

The Second PENANG BRIDGE

A Glorious Chapter in
Modern Bridge Engineering



HEC 中国港湾
CHINA HARBOUR

Chief Editors *Dr. Robin Sham*
Ir. Fang Zhenru
Ir. Meng Fanchao

中国建筑工业出版社

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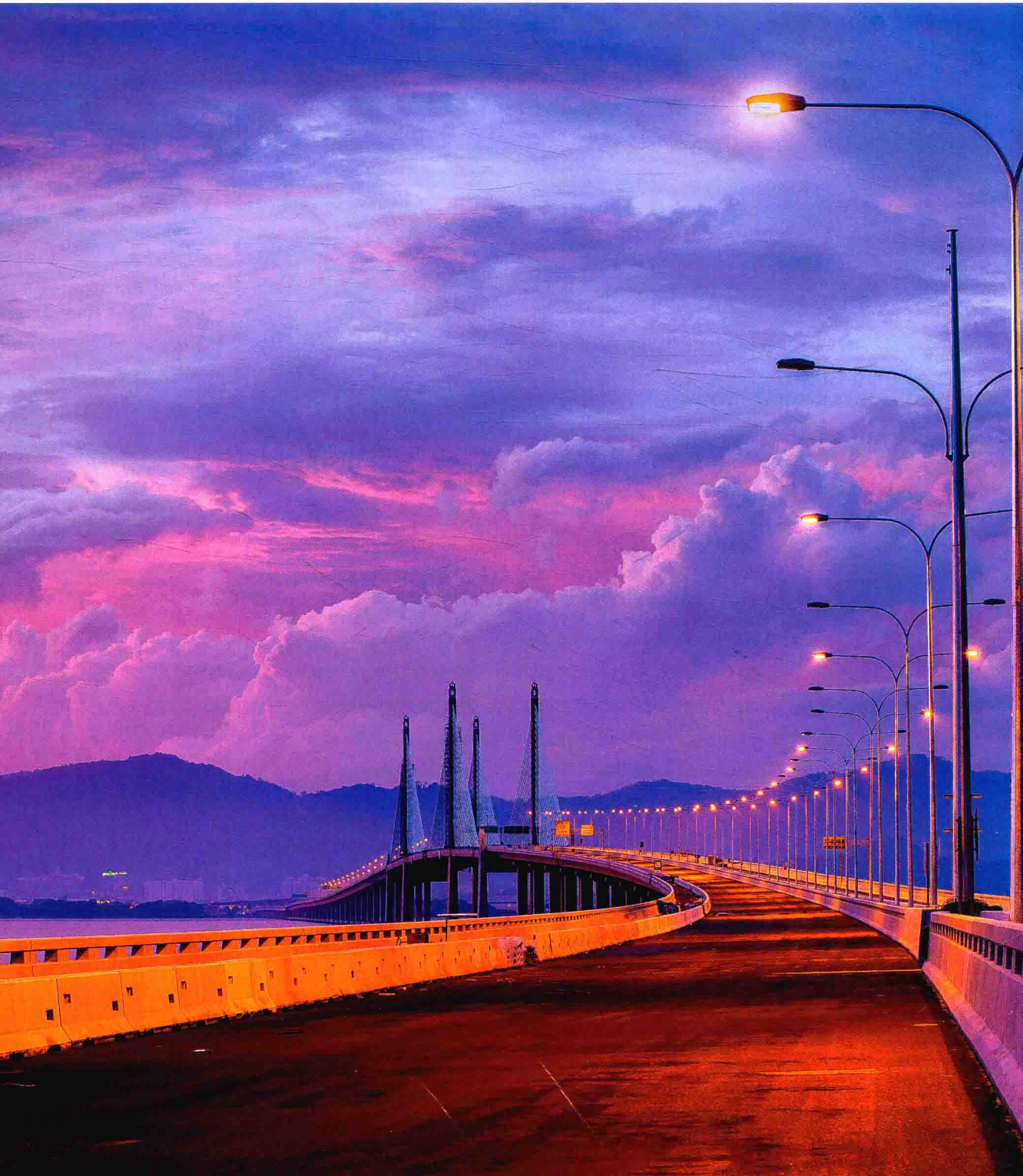
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Foreword



MINISTRY OF WORKS, MALAYSIA

FOREWORD BY THE MINISTER

The official opening of the *Sultan Abdul Halim Muadzam Shah Bridge* or the Second Penang Bridge in 2014 is a memorable event in Malaysian history. Acknowledged as the longest bridge in Malaysia as well as in Southeast Asia, indeed, the bridge is a source of pride for all Malaysians.

Aimed at easing traffic flow in the rapidly industrialising northern state of Penang as well as to spur economic growth in the Northern Corridor Economic Region (NCER), the plan to build the Second Penang Bridge was unveiled by Putrajaya under the Ninth Malaysia Plan. By connecting Penang Island to the mainland, it has brought about greater economic activities to Batu Kawan and its surrounding areas, which are benefitting the people as a whole.

The construction of the second bridge in Penang has incorporated both technological innovation and sustainable elements compared to the first bridge opened in 1985. Built to withstand impact caused by earth movements, this bridge incorporates the High Damping Rubber Bearing (HDRB) which provides an effective seismic isolation system.

The Second Penang Bridge Project makes a valuable contribution to modern bridge engineering. Being one of the recent and technologically challenging sea links in the world, this monumental structure is a testament to the high level of dedication, skill and professionalism of the project team.

It is very encouraging to see the friendship and co-operation between Malaysia and China culminating in the success of this project. I look forward to having more successful collaboration between the two nations. In my view, the past and the future are symbolically linked by the accomplishments of this project.

I wish to congratulate the entire project team for all its efforts, leading to the successful completion of the Second Penang Bridge. I also wish to express my appreciation for the technological innovation and standard of quality achieved by China Harbour Engineering Company Ltd and its consultants. It is my hope that the project team will continue to build on its success and achieve greater success in further.

Thank you



A handwritten signature in black ink, which appears to be 'Fadillah'.

Dato' Sri Haji Fadillah Haji Yusof
Minister of Works, Malaysia

JAMBATAN KEDUA SDN. BHD. (JKSB)

FOREWORD BY THE MANAGING DIRECTOR

We consider it as a great honour to have worked on the Second Penang Bridge project, and contributing to its successful completion. This is an honour that comes with enormous challenges and immense responsibilities.

Our guiding principle has been a staunch commitment to project delivery on time, within budget and to high quality. By any standard, these objectives have been well accomplished. I have no hesitation in attributing the success to a combination of project management flair and technical excellence of the project team.

The design and construction of the Second Penang Bridge have indeed drawn on some of the very best techniques modern bridge engineering can offer. Many times in the project, recalcitrant problems were encountered. If a resolution did not exist, it would have to be invented by the team. Extreme difficulties were dissolved by teamwork and ingenuity. I am deeply appreciative of the dedication and commitment of the CHEC construction team and its consultants HPDI and AECOM.

The project has been delivered to a stringent set of international standards and specifications, and again due credit has to be given to all those involved.

If I were to measure success purely on results and not merely on efforts, I would still have rated the Second Penang Bridge as one of the most significant sea crossing projects in modern times. Of course there has never been one moment that I think results can be achieved without determined efforts.

I hope this book provides you with an insight into the design and construction of this 24 kilometre-long sea link, and into the modern history of international bridge engineering in the making.

A handwritten signature in black ink, which appears to be 'Ismail Bin Mohamed Taib'.

Dato' Ir. Dr. Ismail Bin Mohamed Taib

Managing Director, Jambatan Kedua Sdn. Bhd.

CHINA HARBOUR ENGINEERING COMPANY LTD. (CHEC)

FOREWORD BY THE CHAIRMAN OF THE BOARD

As the longest strait-crossing bridge after completion in Southeast Asia and one of the most striking structures on this planet, the Second Penang Bridge in Malaysia has been successfully delivered with full expectations by all walks of life from both national and local communities over the years, which has also been seen as one of the greatest triumphal achievements of the nations' holistic plan.

As one of world-renowned international contractors and subsidiary of China Communications Construction Company Ltd. (CCCC), China Harbour Engineering Company Ltd. (CHEC) has been dedicatedly and comprehensively involved this splendid large-scale project with the Design-Build(DB) contract. CHEC has dramatically helped reshape the landscape to improve local people's quality of life with full awareness and implementation of environmental sustainability.

The design and construction of the Second Penang Bridge has witnessed the incorporations and implementations of innovative and cutting-edge technologies and methodologies, together with numerous engineering and construction challenges. Nevertheless, by close collaborations with our partners, CHEC's project management team has succeeded in managing the project with sound delivery on time, quality, safety and etc. Meanwhile, the invaluable experiences attained and shared from the project will absolutely benefit not only the parties involved but also the whole industry.

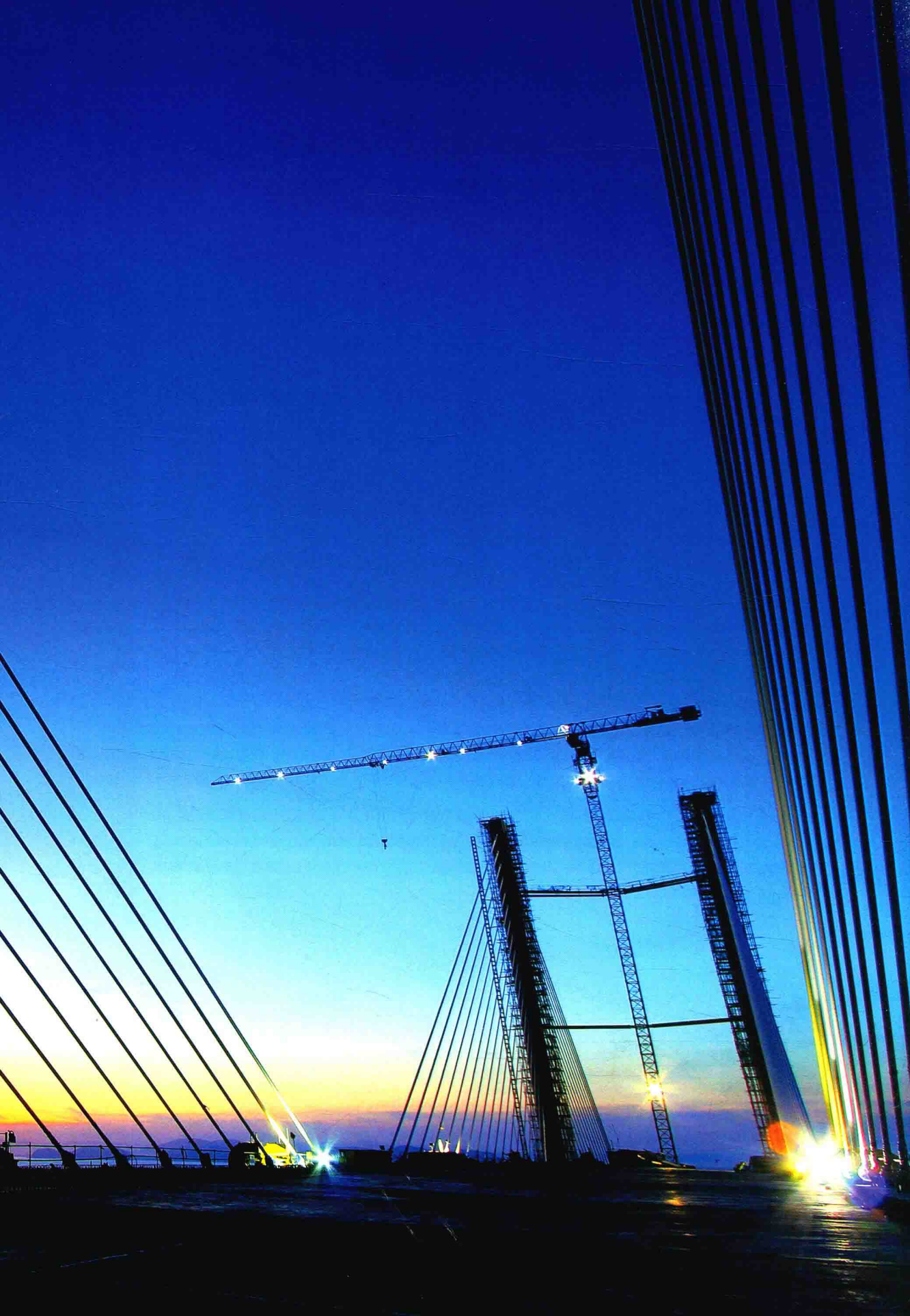
Last but not least, we would like to extend our grateful and sincere thanks to JKSB, LLM, relevant Malaysian Authorities, our partners for all your kind assistance and support. CHEC's growth has been accompanied by your kindness and friendship.



A stylized, handwritten signature in black ink, consisting of several fluid, connected strokes.

Mr. Sun Ziyu

*Vice President & Chief Engineer, China Communication Construction Company Ltd.(CCCC)
Former Chairman of the Board, China Harbour Engineering Company Ltd. (CHEC)*



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01 Introduction



PROLOGUE A MODERN SEA CROSSING

The Second Penang Bridge is the longest sea crossing in Southeast Asia and is one of the largest civil engineering undertakings in the past 20 years in the region. The completion of Second Penang Bridge has accomplished a significant milestone in modern history. The project is a catalyst for further economic expansion in Malaysia, being the top-priority project in the Ninth Malaysia Plan. The project is also one of the most recent and largest sea crossing constructions in the international bridge industry. The Second Penang Bridge project has pioneered new methods in design and construction and has acquired invaluable experience. This book distills the salient endeavours in the bridge design and construction of Contract Package 1 by China Harbour Engineering Company Limited (CHEC), to provide an insight into the gravitas of the achievements. The book pays tribute to the extraordinary accomplishments of the design and construction teams in one of the most significant human endeavours in this century.

IN THE BEGINNING

Penang is Malaysia's second largest city, and Penang Airport is the second largest airport in the country, after Kuala Lumpur International Airport. At the north of Penang Island, there is a natural harbour which is one of the largest in Malaysia. Penang is not only a regional but also an international centre for industry, commerce and tourism. In the past decade, Penang Island's economic development has been rapid and it is one of the fastest growing states in Malaysia. It is forecasted that the GDP of Penang in 2020 will be triple that of 2000.

The existing Penang Bridge is a high standard crossing which links Penang Island with the Malaysia Peninsula. Since the opening of the Penang Bridge in 1985, traffic has continued to grow and the current flow is up to 98,000 vehicles per day, reaching saturation level at peak hours. With the rapid increase of vehicles crossing the bridge, the current traffic conditions are often intolerable. The vehicular traffic crossing the Penang Strait is expected to reach 182,400 vehicles per day by 2020, exceeding the capacity of the existing Penang Bridge and ferry service. In order not to inhibit the economic development of Penang State, traffic demand must be tackled in a safe and well-managed manner and the construction of a second crossing was judged to be the top priority.

Therefore, the Malaysian Government decided to build the Second Penang Bridge in order to promote the development of Penang and also to help relieve traffic congestion in urban areas.

HSS Intergrated Sdn. Bhd. and Yachiyo Engineering Co. Ltd were commissioned by the Kementerian Kerjaraya (Ministry of Highway Planning in Malaysia) to carry out an engineering feasibility study for the Penang Second Bridge, which was completed by August 2002. In early 2003, China Highway Planning and Design Institute Co., Ltd. (HPDI) was appointed to prepare a conceptual design for the Second Penang Bridge.

The Second Penang Bridge is the largest collaborative project between Malaysia and China. The Chinese government preferential credit agreement was completed in July 2007. The Marine portion of the Second Penang Bridge was divided into two packages. Contract Package 1 was undertaken by CHEC Construction(M) Sdn. Bhd., a local subsidiary company of CHEC. CHEC in turn belongs to its parent company of China Communications Construction Company Limited (CCCC). Contract Package 2 was undertaken by UEM Builders Bhd. The ancillary works for the crossing and land-based works were undertaken in seven packages (Contract Packages 3A to 3G).

On 26 April 2010, Jambatan Kedua Sdn. Bhd. (JKSB) and CHEC formally signed the Second Penang Bridge Package 1 design and build contract in Kuala Lumpur, at a contract sum of Malaysian Ringgit 2.2 billion (approximately US\$674 million). This marked a significant milestone of this project, and a new era in the history of modern bridge engineering. HPDI and AECOM are the main consultants to CHEC, working closely together in an extremely challenging project. They are both being key players in the project and dedicated contributors to its successful completion.



The Second Penang Bridge Location Plan

ROUTE OPTIONS

An understanding of the route planning and selection will prove interesting and help gain a good perspective of the project. In the feasibility study, three alignment options were proposed for the Second Penang Bridge.

Option-1, Northern Route –

Connecting the Bagan Jermal of Penang Outer Ring Road and the Bagan Ajam of Butterworth Outer Ring Road on the mainland side. The total length of the alignment is 9.2km, including of a 2.1km tunnel. The effective traffic relief with this alignment would depend on the full implementation of the construction of Penang Outer Ring Road and the Butterworth Outer Ring Road.

Option-2, Mid-Channel Alignment –

Connecting the commercial district in Georgetown and the Butterworth-Kulim Highway on the mainland side. The total length of the alignment is 8.0km, including a 2.6km tunnel. The traffic relief with this alignment would depend on the opening of Jelutong Highway.

Option-3, Southern Route –

Connecting the Bayan Lepas Highway on the Penang Island and Hujung Bukit (or Batu Kawan) in the mainland. The total length of the alignment is approximately 22km, directly linking to the North-South Expressway on the mainland side.

On 18 October 2001, the Malaysian Government adopted Option-3, the Southern Route and a bridge scheme. There were five alignment options on the mainland side for comparison. On 4 January 2002, the Government decided to adopt alignment Route C from Bayan Lepas to Batu Kawan. The selection of alignment Route C was to coordinate with the Batu Kawan's regional planning and development by the Penang Development Corporation.

PROJECT OVERVIEW BRIDGE SITING AND ROAD ALIGNMENTS

The bridge alignments proposed in the feasibility study were optimized by adopting an S-curve for the horizontal alignment and circular curves for the vertical alignment, to improve on bridge aesthetics and riding comfort.

The Second Penang Bridge links the existing Bayan Lepas Expressway at Batu Maung on Penang Island, across the Straits of Penang to Batu Kawan and subsequently connects to the North-South expressway on the mainland. The total length of the sea crossing is some 24km, with the marine structures being 16.9km long.



Work Package Layout

HYDROLOGICAL CONDITIONS

The Malaysian Admiralty adopts the Admiralty Chart Datum (ACD) or National Geodetic Vertical Datum (NGVD). The NGVD at Butterworth (mainland side) was adopted in the design elevation, where an elevation in ACD is equal to a corresponding elevation in NGVD plus 1.72m.

There is a deep water area near to the Penang island side and also towards the mainland side of the bridge site. On the Penang Island side, the water depth exceeds 8m, in a region extending to about 2.5km, and the maximum seabed level is 11.9m (NGVD). On the mainland side, the water depth exceeds 4m, in a region extending to about 2km, and the maximum seabed level is 9.6m (NGVD). The remaining area is relatively shallow, and the average seabed level is between 2.3m to 3.0m (NGVD). Part of the shallow seabed near to the mainland is exposed.

ENGINEERING GEOLOGY

The geological strata at the bridge site are typically of Quaternary horizons and granite layers. The bedrock level is rather deep.

The granite layer which intruded in the Mesozoic era and the Quaternary horizons is deposited in the Holocene and Pleistocene epoch and is composed mainly of silt, silty clay, sandy clay, and fine to coarse grained silty sand with shells in the surface layer.

CONTRACT PACKAGES

The works involved the following Contract Packages:

Package 1 - Main Navigation Spans and the Substructure and Foundation Works of the Approach Spans

Package 2 - Superstructure Works of the Approach Spans

Package 3A - Batu Maung Interchange.

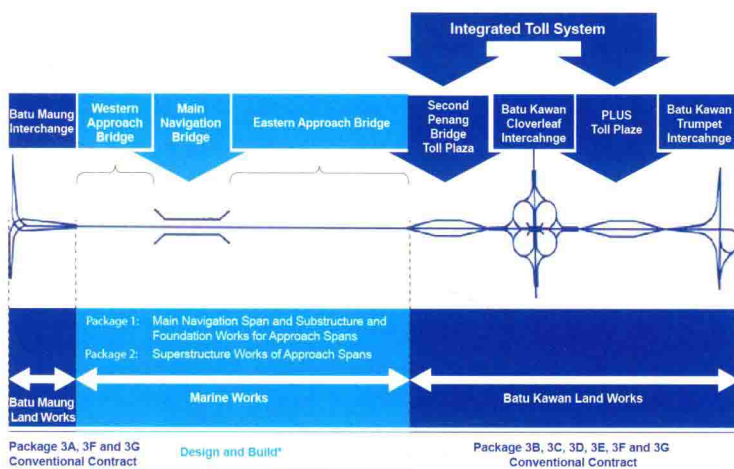
- Package 3B - Batu Kawan Expressway.
- Package 3C - Batu Kawan Trumpet Interchange.
- Package 3D - Toll Plaza, Administration Building and Related Works.
- Package 3E - Toll Collection System (TCS).
- Package 3F - Traffic Control & Surveillance System (TCSS).
- Package 3G: (Mechanical and Electrical Works for P3A and P3C), including street Lighting, floodlight and highmast of the Batu Maung Interchange (Package 3A) up to I CH+500 of the expressway and the Batu Kawan Trumpet Interchange (Package 3C).
- Packages 1 and 2 were procured as Design and Build Contracts, while Package 3 was procured in Conventional Contracts.

CHEC'S SCOPE OF WORK - PACKAGE 1

CHEC is responsible for Package 1 which contains the works from Chainage 0+543.46m to Chainage

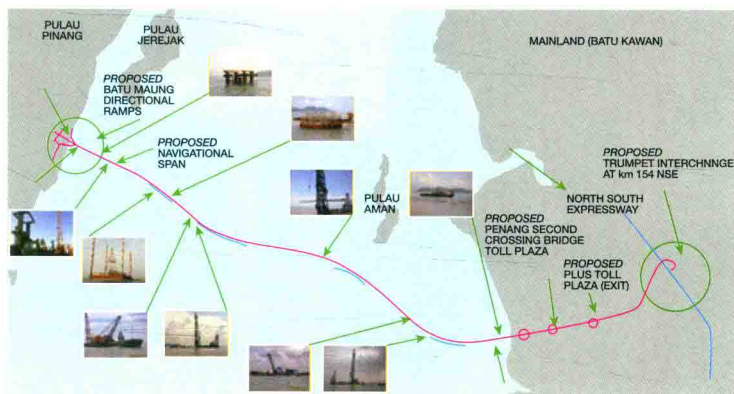
16+913.46m (a total of 16km); comprising -
 The Main Navigation Spans in a span arrangement of 117.5m + 240m + 117.5m (a total of 475m);
 The substructures and foundations of the Approach Spans in a series of 55m span modules (excluding the bridge bearings), together with deck drainage, road pavement, marking and signage, street lighting, architectural lighting, aviation aids and navigation lighting for the main navigation span. Architectural light was provided in the Main Navigations Spans and the Spans on High Piers (P012 - P023 and P028 - P043).

The work in Package 1 posed daunting challenges and is inarguably one of the most comprehensive and demanding in sea crossing construction, relentlessly testing every facet of bridge technology. The ensuing chapters of this book will attempt to provide a concise account of the supreme engineering efforts which underpinned the entire Second Penang Bridge Project.



*A conventional contract 3G is also included for the Main Navigation Spans and Approach Spans.

Work Packages Diagram



Key Construction Works in each Work Packages