

# 21

## Bridge Engineering in Indonesia

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## 21.1 Introduction

### 21.1.1 Geographical Characteristics

Indonesia is the world's largest archipelago country, covers around 17,000 islands, and lies to the north of the equator, between 6° and 11° south latitude and 97° and 114° east longitude (Figure 21.1). Not only is Indonesia located between two great continents, Asia and Australia, but it is also located between two great oceans, the Indian and Pacific Oceans. The accumulation of land and water is around 1.9 million km<sup>2</sup> or approximately 5.8 times that of Malaysia, which is only around 0.3 million km<sup>2</sup>. However, Indonesia is still only around 0.2 times the size of the United States of America, which is around 9.8 million km<sup>2</sup>. Indonesia is the largest among its neighboring countries in Southeast Asia, such as Singapore, Malaysia, the Philippines, Papua New Guinea, and East Timor.

The population in Indonesia is 222 million based on the Badan Pusat Statistik Republik Indonesia (Statistics Indonesia; <http://www.bps.go.id>) of 2006. Over half the population lives on Java Island, which is only around 7% of the total area. The population density is not spread evenly. In general, the population is concentrated on five major islands: Sumatra (474 km<sup>2</sup>), Java (132 km<sup>2</sup>), Kalimantan, the third world's largest island (540 km<sup>2</sup>), Sulawesi (189 km<sup>2</sup>), and Papua New Guinea (422 km<sup>2</sup>). Most of these main islands, except Kalimantan, are located along earthquake rings. The contours of the regions are varied, consisting of mountains, valleys, and many rivers which divide one region from another. This means land transportation requires bridges to connect one roadway to another.

### 21.1.2 Bridge Development

According to the road laws of the Republic of Indonesia (Number 38, 2004), a road, as part of the national transportation system, plays an important role in particularly supporting not only the



FIGURE 21.1 Map of the Republic of Indonesia. (From <http://www.surftrip.com>.)

economic, social, and cultural sectors but the environment as well. Roads are developed by means of a regional expansion approach so interregional development balance and equal distribution can be achieved, thus forming and affirming national unity and national defense and security, as well as forming a spatial structure within the framework of realizing national development's goals. Therefore, the government must provide excellent quality, useful, and sustainable road infrastructure, which is needed to support peace, justice, and democracy, and to improve the people's welfare in Indonesia.

At present, road transportation is the main mode of transportation in Indonesia and far exceeds the volume of other available modes of transportation. About 90% of all goods and more than 95% of all passengers in Indonesia are transported by road. Accordingly, the road networks in Indonesia have been expanded from 85,000 km in 1971 to around 437,759 km by the end of 2008 (BPS Statistics Indonesia). Along these roads, there are approximately 88,000 bridges and other types of crossing methods with a total length of almost 1000 km. Apart from that, 28,000 bridges are located along national and provincial roads and another 60,000 bridges are located along local and urban roads.

From a strategic point of view, it is clear that bridges have an important role in the operation and function of road networks and involve a large initial investment. To accelerate road infrastructure developments, particularly in bridge construction, the government's policies are directed towards superstructure standardization by providing a component stock of bridge standard spans as well as technical construction standard drawings that can be constructed in the fields. The main purpose of bridge superstructure standardization is to guarantee that the quality of the product fulfills the requirements as specified to ease construction works. This reason for standardization is not a surprise because, in reality, there are currently 88,000 bridges, which mostly cross small rivers.

Out of all existing bridges along the national and provincial road links, the number of bridges that cross rivers with a width of more than 100 m is less than 2%. Although there are not so many rivers with big channels compared to other neighboring countries, Indonesia has also adopted advanced bridge structural technology as indicated by the application of prestressed concrete structures, cable-supported structures, and more challenging architectural demands for crossing big rivers as well as for urban infrastructure developments. For bridge spans up to 60 m, superstructure constructions in Indonesia usually follow the Bina Marga bridge standards; for long spans over 60 m, designs are made specifically for the systems of different structures or the existing standard system is modified, resulting in nonstandard bridge constructions.

Construction of nonstandard bridges in Indonesia started in the 1960s; the first implementation was the Ampera Bridge, a continuous steel girder and constructed from 1962 to 1965 in Palembang, South Sumatra. The construction of the Danau Binkuang Bridge in Riau also introduced the construction of continuous composite steel girders from 1968 to 1970. Special bridge constructions have continued to develop with the use of various types of constructions, including continuous concrete box bridges, continuous steel girders, concrete arches, steel arches, suspension bridges, and cable-stayed bridges, among others. These types of bridges are designed to be economical bridge spans and special attention is paid to the aesthetic aspects and compatibility with the surrounding environments.

The trends for choosing proper bridge types are closely linked to the geographical characteristics and the needs of local traffic. Bridges on the island of Java were generally designed to serve dense traffic, crossing rivers or river banks that are relatively short, resulting in wide bridges with short to medium spans. As for some areas of Borneo and some parts of Sumatra, there are many great rivers with heavy water traffic, but the road traffic is not as heavy as in Java. This calls for the availability of bridges with long spans and heights sufficient to accommodate water traffic. [Table 21.1](#) presents a list of nonstandard bridges in Indonesia.

**TABLE 21.1** List of Nonstandard Bridges in Indonesia

No.	Name	Location	Main Span (m)	Total Length (m)	Year Built	Data
1	Continuous Concrete Bridges					
	Rantau Berangin	Riau	121	201	1972–1974	✓
	Rajamandala	West Java	132	222	1972–1979	✓
	Serayu Kesugihan	Central Java	128	274	1978–1985	
	Mojokerto	East Java	62	230	1975–1977	
	Arakundo	Aceh	96	210	1987–1990	✓
	Tonton–Nipah	Riau Isles	160	420	1995–1998	✓
	Setoko–Rempang	Riau Isles	145	365	1994–1997	✓
	Siti Nurbaya	West Sumatra	76	156	1995–2002	
	Tukad Bangkung	Bali	120	360	2006	✓
	Air Teluk II	South Sumatra	104	214	2006	✓
	Perawang	Riau	180	1473	2007	✓
2	Continuous Steel Bridges					
	Ampera	South Sumatra	75	1100	1962–1965	✓
	Danau Bingkuang	Riau	120	200	1968–1970	✓
	Siak I	Riau	52	350	1975–1977	✓
	Kapuas Timpah	Central Kalimantan	105	255	2010	✓
3	Concrete Arch Bridges					
	Karebbe	South Sulawesi	60	60	1996	✓
	Serayu Cindaga	Central Java	90	214	1993–1998	✓
	Rempang–Galang	Riau Isles	245	385	1995–1998	✓
	Besuk Koboan	East Java	80	125	2000	✓
	Pangkep	South Sulawesi	60	84	2006	✓
	Bajulmati	East Java	60	90	2007	✓
4	Steel Arch Bridges					
	Malo	East Java	128	178	2007	
	Ogan Pelengkung	South Sumatra	100	100	2008	
	Kahayan Hulu	Central Kalimantan	80	160	2007	
	Kahayan	Central Kalimantan	150	640	1995–2000	✓
	Rumbai Jaya	Riau	150	780	2003	✓
	Barito Hulu	Central Kalimantan	150	561	2008	✓
	Martadipura	East Kalimantan	200	560	2004	✓
	Mahulu	East Kalimantan	200	800	2003	
	Palu IV	Central Sulawesi	125	300	2006	✓
	Rumpiang	South Kalimantan	200	754	2008	✓
	Batanghari II	Jambi	150	1351	2009	✓
	Teluk Masjid	Riau	250	1650	2012	✓
					(construction finished)	
	Siak III	Riau	120	518	2011	(construction finished)
	Pela	East Kalimantan	150	420	2010	✓
	Sei Tayan	West Kalimantan	200	1420	Under construction	✓
5	Cable-Stayed Bridges					
	Teuku Fisabilillah	Riau Isles	350	642	1998	✓



**TABLE 21.1 (Continued)** List of Nonstandard Bridges in Indonesia

No.	Name	Location	Main Span (m)	Total Length (m)	Year Built	Data
	Pasupati	West Java	106	2282	2005	✓
	Grand Wisata Overpass	West Java	81	81	2007	✓
	Siak Indrapura	Riau	200	1196	2007	✓
	Siak IV	Riau	156	699	Under construction	✓
	Sukarno	North Sulawesi	120	622	Under construction	✓
	Melak	East Kalimantan	340	680	Under construction	✓
	Galalapoka	Maluku	150	1065	Under construction	✓
6	Suspension Bridges					
	Old Bantar	Yogyakarta	80	176	1932	✓
	Memberamo	Papua	235	235	1996	✓
	Barito	South Kalimantan	240	1082	1997	✓
	Kartanegara	East Kalimantan	270	714	2001	✓
	Balang/Teluk Balikpapan	East Kalimantan	708	1344	Design	✓
7	Special Bridges Projects					
	Kelok 9	West Sumatra	90	5 km	2013	✓
	North Java Flyover	Java	Varies	Varies	Under construction	✓
	Suramadu	East Java	434	5438	June 10, 2009	✓
	Bali Strait	East Java–Bali	2000	2000	Preliminary study	✓
	Sunda Strait	Banten	2.2 km	29 km	Preliminary design	✓

## 21.2 Design Practices

### 21.2.1 General Information

Prior to the 1970s, the Department of Public Works had guidelines called “Peraturan Beban PU” as the load regulations for bridge design. Now, we call it load regulation “PU Lama.” In 1970 the Directorate General of Highways (Ditjen Bina Marga) issued regulations about more advanced loading specifications for highway bridges (Peraturan Muatan untuk Djembatan Djalan Raya, No. 12/1970), as a formal reference for bridge designs and construction in Indonesia. From 1971 to the 1990s, there was no significant change in the regulations. Even if there had been, it would be limited to efforts to improve the existing regulations, such as improving the regulations of earthquake specifications for highways and bridges, or improving the existing load regulations (No. 12/1970) to become codes for load designs of highway bridges (Tata Cara Perencanaan Pembebanan Jembatan Jalan Raya, SNI-03-1725-1989).

In 1989, there was collaboration between Indonesia and Australia to produce complete bridge design codes. This collaboration lasted for a fairly long time so that in 1992, not less than 17 modules, popularly known as Bridge Management Systems 1992 (BMS-92), were created. Those modules were relatively complete because they covered all activities in bridge management, starting from managerial activities and bridge operations, including bridge design codes and how to use the manual. The manual, which also showed how to use the modules, could in fact become a practical guideline to choosing and determining construction types. This really simplified preliminary bridge designs. Since the scopes and

substance of the discussions were very broad, BMS-92 made it possible for designers to conduct their activities in designing bridges, particularly ones that extended up to 200 m.

BMS-92 adopted modern design concepts by applying the limit-state design concept. A limit-state design is a term used to describe a design approach in which all of the ways a structure may fail are taken into account. Failure is defined as any state that makes a design objective infeasible (i.e., it will not work for its intended purpose). Such failures are usually grouped into two main categories (or limit states): ultimate limit state (ULS) and serviceability limit state (SLS). This analytical approach was obviously different from its predecessor, which commonly utilized working stress designs, which were based on the elasticity theory. Although these modern design concepts seemed more complex at first, the limit-state design philosophy is a more rational approach than the working stress design approach. A design produced by application of limit-state principles will be more economical and will result in bridges of more uniform capacities or strength reserves. Therefore, the designs tend to be more efficient and reliable. Half of the manuals of BMS-92 have been transformed to Indonesia's Standard (SNI) since 2001, especially for the regulations of bridge designs, such as stress requirements for concrete and steel.

### 21.2.2 Code References

The current bridge design codes in Indonesia are as follows:

- Bridge design code BMS-92 with revisions as follows:
  - Part 2, Bridge Loads (SK.SNI T-02-2005), referring to Kepmen PU No. 498/KPTS/M/2005
  - Part 6, Reinforced Concrete Designs for Bridges (SK.SNI T-12-2004), referring to Kepmen PU No. 260/KPTS/M/2004
  - Part 7, Steel Designs for Bridges (SK.SNI T-03-2005) referring to Kepmen PU No. 498/KPTS/M/2005
- Standard Designs on Earthquake Strength for Bridges (Revised SNI 03-2883-1992)
- Bridge Design Manual BMS-92
- Bridge Design Criteria (referring to the letter of the Directorate General of Highways No. UM 0103-Db/242, March 21, 2008)

The above Bina Marga codes include highway and pedestrian bridge designs. Long-span bridges (more than 200 m long) and bridges with special structures or that are built with new materials and methods will be treated as special bridges.

### 21.2.3 Bridges Loads

#### 21.2.3.1 General Information

Bridge design loads, which cover permanent, traffic, and environmentally induced loads, should refer to the load regulations for bridges (SK.SNI T-02-2005), which is in compliance with Kepmen PU No. 498/KPTS/M/2005, which was a revision of part 2 of BMS-92.

#### 21.2.3.2 Design Vehicle Load

In considering vehicle actions, the vehicle load has three components: a vertical component, a braking component, and a centrifugal component (for horizontally curved bridges). The traffic loads for the design of bridges consist of lane load D and truck load T. The D lane load applies to the entire width of the vehicle's lane with the intensity of the load by 100% for the number of lanes ( $n$ ) and 50% for the rest of the vehicle floor space available. This load is used to calculate the effects on the bridge equivalent to a convoy of actual vehicles. The total number of the D lane load that works depends on the width of the

vehicle's own lane. The T truck load is a heavy vehicle with three axes which is placed in several positions in the traffic lane design. Each axis consists of two loading contact areas which are meant to be a simulation of the influence of the heavy vehicle's wheels. The T load is used more for the calculation of the strength capacity of the deck system of the bridge. In general, the D load will govern the design of medium- to long-span bridges, whereas the T load is used for short spans and deck systems.

### 21.2.3.3 D Lane Load

The D lane load (Figure 21.2) consists of

1. A uniform distributed load (UDL) of intensity  $q$  kPa, where  $q$  depends on the total loaded length  $L$  as follows:

$$L \leq 30 \text{ m } q = 9.0 \text{ kPa} \quad (21.1)$$

$$L > 30 \text{ m } q = 9.0 \times \left( 0.5 + \frac{15}{L} \right) \text{ kPa} \quad (21.2)$$

The UDL may be applied in broken lengths to maximize its effects. In this case  $L$  is the sum of the individual lengths of the broken load. The D lane load is positioned perpendicular to the direction of traffic.

2. A knife edge load (KEL) or line load of  $p$  kN/m, placed in any position along the bridge perpendicular to the traffic direction:

$$q = 49.0 \text{ kN / m} \quad (21.3)$$

In continuous spans, the KEL is placed in the same lateral position perpendicular to the traffic direction in two spans to maximize the negative bending moments.

### 21.2.3.4 T Truck Load

The T truck load consists of a semitrailer truck vehicle that has a structure and axis weight as shown in the Figure 21.3.

Only one truck shall be placed in any design traffic lane for the full length of the bridge. The T truck shall be placed centrally in the traffic lane. The maximum number of the design traffic lanes is given in Table 21.2. These lanes are placed anywhere between the curbs.

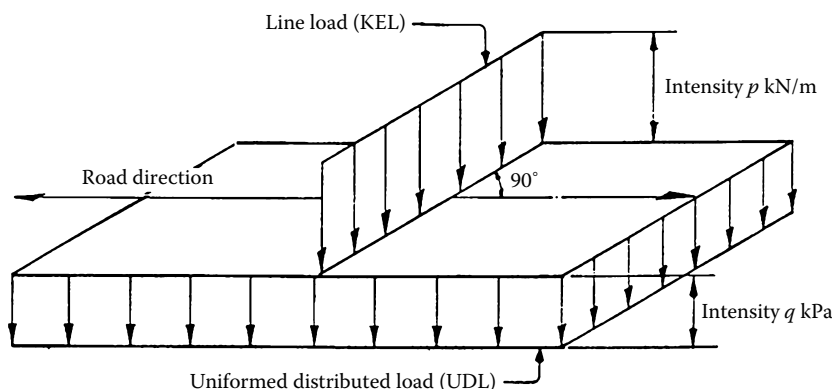


FIGURE 21.2 Specification of the D lane load.

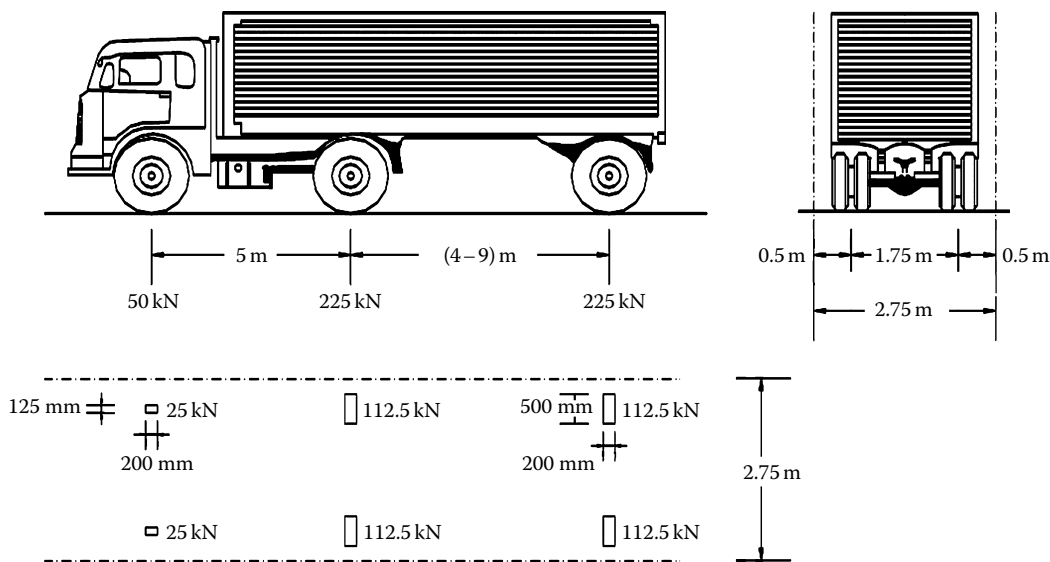


FIGURE 21.3 Specification of the T truck load.

TABLE 21.2 Number of the Design Traffic Lanes

Bridge Type	Bridge Roadway Width (m)	Number of Design Traffic Lanes
Single lane	4–5	1
Two-way, no median	5.5–8.25	2
	11.25–15	4
Multiple roadway	10–12.9	3
	11.25–15	4
	15.1–18.75	5
	18.8–22.5	6

TABLE 21.3 Dynamic Allowance for the D Lane KEL

Equivalent Span $L_E$ (m)	DLA (for both limit states)
$L_E \leq 50$	0.4
$50 < L_E < 90$	$0.525 - 0.0025L_E$
$L_E \geq 90$	0.3

21.2.3.5 Dynamic Load Allowance

A dynamic load allowance (DLA) is applied to the D lane KEL and the T truck to simulate the impact of the moving vehicles on the bridge structure. The DLA applies equally to the SLS and ULS to all parts of the structure to the foundation. For the T truck, the DLA is 0.3. For the D lane, the KEL is listed in Table 21.3.

For a simple span  $L_E$  = actual span length; for a continuous span, use  $L_E = \sqrt{L_{av} \cdot L_{max}}$ , where  $L_{av}$  is an average span length of the continuous spans and  $L_{max}$  is the maximum span length of the continuous spans.

21.2.3.6 Braking Forces

Braking and acceleration effects of the traffic shall be considered as longitudinal forces. This force is independent of the bridge width but is influenced by the length of the bridge structures.

### 21.2.3.7 Collision Loads on Bridge Support System

The bridge support system in traffic areas shall be designed to resist accidental collisions or be provided with a special protective barrier.

## 21.3 Standard Superstructures

### 21.3.1 General

For small spans without specific requirements, the Bina Marga bridge standard is commonly selected based on the economic span and the conditions of the water traffic beneath it. Some design standards for typical bridge superstructures (Directorate General of Highways 2005) are discussed next.

### 21.3.2 Short-Span Bridges (1–25 m)

The available standardization of short span bridges is

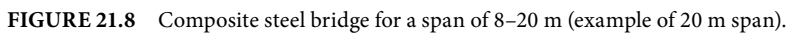
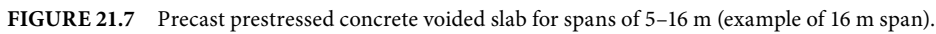
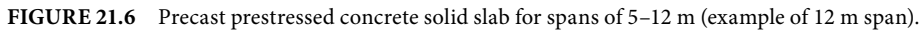
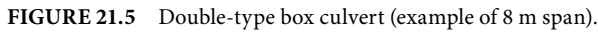
- Reinforced concrete rectangular box culverts, with spans of 1–10 m (see [Figure 21.5](#))
- Pretensioned precast concrete flat slabs, with spans of 5–12 m (see [Figure 21.6](#))
- Pretensioned precast concrete voided slabs, with spans of 5–16 m (see [Figure 21.7](#))
- Steel composite girders, with spans of 8–20 m
- Reinforced concrete tee girders, with spans of 5–25 m (see [Figure 21.8](#))

The square culvert or concrete box culvert is the simplest option for bridges, based on the idea of how to utilize the water channels across the street (the sewer) to serve as well as a bridge in supporting traffic loads. Because of its square shape, the bottom part of the foundation and the top part of the bridge deck are identical. The upper side of the concrete box culvert can be directly used as traffic lanes but if the river has a steep river bank, earth fills can first be added on it.

The Patukiki II Bridge in Sulawesi ([Figure 21.4](#)) is only a 6 m span and therefore adopts the box culvert single-cell type. For a bridge with a larger span, double- or triple-cell box culverts can be adopted. [Figure 21.5](#) shows a detail of a double-type box culvert. A box culvert structure is relatively simple in



**FIGURE 21.4** The Patukiki II Bridge (6 m), Sulawesi.





design, but the construction work at the bottom side is relatively more complex compared to the upper side. If the length of the span is adequate, the river is relatively shallow, and the soil conditions underneath are good enough and easy to dry, then construction is relatively easy.

These systems are often found in constructing bridges over irrigation system, drainages, or creeks, which are quite prevalent in Indonesia. If the river conditions do not allow building of a unified bottom structure, such as for a box culvert, then the bridge needs special substructures and to use a superstructure that follows the reference of the Bina Marga standard. The use of precast prestressed concrete (PC) elements for bridge superstructures would certainly facilitate and accelerate bridge construction. However, precast elements are only economical if they are in large quantities and transportation is available. If this is not possible, then the use of composite steel girders or cast-in-situ reinforced concrete girders can become an alternative.

### 21.3.3 Prestressed Concrete Girders for Spans of 20–40 m

#### 21.3.3.1 General

Concrete structures are popularly used on various development projects in Indonesia, including bridge projects, mainly because aggregate and sand, which are the main materials for concrete structures, are easy to get and are affordable. Another reason is that currently there are more cement factories than steel factories in Indonesia. If the conditions make it possible, concrete bridges, especially using the prestressed concrete structure system, are the best choice for bridges, specifically for the middle spans. Further, the future maintenance costs of concrete bridges are more economical compared to those of steel bridges.

#### 21.3.3.2 Bina Marga Standard of Prestressed Concrete Girders

The Directorate General of Highways (Direktorat Jenderal Bina Marga) provides standard designs of prestressed concrete I-girder bridges for spans of 20 m to 40 m (Figure 21.9) with a traffic lane width of 7 m, footway width of  $2 \times 1$  m, and distance between the two outer edges of the back of 9.92 m.

#### 21.3.3.3 Tol Cipularang Bridges

As evidenced, concrete bridges, especially prestressed concrete bridges, are popular in Indonesia; therefore, the bridges of the Cipularang toll road project (phase II) will be shown. This is a special project within the framework of the Indonesian government in preparing for the Asian-African Summit (2005) in Bandung. All of the bridges built in the project are prestressed concrete girder bridges.

The Cipularang toll road project (Cikampek–Purwakarta–Padalarang) constitutes a toll road which connects the cities of Jakarta and Bandung, particularly the new road segments from Cikampek–Purwakarta until Padalarang. The construction was divided into two phases: phase 1, Cikampek–Sadang and Padalarang–Cikamuning (17.5 km) and phase 2, Sadang–Cikamuning (41 km). The construction of

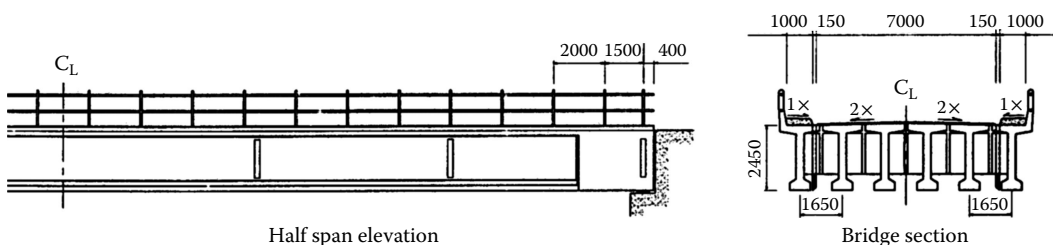


FIGURE 21.9 Prestressed concrete I-girder bridge for a span of 20–40 m (example of 35 m span).

phase 1 was 17.5 km along a relatively flat area and there are no large rivers, so there was no construction of long-span bridges. On the other hand, the construction of phase 2 was 41 km and the area covers some mountains with some steep rivers, so many long and tall bridges were required. Information on the bridges is given in Table 21.4.

Although the terrain is challenging, by cutting through the mountains and steep rivers and due to the anticipated Asian-African Summit in Bandung in April 2005, the project was successfully completed only in one year. With this new toll road, the distance between Jakarta and Bandung, which was previously traveled in about 3 to 4 hours, is now shortened to 1.5 to 2 hours, especially for a normal trip (if there are no traffic jams).

The Cikao Bridge (Figure 21.10) is the first bridge on the segment of phase II of the Cipularang toll road project from Jakarta to Bandung. The Cikao Bridge configuration is a simply supported standard prestressed concrete I-girder bridge. The Ciujung Bridge (Figure 21.11), which is located on the Plered–Cikalong Wetan segment, is a total length of 500 m. The bridge is the second bridge on the segment of phase II of the Cipularang toll road project from Jakarta to Bandung. The Ciujung Bridge configuration is a simply supported standard prestressed concrete I-girder bridge.

The Cisomang Bridge (Figure 21.12) is the third bridge on the segment of phase II of the Cipularang toll road project from Jakarta to Bandung. The superstructure configuration is a combination of simply supported and continuous beams using a precast prestressed concrete bulb T-girder system. The continuous beam structure was achieved by post-tensioning precast segments and embedded directly to the pier head. The integral system of the bridge should be adopted due to high pier characteristics and the requirement that the structure be seismic resistant (Imran et al. 2005).

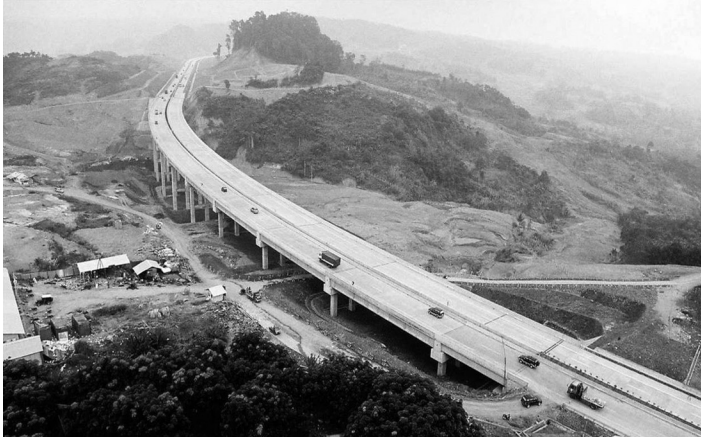
The Cikubang Bridge (Figure 21.13) is one of the bridges on phase II of the Cipularang toll road, and is interesting in terms of location and method of construction. The bridge, with its highest piers of 59 m and total length of 520 m, is located in the village of Cikubang, Cikalongwetan district, Bandung

**TABLE 21.4** Bridges in Phase II of the Cipularang Toll Road Project

Bridge		PC I-Girder		Pier		Location
Name	L (m)	Number	L (m)	Number	h (m)	(km)
Cikao	80	28	35, 45	1	14	81 + 200
Ciujung	500	154	40	11	5–30	95 + 225
Cisomang	252	98	25, 40	6	7–46	100 + 695
Cikubang	520	156	26, 40, 42.8	12	5–59	109 + 535
Cipada	707	192 + 12	40	16	5–35	111 + 804



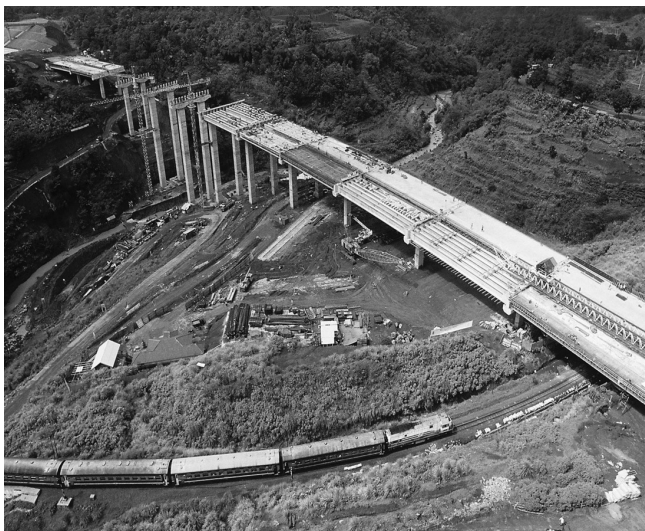
**FIGURE 21.10** The Cikao Bridge (80 m) at km 81 + 200 of the Cipularang toll road, West Java.



**FIGURE 21.11** The Ciujung Bridge (500 m) at km 95 + 225 of the Cipularang toll road, West Java.



**FIGURE 21.12** The Cisomang Bridge (252 m) at km 100 + 695 of the Cipularang toll road, West Java.



**FIGURE 21.13** The Cikubang Bridge (520 m), under construction (2004–2005).

regency. The bridge crosses a valley, the Cikubang River, and railways. The bridge carries  $2 \times 2$  lanes of traffic with a radius of horizontal curvature of 1200 m. The structural system of Cikubang Bridge is similar to Cisomang Bridge except for the type of precast concrete girder. The Cikubang Bridge uses standard prestressed concrete I-girders. A similar system is also used in the Cipada bridge (see Figure 21.14).

### 21.3.4 Steel Bridges for Spans of 40–60 m

#### 21.3.4.1 General

The most popular bridge type in Indonesia is the steel bridge. From 1970 to 1990, steel bridges with a total length of about 237 km were imported from various sources, for instance, the United Kingdom (Callender Hamilton, Compact Bailey), the Netherlands (Hollandia Kloos), Australia (Transfield and Trans Bakrie), and so on. At that time, Indonesia was expected to reach a certain target of road links to open isolated areas with many kind of conditions; therefore, the faster way was to construct standard steel truss bridges. By 2000, the use of steel bridges was declining, although demand was still high in areas with limited transportation access because, after all, steel bridges are superior in terms of ease of construction and uniformed achievements in quality.

#### 21.3.4.2 Bina Marga Standard of Steel Trusses

The Department of Public Works, through the Directorate General of Highways (Ditjen Bina Marga), provides standard designs for steel truss bridge spans of 40 m to 60 m and some up to 80 m and 100 m. The quality of steel material for the main structure of the bridge is SM 490/BJ 55 ( $f_u = 550$  MPa and  $f_y = 410$  MPa) and for others is SS400/BJ 50 ( $f_u = 510$  MPa and  $f_y = 290$  MPa). This means that the strength of the steel material for the bridge is higher than typical steel material used for the building construction, which is generally BJ 37 ( $f_u = 370$  MPa and  $f_y = 240$  MPa). Figure 21.15 shows the Binamarga standard steel bridge.

One of the main reasons for using a steel truss bridge is due to the high strength-to-weight ratio, so that the structure is relatively lighter, which results in smaller foundations. Another special feature is that steel truss elements are prefabricated in workshops and assembled on the project site by bolting small segments together. Standardized elements and products have made the segments easy to put



FIGURE 21.14 The Cipada Bridge (707 m) at km 111 + 804 of the Cipularang toll road, West Java.

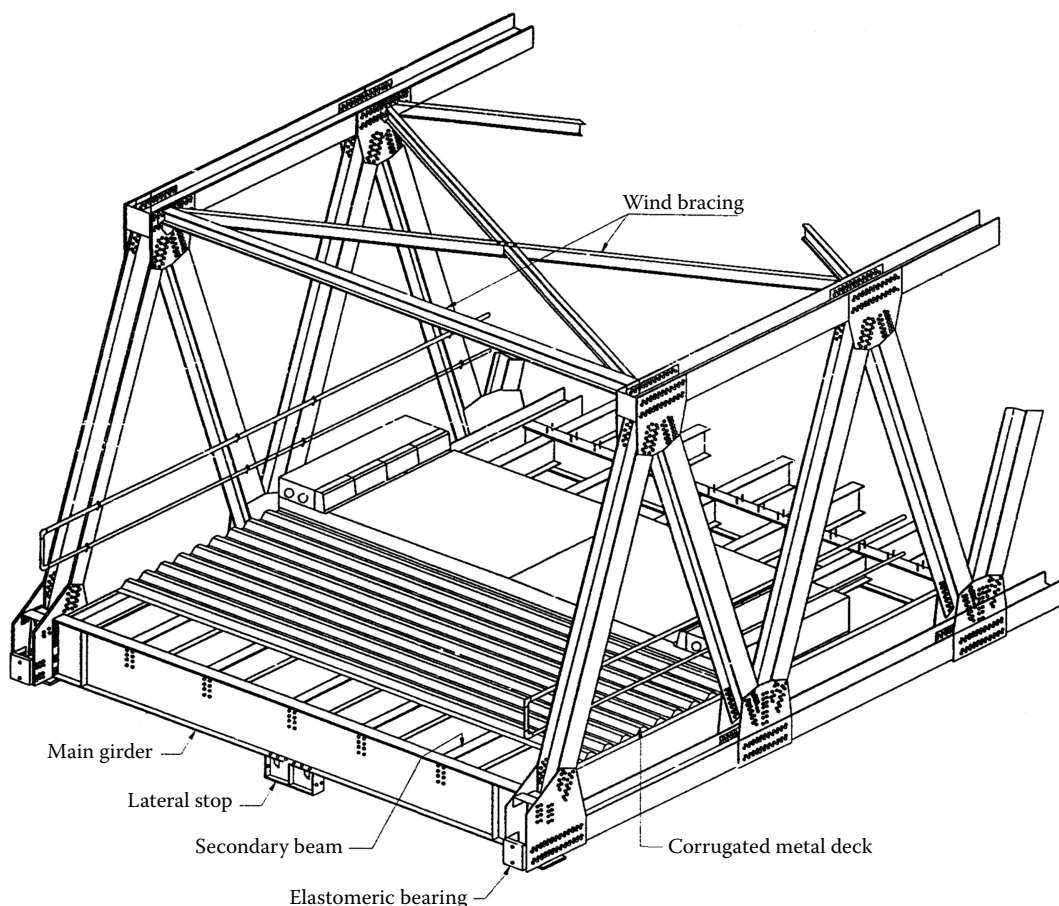


FIGURE 21.15 A perspective of the Binamarga standard steel bridge.

together with high quality control and high precision. The typical erection of structural steel segments to form a bridge on-site is to place a falsework (temporary support) in the middle of the river while the superstructure is being assembled, as shown in Figure 21.16. After the bridge is erected and before pouring the concrete deck, the falsework is removed. This allows the superstructure to deflect as designed when the deck is poured.

The biggest advantage of this method is that there is no need for additional anchor spans linking the kit or kentledge (counterweight), which the piece-by-piece cantilever method employs. In addition, there is no need for any heavy lifting equipment as the heaviest component is only  $\pm 1.5$  tons. However, it is a labor intensive method with a minimum amount of lifting equipment required. On many sites, the existing bridge can be used as the basis for the falsework support to reduce construction costs. In general, a falsework pier or trestle is set up under each cross girder, with a space of about 5 m. Since the segments of the steel truss elements are prefabricated in workshops and they are only assembled by using bolts, the construction speed is relatively faster when compared with that of a concrete bridge.

The use of the falsework system will certainly create a problem if the river is too deep or there is heavy traffic in the river, or if floods may suddenly occur in the wet season. Construction seasons should also be considered carefully. When using a falsework is infeasible, a standard steel truss bridge can be used as a construction tool on the site, namely by using the method of piece-by-piece cantilever construction, as shown in Figure 21.17. To use this method, it is necessary to have the following tools: additional anchor



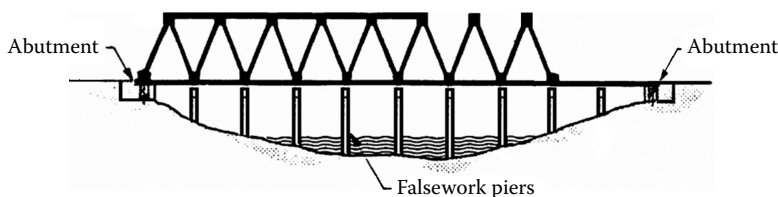


FIGURE 21.16 Erection of the falsework.

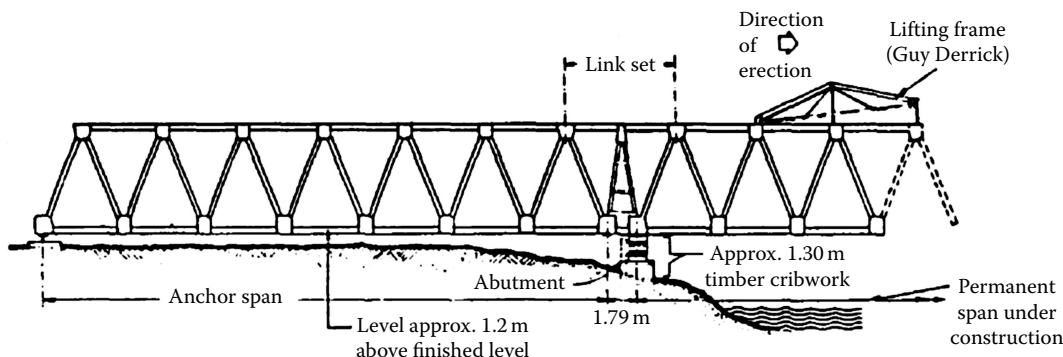


FIGURE 21.17 Piece-by-piece cantilever construction of steel truss bridges.

spans, linking kits, and a kentledge (counterweight). Since it is necessary to have a steel truss bridge to serve as the anchor span, there are two structural frameworks of the bridge; it is economical to construct a bridge consisting of two or more spans. It is thus appropriate to be used over a deep river or over a river with heavy water traffic.

#### 21.3.4.3 Other Standards for Steel Bridges

Although the Directorate General of Highways (Ditjen Bina Marga) has its own standards for steel truss bridges, each with several benefits, there are also various standards for steel truss bridges which vary depending on the origin country. Table 21.5 lists a number of steel bridges by country, together with their construction periods, with a total length of 296.7 km.

From Table 21.5, note that the most widely used type of standard steel truss bridge is the Australian (Transfield and Trans Bakrie) and was built from 1984 to 1993. This type of bridge is about 35% of the total number of standard steel bridges constructed until the year 2007. So, it is quite understandable why Australia was interested in helping Indonesia produce the most comprehensive bridge regulations, BMS-92. The Australian (Transfield and Trans Bakrie) system (Figure 21.18) provides bridge spans with a range of 35 m to 60 m of through-truss designs. The permanent spans are supplied in three classes, A, B, and C, which only differ in roadway width and curb/footway configurations. The spans in all classes have composite reinforced concrete decks. This bridging system is planned to have low maintenance characteristics. To this end, all of the steelwork and bolts are galvanized and the bearings are elastomeric.

The Australian system has more advantages over the Bina Marga system, especially in the construction methods, in which the single-span launching (SSL) method (Figure 21.19) can be used. With this method of erection, the truss span is completely assembled on one bank and rolled out into position using an anchor and kentledge (counterweight). No falsework is required within the crossing since the span is designed to be fully cantilever. The SSL method is suitable for a single span or the first span



TABLE 21.5 Construction of Steel Truss Bridges in Indonesia

No.	Country/Bridge System	Year	Production (m)
1	Britain (Callender–Hamilton bridge)	1970–1980	17,269
2	Britain (compact Bailey bridge)	1986	12,108
3	Britain (compact Bailey bridge)	1990	5,100
4	Holland/the Netherlands (Hollandia Kloos)	1979–1993	32,130
5	Australia (Transfield and Trans Bakrie)	1984–1993	104,480
6	Indonesia (Marubeni, KBI and Bakrie IBRD, Loan No. 2717–IND)	1985–1987	11,175
7	Indonesia (BTU/Credit Export)	1996	26,740
8	Austria (Wagner Biro)	1987–1998	56,495
9	Spain (Centurion and PT. Wika)	1998–2002	8,055
10	Indonesia (KBI/OECF, Loan IP–444)	1999	4,500
11	Indonesia (Trans Bakrie and DSD/OECF, Loan IP 444)	2001	3,715
12	Indonesia (Trans Bakrie/IBRD, Loan No. 4643–IND)	2002	3,926
13	Indonesia (Bukaka and WBI/APBN)	2003	2,045
14	Indonesia (Bukaka and WBI/APBN)	2004	1,765
15	Indonesia (Bukaka and WBI/APBN)	2005	1,465
16	Indonesia (WBI WBBB/IBRD, Loan No.4744 IND)	2005	1,230
17	Indonesia (KBI, WBI, and BTU/APBN)	2006	2,230
18	Indonesia (KBI and BTU/APBN)	2007	2,235

Source: Vaza, H. 2008. *Indonesia Bridges: Now and Later*. Directorate of Technical Affairs, Directorate General of Highways, Department of Public Works (in Bahasa Indonesian).

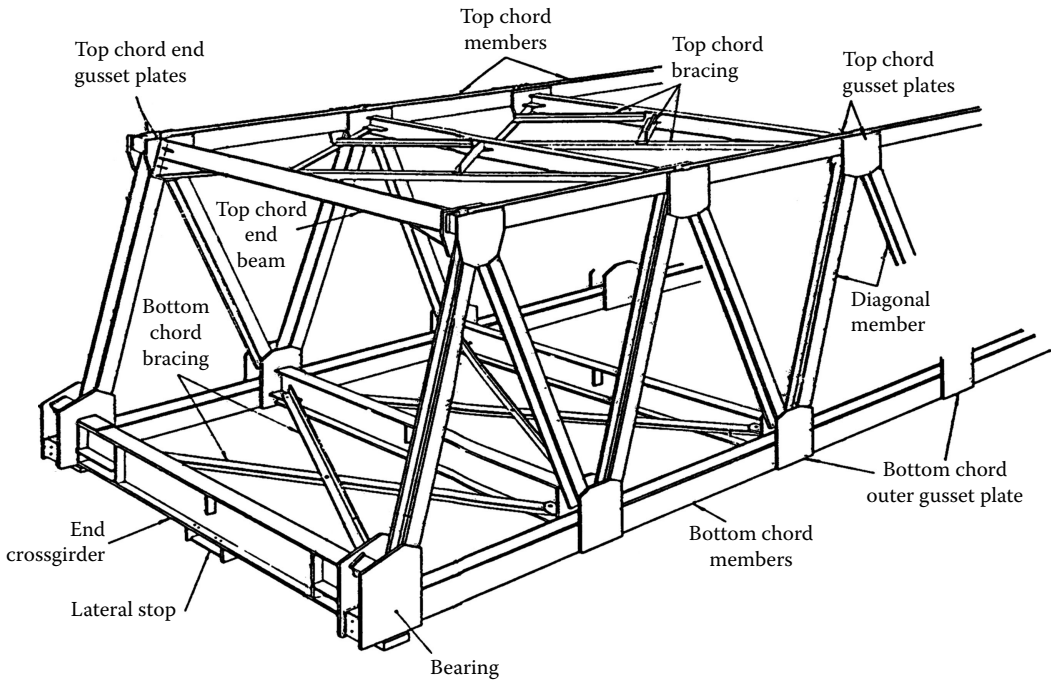
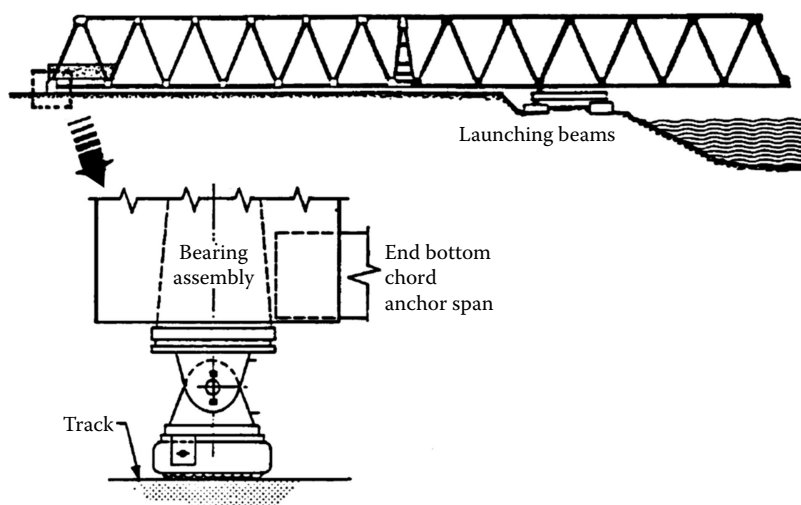
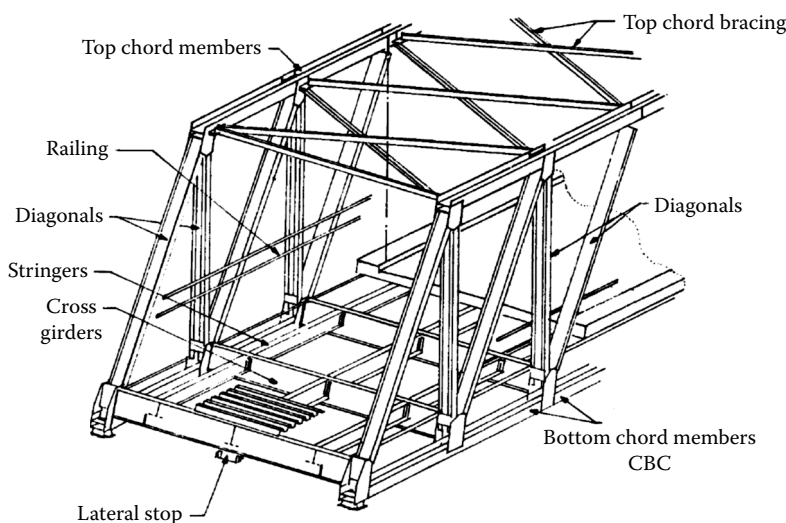


FIGURE 21.18 A perspective of the Australian (Transfield and Trans Bakrie) steel bridge.



**FIGURE 21.19** A single-span launching method and its device.



**FIGURE 21.20** A perspective of the Austrian (Wagner Biro) steel bridge.

of a multispan bridge. It is particularly suited to a bridge site of one span which cannot be erected on falsework. Not all bridge sites are suitable for this system, because a longer assembly area is required on the bank, from which the launching process is carried out, compared to the piece-by-piece cantilever method, where no assembly area is needed on the river bank other than what has been specified previously for the assembly of the anchor span. The additional area required for the SSL method is due to the need for rolling tracks, which must be constructed to accommodate both the main span and anchor span. The area required on the river bank will depend on the length of the main span and anchor span plus the work area surrounding the spans.

The second most used type of standard steel truss bridges is the Austrian (Wagner Biro) system, which covers approximately 19% of the total number of standard steel truss bridges built so far. The Austrian system of truss bridges (Figure 21.20) comprises precision-made standard steel components which are assembled by bolting together to form a bridge span of a continuous truss design in a range of 35 m to

60 m. The various spans available are classes A, B, and C, which differ in roadway widths and curb/footway configurations. The spans in all classes have concrete decks supported by corrugated trapezoidal steel sheets, supplied as part of the bridge system. The system has been designed to permit progressive assembly by cantilever working from one bank, without the use of a falsework on the river. Other methods of assembly and erection, such as part cantilever or erection on a falsework, are feasible. The Austrian bridge system is designed to be of low maintenance, so all steel work and bolts are galvanized.

The third most used type of standard steel truss bridges is the Dutch (Hollandia Kloos) system (Figure 21.21), which covers approximately 11% of the total number of bridges. Its unique features, if compared with the other standard steel-framed bridges, are the availability of 40 m to 105 m bridge spans, which is approximately 175% longer than existing standard steel truss bridges. In addition, just like the other standard steel truss bridges, which require low maintenance, all the steel components and bolts are galvanized.

#### 21.3.4.4 Steel Truss Standards for Crossing Wide Rivers

The maximum span of a standard steel truss is generally 60 m. However, a standard steel truss bridge is also often used on bridges over wide rivers, especially if bridge piers can be built on the river. There are a lot of Australian (Transfield & Trans Bakrie) steel truss bridges built along the provincial roads on the island of Java and some also on other islands too. The following bridge projects will illustrate their application.

##### 21.3.4.4.1 Bantar II Bridge

The Bantar II Bridge is located on the Progo River, Bantar village, Wates, between the roads of Yogyakarta and Purworejo. The bridge total length is 226 m, composed of four spans (51.4 m + 2 × 61.6 m + 51.4 m) with a width of 9 m (1 m + 7 m + 1 m). The maximum span length is 61.6 m. This bridge is the one that has taken over the role of the old Bantar Bridge, a suspension bridge inherited from the Dutch (before the independence of Indonesia). The image in Figure 21.22 was taken from the old Bantar bridge. At the time the photo was taken, the Bantar III Bridge (prestressed concrete girder), located between the old Bantar Bridge and the Bantar II Bridge, was not built. Currently the old Bantar Bridge, Bantar II Bridge, and Bantar III Bridge are lined up in parallel in that location.

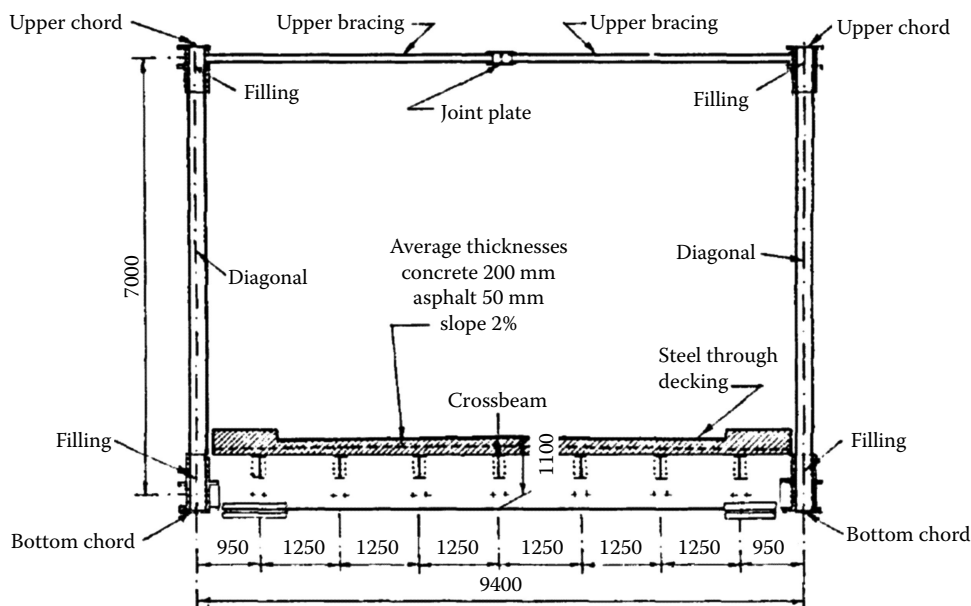


FIGURE 21.21 Typical section of a Hollandia Kloos (class A) steel bridge.

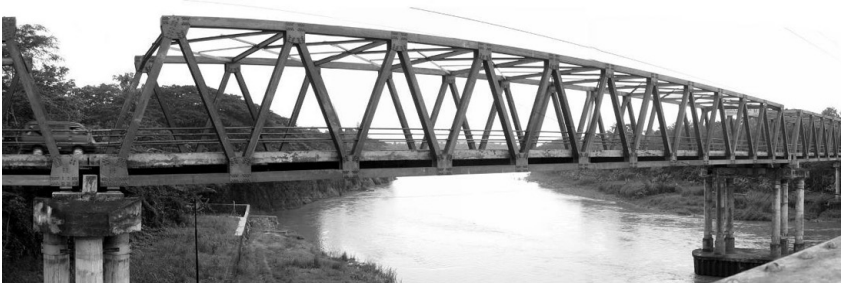


FIGURE 21.22 Bantar II Bridge (226 m), Yogyakarta.



FIGURE 21.23 Koto Panjang Bridge (295 m), Riau.

#### 21.3.4.4.2 Koto Panjang Bridge

The Koto Panjang Bridge, in Kampar regency, Riau, Sumatra, was built over a lake that formed as a result of a barrier of the Kampar River for the construction of a dam for a hydropowered electricity source for Koto Panjang (Figure 21.23). The bridge total length is 295 m, composed of five spans with a width of 6 m. The maximum span length is 60 m.

#### 21.3.4.4.3 Berbak Bridge

The Berbak Bridge, located at a distance of 40 km from the city of Muarosabak and 70 km from the city of Jambi, was precisely situated in the district of Berbak, Tanjung Jabung Timur regency, Jambi, Sumatra. The steel truss bridge (Figure 21.24), with a length of 369 m and a width of 9 m, crosses the Batanghari River. Construction started in 2003 and was completed in 2007. This bridge is a support bridge for the Batanghari II Bridge in the direction of East Jambi province, providing public access to residents in Nipang Panjang, Rantau Rasau, and Berbak when they travel to the city of Jambi. The bridge is also to support the growth of the port of Muara Sabak, where loading and unloading containers is a big business.

#### 21.3.4.4.4 Batanghari I Bridge

The Batanghari I Bridge (Figure 21.25) is located on the Batanghari River, in the village of Aur Duri, district of Telanaipura, five kilometers west of the Jambi city center, Sumatra. The bridge is the only link connecting the economic and social interests from Jambi province to Riau via the eastern traffic lines.

#### 21.3.4.4.5 Mahakam Bridge

The Mahakam Bridge (Figure 21.26), which is also called the Mahkota I Bridge, is a bridge which connects the off-shore Samarinda region with the city of Samarinda, Kalimantan. The Mahakam Bridge was



**FIGURE 21.24** Berbak Bridge (369 m), Jambi.



**FIGURE 21.25** Batanghari I Bridge, Jambi.



**FIGURE 21.26** Mahakam Bridge (400 m), Samarinda.

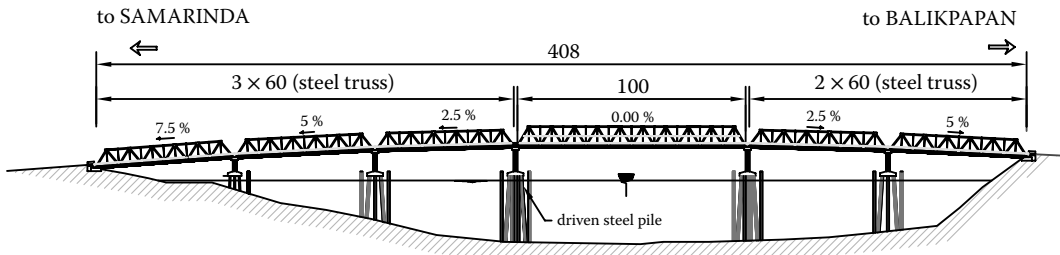


FIGURE 21.27 The Hollandia Kloos truss elevation of Mahakam Bridge.

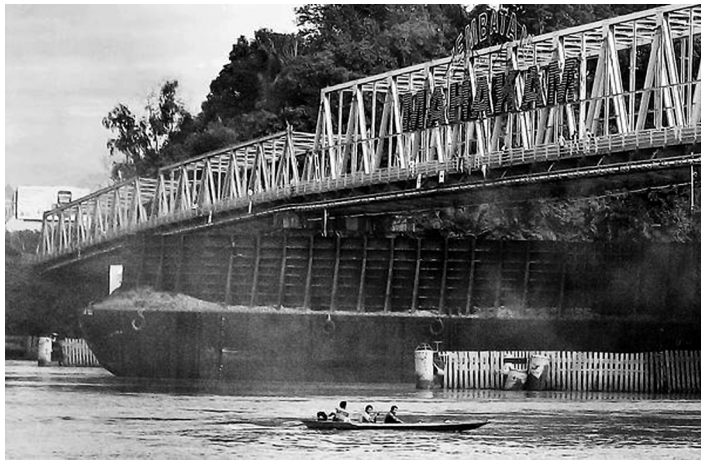


FIGURE 21.28 Collision due to the RM 352 pontoon (Kompas, 24/01/2010).

built in 1987 and was inaugurated by President Soeharto. This bridge utilized a Dutch (Hollandia Kloos) type of steel frames, having a frame length of 60 m and 100 m, a total length of 400 m, and a total width of 10.3 m (Figure 21.27).

Although a standard steel truss bridge can also be used on a wide river, the 100 m span of the standard steel truss bridge is still too narrow for heavy water traffic. This will put the bridge piers at a high risk of vessel collisions. On Saturday, January 23, 2010, the Mahakam Bridge was hit by an RM 352 pontoon (Figure 21.28). Fortunately, the bridge survived without collapse. A nonstandard bridge with a larger span is required to avoid vessel collisions.

## 21.4 Concrete Continuous Bridges

### 21.4.1 Rantau Berangin Bridge (198 m), Riau (1974)

The Rantau Berangin Bridge is a modern prestressed concrete box girder bridge constructed in 1972–1974 by the cantilever segmental system (*freie vorbau*) and which was the first bridge of its kind to be built in Indonesia (Figure 21.29). It crosses the Batanghari River, Riau Province, Sumatra. The total length of the bridge is 201 m, the main span is 121 m, and the side spans (right and left) are 40 m.

The bridge designer was NV IBIS from the Netherlands. Prof. Dr. (HC) Ir. Roosseno Soerjohadikoesoemo, a professor of the Institute of Technology Bandung who was later known as the father of concrete structures in Indonesia, was actively involved as an expert advisor to monitor the implementation of the project and at the same time to learn the new techniques. Thus, the success of the bridge construction project of the Rantau Berangin Bridge not only produced the physical





**FIGURE 21.29** The Rantau Berangin Bridge (201 m), the first cantilever segmental concrete bridge in Indonesia.



**FIGURE 21.30** Rajamandala Bridge (222 m), Cianjur, West Java.

construction, but also became an important milestone in the transferring technology from other nations. This is, of course, very important for the self-reliance of the nation, particularly in the field of construction engineering.

The process of transferring the technology from the project, which was led by Professor Roosseno and also Lanneke Tristanto (now a research professor at the Department of Public Works). The construction of similar bridges in several other places in Indonesia without the need to involve foreign experts later proved how well the the knowledge and modern technologies has been absorbed. The bridges were fully constructed by Indonesian experts.

#### **21.4.2 Rajamandala Bridge (222 m), Cianjur, West Java (1979)**

The Rajamandala Bridge (Figure 21.30) is located on the Citarum River, Cianjur regency, West Java. If observed carefully, it is seemingly similar in shape to the Rantau Berangin Bridge in Riau. The only difference is in the bridge pier (hollow box cross section), which is higher. It could have indeed happened that way because the designer of this bridge was Professor Roosseno, who had previously been actively involved as an expert advisor in the construction of the Rantau Berangin Bridge. The bridge has a total length of 222 m with a central span of 132 m and side spans of 45 m (right and left). The bridge has a width of 9 m to carry two lanes of highway traffic. Since the successful construction of this bridge, Indonesian experts became more confident in engaging independently in large-span bridge projects, especially involving the construction of prestressed concrete bridges.

### 21.4.3 Arakundo Bridge (210 m), East Aceh, Aceh (1990)

The Arakundo Bridge (Figure 21.31) is located on the segment of the roads of Lhokseumawe–Langsa at km 342 + 580, East Aceh regency, Aceh province. The bridge was built between September 12, 1987 and July 31, 1990. The length of the bridge is  $57\text{ m} + 96\text{ m} + 57\text{ m} = 210\text{ m}$ ; the width is  $1.5\text{ m} + 7\text{ m} + 1.5\text{ m} = 10\text{ m}$ . This superstructure is a continuous cast-in-place prestressed concrete box girder, constructed by the balanced cantilever method. The bridge was designed by Rendall Parkman, England and PT Indah Karya, Indonesia. This bridge was part of the Arakundo–Jambo Aye Irrigation and Flood Control Project that got a loan from the Saudi Fund for Development (SFD), with the purpose of developing irrigation, flood control, and the transportation roads surrounding the Jambo Aye River in Arakundo.

### 21.4.4 Tonton–Nipah Bridge (420 m), Riau Isles (1997)

The Tonton–Nipah Bridge (Figure 21.32), which connects the islands of Tonton and Nipah, is one of the few bridges built together in Batam and is also called the Bareleng Bridge. The bridge was built to promote tourism and industry on the island of Batam. The Tonton–Nipah Bridge is a cantilever segmental prestressed concrete bridge with a total length of 420 m and a main span of 160 m. This bridge is one of the Bareleng bridges.



FIGURE 21.31 Arakundo Bridge (210 m), Aceh.

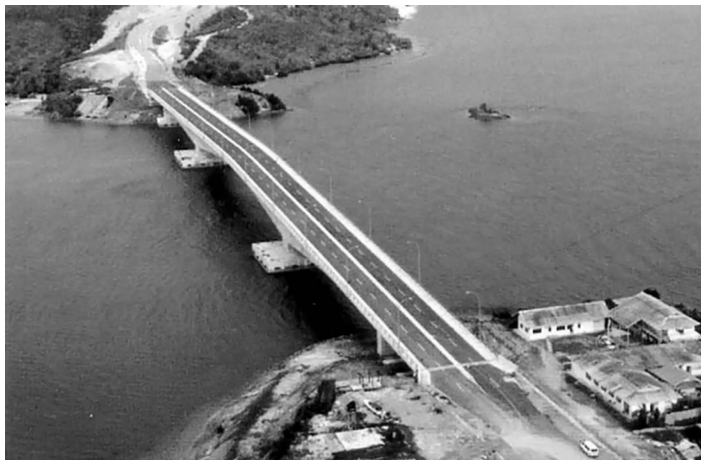


FIGURE 21.32 Tonton–Nipah Bridge (420 m), Riau Isles.

### 21.4.5 Setoko–Rempang Bridge (365 m), Riau Isles (1997)

The Setoko–Rempang Bridge (Figure 21.33), which connects Setoko and Rempang islands, is one of the Bareleng bridges. The bridge is a concrete box girder which was constructed by means of a balanced cantilever. The designer was LAPI ITB. The bridge, with a width of 18 m, a total length of 365 m, and a greatest span of 145 m, was the second-longest balanced cantilever bridge built in Indonesia at the time of its construction in 1997. There were two technological innovations for this bridge. The first was the marine foundation work and the creation of the traveler form module. The results of these innovations provided many benefits: being lighter, being stronger in carrying loads, being more easily manufactured and operated, having smaller effects of deflections, and resulting in faster molding cycle times per segment.

### 21.4.6 Tukad Bangkung Bridge (360 m), Badung, Bali Island (2006)

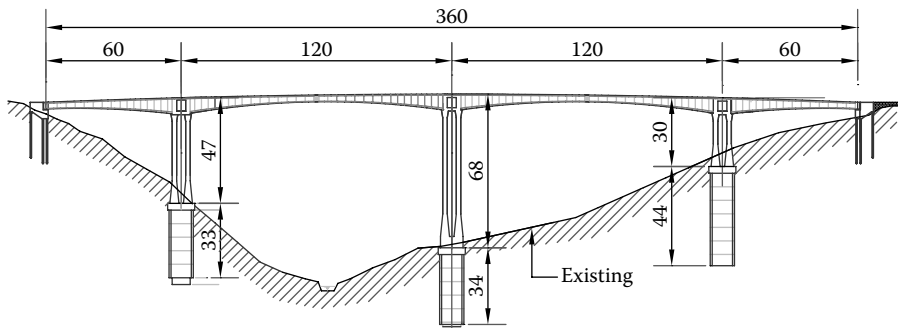
The Tukad Bangkung Bridge (Figure 21.34) is located at the village of Plaga, Petang district, Badung regency, Bali. It opened to the public on December 19, 2006. The bridge, which connects three districts, Badung, Bangli, and Buleleng, was the longest bridge in at the time. (The superstructure is



FIGURE 21.33 The Setoko–Rempang Bridge (365 m), Riau Isles.



FIGURE 21.34 Tukad Bangkung Bridge (360 m), Bali.



**FIGURE 21.35** Elevation of the Tukad Bangkung Bridge.

a continuous prestressed concrete single-cell box girder built by balanced cantilever construction. The total length of the bridge is 360 m, with a long span of 120 m and a width of 9.6 m. The box girder is supported by double prestressed concrete piers 47–68 m high fixed connected on  $\phi$  9 m caisson foundations 33–44 m deep. The abutments are supported on concrete piles with a diameter of 60 cm (see Figure 21.35).

#### 21.4.7 Air Teluk II Bridge (214 m), Sekayu, South Sumatra (2006)

The Air Teluk II Bridge (Figure 21.36), Sekayu, South Sumatra, is a concrete box girder balanced cantilever bridge, with spans of 104 m + 55 m + 55 m and a total length of 214 m. It was completed in 2006. Within a distance of 100 m from the bridge, there is an old concrete arch bridge built in the era of the Dutch colonialization. In order to maintain the historical value of the old bridge, therefore, an additional arch steel ornament, which does not function as a structural element, has been installed in the new Air Teluk II Bridge.

#### 21.4.8 Perawang Bridge (1473 m), Siak, Riau (2007)

The Perawang Bridge is located in Maretan, Tualang district, Siak regency, Riau. The distance is approximately 80 km from the city of Pekanbaru. In this city, there is the second-largest paper company in Indonesia, PT Indah Kiat Pulp Paper. The bridge is a type of box balanced cantilever bridge



**FIGURE 21.36** Air Teluk II Bridge (569 m), Sekayu, South Sumatra.



**FIGURE 21.37** Site view of the Perawang Bridge (1473 m), Maredan, Riau.

with 14 piers and 4 abutments. The total span is 1473.4 m, consisting of the main span of 180 m, side spans of 101 m each, approach spans of 254 m each, slabs-on-pile of 321.7 m and 261.7 m, and a width of 12.7 m (Figure 21.37). The Perawang Bridge forms an alternative path from the eastern path of Sumatra, which is an alternative road connecting the towns of Simpang Lago, Perawang, and the city of Minas. This is a new path that is shorter because the local residents do not need to go around the city of Pekanbaru.

## 21.5 Steel Continuous Bridges

### 21.5.1 Ampera Bridge (1100 m), Palembang, South Sumatra (1965)

The Ampera Bridge (Figure 21.38) over the Musi River is an icon of the city of Palembang. It was constructed between April 1962 and May 1965 on a 350 m width of Musi river to connect the area of Plaju and Palembang. It was proposed as vertical lift bridge in Indonesia. The total length of the bridge is about 1100 m (including approach). The main bridge consists of spans of  $22.5\text{ m} + 58.5\text{ m} + 58.5\text{ m} + 75\text{ m} + 58.5\text{ m} + 58.5\text{ m} + 22.5\text{ m} = 354\text{ m}$ . The bridge width is 22 m, including four lane of carriage-way  $4 \times 3.5\text{ m} = 14\text{ m}$ , a bicycle way on both sides  $2 \times 1.75\text{ m} = 3.5\text{ m}$ , and sidewalks on both sides  $2 \times 2.25\text{ m} = 4.5\text{ m}$ .

The side spans comprise two-span continuous plate girders of 58.5 m, and two simple span plate girders of 22.5 m for each side. The approach bridge at the Palembang side consists of  $27\text{ m} + 30\text{ m} = 57\text{ m}$ , and at the Plaju side is  $27\text{ m} + 6 \times 30\text{ m} + 27\text{ m} = 234\text{ m}$ . The tower of the bridge is 78 m high. The central part of the superstructure can be lifted up to allow large ships to pass (see inset in Figure 21.39). It consists of a simple plate girder 75 m long, with a weight of about 100 tons. However, this special mechanism no longer works. In fact, it was the only bridge in Indonesia bridge history with such a mechanism.

### 21.5.2 Danau Binkuang Bridge (120 m), Kampar, Riau (1970)

The Danau Binkuang Bridge (Figure 21.40) is over the Kampar River, Kampar regency, Riau. The bridge connects the cities of Pekanbaru and Bangkinang. The bridge is a part of the early construction of nonstandard bridges in Indonesia in the era of the 1960s. The Danau Binkuang Bridge consists of three spans of continuous steel trusses with a configuration of  $40\text{ m} + 120\text{ m} + 40\text{ m}$ . The bridge has a width of 9 m to carry two lanes of highway traffic.

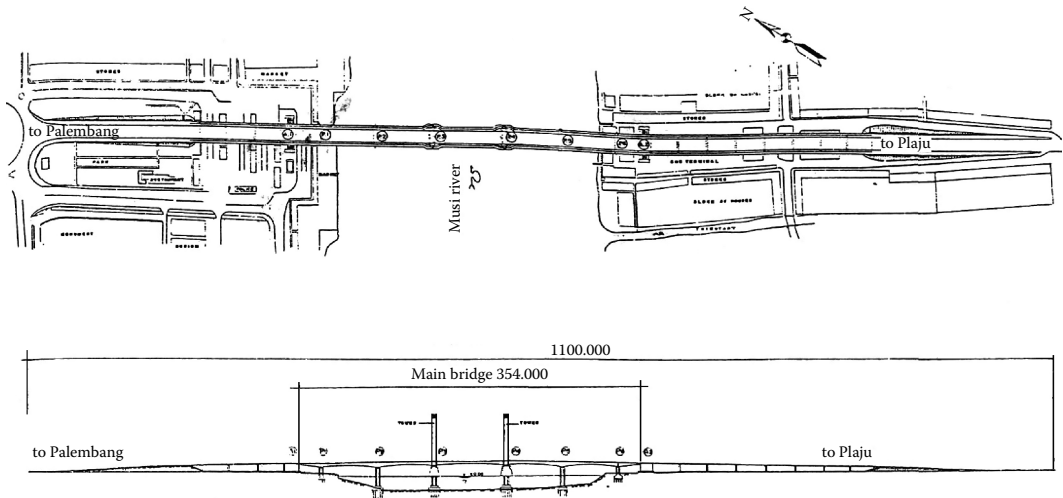


FIGURE 21.38 Plan and elevation of Ampera Bridge, Palembang, South Sumatra.



FIGURE 21.39 Ampera's main bridge (inset: the lifting of the central span).



FIGURE 21.40 Danau Binkuang Bridge (120 m), Kampar, Riau.



21.5.3 Siak I Bridge (349 m), Riau (1977)

The Siak I Bridge (Figure 21.41 for the elevation and Figure 21.42 for the site view), better known as the Leighton Bridge, has a length of 349 m and connects the city of Pekanbaru with the coastal Rumbai district. This bridge is the first permanent bridge over the Siak River, was a contribution of PT Chevron Pacific Indonesia (formerly known as PT Caltex Pacific Indonesia), and construction was carried out by the Leighton Company from Australia between 1975 and 1977. The current capacity of the bridge is no longer sufficient to support the mobility of the local residents. Frequent traffic jams on the bridge have worsened the situation. As a result, more bridges have been built over the Siak River, notably the Siak II, Siak III, and Siak IV bridges. The inset figure in Figure 21.42 depicts a convoy of vehicles across the Siak River through the Poton Bridge, which is limited in its use. With the construction of the Siak I Bridge with a larger capacity, the development of the Riau region was significantly influenced.

21.5.4 Kapuas Timpah Bridge (255 m), Central Kalimantan (2010)

The Kapuas Timpah Bridge (Figure 21.43) over the Kapuas River is located in Lungkuh Layang, Timpah district, Kapuas regency, Central Kalimantan province. The bridge connects the road from Palangkaraya to Buntok. The bridge was constructed using a continuous steel truss that consist of three spans (62.5 m + 105 m + 62.5 m) and one side of approach composite steel girder 25 m long. The total length of the bridge is 255 m and the width is 9 m (1 m + 7 m + 1 m). Construction began in 2006/2007 and it opened to the public in April 2010.

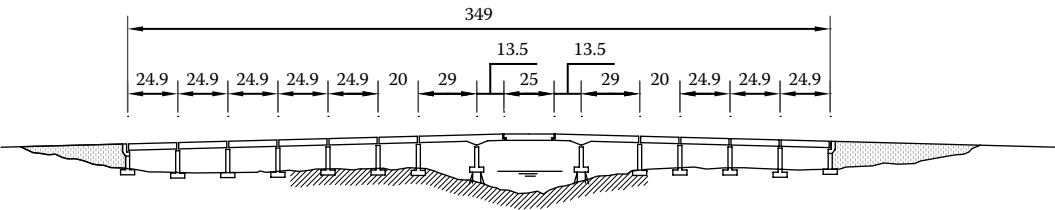


FIGURE 21.41 Elevation of the Siak I Bridge, Riau.



FIGURE 21.42 Siak I Bridge (349 m), Riau.

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FIGURE 21.43 Kapuas Timpah Bridge (255 m), Central Kalimantan.

## 21.6 Arch Bridges

### 21.6.1 Concrete Arch Bridges

#### 21.6.1.1 Karebbe Bridge (60 m), East Luwu, South Sulawesi (1996)

The Karebbe Bridge (Figure 21.44) is located in the road segment of Malili–BTS Sultra, km 574, Malili district, capital city of the East Luwu regency, South Sulawesi, Indonesia, about 565 km off Makassar. The bridge is a fixed-arch type structure, with total length 60 m and crown span ratio 1:5. The thickness of the arch at the support is 90 cm and at the crown (top center) is 60 m. For the construction of the bridge, the full shoring system was used.

#### 21.6.1.2 New Serayu Cindaga Bridge (214 m), Banyumas, Central Java (1996)

The New Serayu Cindaga Bridge (Figure 21.45) is located in Banyumas District, Central Java and has a main span of 90 m; each side span is 31 m and has a width of 9 m. The foundation consists of prestressed concrete piles. The bridge was built from 1993 to 1998.

#### 21.6.1.3 Rempang–Galang Bridge (385 m), Riau Isles (1998)

The Rempang–Galang Bridge (Figure 21.46), which is now called the Tuanku Tambusai Bridge, is part of the Bareleng bridges, located on the island of Batam, Riau Islands province. This bridge has the form of a concrete arch bridge, the longest ever built in Indonesia, with a total length of  $11 \times 35 \text{ m} = 385 \text{ m}$ , with a bow span of 245 m, symmetrical side spans on either side of 35 m, and wide decks of 18 m. The bridge was built from 1995 to 1998.

#### 21.6.1.4 Besuk Koboan Bridge (125 m), Lumajang, East Java (2000)

The Besuk Koboan Bridge (Figure 21.47), in Lumajang, East Java has a main span of 80 m and side spans of 20 m and 25 m, and was completed in 2000.

#### 21.6.1.5 Pangkep Bridge (86 m), Pangkep, South Sulawesi (2006)

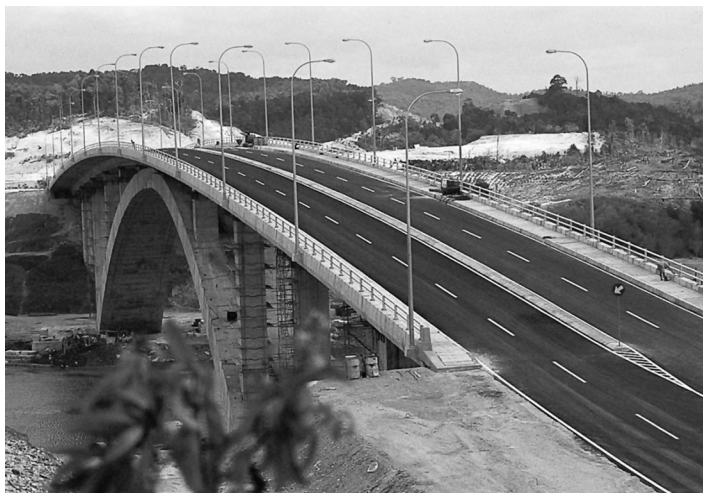
The Pangkep Bridge (Figure 21.48) is located in Pangkep regency, South Sulawesi. The bridge is in the road connecting Bungoro and the Maros region. The Pangkep Bridge has a length of 86 m, consisting of three spans (12 m + 60 m + 12 m) and width of 10 m.



**FIGURE 21.44** Karebbe Bridge (60 m), East Luwu, South Sulawesi.



**FIGURE 21.45** New (foreground) and old Serayu Cindaga Bridges, Banyumas, Central Java.



**FIGURE 21.46** Tuanku Tambusai Bridge (385 m), Batam, Riau Isles.

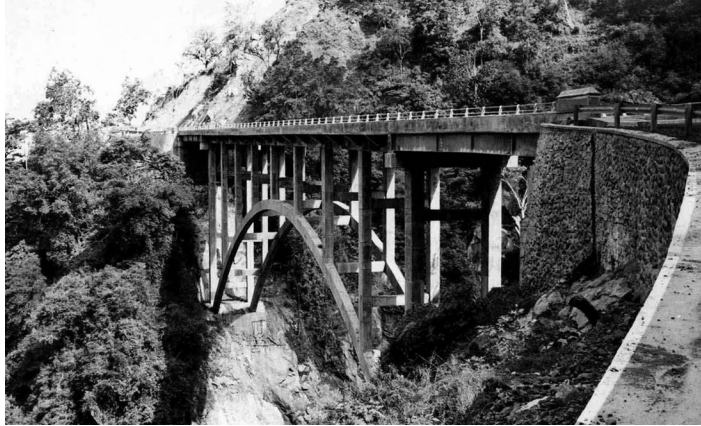


FIGURE 21.47 Besuk Koboan Bridge (125 m), Lumajang, East Java.



FIGURE 21.48 Pangkep Bridge (86 m), Pangkep, South Sulawesi.

#### 21.6.1.6 Bajulmati Bridge (90 m), Malang, East Java (2007)

The Bajulmati Bridge (Figure 21.49) is located in the Malang regency, precisely in the road segment of the southern coast line of East Java (662 km). Its construction was to support the improvement of the natural resource sectors and tourism, which have not been optimally explored in the southern region of East Java. Therefore, a unique form has been chosen for this bridge, namely the construction of a reinforced concrete suspension bridge with a single arch pylon as a supporter of the steel cable located in the middle. The Bajulmati Bridge has a length of 90 m, consisting of three spans (15 m + 60 m + 15 m) with a width of 15 m. With the Bajulmati Bridge, tourists going from Surabaya to tourist resorts around Malang are expected to continue their journeys to the Kondangmerak and Sendangbiru beaches, which have not been optimally explored, and at the same time they can save a distance of 80 km.

### 21.6.2 Steel Arch Bridges

#### 21.6.2.1 Kahayan Bridge (640 m), Palangkaraya, Central Kalimantan (2000)

The Kahayan Bridge (Figure 21.50) is located on the segment of Palangkaraya–Buntok streets, crossing the Kahayan river, Palangkaraya, Central Kalimantan. The bridge was built from 1995 to 2002 to





FIGURE 21.49 Bajulmati Bridge (90 m), Malang, East Java.



FIGURE 21.50 Kahayan Bridge (640 m), Palangkaraya, Central Kalimantan.

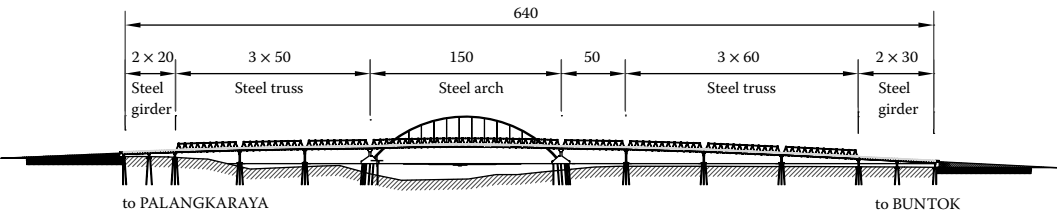


FIGURE 21.51 Elevation of the Kahayan Bridge, Palangkaraya, Central Kalimantan.

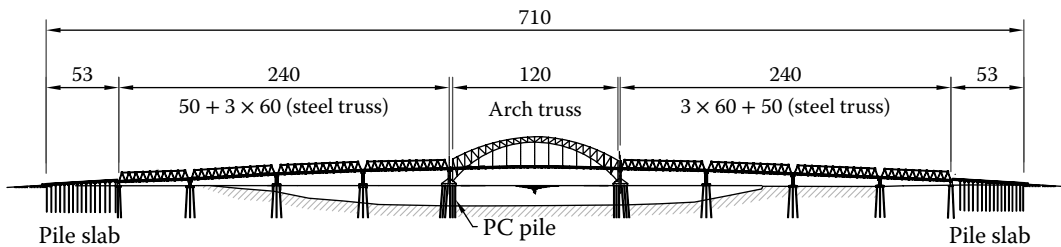
connect the city of Palangkaraya to the South Barito and North Barito regencies. The bridge has a length of 640 m and a width of 9 m (7 m wide for vehicles and a 1 m footway on both sides), consisting of 12 spans with a particular span of 150 m at the river cruise line (Figure 21.51). The Kahayan River has shipping traffic which requires a free space of 14 m from the highest water surface and 18 m from the normal water surface.

21.6.2.2 Rumbai Jaya Bridge (710 m), Indragiri Hilir, Riau (2004)

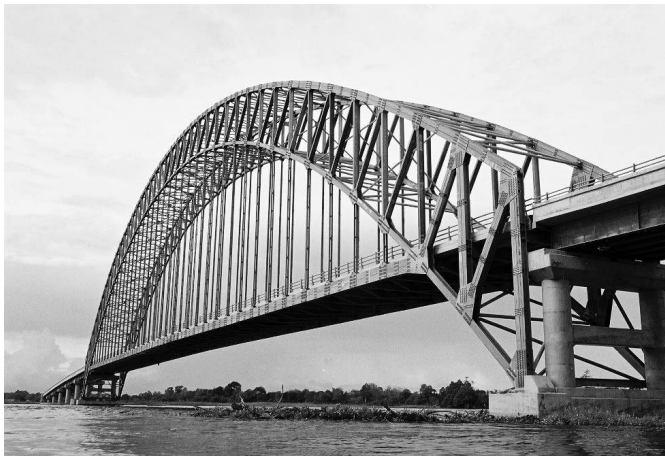
The Rumbai Jaya Bridge (Figure 21.52), which crosses over the Indragiri River in Indragiri Hilir, on the segment of Pekanbaru–Tembilahan streets, is the longest bridge in the area of the Riau mainland.



**FIGURE 21.52** Rumbai Jaya Bridge (710 m), Indragiri Hilir, Riau.



**FIGURE 21.53** Elevation of the Rumbai Jaya Bridge, Indragiri Hilir, Riau.



**FIGURE 21.54** Martadipura Bridge (569 m), Kotabangun, East Kalimantan.

The Rumbai Jaya Bridge has a total length of 710 m, with its largest span of 120 m and a width of 7 m (Figure 21.53). Its structural system is that of a steel truss arch bridge. The bridge was inaugurated by President Megawati on March 13, 2004.

### 21.6.2.3 Martadipura Bridge (569 m), Kotabangun, East Kalimantan (2004)

The Martadipura Bridge (Figure 21.54) in Kotabangun, East Kalimantan is the third bridge crossing the Mahakam River. The first is the Mahakam I Bridge in Samarinda and the second is the Kartanegara Bridge in Tenggarong. The Martadipura Bridge is the second bridge built of its kind in Indonesia, after the Rumbai Bridge in Riau, and the longest span ever built, with a main span of 200 m. The bridge width is 9 m and its total length is 569 m. Its main vertical clearance is 15 m. That superstructure consists of steel truss (SM 490 YB) with an arch height of 36 m (see Figure 21.55). The deck employs reinforced

concrete K-350 U-40 and a substructure steel pipe with a diameter of 1000 mm. The approach spans are H-beam composite steel girders with span lengths of  $2 \times 6 \times 30$  m (see Figure 21.55) and its substructure is in the form of a steel pipe with a diameter of 600 mm.

21.6.2.4 Palu IV Bridge (300 m), Palu, Central Sulawesi (2006)

The Palu IV Bridge (Figure 21.56) spans the Talise Bay, linking the East Palu district and West Palu, in the city of Palu, Central Sulawesi. The bridge is located in the segment of the Palu Gulf coastal ring road. The bridge is also a landmark of the city of Palu because, philosophically, the curved shapes represent the two major mountains flanking the city. The bridge was inaugurated by President Susilo Bambang Yudhoyono in May 2006. The total length of the bridge is 300 m, with two main spans of 125 m in the form of twin steel squares, and a width of 7 m for vehicles. The links on the right and left are composite girders with measurements of 25 m (see Figure 21.57).

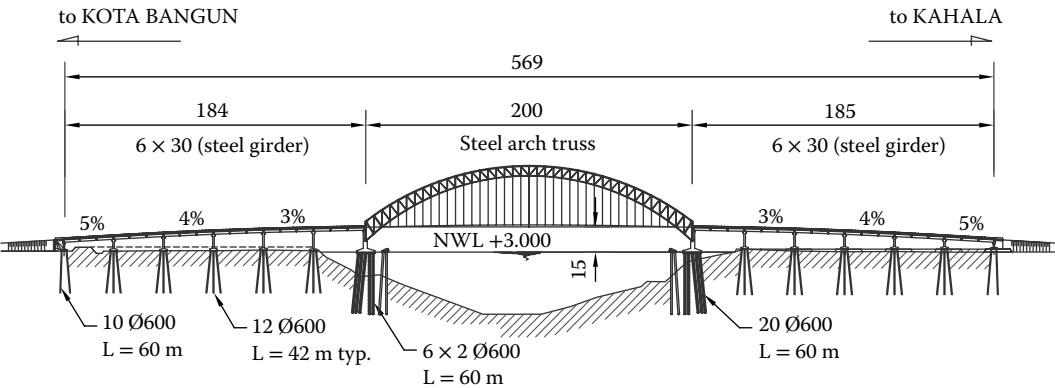


FIGURE 21.55 Elevation of the Martadipura Bridge, Kotabangun, East Kalimantan.



FIGURE 21.56 (See color insert.) Palu IV Bridge (300 m), Palu, Central Sulawesi.

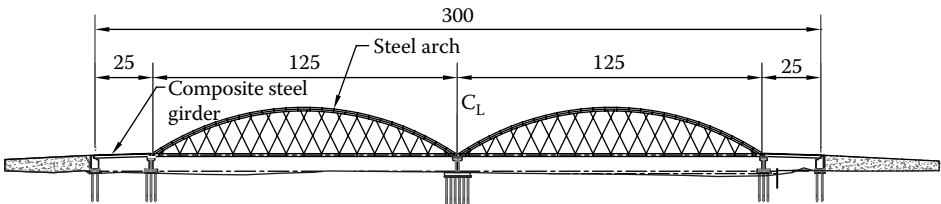


FIGURE 21.57 Elevation of the Palu IV Bridge, Palu, Central Sulawesi.



21.6.2.5 Barito Hulu Bridge (561 m), Puruk Cahu, Central Kalimantan (2008)

The Barito Hulu Bridge (Figure 21.58), which is now called the Merdeka Bridge, crosses over the Barito River, Puruk Cahu city, Murung Raya (Mura) regency, Central Kalimantan. This bridge connects the Puruk Cahu region with Muara Teweh, North Barito (Barut) regency and the surrounding areas. The total bridge length is 561 m and its width is 9 m, with a configuration as shown in Figure 21.59. The bridge was designed by PT Perencana Jaya, Jakarta, and construction took approximately five years (2003–2008). The main structure is a steel arch bridge truss, with spans of 62 m + 153 m + 62 m. At first glance, it looks like the Batanghari II Bridge, on the Batanghari River, Jambi, Sumatra.

21.6.2.6 Rumpiang Bridge (754 m), Barito Kuala, South Kalimantan (2008)

The Rumpiang Bridge (Figure 21.60) is located above the Barito River, Barito Kuala regency, South Kalimantan province. The construction of the bridge began on December 1, 2003, and was completed on April 25, 2008. The total length of the bridge is 754 m with a width of 9 m (see the elevation in Figure 21.61). The configuration is that of a main bridge flanked by approach bridges, which consist of several composite steel girders.

Next, with the advantages of standard steel truss bridges in general, an arc shape pointing upward means the bridge can be easily erected by applying piece-by-piece cantilever construction, without the need for the tools of complex constructions except for an additional temporary tower at the end of the bridge to put the pull cables to produce a cantilever effect, as seen in Figure 21.62 of the erection of



FIGURE 21.58 Merdeka Bridge (561 m), Puruk Cahu, Central Kalimantan.

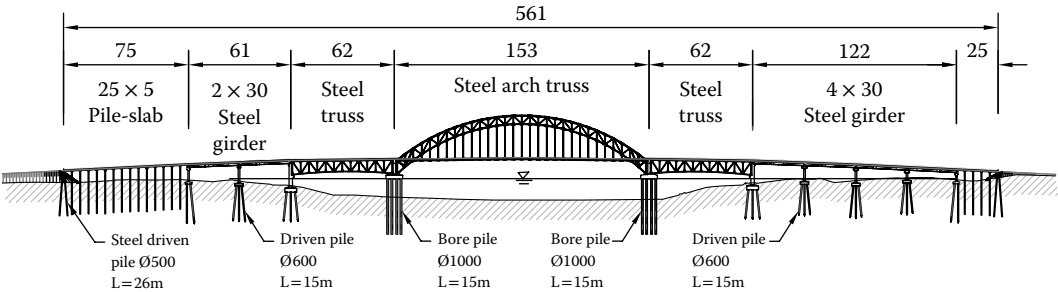
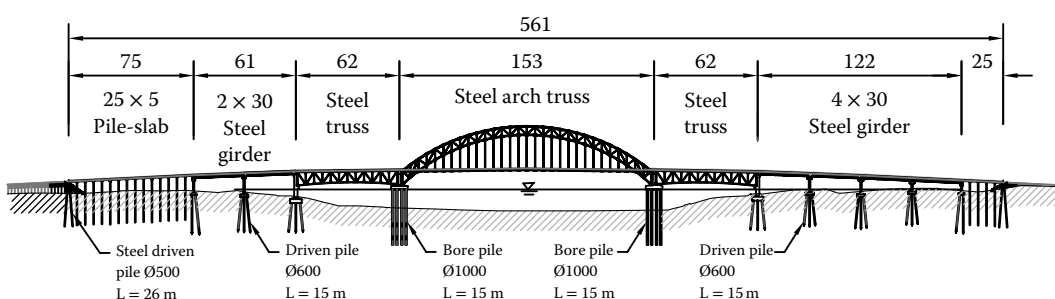


FIGURE 21.59 Elevation of the Merdeka Bridge, Puruk Cahu, Central Kalimantan.



**FIGURE 21.60** Rumpiang Bridge (754 m), Barito Kuala, South Kalimantan.



**FIGURE 21.61** Elevation of the Rumpiang Bridge, Barito Kuala, South Kalimantan.



**FIGURE 21.62** Erection of the main span of the bridge.

the main span on the bridge. After the steel truss arch on the top has been completed, then the road body underneath the bridge may be installed. The final result is depicted in Figure 21.62.

#### 21.6.2.7 Mahulu Bridge (800 m), Samarinda, East Kalimantan (2008)

The Mahakam Ulu (Mahulu) Bridge ([Figure 21.63](#)) crosses the Mahakam River, which connects the village of Loa Buah and the Kujang River with Sengkotek regency, East Kalimantan. The bridge is one of five other bridges across the Mahakam River: the Martadipura Bridge, the Kertanagara Bridge, the Mahakam Ulu Bridge, and the Mahkota I and Mahkota II bridges (which were under construction as of April 2013). This bridge length is 800 m with a central span of 200 m and a width of 11 m. The distance between the bridge and the water surface is 18 m. Bridge construction was carried out in two parts, notably the bridge approaching from Loa Janan (six spans, 240 m) and from Loa Buah (nine spans, 360 m) using prestressed concrete I-girders, and its main span is a steel arch (200 m).



FIGURE 21.63 Mahulu Bridge (800 m), East Kalimantan.



FIGURE 21.64 Batanghari II Bridge (1351 m), Sijenjang, Jambi.

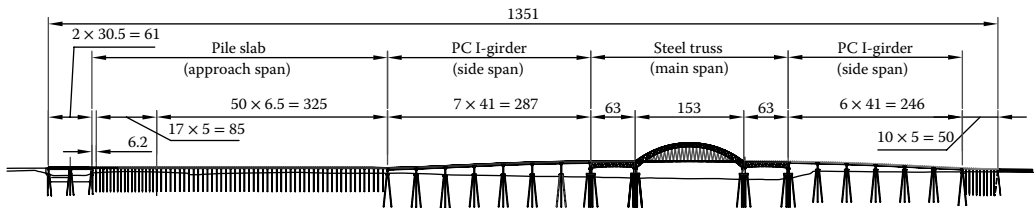


FIGURE 21.65 Elevation of the Batanghari II Bridge, Jambi, Sumatra.

**21.6.2.8 Batanghari II Bridge (1351 m), Sijenjang, Jambi (2009)**

The Batanghari II Bridge (Figure 21.64) crosses over the Batanghari River in the Sijenjang rency, Jambi, Sumatra. The location is approximately 6 miles east of the downtown area. The total length is 1351 m with a width of 9 m, including a 1 m footway on the right and left sides of the bridge (see Figure 21.65). The Batanghari II Bridge is also safe for shipping traffic on the Batanghari River. The distance or height between the water surface and the bridge floor (clearance) at times of flooding is 15 m and at low tide is 17.5 m.

For the province of Jambi, the Batanghari II Bridge provides a significant contribution in terms of transportation as well as in enhancing business relations between the regions, namely between the city of Jambi and the rency of Jambi Muaro, including the Eastern Tanjung Jabung rency. This bridge

has provided economic access to most parts of Muaro Jabung, Jambi, and Eastern Tanjung Jabung, which have been constrained in that the two areas have been separated by the Batanghari River so that different water transport systems should be utilized.

21.6.2.9 Pela Bridge (420 m), Kota Bangun, East Kalimantan (2010)

The Pela Bridge (Figure 21.66) crosses over the Mahakam River connecting the road of Kahala to Pelabaru. It is located in the village of Pela, in Kota Bangun district, Kutai Kartanegara Regency, East Kalimantan Province. Pela Bridge’s superstructure is a through-deck steel box arch bridge with simple supported restraints. The total length is 420 m, composed of two 45 m steel girders, a 45 m side truss, a 150 m steel arch as the main span, a 45 m side truss, and two 45 m steel girders (see Figure 21.67).

The arch is formed by a prismatic box member along the span (1 m × 1.2 m) except for the origin side, which is bigger (1.6 m × 1.2 m). The bridge’s horizontal beam is straight and strengthened by 8 prestressing tendons, each composed by 19 strands with 0.5 inch diameters. These prestressed strands allow the bridge’s superstructure to develop horizontal force optimally since most of the horizontal force due to dead load and life load are directly diminished by the prestressed force. Hence, the bridge’s foundation bears only a small horizontal force. The bridge’s camber is formed by several cross girders attached to the straight horizontal beam.



FIGURE 21.66 Pela Bridge (420 m), Kutai Kartanegara, East Kalimantan.

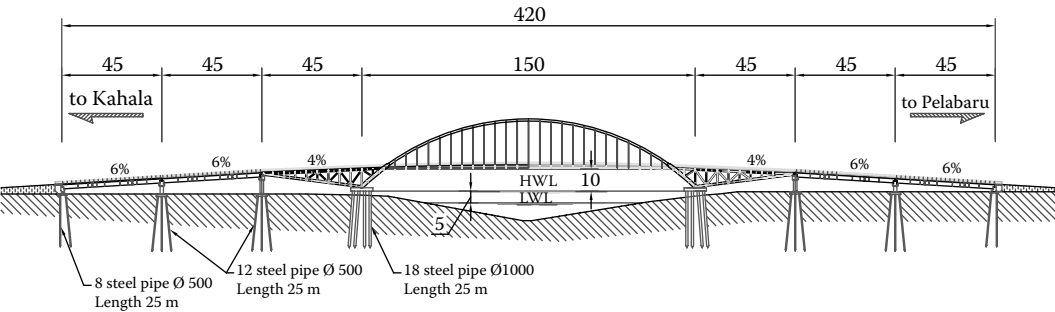


FIGURE 21.67 Elevation of the Pela Bridge, Kutai Kartanegara, East Kalimantan.

#### 21.6.2.10 Sei Tayan Bridge (1420 m), Tayan, West Kalimantan

The Sei Tayan Bridge, which is under construction in the lower Tayan district, has been designed to cross the Kapuas River to connect the cities of Tayak and Piasak, in the Sanggau regency, approximately 112 km from the city of Pontianak. The bridge crosses the island of Tayan, which is relatively small in size (58 ha) with about 2100 residents. Bridge construction is intended to replace the ferry transportation that functions to serve the local people's activities. When the Sei Tayan Bridge is finished, it will be part of a road segment of the South Kalimantan ring, which connects West Kalimantan and Central Kalimantan.

The bridge consists of two parts, with a total length of 1420 m and a width of 11.5 m ( $2 \times 2$  lanes). The first bridge can be accessed from the northern part of Tayan to the island with a length of 280 m (see Figure 21.68). The second bridge, which is the main bridge, extends from Tayan Island towards Piasak with a distance of 1074 m. The main bridge is a continuous truss arch with a span of 350 m, which has been designed to accommodate shipping traffic navigations (see Figure 21.69). A detailed description of the second bridge is given in Table 21.6 and Figure 21.70.



**FIGURE 21.68** An artist's impression of the first segment of the Sei Tayan Bridge (280 m), Pontianak, West Kalimantan.



**FIGURE 21.69** An artist's impression of the second segment of the Sei Tayan Bridge (1074 m), Pontianak, West Kalimantan.

TABLE 21.6 Second Bridge of the Sei Tayan Project

Segment	Superstructure	Length of Span
2A	Steel composite girders	120 m (3 × 40 m)
2B	Continuous steel composite girders	600 m (4 × 45 m + 4 × 60 m + 4 × 45 m)
2C	Continuous steel arch truss	350 m (75 m + 200 m + 75 m)
2D	Pile slab	70 m (14 × 5 m)

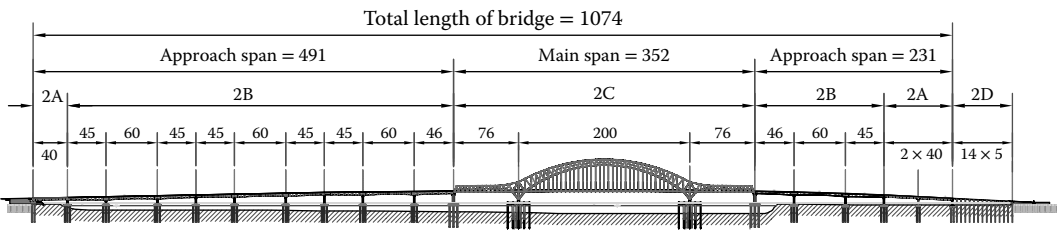


FIGURE 21.70 The second segment of the Sei Tayan Bridge, Pontianak, West Kalimantan.

## 21.7 Cable-Stayed Bridges

### 21.7.1 Teuku Fisabilillah Bridge (642 m), Riau Isles (1998)

The Teuku Fisabilillah Bridge (Figure 21.71) is part of the Bareleng bridges, a chain of six bridges of various types, and connects the islands of Batam, Rempang, and Galang. The bridge is an icon of the local area and is a popular tourist destination. The full stretch of the six bridges reaches a total of 2 km. Traveling from the first bridge to the last is about 50 km and takes about 50 minutes. The construction of the bridges started in 1992, and this bridge was named Teuku Fisabilillah, after the fifteenth to eighteenth century rulers of the Melayu–Riau Kingdom.

The Teuku Fisabilillah Bridge is the first cable-stayed bridge built in this country and it was the longest cable-stayed bridge span in the southern hemisphere at the time of its completion. The total length of the bridge is 642 m with a 350 m main span and 2 × 146 m side spans. The bridge is supported by a concrete pylon 124 m high. The width is 21.5 m and the vertical clearance below the main span is 38 m. The VSL-200-SSI-type stays were installed in two planes of a semi-fan arrangement with their backstays tied to 20,000 ton weight abutments. The pylon legs stand on concrete pile caps with diameters of 24 m and 12.5 m thickness and are also supported by 2 × 30 pieces of 40 m deep concrete bore piles with diameters of 1 m.

### 21.7.2 Pasupati Bridge (2282 m), Bandung, West Java (2005)

The Pasupati Bridge is the incoming elevated highway in central Bandung, West Java, Indonesia. The bridge connects the western and eastern parts of the city of Bandung, lies in the northern part of the Bandung downtown, and passes through the Cikapundung valley. The 2282.4 m long elevated road consists of a 1278.7 m long west viaduct followed by a 303.5 m long main cable-stayed bridge and a 700.2 m long east viaduct (VSL Brochure, 2013). This bridge resolved the traffic congestions in North Bandung. Above the Cikapundung valley, a cable-stayed structure is particularly used so that the bridge also serves as an icon of the city. The designers were Sir William Halcrow and Partners Ltd. (UK), Inco (Kuwait), and PT Indec & Lapi ITB (Indonesia).

The Surapati Bridge can be divided into two main parts, a viaduct and a main cable-stayed bridge.

The viaduct (Figure 21.72) is a bridge road over the highway between Pasteur Street and the Cikapundung valley. The 44.5 m typical span viaduct is formed of a 2.95 m long precast segmental, three-cell, concrete box girder. The 21.53 m wide single deck is designed to accommodate a two-way





**FIGURE 21.71** Teuku Fisabilillah Bridge (642 m), Bantam, Riau.



**FIGURE 21.72** Precast segmental concrete box girder of the Surapati Viaduct.

road with two traffic lanes in each direction. The viaduct was built by launching gantry using the segmental balanced cantilever method and is supported by 48 Y-shaped piers.

The main span cable-stayed asymmetrical single pylon ([Figure 21.73](#)) stands over the Cikapundung valley with a single pylon at a height of 52 m off the ground, or about 38 m of the bridge deck. The pylon height of the bridge is suited to the regulations of Husein Sastranegara Airport, which is nearby. The span between the pylons is 55 m on the west side/back span and 106 m on the east side/main span. The width of the superstructure is  $3 \times 3.5$  m for each direction (see [Figure 21.74](#)).

### 21.7.3 Grand Wisata Overpass (81 m), Bekasi, West Java (2007)

The Grand Wisata cable-stayed overpass is located in eastern Bekasi, around 20 km off Jakarta (see [Figure 21.75](#)). The bridge opened to traffic in July 2007. The overpass has a span length of 81 m, and was designed mainly for aesthetic purposes. It consists of a single pylon with two inclined concrete columns interconnected by an arch at the top and precast prestressed concrete girders overcrossing an expressway.

Due to the three-dimensional inclination and nonprism shapes of the pylon's sections, a full support system was used for concrete pouring on the 40 m high pylon (see [Figure 21.76](#)). A careful design of the scaffolding was considered, particularly to resist the lateral forces induced by the pylon's self-weight



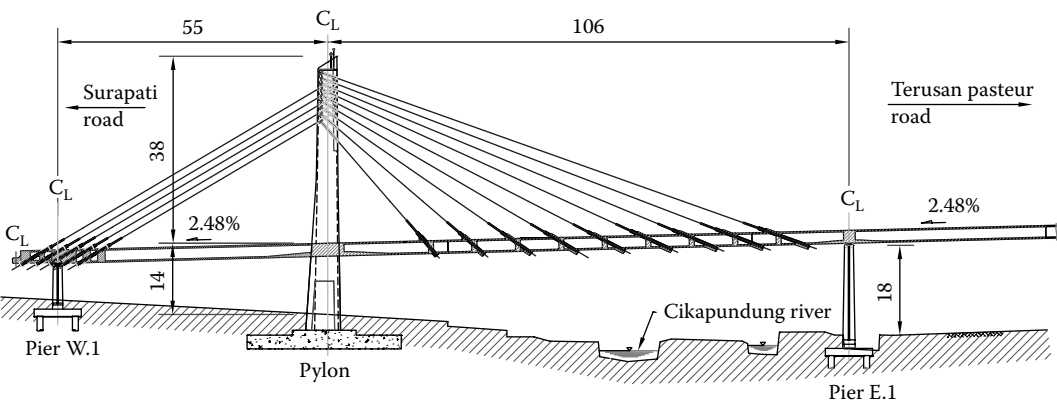


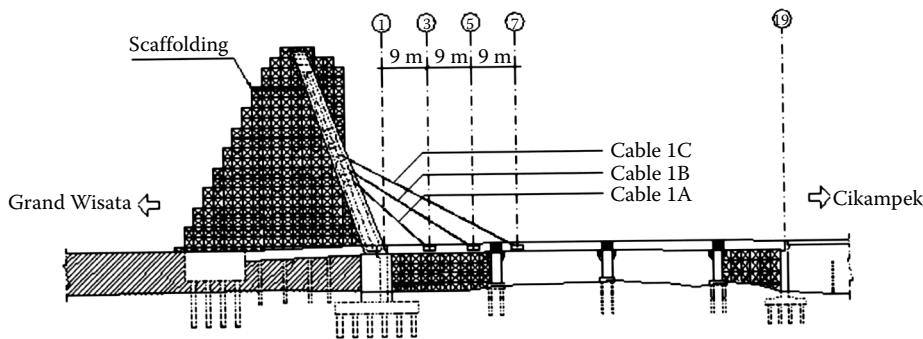
FIGURE 21.73 Elevation of the Surapati main bridge span, Bandung, West Java.



FIGURE 21.74 The Surapati main bridge span (161 m), Bandung, West Java.



FIGURE 21.75 Grand Wisata Overpass (81 m), Bekasi, West Java.



**FIGURE 21.76** A fully supported scaffolding system for the pylon construction. (From Supartono, F.X. 2009. *Structural Engineering International* 19(1).)



**FIGURE 21.77** Siak Indrapura Bridge (1196 m), Siak, Riau.

during concreting. Meanwhile, a step-by-step deflection analysis was performed to accommodate the pylon's deformation during the construction of the overpass. Due to nonprism hollow shapes of pylon's sections, in particular for the top arch connection, special care was taken on the concrete compactness. A high-performance and self-compacting concrete of 60 MPa cylindrical strength, with a slump flow criteria of 65–75 cm, was used for the pylon. This represents the highest grade of self-compacting concrete produced in Indonesia for cast-in-place concrete.

The deck system consists of a longitudinal main girder and crossbeams that are interconnected with its longitudinal ribs (secondary beams). The deck slab consists of a precast half slab 100 mm thick and a cast-in-place top slab 120 mm thick. Due to the limited capacity of the temporary support in the median of the expressway, the erection of the precast girder was combined with partial stressing of the stayed cables before completely pouring the concrete top slabs, in order to decrease the dead weight being loaded on the temporary support. The stayed cables are unbonded high-strength epoxy-coated strands with a diameter of 0.6 in (15.2 mm) and are protected by HDPE (high-density polyethylene) pipes. This type of cable-stayed bridge was used for the first time in Indonesia.

#### 21.7.4 Siak Indrapura Bridge (1196 m), Siak, Riau (2007)

The Siak Indrapura Bridge, an icon of the region, lies on the Siak River, in Siak regency, Riau, Sumatra (Figure 21.77). This bridge is important for the development of the area because it connects the northern and southern regencies. This bridge has unique features and may even be the only one in Indonesia. The 77 m high bridge pylon has a slightly curved “A” shape. Its peak has become a diorama on the north side of the pier and a restaurant on the south side of the pier. The total length of the bridge is 1196 m ( $2 \times 150 \text{ m} + 8 \times 51 \text{ m} + 2 \times 94 \text{ m} + 200 \text{ m}$ ), whereas the width of the bridge is 16.95 m to accommodate

the four 2.75 m vehicle lanes and two 2.25 m footways. The pylon legs sit on an individual pile cap of  $12\text{ m} \times 24\text{ m} \times 4\text{ m}$  and are supported by 24 steel pipe piles.

The Siak Bridge is similar to the Batam–Tonton Bridge in Batam (Sucipto and Lontoh 2003). However, several modifications were made to overcome specific problems in different locations. The Siak cable-stayed bridge was built to replace the existing ferry transportation on the river. The bridge provides a 24 m freeboard that enables vessels to pass through.

### 21.7.5 Siak IV Bridge (699 m), Pekanbaru, Riau

The city of Pekanbaru is divided by the Siak River into two areas. This bridge was built to accommodate rapid urban development in the region (see Figures 21.78 and 21.79). Except for highway traffic, the bridge will be used as an icon of Pekanbaru, particularly to welcome National Sports Competition (PON) XVIII in 2012. Hence, the cable-stayed bridge system was selected. Because the Siak Indrapura Bridge adopted the same system, the Siak IV Bridge was made differently by using a tilted single pier so that the bridge becomes asymmetric. It was designed so that the height of the bridge deck is 14 m and its length is 699 m. Its main stretch is that of a cable-stayed system with a length of 156 m. Its width is 20 m and the slope of the elongated part is 3.5–5%. The bridge has four lanes, with each direction consisting of two lanes. The bridge is expected to be completed by 2014.

### 21.7.6 Sukarno Bridge (622 m), Manado, North Sulawesi

The Sukarno Bridge (Figure 21.80) is part of the Manado ring road in Manado and is expected to accelerate the development of cities in North Sulawesi. It is a cable-stayed bridge, with a main span of 240 m and a free vertical height of 15 m. The bridge is expected to be completed by the end of 2013.

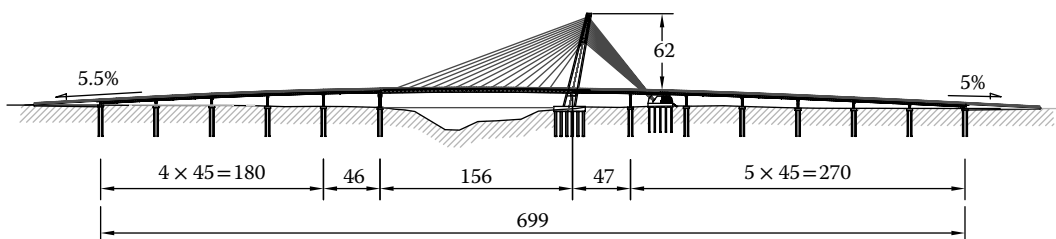


FIGURE 21.78 Elevation of the Siak IV Bridge, Pekanbaru, Riau.



FIGURE 21.79 An artist's impression of the Siak IV Bridge (699 m), Pekanbaru, Riau.

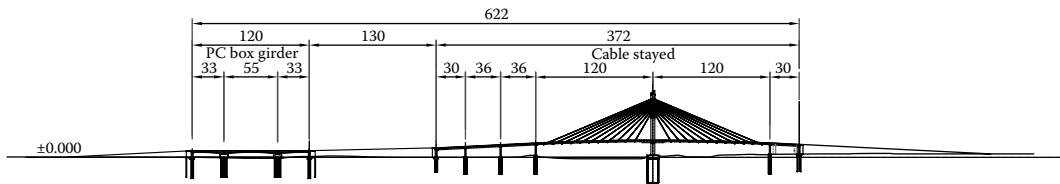


FIGURE 21.80 Sukarno Bridge, Manado, North Sulawesi.



FIGURE 21.81 An artist's impression of the Melak Bridge (680 m), West Kutai, East Kalimantan.

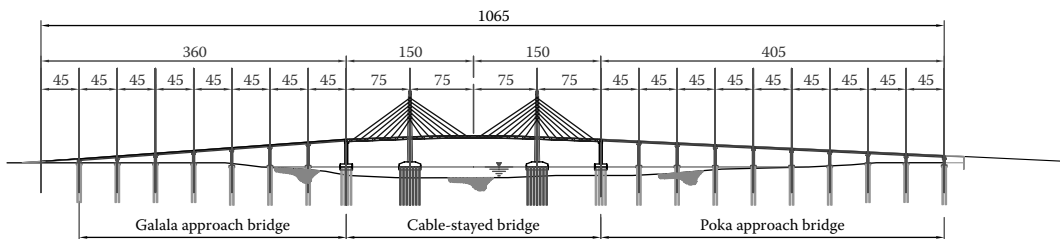


FIGURE 21.82 Elevation of the Merah Putih Bridge, Ambon, Maluku.

### 21.7.7 Melak Bridge (680 m), West Kutai, East Kalimantan

The Melak Bridge is located in West Kutai, East Kalimantan, and is a double-pylon cable-stayed bridge with three spans of 170 m + 340 m + 170 m. The bridge deck also represents an open crossed section with twin side girders of prestressed concrete with a width of 14.2 m and a height of 2.4 m. The pylons have a slightly curved "A" shape with a height of about 108 m. Construction of the bridge began in 2010.

### 21.7.8 Merah Putih Bridge (1065 m), Ambon, Maluku (under construction)

The Merah Putih Bridge (Figure 21.82) crosses over Ambon Bay, connecting Galala, in the Sirimau subdistrict, with Poka, in the Ambon Bay subdistrict. The bridge will serve as a shortcut from Galala and Poka (around the Pattimura International Airport) to Ambon. The total length of the bridge is 1065 m. The main span is a cable-stayed system consisting of three spans of 75 m + 150 m + 75 m with prestressed floor systems and a width of 22.3 m. The pylon height is 110 m above the pile cap. The approach bridge is a prestressed concrete I-girder. The bridge is expected to be completed by 2014.

## 21.8 Suspension Bridges

### 21.8.1 Old Bantar Bridge (176 m), Kulon Progo, Jogjakarta (1932)

The Old Bantar Bridge, a suspension bridge, was the first bridge to cross the Progo River in the village of Bantar, Kulon Progo regency, Jogjakarta (Figure 21.83). The bridge was built a long time ago during Dutch colonial times. The total length of the bridge is 176 m, consisting of three continuous spans with a main span of 80 m and a width of 7 m. The road segment above it belongs to the southern path of Java Island, which is an alternative national road to serve the southern region of Java Island. Due to the increased traffic volume from year to year and also the age factor, the bridge is no longer used for highway traffic. Only light traffic, such as motorcycles and the like, is allowed to pass over the bridge. Furthermore, at the same place, next to the Old Bantar Bridge, two parallel bridges have been built side by side, namely the Bantar II and Bantar III bridges. Both of the two newly built bridges are actively used for traffic. The Old Bantar Bridge is still retained for its historic value and artistic shape.

### 21.8.2 Mamberamo Bridge (235 m), Papua (1996)

The Mamberamo Bridge, over the Mamberamo River in Papua, was built in 1996 as part of a road development project in an agricultural area (Figures 21.84 and 21.85). Since the road works were incomplete at the time of the construction, the transport of materials to the bridge site was a particular challenge in this project. A suspension bridge with a single span of 235 m using a double cable system was designed to overcome rapid river flow and a rocky river bed. The towers are prefabricated steel frames with site-bolted connections. The main cables are in dual asymmetric arrangements for optimum stiffness. The



FIGURE 21.83 Old Bantar Bridge (176 m), Kulon Progo, Yogyakarta.

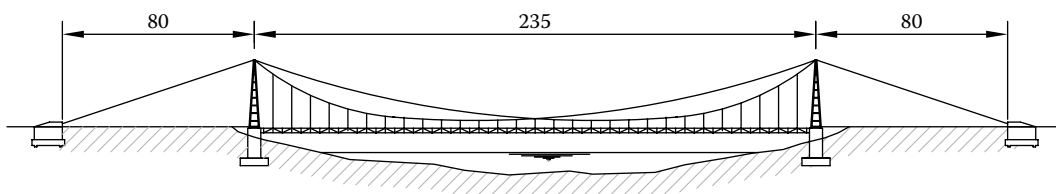


FIGURE 21.84 Elevation of the Mamberamo Bridge (235 m), Papua.

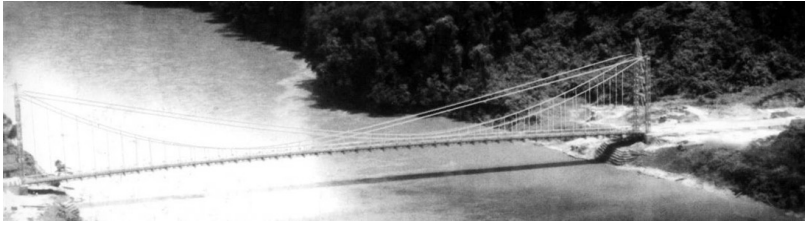


FIGURE 21.85 The Mamberamo Bridge (235 m), Papua.

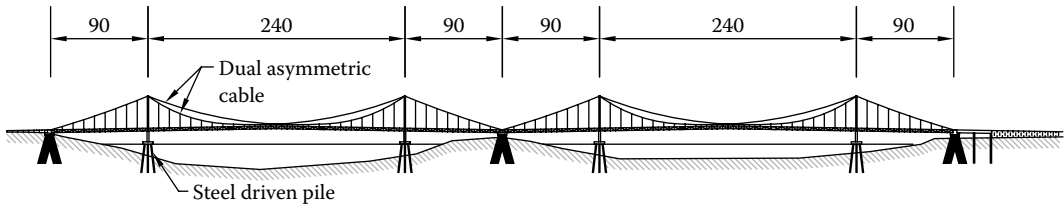


FIGURE 21.86 Elevation of the Barito Bridge (1082 m), Banjarmasin, South Kalimantan.



FIGURE 21.87 Barito Bridge (1082 m), Banjarmasin, South Kalimantan.

total weight of the cables is about 120 tons. The timber deck consists of transverse deck planks with timber curbs to delineate the carriageway. The cables were anchored into rock anchorages.

### 21.8.3 Barito Bridge (1082 m), Banjarmasin, South Kalimantan (1995)

The Barito Bridge over the Barito River, Banjarmasin, South Kalimantan, is a twin suspension bridge  $2 \times 90 \text{ m} + 2 \times 240 \text{ m} + 2 \times 90 \text{ m}$  (see Figure 21.86), with a total length of about 1082 m. The designers were McMillan, Britton & Kell, the superstructure engineering site works contractor was PT Adhi Karya, and the main subcontractor was Transfield Construction. The engineering supervision was carried out by PT Perencana Jaya, Jakarta. The construction period was from 1993 to 1997. The bridge comprises two 3.5 m traffic lanes and a 1.5 m footway on each side, with a total width of 10 m. The width between the cables is approximately 12 m. A key feature of the design is the dual asymmetric cable arrangement, which provides a 70% increase in bridge stiffness when compared to a conventional single cable arrangement (see Figure 21.87 for the site view).

21.8.4 Kartanegara Bridge (714 m), Kutai Kartanegara, East Kalimantan (2001)

The Kartanegara Bridge (Figure 21.88) in Tenggarong, Kutai Kartanegara, is the second bridge that crosses over the Mahakam River, after the Mahakam I Bridge in the city of Samarinda. Both bridges are located in East Kalimantan. This bridge is part of the Kalimantan central axis lane, which connects the cities of Samarinda and Tenggarong. The main bridge span is 270 m and is the third-longest suspension bridge in Indonesia, after the Mamberamo Bridge (235 m) in Papua and the Barito Bridge (240 m) in South Kalimantan.

The bridge used a single catenary cable with a stiffening truss of modified Bina Marga steel bridge standard of A45 class. The total length of the stiffening truss is 470 m with a lane width of 7 m, equipped with a 1 m footway on both sides of the lane. The entire deck of the bridge is reinforced concrete K-350/U-40 with a wearing course in the form of 40 mm thick Hot Rolled Sheet (HRS) asphalt. The structure of the tower legs constitutes a series of four steel pipes  $\phi$  600 mm, with a height of 37 m, supported by the 15 m tall concrete construction. Figure 21.89 shows the process of erection of the stiffening truss segments, which form a bridge with an A45 class standard framework. See Figure 21.90 for site view of the bridge. On November 26, 2011, the bridge had collapsed at the time of maintenance efforts; therefore, it only functioned for ten years after it was completed. The failure of the bridge killed at least 20 people and injured 40.

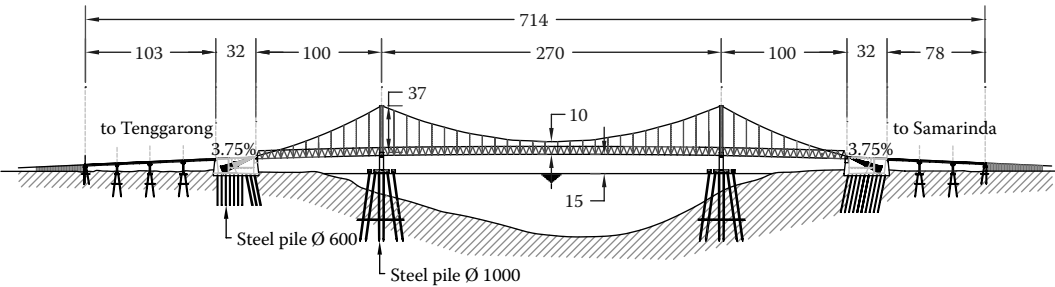


FIGURE 21.88 Elevation of the Kartanegara Bridge, Kutai Kartanegara, East Kalimantan.

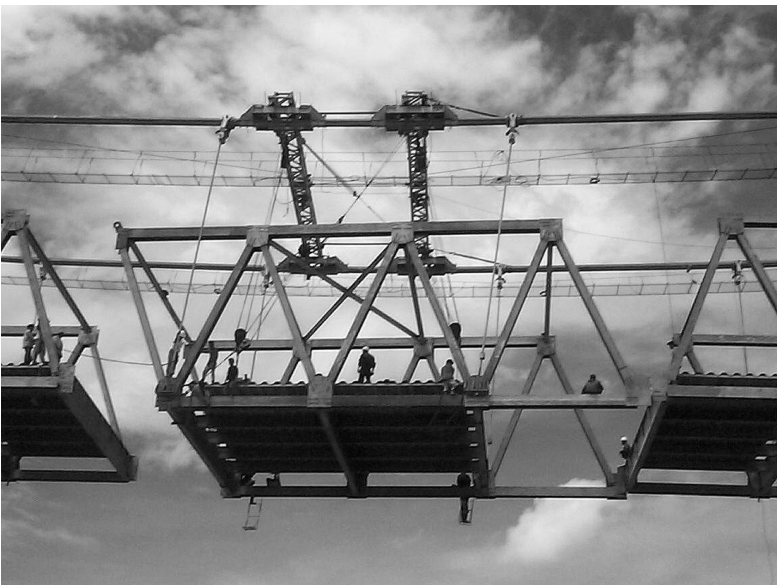


FIGURE 21.89 The piece-by-piece erection of the stiffening truss segments.





**FIGURE 21.90** Kartanegara Bridge (714 m), Kutai Kartanegara, East Kalimantan.



**FIGURE 21.91** An artist's impression of the Pulau Balang Bridge (1344 m), Balikpapan, East Kalimantan.

### 21.8.5 Balikpapan Bay Bridge (1344 m), East Kalimantan

Of the entire trans-Kalimantan road, Kalimantan Island, with its rivers that are generally in the shape of deep trenches, still has some road segments that are not yet connected directly through the land infrastructure, such as the Balikpapan Bay lane via Balang Island and the road crossing the Kapuas River via Tayan Island. The two lanes have a relatively large stretch of approximately 1000 m to 2000 m. This proposed bridge will connect both sides of the bay, between the city of Balikpapan and the North Penajam Paser regency and will pass Balang Island, such that it is also called the Pulau Balang Bridge (see Figure 21.91 for an artist's impression of the bridge).

The bridge was designed as a suspension bridge for four-lane traffic from both directions, with a main span of 708 m and a width of 22 m (see Figure 21.92). The stiffening system of the suspension bridge is in the form of a galvanized steel truss with a pylon height of approximately 80 m above the elevation of the road. The 20 m bridge elevation was designed to cater to marine navigation below the deck of the

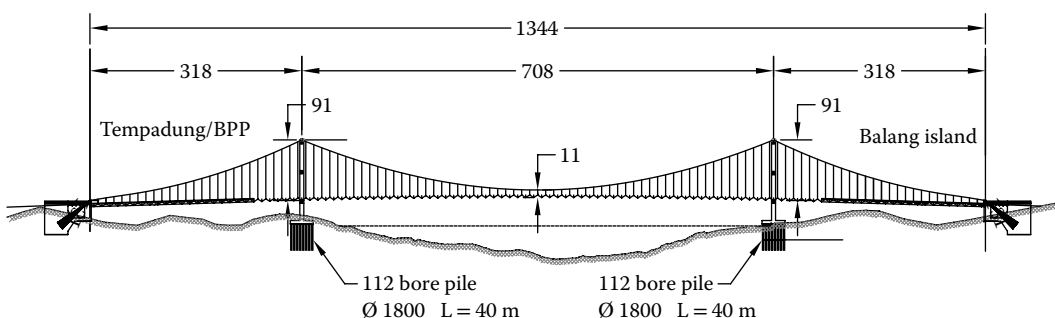


FIGURE 21.92 Main Span Elevation of the Pulau Balang bridge, East Kalimantan.

bridge. When completed, the bridge will be part of the trans-Borneo ring road from the south lane and is expected to support regional transportation and development of the Kariangau Balikpapan industrial area, which is yet to be realized.

## 21.9 Special Bridge Projects

### 21.9.1 Road Improvement Projects

#### 21.9.1.1 Kelok-9 Project, Lima Puluh Kota, West Sumatra

The Kelok-9 bridge project is located in the regency of Lima Puluh Kota, West Sumatra Province. This project is part of the Payakumbuh–Batas Riau road improvement project (km 130 + 000 to km 148 + 000), which functions as a connecting road between the central Sumatra lane and the eastern coast of Sumatra. The project consists of a 5 km road and a  $\pm 1$  km bridge. The condition of the Kelok-9 area reflects its own name, that is, winding or turning. Naturally, the road is very curvy, as shown in Figure 21.93.

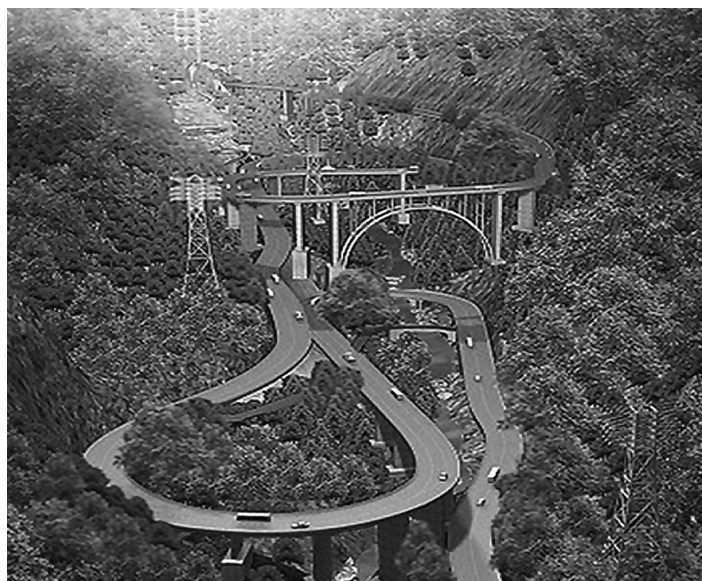
With steep and winding road conditions, the smooth flow of the traffic is reduced. Semitrailer trucks or trailers cannot pass this road. The road via the Kelok-9 route is a national road which greatly affects the life of the surrounding communities. As a result, the improvement project has been designed not only to widen the existing road but also to make a new route to accommodate heavy vehicles. In seeking a new route, the route of the old site will be retained. Furthermore, since the Kelok-9 project also requires almost 20% of its entire design to be bridges, surely this bridge will become a new icon for the area.

An estimate of the new road by an artist's description is shown in Figure 21.94, in which the bridge is seen from the city of Bukittinggi. The arch bridge that can be seen most prominently is part of Bridge IV (454 m). The segments of the other bridges, which consist of six segments, together with their locations and information, can be seen in the map in Figure 21.95. Table 21.7 presents a list of detailed configurations of bridges in the Kelok-9 road project.

The elevation of Bridges II, IV, and VI can be seen in Figures 21.96 through 21.98. Because of the difficult conditions of the area, that is, the location in a hilly and steep area, it is sometimes necessary to create a special access road to reach the location and stage constructions are necessary. Bridge VI (Figure 21.98) was built in 2005 and required open road and blast rocks. The level of difficulty can be seen in Figure 21.99. Although the bridge has been completed, the end of the road is still blocked by the hill and needs to be cleared. In order to clear the hill, explosives should be used. However, the intervention of manual workers using heavy equipment is definitely still required. The bridge project is expected to be completed by the end of 2013.



**FIGURE 21.93** The existing Kelok-9 road, West Sumatra.



**FIGURE 21.94** An artist's impression of the Kelok-9 bridge, West Sumatra.

### 21.9.1.2 North Java Corridor Flyover Project

Motor vehicle transportation on the road, either for public or private vehicles, is still a major concern of the community, especially in Java. However, the railway network in Java is relatively complete compared to those on other islands of Indonesia. Because the local residents still rely on road traffic, it is very natural that on certain days, particularly national holidays, congestion will always hit some street segments. In facing these conditions, the Directorate General of Highways (Ditjen Bina Marga), Ministry of Public Works, will build a bridge overpass using a Japanese government grant in order

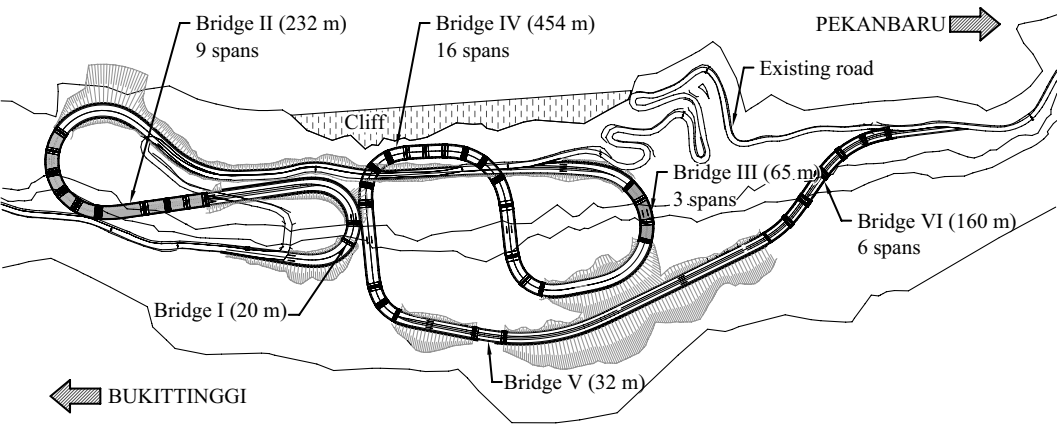


FIGURE 21.95 Map Location of the Kelok-9 bridge, West Sumatra.

TABLE 21.7 The Bridge Segments of the Kelok-9 Project

No.	Station	Abutment/ Pier	Bridge Type	Segment Span (m)	Total Length (m)
I	3 + 018–3 + 038	2	RC box girder	20	20
II	3 + 225–3 + 265	2	PC I-girder	20–20	230
	3 + 265–3 + 365	4	PC box girder	25–50–25	
	3 + 365–3 + 455	5	RC box girder	22–23–23–22	
III*	4 + 103–4 + 168	4	RC box girder	20–25–20	65
IV	4 + 301–4 + 321	2	RC box girder	20	462
	4 + 321–4 + 436	4	PC box girder	30–55–30	
	4 + 436–4 + 506	4	RC box girder	25–21.5–21.5	
	4 + 506–4 + 546	3	PC I-girder	20–20	
	4 + 546–4 + 626	5	RC box girder	20–20–20–20	
	4 + 626–4 + 716	2	Arch bridge	90	
	4 + 716–4 + 756	3	RC box girder	20–20	
V	4 + 844–4 + 876	2	PC I-girder	31	31
VI*	5 + 181–5 + 366	7	PC I-girder	27–29–35–29–29–27	176

\*The bridge has already been finished.

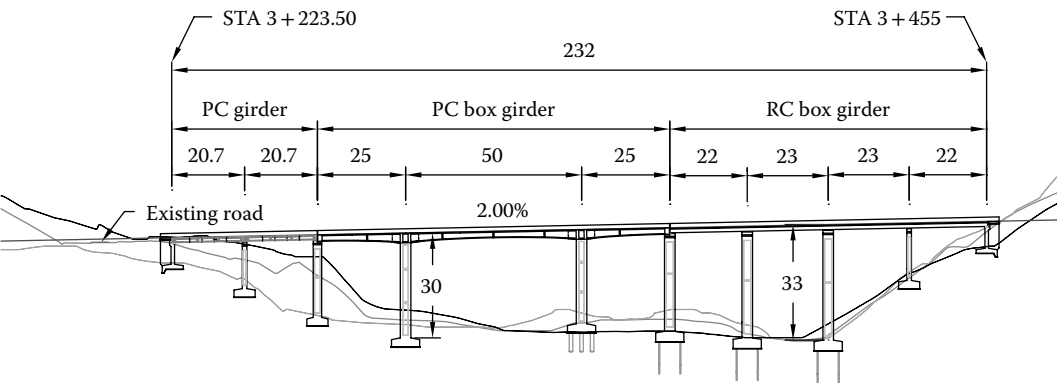


FIGURE 21.96 The Kelok-9 bridge project: Bridge II.

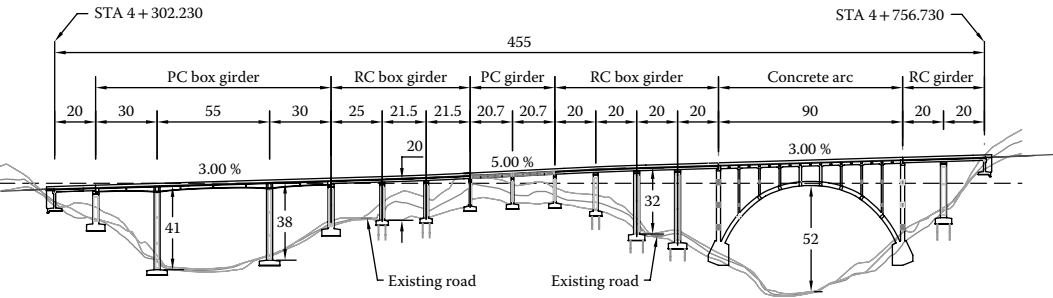


FIGURE 21.97 The Kelok-9 bridge project: Bridge IV.

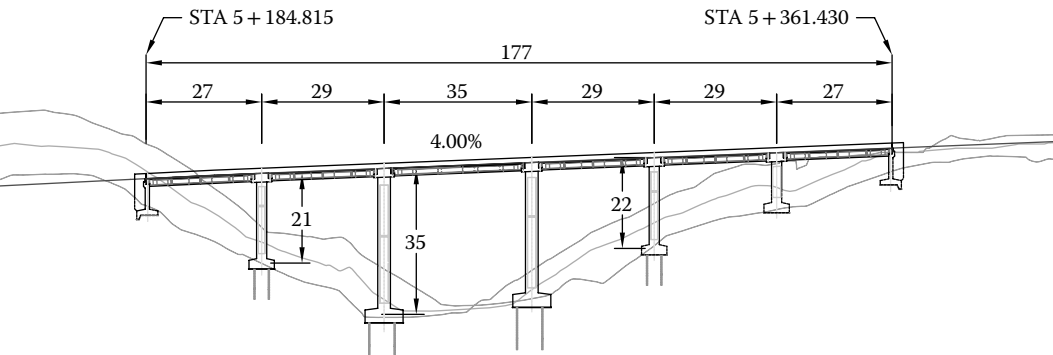


FIGURE 21.98 The Kelok-9 bridge project: Bridge VI.



FIGURE 21.99 Site condition of the Kelok-9 bridge project, West Sumatra.

to enhance the transportation capacity of the North Java Corridor (Figure 21.100). This will provide east–west linkage in northern Java Island to reduce traffic congestion and thereby improve the climate in the Java region. The project includes the construction of flyovers, which will carry both road and railway traffic at six intersections along the North Java Corridor and its alternative routes: Merak, Balaraja, Nagreg, Gebang, Peterongan, and Tanggulangin. In this flyover project, prestressed steel or concrete bridges will be used, where the shapes and lengths will be adapted to the conditions and needs of each location. The quantitative information on the bridges in the project plan can be seen in the Table 21.8.

For the section of the flyover at Tanggulangin, the details are not available yet. However, it is already known that its location is in East Java so that it is relatively close to the Peterongan flyover. The Merak and Balaraja flyovers constitute the part of the road segment that connects Merak Port and Jakarta, which carries vehicles from the island of Sumatra to Java Island. The vehicles that generally dominate are those for transporting goods. The Nagrek flyover over the railway line is located in the road segment from Bandung to Malangbong, the part of the road that is often referred to as the “Southern Route” to get to Central Java. The road segments that pass through the northern coast of Java are the national roads connecting Banten, West Java, Central Java, and East Java.

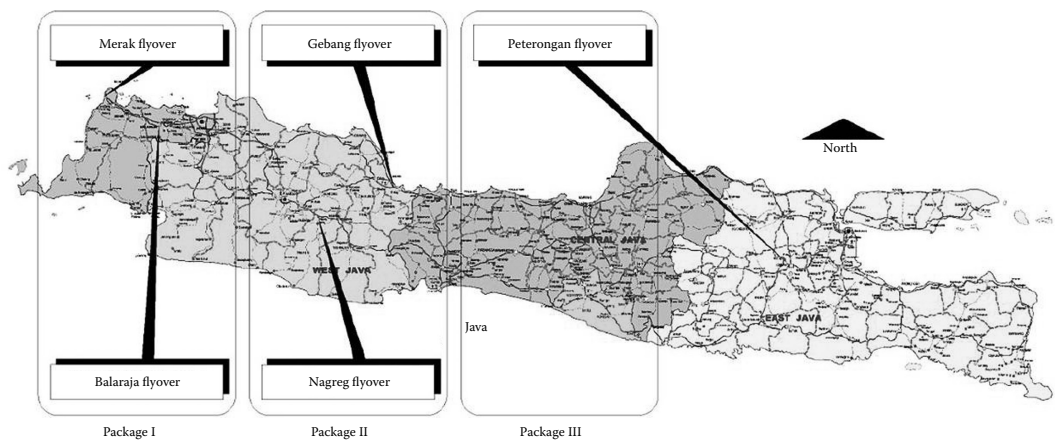


FIGURE 21.100 The location of the flyover of the North Java corridor project.

TABLE 21.8 Flyover Bridges of the North Java Corridor Project

Flyover	Width (m)	Length (m)		
		Total	Steel	Concrete
Merak (Pulorida side)	6.75	285	125	160
Merak (Jakarta side)	9	60	–	60
Merak (terminal exit)	7	70	60	110
Balaraja	13	221	81	140
Nagrek	13	224	104	120
Gebang	9	385	225	160
Peterongan	13	262	82	180
Tanggulangin	13	200	100	100
Total		1807	777	1030

## 21.9.2 Island-Crossing Bridges

In a speech delivered at the Bandung Institute of Technology (ITB) in 1960, Professor Ir. R. Sedyatmo proposed the idea of permanently connecting the islands of the archipelago. At that time the main topic was a fixed crossing system between Java and Sumatra across the Sunda Strait. Further discussions were also developing as to how connect the island of Java, which is regarded as the center, with the large islands nearby, notably the islands of Bali and Madura.

In 1986, the government of Indonesia launched the Three-Island Linkage project (Tri Nusa Bima Sakti), a study on the connection of the three islands of Bali, Java, and Sumatra, conducted by the Agency for the Assessment and Application of Technology (BPPT) and the Department of Public Works. The purpose of the study was to find the most suitable fixed crossing system between the three islands, whether using a bridge or tunnel system. For the Sunda Strait crossing system between Java and Sumatra, no distinct conclusion was indicated.

Later in 1989, a memorandum of agreement (MoA) between BPPT, the Ministry of Public Works, and the national development planning board of the study was reached, which was later expanded into the “Three-Island Linkage project and main crossing system” to carry out some preliminary studies to connect Sumatra, Java, and Madura/Bali. The implementation of the above studies is discussed next.

### 21.9.2.1 Suramadu Bridge (5438 m), East Java (2009)

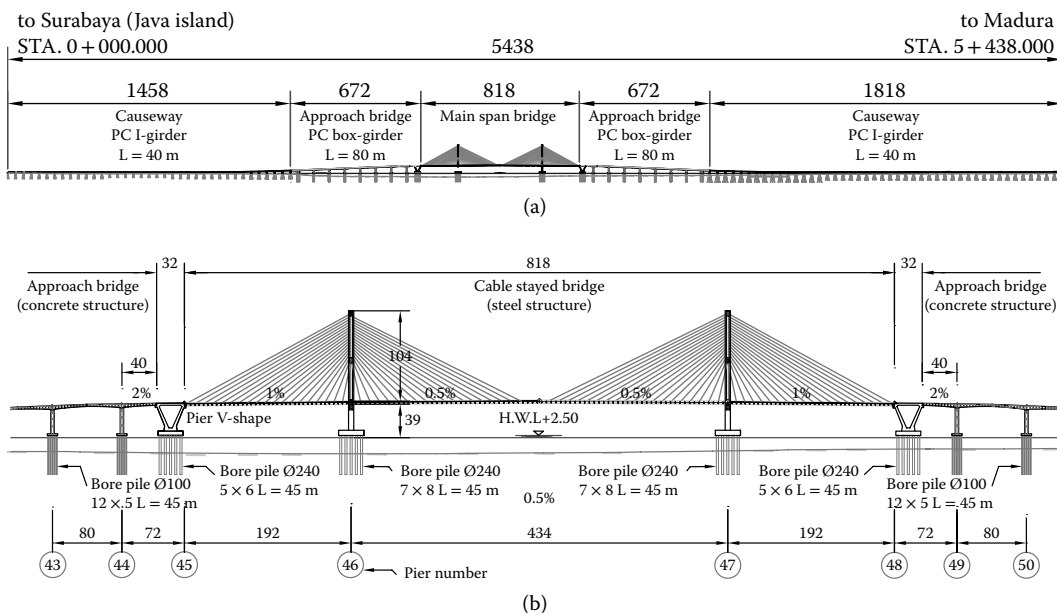
Twenty-three years after the Three-Island Linkage project was launched, only one bridge over the strait of Madura was successfully constructed. Various studies indicated that a bridge over the strait of Madura was the most feasible link to be completed first in terms of funding limitations, engineering capabilities, and experiences. The Suramadu Bridge (Figure 21.101) is not the first inter-island bridge in Indonesia. The first was the Borelang Bridge, a chain of six bridges of various types that connect the islands of Batam, Rempang, and Galang, in the province of Riau Isles, giving the system its name.

The bridge, which spans over the Madura Strait, is located in the northern part of East Java province, and connects Surabaya on the island of Java with Bangkalan on the island of Madura. The name “Suramadu” comes from the special abbreviation of the names of *Surabaya* and *Madura*. The successful construction of the Suramadu Bridge can be considered the most significant collaborative project between China and Indonesia, because China was the donor country and, concurrently, provided the designers as well as the technology transfer and major implementation of the bridge construction. The construction contract was signed for the first time in September 2004, whereas the real construction work began in October 2005, and was completed in June 2009. The total length of the bridge is 5438 m (Figure 21.102a) and the navigation channel is 400 m × 35 m. This is the largest and longest bridge ever built in Indonesia until 2009.



**FIGURE 21.101** (See color insert.) The Suramadu Bridge (5438 m), over the Madura Strait (June 2009).





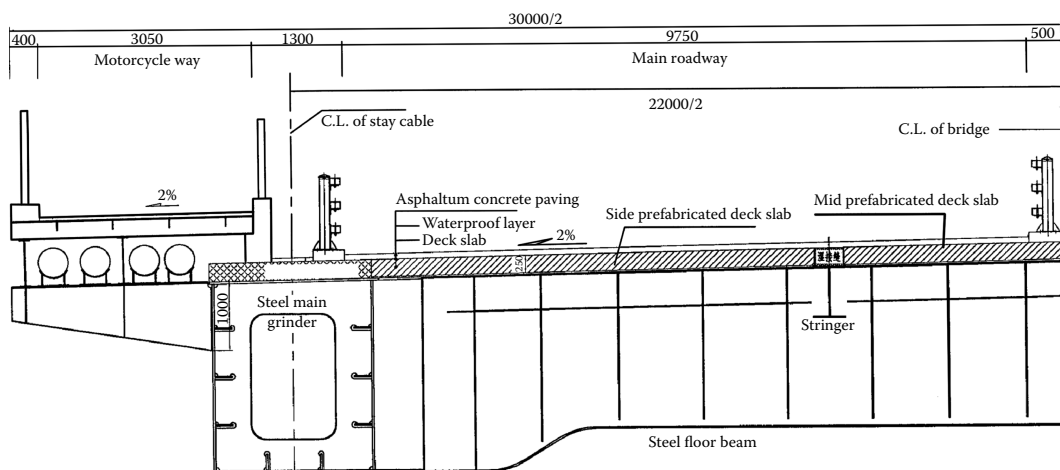
**FIGURE 21.102** Suramadu Bridge, between Java and Madura islands (5438 m): (a) full elevation of the bridge, (b) main bridge span.

Because the design and construction of the bridge was contracted by the Consortium of Chinese Contractors (CCC), Chinese, Indonesian, and British standards were utilized as references for the design (Binli and Yiqian 2005). The Indonesian BMS-92 standard is convenient to provide the design of normal bridges with span lengths of less than 200 m. For the Suramadu Bridge, which should be a special large bridge according to the code, BMS-92 is not commonly applicable. A design life of 100 years is assumed in the Chinese standards, 120 years in the BS5400, and 50 years in the BMS-92. Since a design life of 100 years is specified for the Suramadu Bridge, it was designed as a special bridge. As designated in the main contract, the Suramadu Bridge was mainly designed in accordance with the Chinese standards. Allowing for some special features of this project, some specifications in the Indonesian BMS-92 and British BS5400 would be taken as references for checking the reliability of the superstructure.

In fact, to ensure the technical reliability of the Suramadu Bridge, the results of the CCC design needed to be reviewed separately by an independent and competent bridge consultant. In this case, Cowi of Denmark was chosen. The Indonesian government also formed an expert team under the coordination of the National Road V Implementation Task Force (Balai Besar Pelaksanaan Jalan Nasional V), Directorate General of Highways, Department of Public Works, Republic of Indonesia. The expert team referred to selected specialists who were expert academics considered competent to help monitor the design and implementation stages of the project (Ismail et al. 2009).

The Suramadu Bridge consists of a cable-stayed bridge system as the main span structure with a steel composite girder deck, supported by twin pylons with heights of 146 m. The main span configuration is 192 m + 434 m + 192 m = 818 m (see Figure 21.102b). The approach bridge at each side is a continuous prestressed concrete box girder bridge built by the cantilever method with a length of 40 m + 7 × 80 m + 40 m = 640 m. The main span and approach bridges are connected with V-shaped concrete piers with a span of 32 m.

The steel structures of the main span of the bridge are composed of the steel main girders, steel floor beams, and stringers. In the cross section of the bridge, two steel main girders are arranged at the outer sides and two stringers at the inner sides (Figure 21.103). For a standard segment, the steel floor beams are set every 4 m along the bridge. The connections for every part of the steel structure segment use high-strength bolts (see Figure 21.104). The main span of the bridge is set up in a floating system,



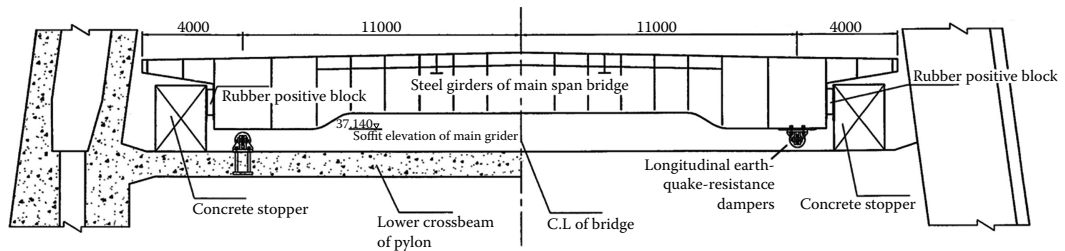
**FIGURE 21.103** Half section of the main bridge span.



**FIGURE 21.104** The segment of the main bridge span after erection.

hanging on a cable to the pylon. The vertical bearings are set only at the side piers. To limit movements along the bridge, longitudinal earthquake-resistant dampers are set at the pylon towers. In the transverse direction, rubber positive blocks are arranged between the main girders and pylon shafts at the pylon, and concrete stoppers are set on the V-shaped piers to restrain the transverse movements at the bridge ends (see [Figure 21.105](#)).

For the process of erection of the steel girder segment of the main bridge span, a special crane was placed at the end of the steel girder. The installation started from the edge (pylon), moving to the center. The crane would then lift the steel girder segment, which was transported from the factory by ship and was finally installed at the end of the bridge (see [Figure 21.106](#)). The cable-stayed construction was then installed, and then the crane moved forward. That was the steel girder assembly implementation progress until finally the two ends of the bridge floor were united. The assembly process of the steel girder of the main bridge span started from the pylon first, from the two directions symmetrically. Because there



**FIGURE 21.105** The floating system of the main bridge span.



**FIGURE 21.106** Typical erection of the steel box girder segments.

were two pylons, four cranes were used in parallel (see [Figure 21.107](#)). Because the steel girder was used after the bolts and the cables were also secure, the structure worked fully.

At the main span of the bridge, a steel girder is used, while some parts of the approach bridge use concrete construction, namely the prestressed concrete segmental cantilever box girder, where the new structure would work fully when the concrete strength has reached a certain age (see [Figure 21.108](#)). The construction of the bridge utilized the balanced cantilever method, while in the beginning, before the ends of the bridge were connected with each other, the bridge behavior during construction was cantilever. Consequently, the cross section of the bridge at the pier was at a greater depth compared with the sectional girder in the center of the span. The cross sections in question can be seen in [Figure 21.109](#).



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The Suramadu Bridge has been operated as a toll road, where the users must pay in advance before they pass the bridge. Nevertheless, the character of the traffic crossing the bridge is interesting because it not only consists of four-wheeled vehicles but also two-wheelers. As a result, dedicated lanes for motorcycles are provided on the outer edge of each side of the bridge, as shown in the Figure 21.110. This is, of course, something new and the first time in Indonesia for such a toll road.

#### 21.9.2.2 Bali Strait Bridge ( $\pm 2$ km), East Java, Bali (Proposal Study)

The Bali Strait Bridge is one of the bridges recommended by the Three-Island Linkage project study. In 1992, there were some private parties who responded: the Scotia International Associates (UK), PT Mitra Trans Balongan (Indonesia), and Brown Beech and Associates Ltd. (UK Consultant). All the three combined themselves to form the Scotia Bali Bridge Co., Ltd. to submit a proposal to the government of Indonesia. In 1996, the minister of public works approved a 1-year study. The result was the third generation of the Bali Strait suspension bridge, designed by Brown Beech & Associates, which was a build-operate-transfer (BOT) proposal submitted to the Department of Public Works by the Scotia Bali Bridge Co., Ltd. The bridge has a total length of 2900 m with a main span of 2300 m and has a six-lane bridge floor (see Figure 21.111). The location of the bridge, as proposed by them, is in a narrow area of the strait of Bali, which has a width of 2 km and is located approximately 6 km to the north of the Ketapang–Gilimanuk ferry crossing area.



FIGURE 21.110 A view of the roadway on the Suramadu Bridge.

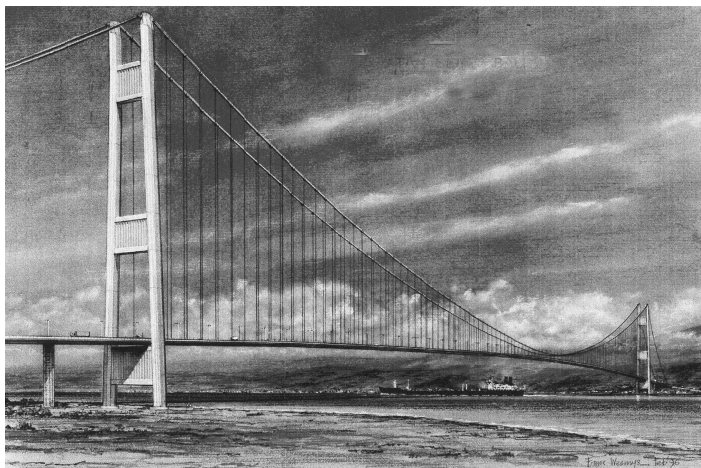


FIGURE 21.111 Proposal of the Bali Strait Bridge.

The plan to construct a bridge which connects Java and Bali will be an attractive infrastructure project in Indonesia. Its presence will increase the accessibility and economic prospects of the two provinces. The island of Bali is rich in its tourist potential, while the island of Java is a supplier for the basic needs of community life in general. However, since the Bali bombings (in 2002 and 2005), which were carried out by people outside the island, the desire to permanently unite the two provinces with the bridge has no longer resonated strongly.

### 21.9.2.3 Sunda Strait Bridge (29 km), West Java, Sumatra (Preliminary Design)

Since the disclosure of the idea to build a connection between Java and Sumatra by Professor Ir. R. Sedyatmo in 1960, there have been several attempts to respond to the idea. In 1986, the government of Indonesia launched the Three-Island Linkage project to study how to connect the three main islands: Sumatra, Java, and Bali. In 1989, there was an additional follow-up study, which included the island of Madura. The study was then known as the “Three-Island Linkage and main crossing” project. Twenty years later, this study finally led to the construction of the Suramadu Bridge (2009). Although some studies have also been conducted on the Sunda Strait, a definite conclusion has not been obtained as to whether the link should be in the form of a tunnel, bridge, or ship.

From 1986 to early 1997 there was no further news about the link. In May 1997, Dr. Ir. Wiratman Wangsadinata submitted a study report to BPPT, entitled “The Sunda Strait crossing and its feasibility as a link between Java and Sumatra.” The study report was the result of an assignment from the state minister of Indonesia for research and technology to study the feasibility of a bridge crossing between Java and Sumatra. This study indicated that a bridge crossing between Java and Sumatra was feasible, provided that the building techniques for an ultra-long-span suspension bridge similar to the strait of Messina crossing were applied.

Professor Wiratman’s proposal was quite attractive because it was supported by conditions which showed that the traffic across the two islands was so high that the current ferry system was not able to meet the growing demands. Even from records in 2002 it was known that more than 19,000 tons of goods per day from Sumatra Island were transported to Java Island through the Lampung Province. Also, more than 25,000 people and 6,000 vehicles, such as trucks, buses, private cars, and motorbikes, passed over the Sunda Strait per day. During the Eid holidays, the number could increase sharply to about 85,000 people and 11,500 vehicles. In these conditions, the capacity of the ferry crossing system was not enough, causing long queues of vehicles and causing extraordinary traffic jams. Consequently, passengers had to wait for hours just to cross the strait. If the ultra-long-span suspension bridge were completed, such terrible situations would not happen.

In May 2005, an idea of building the bridge was supported. PT Wiratman and associates was invited to collaborate with PT Bangungraha Sejahtera Mulia (BSM) to set up a consortium for the infrastructure construction of the Sunda Strait Bridge. Next, the consortium actively lobbied the governor of Banten in 2007, and even the president and the presidential staff in 2008, all of which was positively welcomed. Therefore, in May 2009, PT Wiratman was asked by BSM to carry out a preliminary study on the Sunda Strait Bridge, which was then equipped with bathymetric and topometric surveys (Wiratman 2009). The purpose of this survey was to produce a topographic contour map of the seabed and a topographic profile along the surveyed area.

It will take three more years to conduct the feasibility study before the construction process will begin. The entire project is expected to be completed in 2025. When the bridge is successfully completed, it will be the world’s longest suspension bridge, passing about 50 km across the Sunda Strait from the active Krakatau volcano, traversing 29 km in length.

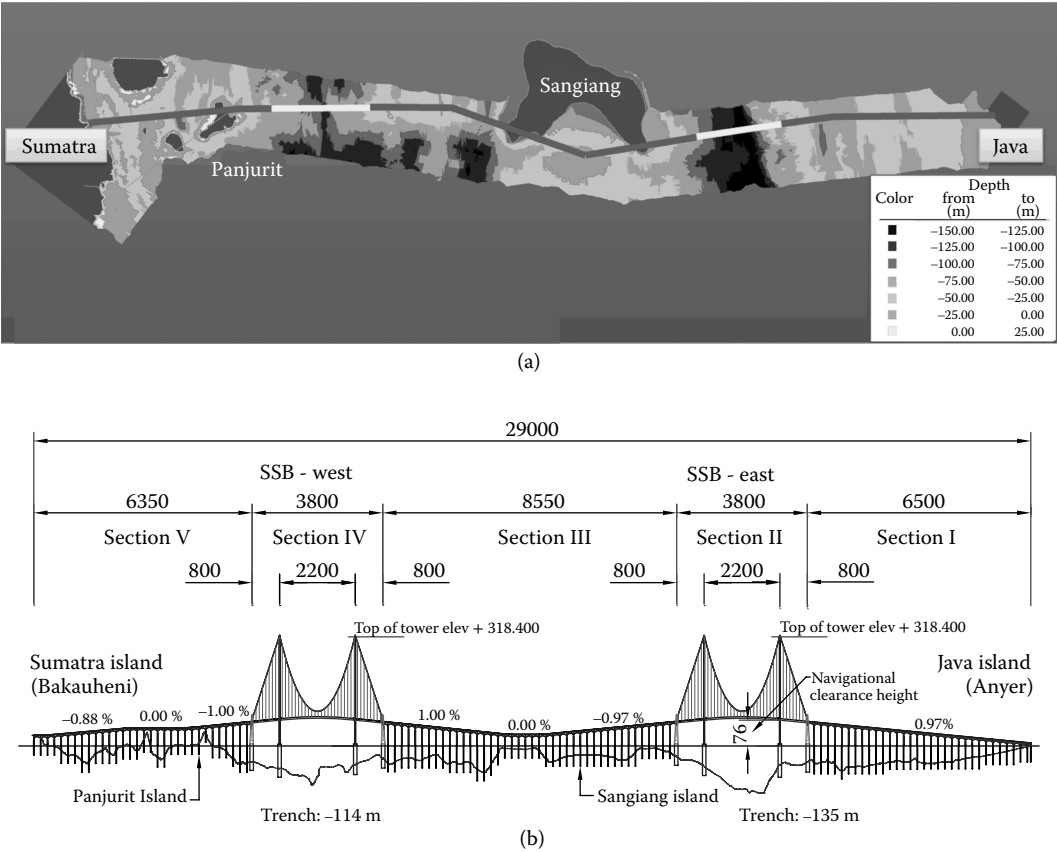
As the bridge is located in the Sunda Strait, which is prone to earthquakes and tsunamis, its construction would include four important phases involving hydrographic, oceanographic, geologic, seismological, climatological, and environmental aspects. Experts say the bridge is technologically feasible but extensive and expensive safety measures are essential to withstand earthquakes. Several quakes



measuring more than 7 on the Richter scale have struck the waters of Sumatra and a stronger quake caused a massive tsunami of the west coast in 2004. According to a senior design consultant, Professor Wiratman Wangsadinata, flexible construction materials would be used to protect the bridge against earthquakes of up to magnitude 9, based on the Messina Strait bridge in Italy. Thus, the Sunda Strait Bridge will use technology of the third generation with the following specific advantages, especially on ultra-long-span suspension bridges: a relatively flexible pylon structure and a very light and aerodynamic multiple box girder. As a result, the bridge will have very small wind-drag forces, be insensitive to flutters, and will respond as required to earthquakes.

According to the study, the Sunda Strait Bridge will cross over Sangiang Island between Java and Sumatra and Panjurit Island near Sumatra, the most suitable locations. The bridges themselves consist of two ultra-long-span suspension bridges to span the two very wide and deep valleys of the Sunda Strait, and the overall bridge length is 29 km. The ultra-long-span suspension bridge near Anyer in the east of the strait and the ultra-long-span suspension bridge near Bakauheni in the west have the same dimensions, which were very advantageous for their design and construction. The five sections of the Sunda Strait Bridge are shown in Figure 21.112, indicating a general arrangement of the bridge elevations. Note that the vertical scale is different from the horizontal scale.

The two ultra-long-span suspension bridges are made up of high-strength steel materials, each with a main span 2200 m in length and two side spans 800 m in length. The ultra-long-span



**FIGURE 21.112** Route of the Sunda Strait Bridge (based on Wiratman’s concept): (a) the islands connected by the bridge plan; (b) the longitudinal section.

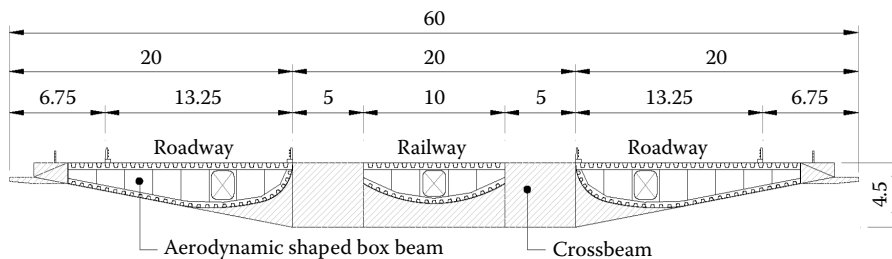


FIGURE 21.113 The ultra-long-span suspension bridge deck (based on Wiratman's concept).

suspension bridge decks are adopted from the concepts of the Messina Strait Bridge, an aerodynamic shaped orthotropic triple box, two carrying roadway traffic and one carrying railway traffic, supported by 4.5 m deep crossbeams spaced at 30 m apart (see Figure 21.113). The deck accommodates six lanes of roadway traffic, one double-track railway, one maintenance path, and a pedestrian way on each side.

The Sunda Strait Bridge, with a total length of 29000 m, is divided into five sections as follows:

Section I: This section consists of 32 balanced cantilever bridges, each of which is 200 m in span length, and 1 transitional balanced cantilever bridge with a span length of 100 m. The total length of Section I is 6500 m.

Section II: This section consists of one ultra-long-span suspension bridge, ULSB East, spanning over a wide and deep sea valley (trough). ULSB East has a main span of 2200 m and two side spans 800 m in length. The total length of Section II is 3800 m.

Section III: These sections consist of 42 balanced cantilever bridges, each of which is 200 m in span length, and 1 transitional balanced cantilever bridge with a span length of 150 m. The total length of Section III is 8550 m.

Section IV: This section consists of one ultra-long-span suspension bridge, ULSB West, spanning over a wide and deep sea valley (trough). ULSB West has a main span of 2200 m and two side spans 800 m in length. The total length of Section IV is 3800 m.

Section V: This section consists of 31 balanced cantilever bridges, each of which is 200 m in span length, and 1 transitional balanced cantilever bridge with a span length of 150 m. The total length of Section V is 6350 m.

The location of the Sunda Strait Bridge is inside the Indonesian Islands Sea Water Channel for international sea vessels; therefore, a minimum navigational clearance height of 75 m is mandatory. This navigational clearance height is taken as the distance measured from the high water level ( $\pm 1$  m from the sea level mean) up to the soffit of the deck at the pylon location. The steel pylons of the ultra-long-span suspension bridge will reach a height of 318.4 m above the sea level mean. This distance takes into account the deck sloping height, navigational clearance height, and a sag-to-span ratio of 1:10. A prefabricated panel with longitudinal stiffeners is adopted for the pylon's cross section. The foundation for each pylon consists of a hollow with a diameter of 100 m and a caisson with a 15 m wall thickness filled with lean concrete.

The ultra-long suspension bridge system used is like that of the suspension bridge of San Francisco's Golden Gate Bridge. However, the Golden Gate Bridge is a suspension bridge of the first generation, whereas the Sunda Strait Bridge uses third generation technology, almost similar to the Xihoumen Bridge in China, except that the designer only uses a twin box concept without the railway lines. Figure 21.114 shows an artist's impression of the completed Sunda Strait Bridge. Notice that Krakatoa Island can be seen in the distance, and with a clearance height of  $\pm 76$  m above sea level, the merchant vessels which pass through will seem small.



**FIGURE 21.114** An artist's impression of the Sunda Strait Bridge (based on Wiratman's concept).

The plan sustainability of the Sunda Strait Bridge construction has become a powerful issue in the Indonesian media, especially based on the fact that the Suramadu Bridge, in East Java, which is Indonesia's longest bridge (5438 m) is now open to the public. Therefore, the government is confident enough to include it as a project on the Blue Book of the National Development Planning Agency (Bappenas).

The team for the national development of the Sunda Strait Bridge was established under presidential decree (Ref. No. 39 of 2009), dated December 28, 2009. This team is cochaired by the coordinating minister for economic affairs and deputy chairman of the coordinating minister for political, legal, and security affairs. The executive chiefs are the minister of public works and deputy executive chief of the Ministry of Transportation. Although it is still a dream, it is certain that the majority of the Indonesian people hope that the construction of the Sunda Strait ultra-long-span suspension bridge can really come true in the future. Only time will tell whether it is just a dream or a reality.

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