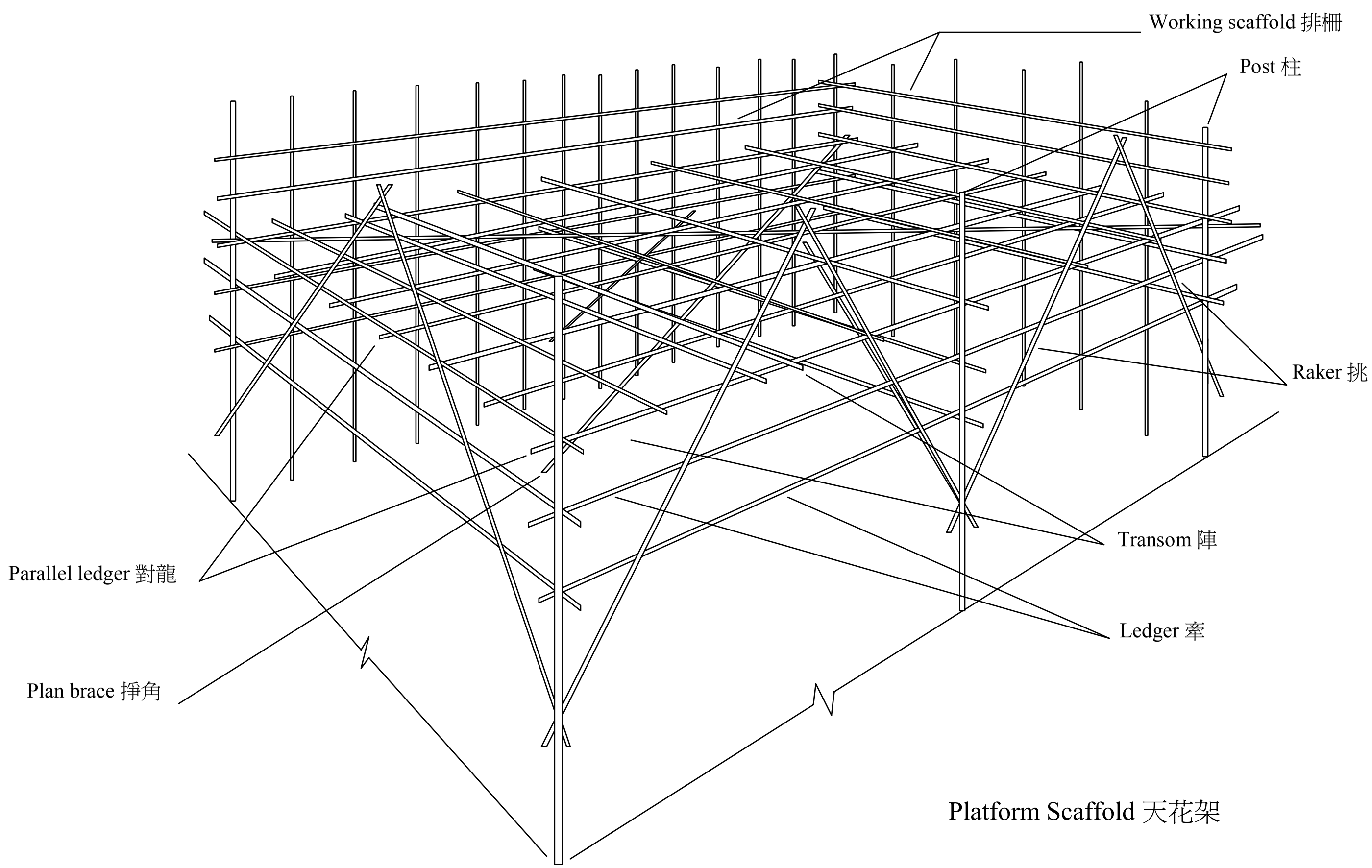


Figure 5.5d Stage 4/5

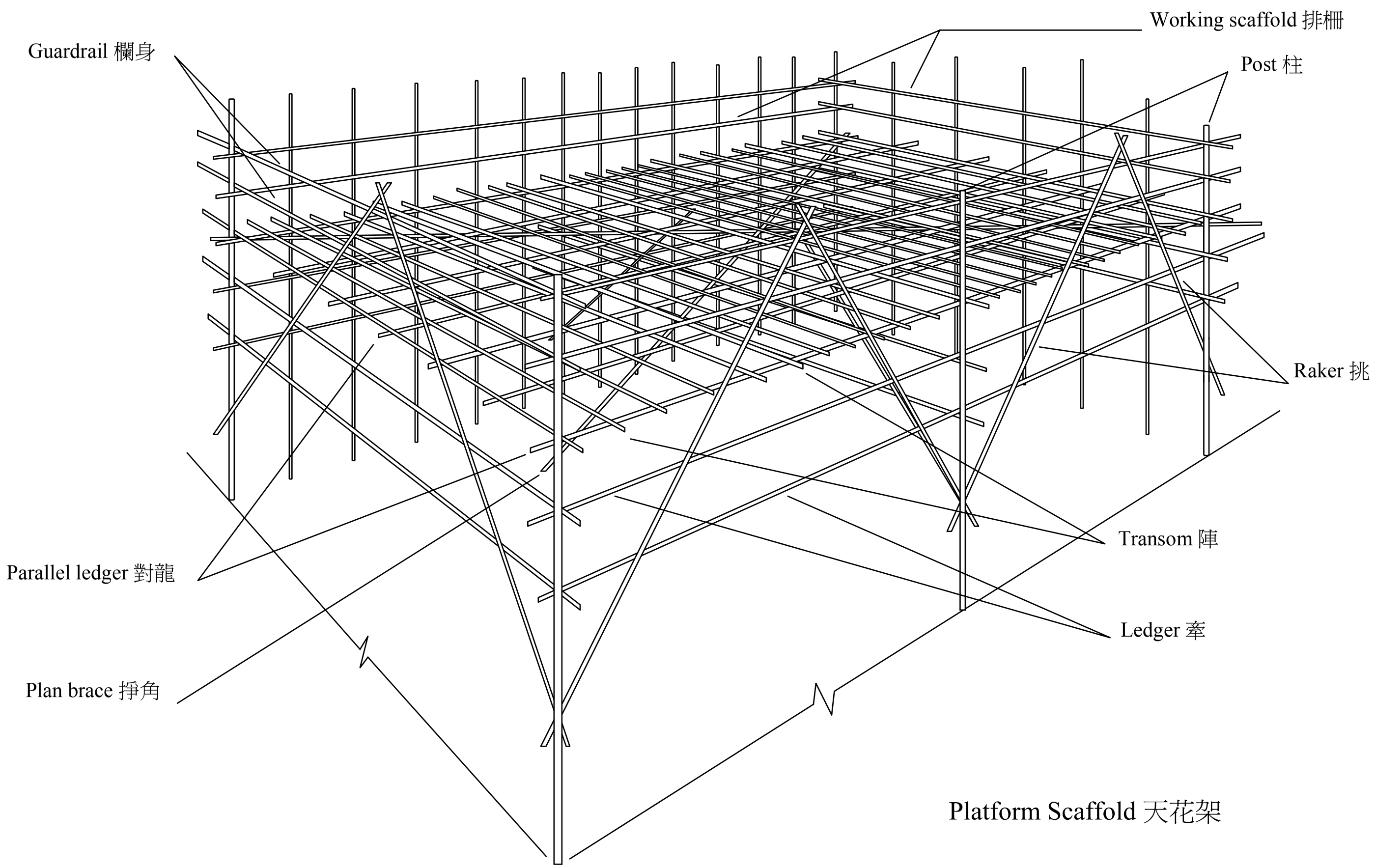


Figure 5.5e Stage 5/5

6 Knots in bamboo scaffolds

Knots in bamboo scaffolds are primarily hand-made fastenings with plastic strips between bamboo members which are made on site for easily erection and dismantle.

6.1 Common knots

Three main types of knots are illustrated in Figure 6.1 as follows:

a. Basic knot

It is a simple knot commonly used in connecting two bamboo members with plastic strips. The knots should be tight and secure with 5 round turns to form a tight fastening. It is commonly used in connecting a standard or a post with a ledger, and also a bracing with a ledger.

b. Restrained knot

It is a basic knot restrained by another plastic strip or a bunch of galvanized wires for improved strength and stiffness.

Figure 6.1 Knots in bamboo scaffolds

c. Reinforced knot

Similar to a restrained knot, it is an extended basic knot restrained by plastic strips or wires covering most parts of the intersection. It is often applied to heavy-duty members such as wind braces, and rakers.

Figure 6.1 Knots in bamboo scaffolds (continued)

6.2 Tightening sequence of a lap in parallel members

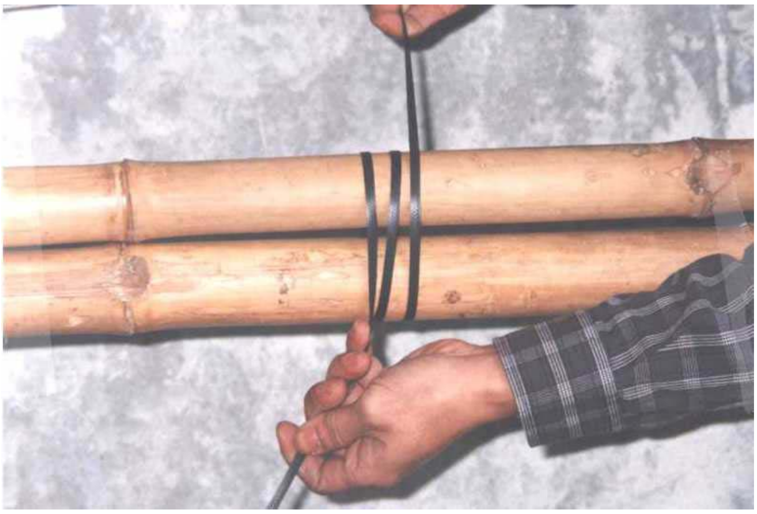
The tightening sequence is illustrated in Figure 6.2.

Step 1

Place the plastic strip in position.

Step 2

Tighten the plastic strip after two round turns.



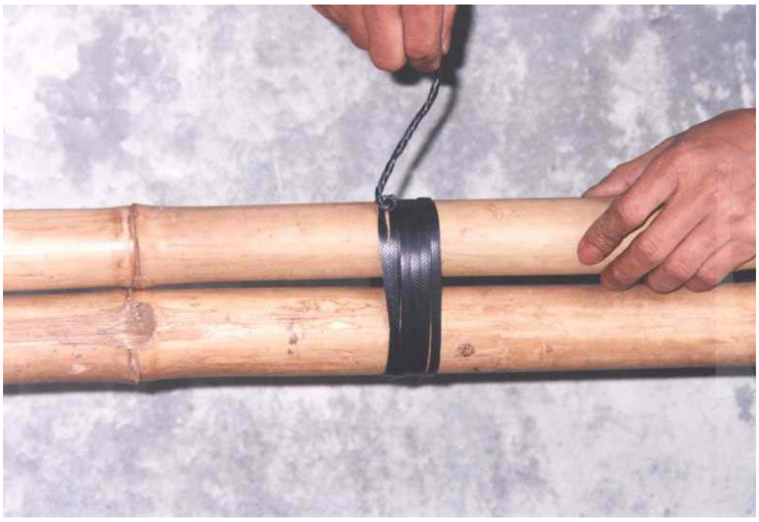
Step 3

Tighten the plastic strips again after 5 round turns.

Figure 6.2 Tightening sequence of a lap in parallel members

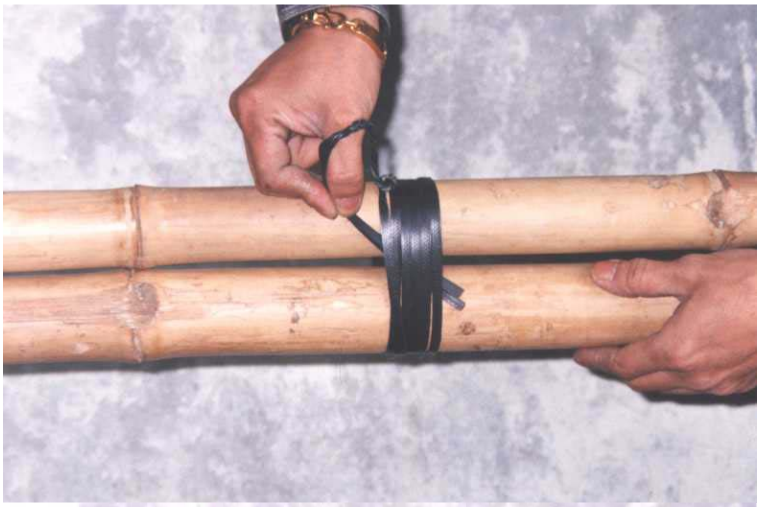
Step 4

The ends of the plastic strips are then crossed and twisted together to form a twisted end.



Step 5

The twisted end is passed through the fastening twice to give one round turn for anchorage.



Step 6

A fastening with plastic strips of 5 round turns with proper anchorage is thus completed.

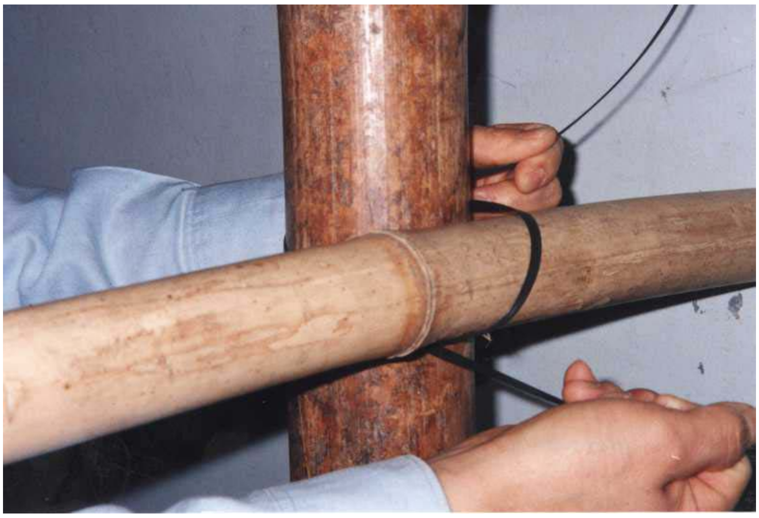
Figure 6.2 Tightening sequence of a lap in parallel members (continued)

6.3 Tightening sequence of a joint between orthogonal members

The tightening sequence is illustrated in Figure 6.3.

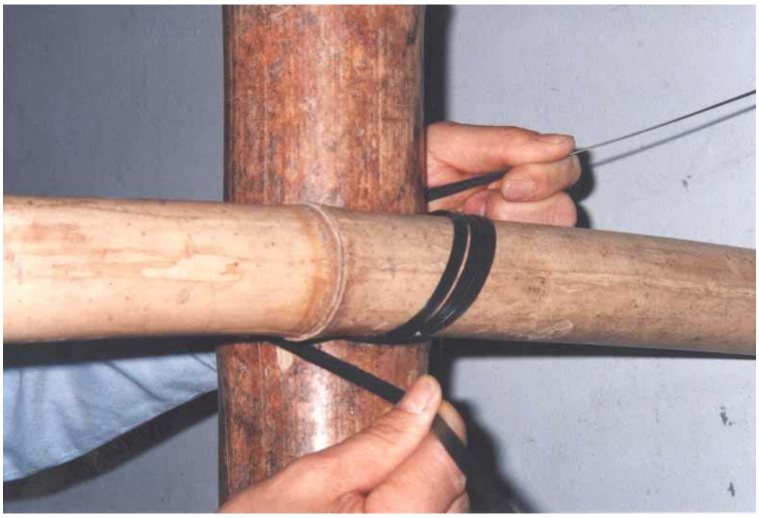
Step 1

Place the plastic strip in position.



Step 2

Tighten the plastic strip after two round turns.



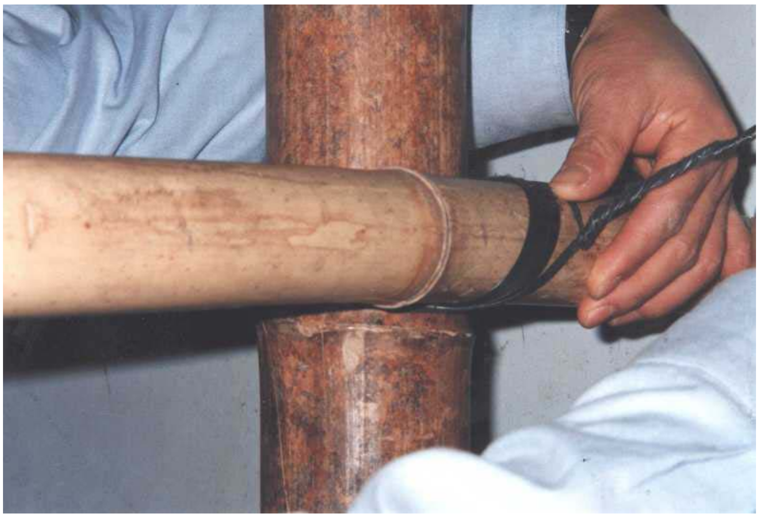
Step 3

Tighten the plastic strips again after 5 round turns.

Figure 6.3 Tightening sequence of a joint between orthogonal members

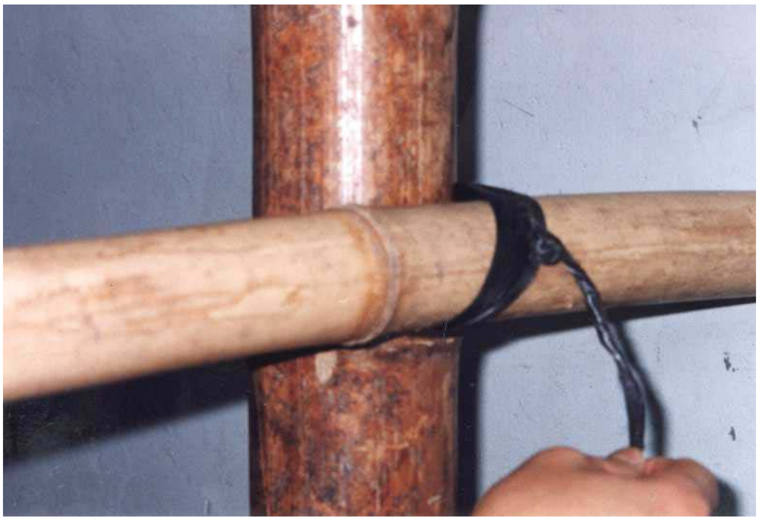
Step 4

The ends of the plastic strips are then crossed and twisted together to form a twisted end.



Step 5

The twisted end is passed through the fastening twice to give one round turn for anchorage.



Step 6

A fastening with plastic strips of 5 round turns with proper anchorage is thus completed.

Figure 6.3 Tightening sequence of a joint between orthogonal members (continued)

6.4 Tightening sequence of a restrained knot between inclined members

The tightening sequence is illustrated in Figure 6.4.

Step 1

After the basic fastening is formed between inclined members, place another plastic strip across the fastening.

Step 2

Tighten the basic fastening after 3 to 5 round turns of the plastic strip. The ends of the plastic strips are then crossed and twisted together to form a twisted end.

Step 3

The twisted end is passed through the fastening twice to give one round turn for anchorage. A fastening with plastic strips of 5 round turns with proper anchorage is thus completed.

Figure 6.4 Tightening sequence of a restrained knot between inclined members

Glossary

Element	Chinese Name	Explanation
Anchorage (steel rod)	錨釘	
Base plate	墊板 (腳掌)	Thick mild steel plate to spread loads under posts to avoid excessive settlement or local cracking.
Bracings	暢 (斜撐)	Pairs of diagonal members connected to posts and standards in order to form triangulated frameworks.
Plan braces	撐角	Bracings provided to prevent in-plan deformation of skeletonal frameworks.
Canvas	帆布 (膠布)	
Catch fans	斜板	Simple triangulated frameworks covered with nylon or galvanized zinc sheets to prevent debris falling from height for protection of the public.
Fencing	圍欄	
Fir	杉木	
Dead shore (fir)	企頂	Primary fir post for heavy load.
Fir parallel ledger	對龍	Parallel ledger using fir to carry heavy load.
Fir transom	陣	Transom using fir to carry heacy load.
Linking to fir pole	根引	Additional pole in connecting post, ledger and transom under heavy load.
Guardrail	欄身	
Ledger	牽	Horizontal member in bamboo scaffolds.
Base ledger	底牽 (打底)	Primary (load bearing) horizontal member supported by posts.
Parallel ledger	對龍	Ledger parallel to the base ledger and connected with posts and standards.
Obstruct plates	渾身橋	Simple triangulated frameworks covered with bamboo members and galvanized zinc sheets as safety barriers for protection of workers.
Pole	杆	
Bear pole	擔杆	Load bearing pole in signage scaffolds which supports pulleys.
Clamp pole	夾竹	Short pole used in catch fans for the positioning of zinc sheets.
Hang pole	吊竹	Load bearing (tension) pole in signage scaffolds, either vertical or diagonal.
Linking pole	拖龍竹	Closely spaced pole supporting canvas, zinc sheets, or planks in truss-out scaffolds.
Slope pole	八字竹	Load-bearing (compression) pole in truss-out scaffolds supporting linking poles. Also referred as rafter.
Post	柱	Vertical member rest on the ground or steel brackets as the primary load-bearing member.
Prop	頂竹 (拉搖竹)	Short piece of bamboo pole acting together with a mild steel bar to form a 'putlog', i.e. a lateral support to bamboo scaffolds.
Putlog	拉搖 (連墻器)	A mild steel bar acting together with a short piece of bamboo to form a 'putlog', i.e. a lateral support to bamboo scaffolds.
Putlog wire	抽鐵綫	Mild steel bar of 6 mm in diameter.
Raker	挑撐	Load-bearing (compression) pole inclined to the vertical.

Glossary (continued)

Element	Chinese Name	Explanation
Scaffolds	棚架	
Civil work scaffolds	杉架 (杉台)	Single layered scaffolds with large working platforms for construction activities.
Demolition scaffolds	拆樓棚	Single layered scaffolds covered by canvas to collect dust and debris for demolition work.
Double layer scaffolds	雙行棚架	An outer layer and an inner layer of scaffolds for provision of access together with working platforms for various construction activities.
Foot-bridge scaffolds	行人橋架	Assemblies of skeletonal frameworks to provide passage at elevation.
Platform scaffolds	平台棚架 (天花架)	Large working platforms covered with closely spaced horizontal bamboo poles for provision of working spaces for construction activities.
Signage scaffolds	招牌棚架	Cantilever structures with direct supports from permanent structures at only one end of the scaffold.
Single layer scaffolds	單行棚架 (排柵)	Basic structural units of scaffolds consisting of posts, standards, ledgers and bracings for provision of access.
Truss-out scaffolds	吊棚	Simple triangulated frameworks used in locations where it is not pratical to erect scaffolds from the ground.
Standard	針	Vertical member which does not rest on the ground or steel brackets and is attached to the base ledger as secondary member with little load-bearing capacity.
Support	支點	
Lateral support	橫向支點	Lateral support from permanent structures which restrict bamboo scaffolds from inward or outward movement.
Vertical support	縱向支點	Vertical support from the ground or steel brackets for overall equilibrium of bamboo scaffolds.
Tie	拉搖	Lateral restrict from permanent structures to scaffolds, such as putlog, to prevent inward and outward movements.
Project tie	橫身拉搖	Lateral restrict to projecting cantilever scaffolds to prevent sideway movements.
Transom	陣	Short horizontal member connected orthogonal to ledgers in order to support working platforms.
Working scaffold	排柵	Large single layered scaffold for erection of platform scaffolds.
Zinc sheet	鍍鋅鐵片	

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THE HONG KONG POLYTECHNIC UNIVERSITY

TECHNICAL REPORT NO.24

Bamboo scaffolds have been widely used in construction applications in South East Asia, in particular, Hong Kong for many years. Because of their high adaptability and low construction cost, bamboo scaffolds can be constructed in different shapes to follow any irregular architectural features of a building within a comparatively short period of time. In general, bamboo scaffolds are mainly used to provide access of workers to different exposed locations to facilitate various construction and maintenance process. Besides widely erected on construction sites, bamboo scaffolds are also used in signage erection, decoration work, demolition work and civil work.

This document ***Erection of Bamboo Scaffolds*** presents the basic features of bamboo scaffolds and the respective practical applications in building construction. It covers material selection, typical configurations with details, and erection procedures for builders and scaffolding practitioners.

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