JAMBATAN SULTAN ABDUL HALIM MU'ADZAM SHAH
SUSTAINABLE DESIGN, CONSTRUCTION & MAINTENANCE

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KERAJAAN MALAYSIA

LEMBAGA LEBUHRAYA MALAYSIA

JAMBATAN KEDUA SDN. BHD.

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❖ PROJECT INTRODUCTION

- Jambatan Kedua Sdn Bhd (JKSB), a wholly-owned company of the Minister of Finance (MoF Inc.) the concessionaire for the Second Penang Bridge Project (PB2X).
- The bridge project which cost RM4.5 billion is the longest in South-East Asia with a total length of 16.9 km over water.
- The construction of The Second Penang Bridge commenced in November, 2008 and open to traffic on 1st March 2014.
- The project faces various challenges in applying sustainability to both design, construction and maintenance.
- It is also pioneering in Malaysia to be fully designed for seismic load for a 475 year return period earthquake and a 2500 year return period earthquake with "no collapse" criteria.

JKSB was appointed as concessionaire for PB2X in August 2008 for period of 45 years. It is responsible for the project management, design, construction, operation and maintenance.

Overall View of Jambatan Sultan Abdul Halim Mu'adzam Shah, Malaysia (Second Penang Bridge)

Organization set-up
Project Org. Chart (Construction)

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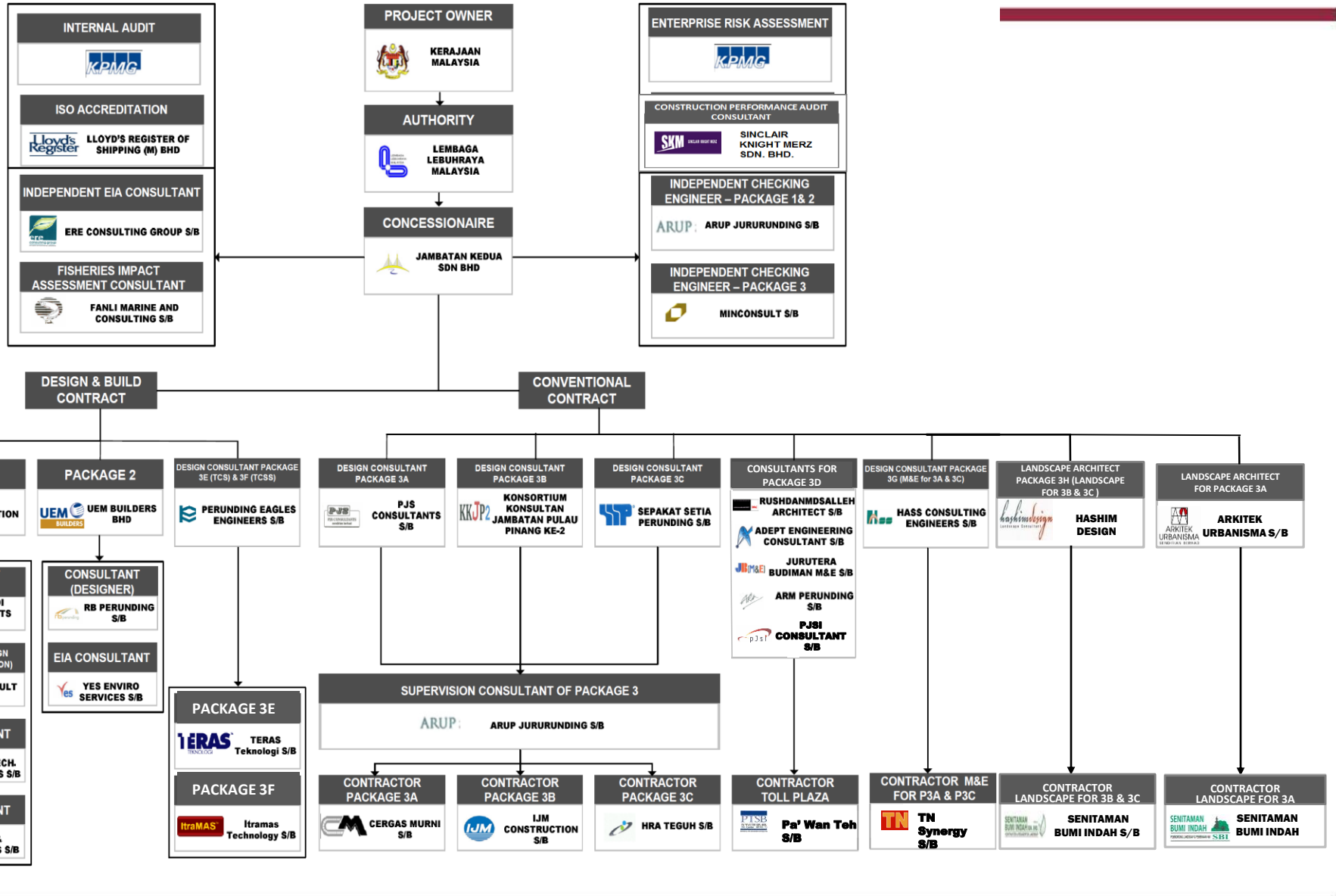
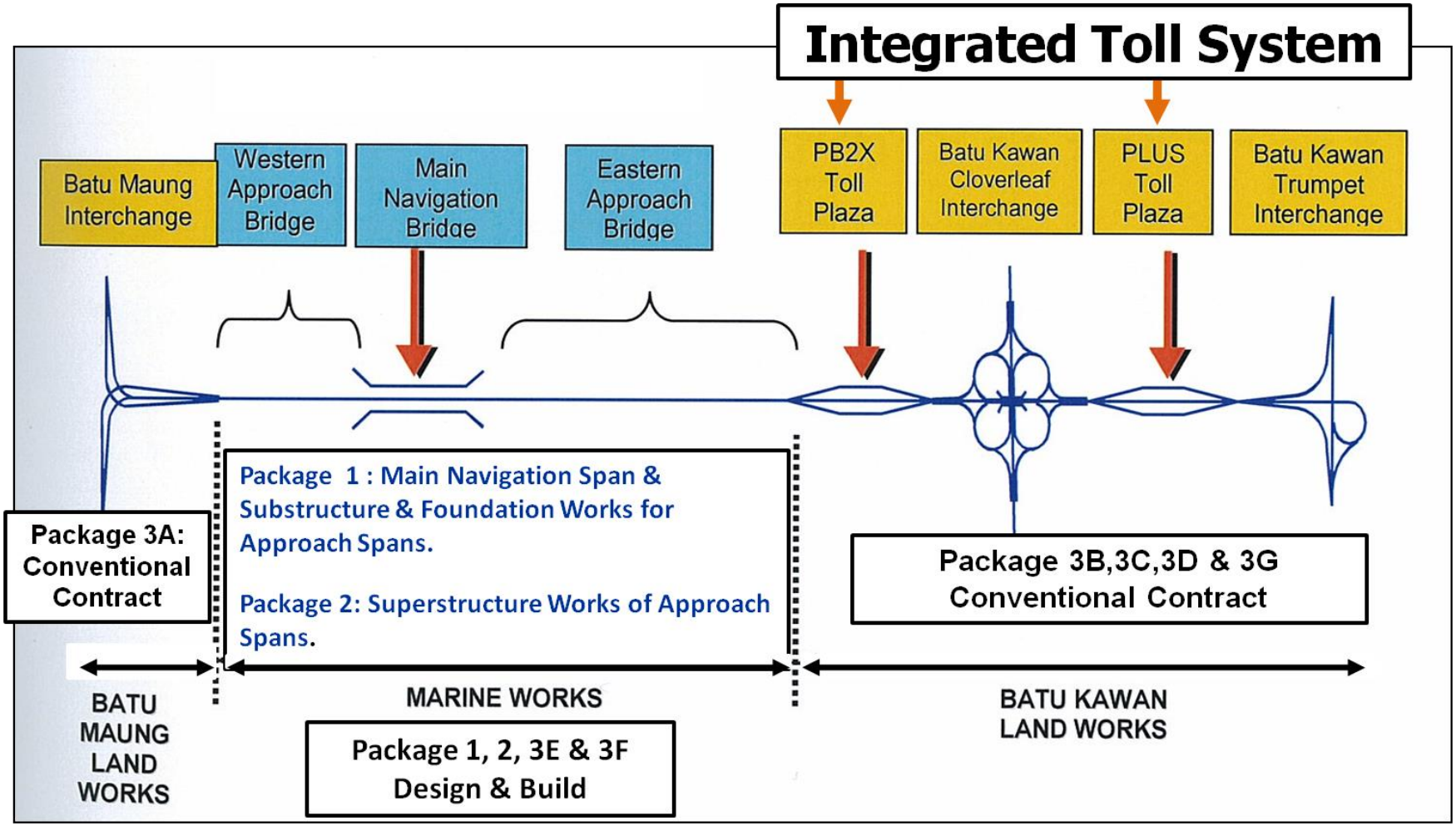


Distribution of Contract Packages

- **PB2X is divided into the following packages :-**



❖ SUSTAINABLE DEVELOPMENT

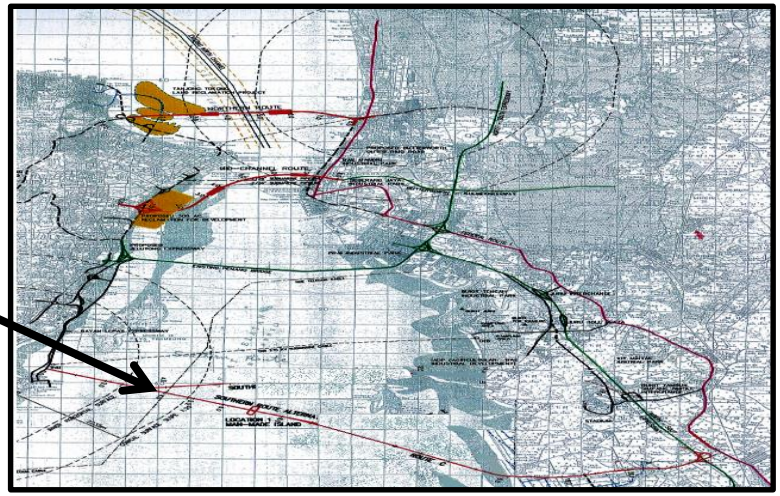
- **JKSB has undertaken the lifecycle management of PB2X where sustainable development and green technology are the key to building the future.**
- **Sustainable development is an enduring balanced approach to social progress, economic activity and environmental responsibility.**
- **The emphasis to a lowest whole life cost is to promote the concept of design for durability. Durability is influenced by the following factors:**
  - **Design and detailing**
  - **Specification of materials used in construction**
  - **Quality of construction**
- **In effort to conserve natural resources and protect the environment, high standards of environment protection were incorporated.**
- **Marine fauna were closely monitored to avoid changes to the sensitive marine environment.**

Planning Stage

- **In the feasibility study, alternative alignments considered were:**
  - **i. The Northern Route (highest IRR)**
  - **ii. The Mid-Channel Route**
  - **iii. The Southern Route**

- **However, the alignment of the Southern route was chosen as to promote socio-economics development in the south that would provide a balanced development across Penang state.**

The Southern Road



Design Stage

- **Most of the bridge sections utilized IBS and prefabricated on land to reduce the amount of time spent at sea and the risks of damaging or polluting the marine environment.**
- **The segmental box girders (SBG) were optimally design for minimum weight and lesser embodied energy by adopting higher reinforcement ratios and less but higher strength concrete .**
- **The use of hybrid pre-stressing encompassing both external and internal pre-stressing increases design economy.**
- **All concrete use of high performance concrete with RCPT < 800 coulombs in 56 days, concrete cover and crack width conforming to latest Eurocode requirement.**

Design Stage (con't)

- Fly ash-based green cement are to be used for low temperature rises of the pile caps and piers to reduce risk of thermal cracking during concreting.
- Use of Dry bottom feed method for the Stone Column installation.
- The geotechnical design of the land expressway complies with 100% primary consolidation and a settlement requirement of 50mm in 20 years.
- Embankment are to be compacted to not less than 98% of the optimum dry density using the modified compaction test.
- The bridge articulation use high density rubber bearings (HDRB) for seismic protection. HDRB use natural rubber, possess high damping properties and lower embodied energy.

Construction Stage

Occupational Safety

- **Safety measures are implemented which include detailed planning of construction activities, safety training and education, inspections by safety officers and health checks.**
- **A well balanced training/ penalty/ award system is utilized to keep all management staff and workers up to date with the latest HSE standards and to ensure their compliance.**
- **Safety features during construction is of prime concern, the recorded Lost Time Accident Rate (LTAR) at Second Penang Bridge is 8.98 Nos./million.Hr on the entire project.**
- **By comparison, one of Europe safest record is accorded to the 12km Oresund Crossing (connecting Sweden & Denmark) recording 11 Nos/million.Hr with 1 death case.**

(Case study 49; Aspect of Sustainability, Oresund Bridge, Sweden & Denmark; January 2009 49cs:V1)

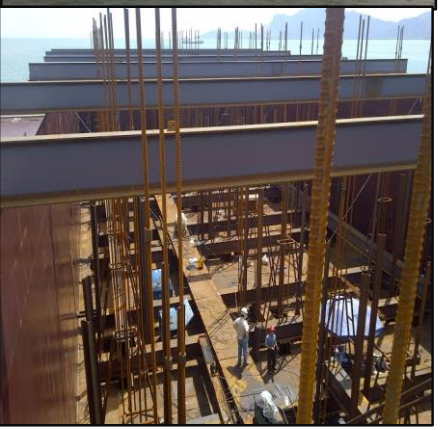
Quality Control

- Stringent quality control in accordance to project specification were enforced to ensure minimal maintenance.
- The best practice was adopted for the bridge construction including equipment selection and working method statements.
- Every 2 months, periodic site audit are done by the Independent Checking Engineer.
- The dredging of the 270m wide construction channel involving 14 million cubic metres of the Great Kra Flats seabed.
- The sludge was disposed off Pulau Kendi by barges installed with satellite tracking, trap door and depth sensor devices.
- PB2X construction use repetitive steel formwork and machineries for casting of 291 nos. pile caps, piers, pylons and 8092 nos. of SBG.
- A monthly environmental monitoring audit is done by and independent EIA consultant. Quarterly fisheries impact assessment for marine and fisheries resources including aquatic environment and aquaculture are also done.

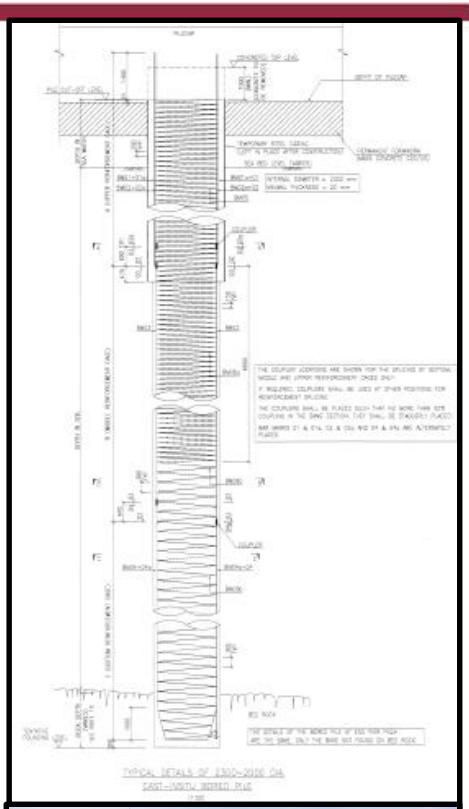
Main Navigation Span

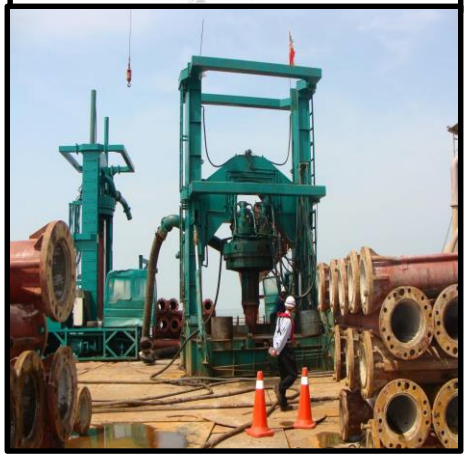
- For the marine portion, Soil Investigation (SI) works were carried out with 205 nos. of boreholes drilled of which 50% were technical boreholes and 50% were common geological boreholes.

BORED PILES



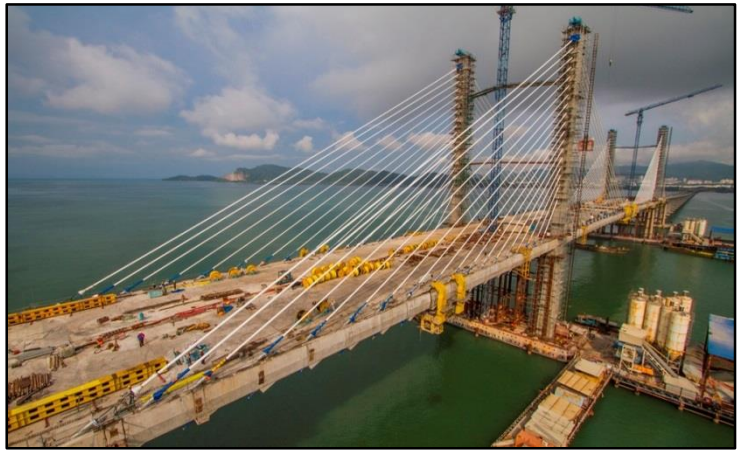
- 2.0m diameter with average of 120m were adopted for Cable-Stayed Bridge.
- Achieved a capacity of 25 MN at 120m depth with 8m socketed in bedrock.
- Reversed Circulation Drilling (RCD) method was adopted and the total time taken is 2 weeks to complete one point for each RCD.
- Bentonite recycled and sludge disposed on land.
- The platform constructed for the bored piling works which after the piling works are lowered down together with the Steel Fender to be reused as a pilecap soffit and side formwork for the Cable-Stayed Bridge pile caps.





Main Span Stay Cables

- The cable stayed bridge utilizes post tensioned concrete beam-and-slab decks. The concrete cross girders are cast in-situ with a 250mm deck slab. At the pylon the deck is built-in into the legs to provide fixed support.
- The semi fan layout stay cables system is designed based on parallel strand system with associated anchorages and deviation saddles of low relaxing high strength steel strands of diameter 15.7mm are arranged symmetrically in 2 planes of 18nos. of cables.
- The typical spacing of the cables at the edge beam and pylon is 6m and 2.525m respectively.
- The cables are symmetrically tensioned and anchored both at the edge beams and at the pylons with cable saddles at the pylon.



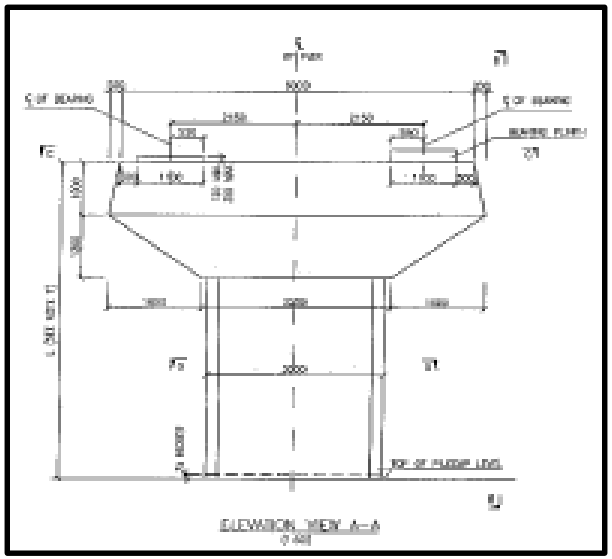
Approach Span

For Approach spans, different types of piling are adopted as stated below:-

Spun Piles	•	**1.0 m diameter with prefabrication length of 65m with no joints were used over 85% of the entire approach spans substructure.**
Steel tubular piles	•	**High load carrying capacity of 1.6 m diameter steel tubular piles with average driven length of 80 m were used in deep water area (adjacent to the Main Navigation Span).**
Bored piles	•	**1.5 m bored of average length 80 m were used at mudflats near to mainland due to difficulty in dredging.**

Pilecap Construction

- Precast Concrete Shells are used as a formwork for the second layer casting and permanently incorporated into the pile cap
- 6 pieces of Precast Concrete Shells are required for each pilecap
- Total of 3,468 nos of Precast Concrete Shell are used
- Precast Concrete Shells are adopted for:
  - Minimisation of temporary works (no cofferdams).
  - Minimisation of insitu works
  - Speed of construction
  - Better surface finishing work



Columns and Crossheads

- Pile caps, Columns and Crossheads are designed as reinforced concrete structures
- Total no of Piers – 289 nos at Approach Spans
- The sections and shapes of the pile caps, columns and crossheads are designed to enhance constructability, optimise cost and still aesthetically pleasing.
- 518 nos. low piers (max height 6m) are cast in one complete operation using reusable steel formwork.
- 60 nos. high piers (>6m to 21.6m) constructed in stages.

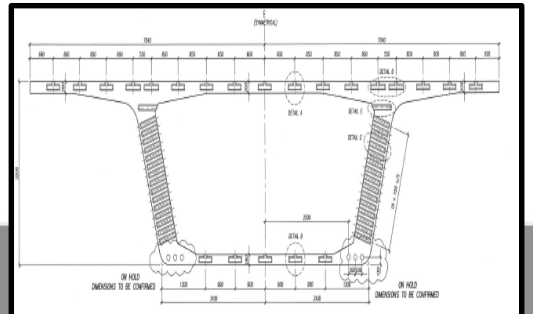
Superstructure at the Approach Span – Segmental Box Girder (SBG)

- **The superstructure of approach spans adopts SBG 14.08m width, 4.0m length and 3.20m depth. Short line casting was selected because it does not require extensive casting facilities, special heavy lifting equipment and storage.**

- **The specific data SBG casting requirements as below:-**

  - Weight of each SBG – 65 - 100 tonnes
  - Early strength – 12 N/mm² (after 12 hours is required for internal, side, and cantilever formwork to stripped)
  - Daily output – 15 nos/day (at peak)
  - Total moulds – 21 moulds

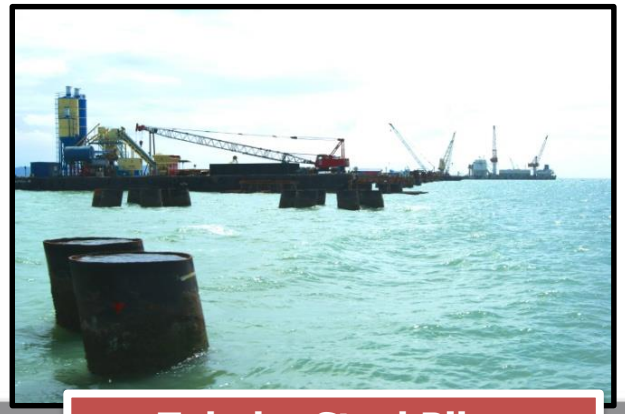
- **The segments are launched to the sea via barges and erected on a span-by-span using overhead self launching girder.**
- **40 nos. complete spans of 14 segments are easily able to be completed within one month period.**



Bridge Durability

The Second Penang Bridge is designed to have an design lifespan of 120 years and service life of 500 years. For this project :

- **Cathodic protection system and special coating are applied to the tubular steel piles for protection against corrosion.**
- **High strength concrete with Ground Granular Blastfurnace Slag (GGBS) and Pulverised Fuel Ash (PFA) are used for the pilecap, pier column, crosshead and SBG. This will prevent sulphate and chloride attack that can cause corrosion to the reinforcement bar.**
- **Concrete cover was designed to latest Eurocode: pilecap (75 mm), pier column (65mm), crosshead (60 mm) to protect the reinforcement bar against corrosion.**



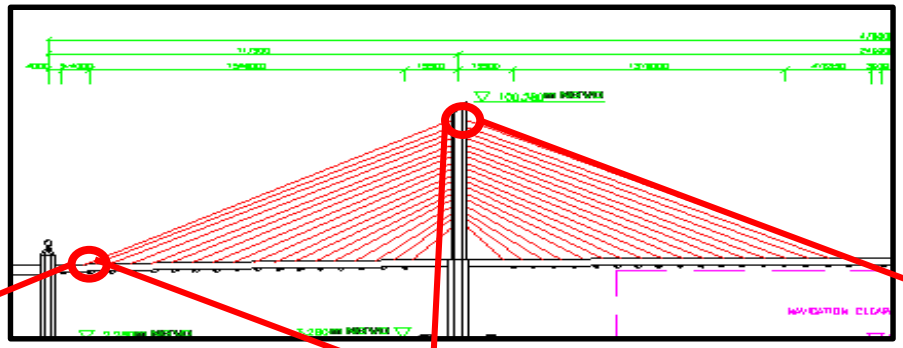
Tubular Steel Piles

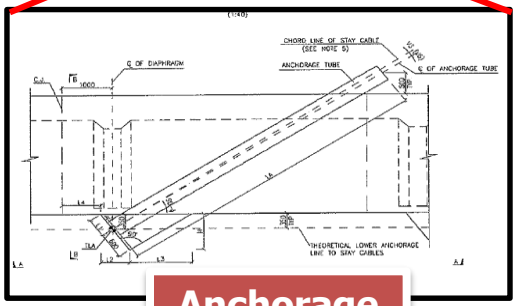
View of Completed Piers

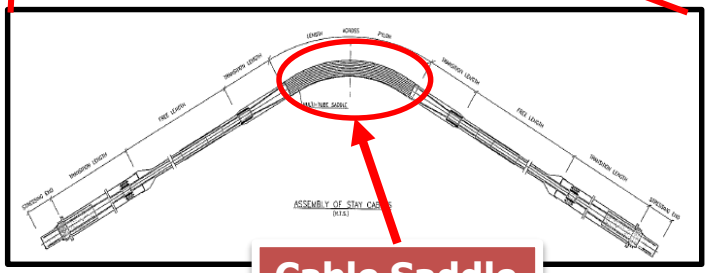
View of Completed SBG

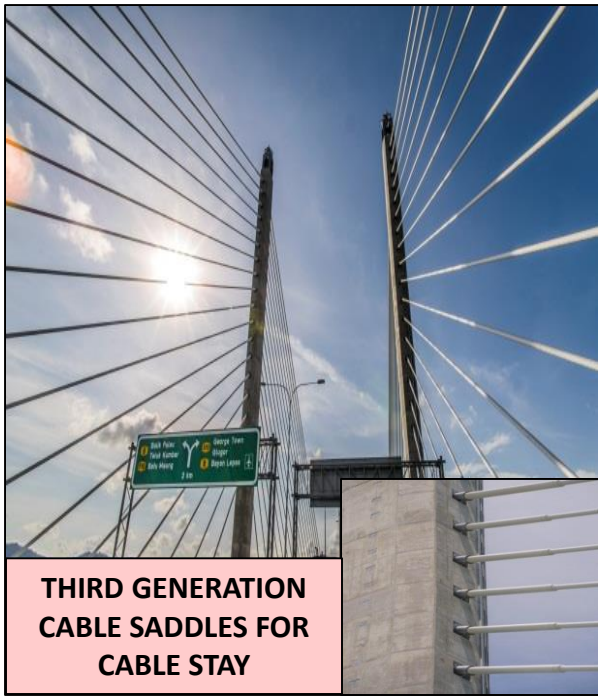
Main Span Stay Cables

- **Design life of stay cables is 60 years and designed to be replaceable. For non-replacement components (such as cable saddle) the design life is 125 years.**
- **For the anchorage components which are accessible for maintenance operation in-situ, the corrosion protection system have a design life of 25 years. After this period of 25 years, if necessary, the protection system will be renewed in-situ at regular intervals of 15 years corresponding to the maintenance operations.**



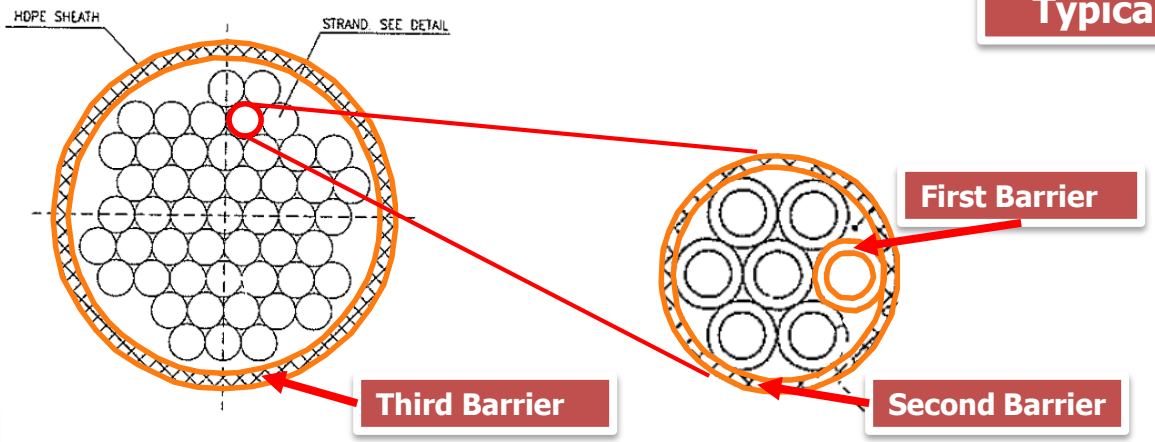




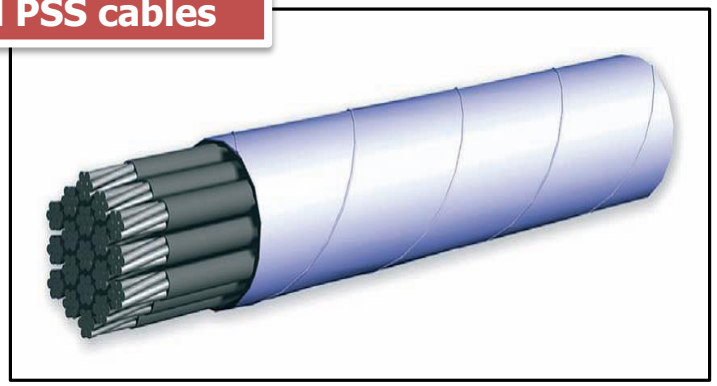


THIRD GENERATION CABLE SADDLES FOR CABLE STAY

Main Span Stay Cables (con't)



Typical PSS cables



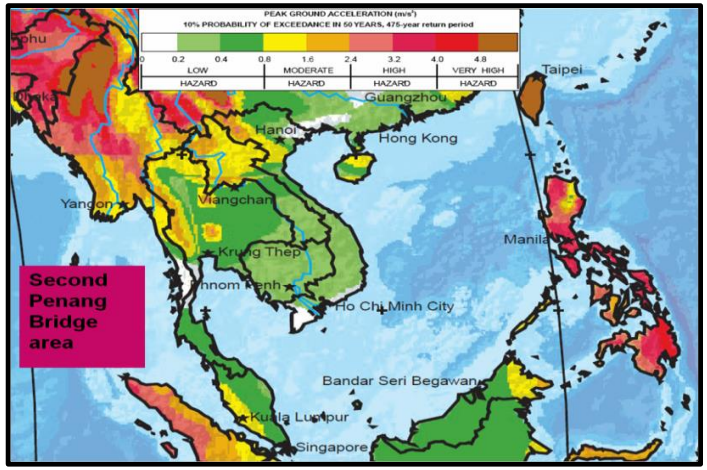
- **Corrosion protection is provided for the main tension elements by using at least 3 complete nested barriers.**
- **The strands are galvanized and individually sheath inside a grease filled HDPE duct and additionally surrounded by external HDPE duct.**
- **The construction cycle for each segment is typically 13 days.**

Design Consideration

Seismic Design Consideration

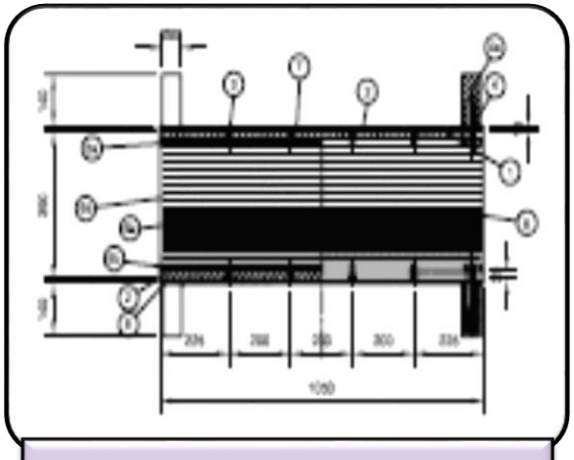
- Second Penang Bridge area is located within the stable Sunda tectonic plate with low seismic activity level. However, this low seismic region is situated about 300-600 km from Sumatran faults which have produced earthquakes with ground motions that are felt in buildings in Kuala Lumpur and Singapore.
- In line with the current design requirement, the Second Penang Bridge is pioneering in Malaysia to be fully designed for seismic load for a 475 year return period earthquake and a 2500 year return period earthquake with 'no collapse' criteria.
- The seismic design was based on the Design Response Spectrum obtained from a Seismic Hazard Assessment Study carried out for the Project.
- The seismic design criteria as below: -

Return Period (Years)	Peak Bedrock Acceleration (PBA)	Peak Response Acceleration (PRA)	Damage Performance Level		
			Marine Bridge	Land Expressway	
				Critical Bridge	Other Bridges
475	0.0555g	0.1773g	Minimal damage	Minimal damage	Repairable damage
2500	0.11g	0.3261g	No collapse		

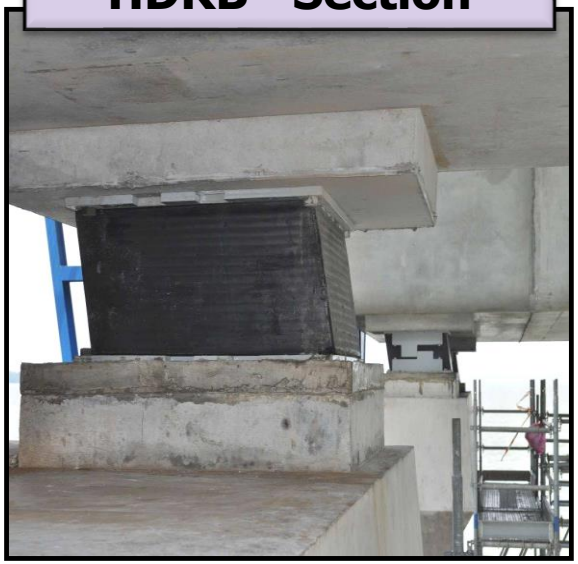


High Damping Rubber Bearing (HDRB)

- During the design review process, the Independent Checking Engineer (ICE) had highlighted that the spun piles at the approach marine bridge by Package 1 Contractor could only safely cater for the 475 year earthquake and found to be overstressed under the 2500 year earthquake event and the piles would experience section failure due to brittleness.
- A resolution between JKSB, ICE and Package 1 designer was reached by changing the bridge articulation via introducing seismic bearing as construction was already at an advanced stage.
- HDRB has the ability to withstand large displacement in bilateral and rotational direction, durable with minimal maintenance as well as utilizing natural rubber available locally
- Package 2 Contractor was instructed to adopt High Damping Rubber Bearings (HDRB) to replace the conventional mechanical pot bearings.
- HDRB was designed by Tun Abdul Razak Research Centre (TARRC) at Brickendonbury, United Kingdom, a laboratory of the Malaysian Rubber Board (MRB).



HDRB –Section



Ship Collision Impact Load

- **The following Ship Collision Impact Loads are adopted in the design following the guidelines in "AASHTO LRFD Bridge Design Specifications 2004". A risk assessment was conducted to verify the following ship collision impact loads to meet with the Government Requirements.**

No.	Location	Design Criteria
1.	Main Navigation Bridge pylons	• Design loads are 27.6 MN • The resistance will be sufficient to withstand impacts from 4,500DWT ship at a speed of 6.7 knots at pylons.
2.	Transition Piers adjacent to the Main Navigation Bridge	• Design loads are 13 MN • The resistance will be sufficient to withstand impacts 4,500DWT ship at speed 3.3knots, and 1,540DWT barge at speed 2 knots.
3.	Approach span piers adjacent to the Transition Piers	• Design loads of 6MN • This resistance will be sufficient to withstand impacts from 4500DWT ship at an impact speed of 1.7 knots, and 1,540DWT hopper barges at a drifting speed of 2 knots.
4.	All other Approach Span piers	• Design loads of 1 MN • This resistance is sufficient to withstand impacts from 1,540DWT empty barges with 200 ton displacement at drifting speeds of 1.5 knots, and impacts from 200 ton displacement small boats at drifting speed of 1.5 knots. • Approach Span pier design resistance is examined in terms of safety level against impact due to 1,540DWT fully laden barge drifting at a speed of 2 knots (1m/s).

Risk Assessment On Fire Hazard

- **The design approach is to allow for the loss of any individual stay cable and not to provide specific fire protection to the cables. It could allow any two cables being removed simultaneously in combination of 10% life loading at ultimate limit state. The Second Penang Bridge is design for the dynamics affect of a sudden cable rupture.**
- **The stay cables are located outside the external parapets of the deck structure. The possibility of impact, vandalism or fire on the stay cables is indeed very low.**
- **Emergency response capability for a fire hazard was incorporated in operational management to ensure lower residual risk.**

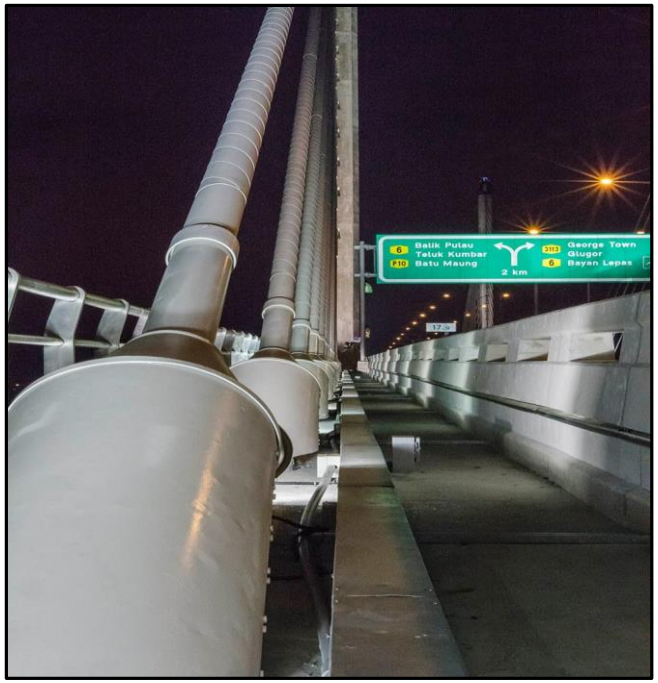
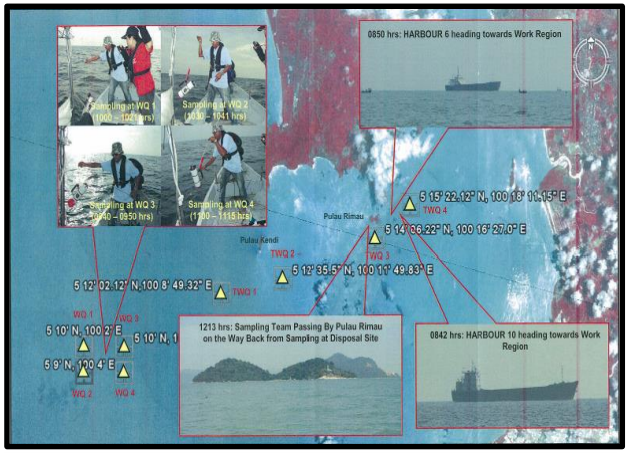


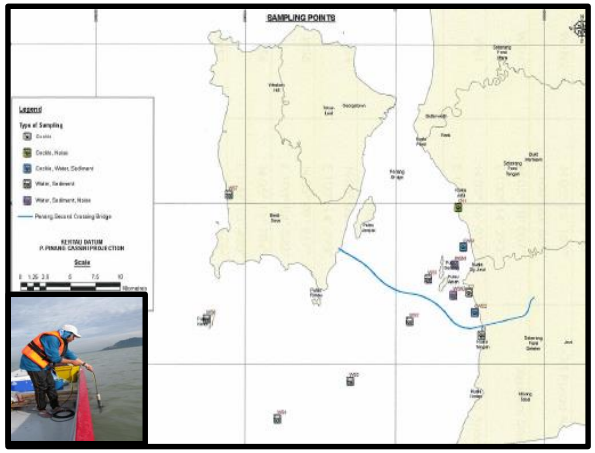
Photo by Rashdan

Environmental Monitoring and Auditing (EMA)

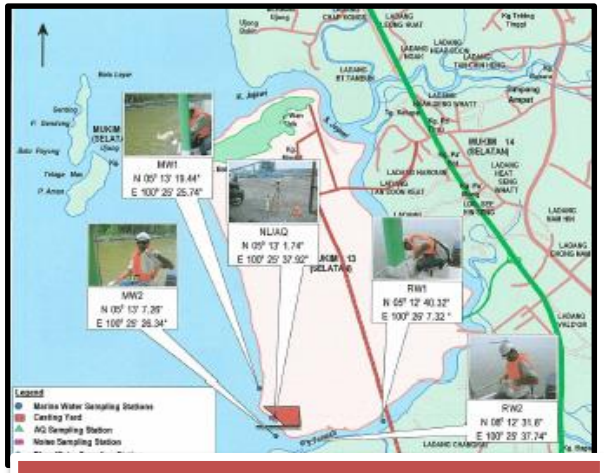
Base line data have been established by the respective Package 1 and 2 contractors as referenced data for EMA for dredging and offshore disposal of spoils, piling, construction machineries and equipment during the Construction Phase of the Penang Second Bridge.



Location of Water Quality Sampling Works

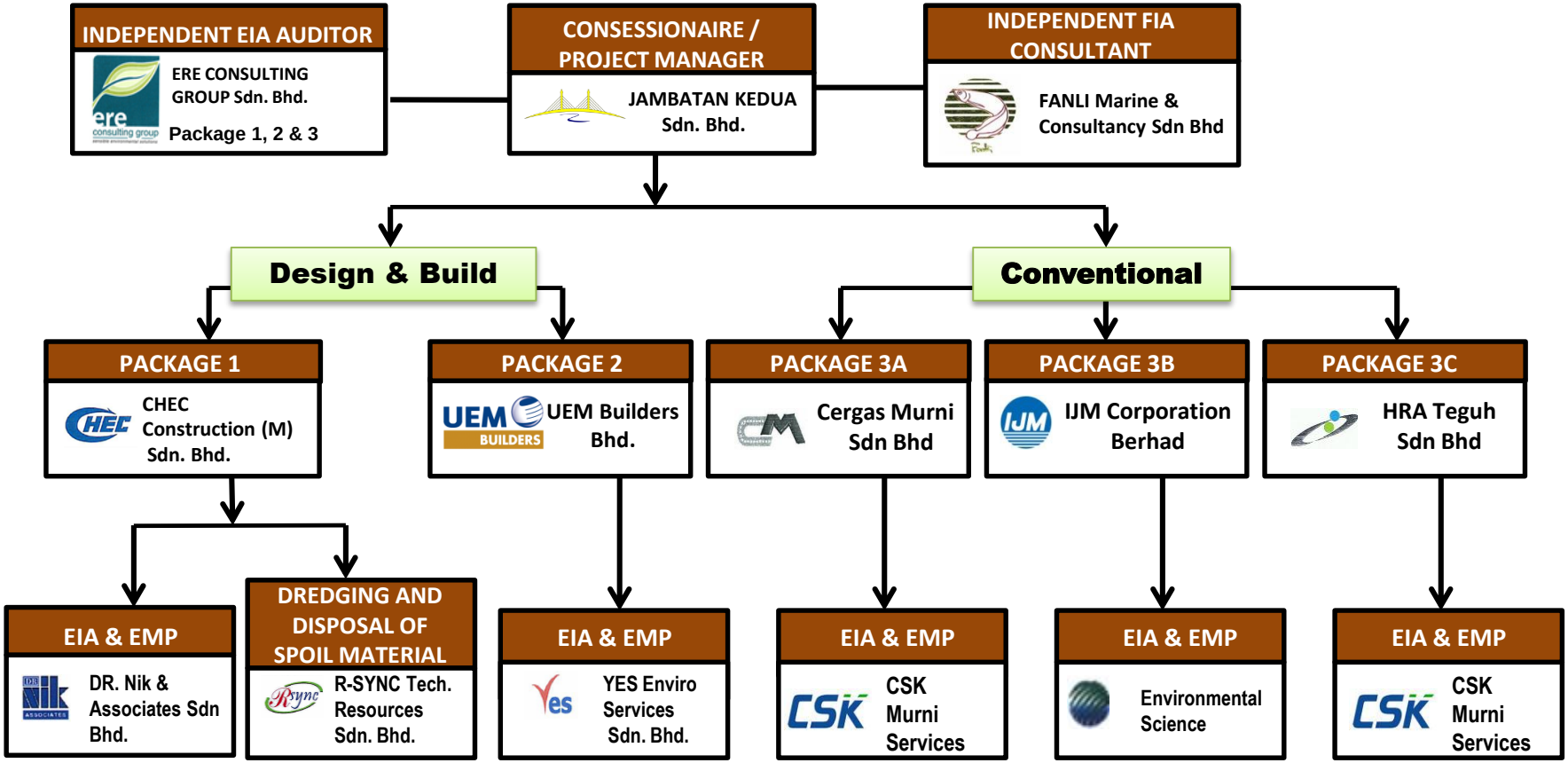


Sampling Points for the Monitoring Study



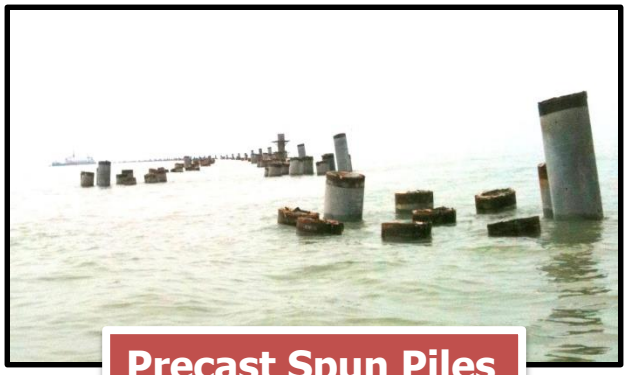
Location of Ambient Environmental Monitoring Station

Various environmental consultants were appointed to conduct a comprehensive monitoring regime through Environmental Impact Assessment (EIA), Environmental Management Plan (EMP) and the Fisheries Impact Assessment (FIA).



Managing Environmental Issues

Most of the bridge sections including tubular steel piles, precast spun piles, reinforcement caging, precast shell and Segmental Box Girder are IBS components that are prefabricated on land to reduce the amount of time spent at the bridging line and the risk of damaging or polluting the marine environment.



Precast Spun Piles

Reinforcement Caging

Precast Shell

Segmental Box Girder

Managing Environmental Issues

WATER BROWSER REDUCE FLYING DUST

HYDRAULIC PILING HAMMER

CONTAINMENT WALL AT DIESEL STORAGE TANK

NOISE REDUCTION EXPANTION JOINT

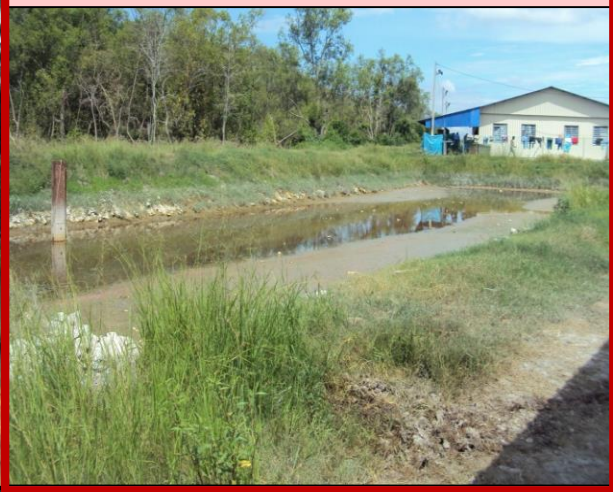
MARINE WATER MONITORING

RORO BIN FOR SOLID WASTE DISPOSAL

PROPER SCHEDULED WASTE AREA

MAINTENANCE OF SILT TRAP

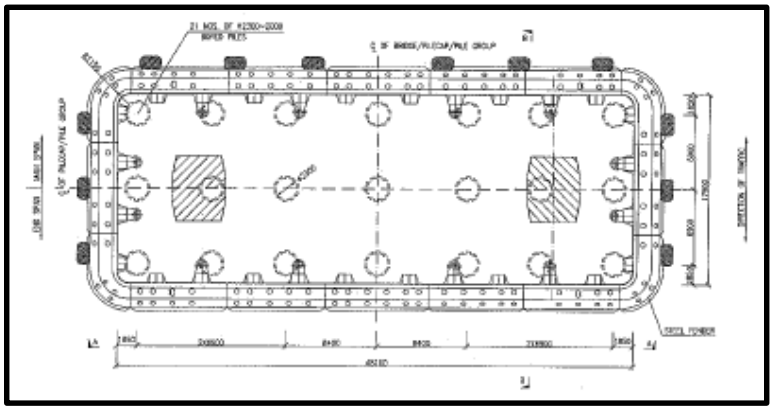
GOOD MAINTENANCE OF DETENTION POND



MATERIAL STORAGE AREA WAS STACKED IN ACCORDANCE WITH THE MATERIAL SAFETY DATA SHEET (MSDS) ON SITE

Minimal Impact On Water Flow

MAIN NAVIGATION SPANS

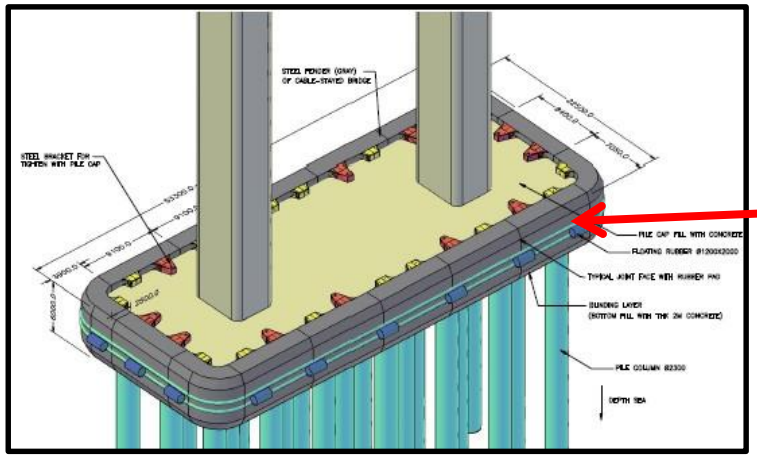


Substructure

Total pilecap : 4 nos
Pilecap size (P25 & P26) : 48.1m x 17.5m x 6m
Pilecap size (P24 & P27) : 42.7m x 10.6m x 4m

Steel Fender System

The steel fender system was adopted due to its environmental friendliness, cost saving and shorter construction period.



Reducing The Impact Of Dredging

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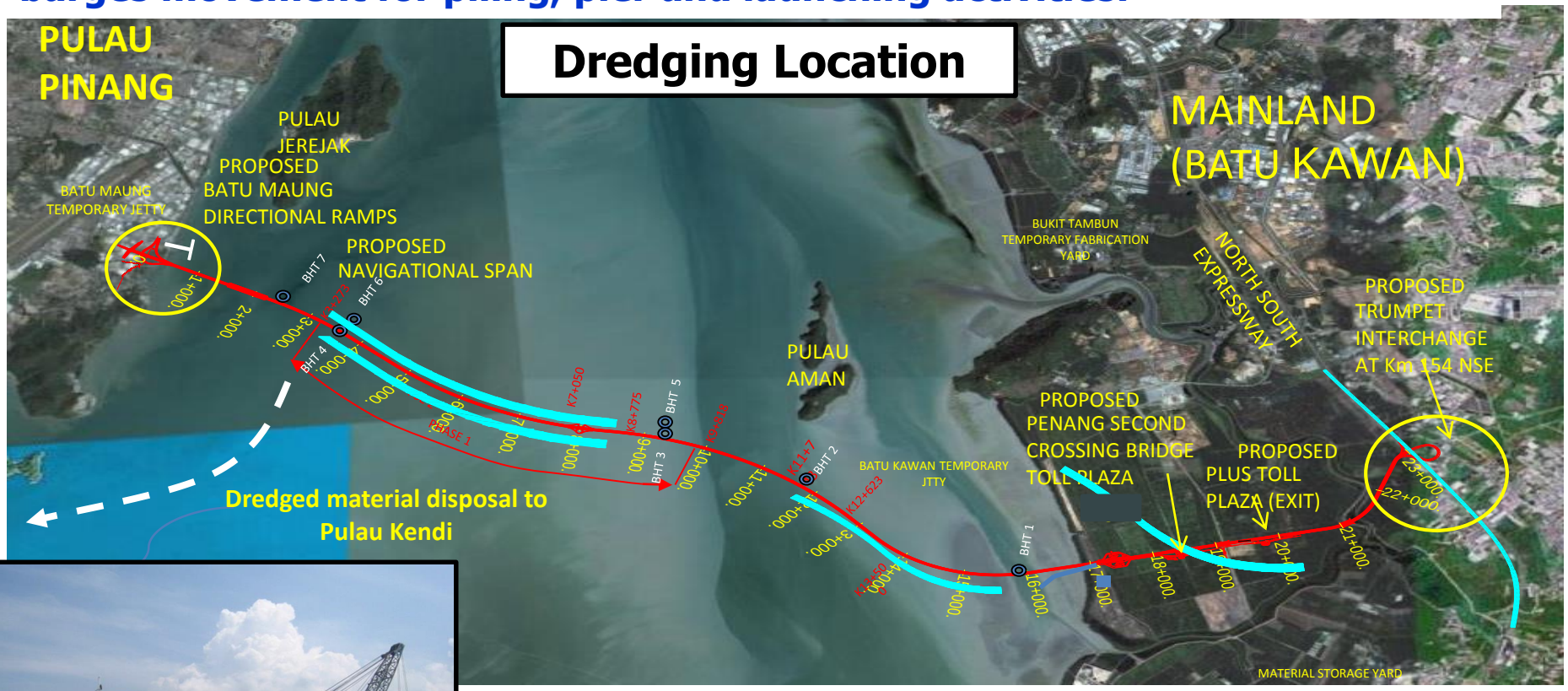
The dredging activities have to be carried out due to shallow water conditions at major portions of the bridge alignment which affect the barges movement for piling, pier and launching activities.



LEGEND

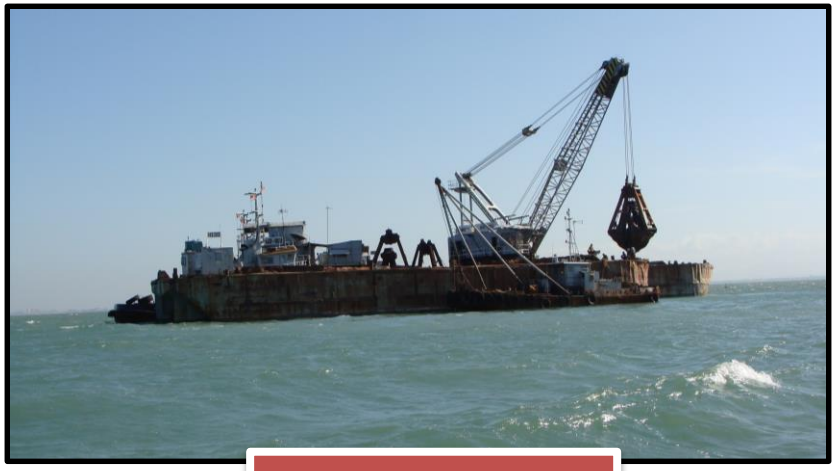
Dredging works for 270m width Temporary Navigational Channel
Total volume 11 million m³ of Dredged Materials

cont'd

- **In total, 11 million m³ of material was dredged from the seabed in the Penang Strait. Dredging was done carefully and spillage was minimised to avoid suspended sediment that could shade and potentially endanger the marine life.**

- **Disposal barge are monitor through:**
  - **GPS**
  - **Depth monitor**
  - **Discharge opening sensor**

Silt curtain was erected and maintained properly

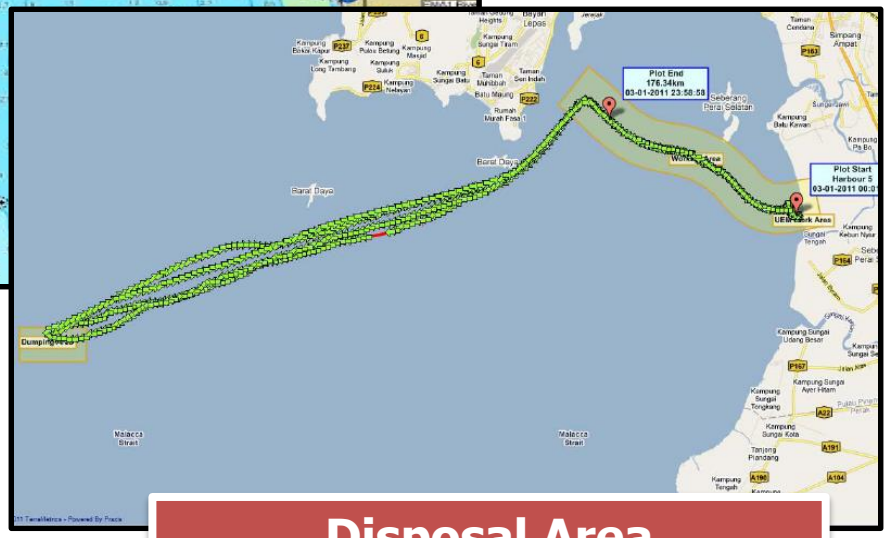


Dredging Work

cont'd

Package 1 : Location of Water Quality Sampling by R-Sync Sdn Bhd

Water Quality sampling location at disposal route



Disposal Area

Flora & Fauna Monitoring

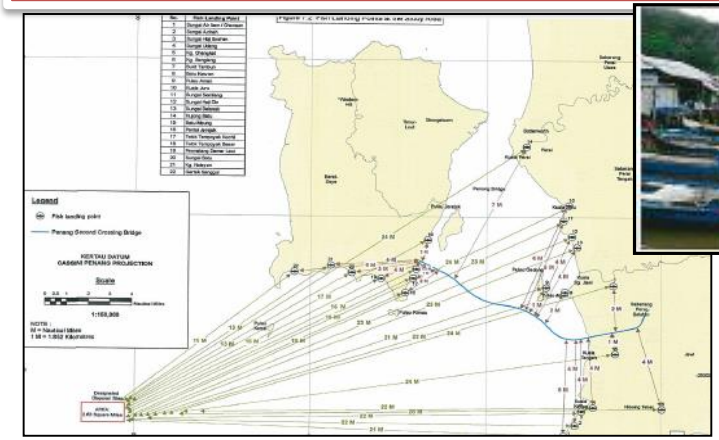
- **Marine flora and fauna are monitored throughout the construction phase to reduce demands and complaints from fishermen and fish farmers who ostensibly incurred losses as a result of the bridge construction.**
- **To ensure the aquatic life is not effected by the construction of Second Penang Bridge, Fanli Marine & Consultancy Ptd. Ltd. (Fanli) is appointed by JKSB as an Independent Consultant to monitor the Fisheries Impact Assessment (FIA) for this project. Fanli had earlier completed the base line study in 2007 for the Fisheries Department.**

Overview Fisheries Industry in Penang

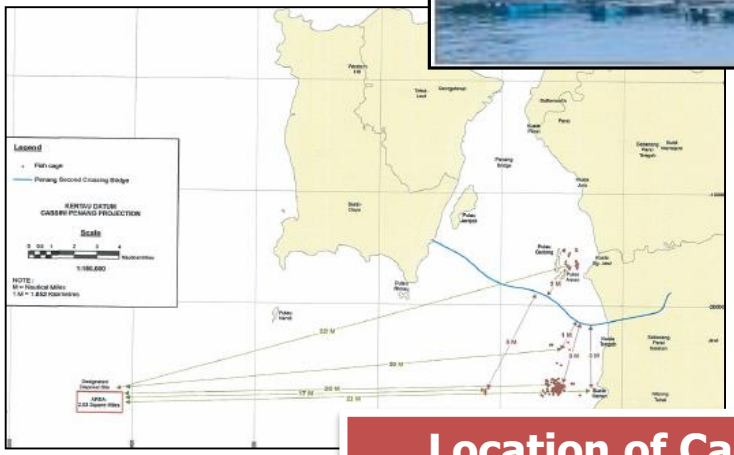
- **There are 17 fishing villages on the island and 14 fishing landing point on the main land.**
- **In 2007, marine fisheries catch in Penang amounted to 37,774 tonnes worth RM 218.9 million.**
- **The industry provides livelihood to nearly 3,193 fulltime fishermen.**

cont'd

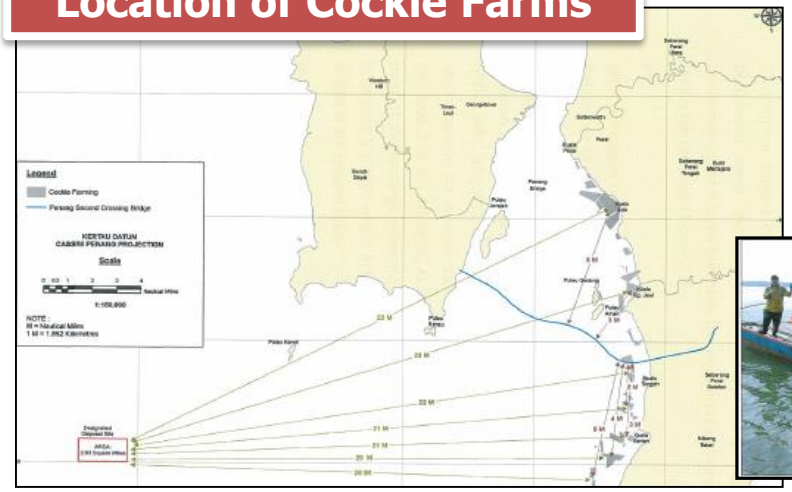
Location of Fisheries Landing Points



Fisheries Location



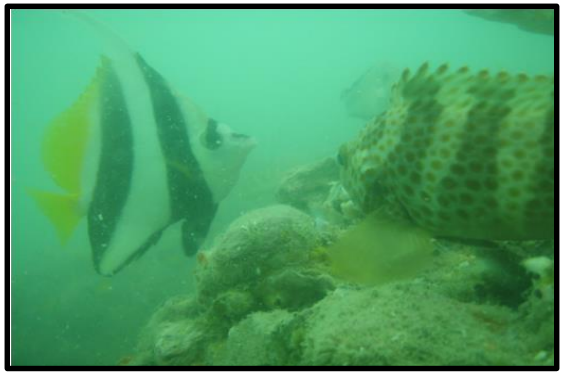
Location of Cockle Farms



Location of Cage Culture Farms

Habitat Creation

- Research by Lund University in Sweden has discovered that the Oresund Bridge connecting Denmark and Sweden has improved the Marine Environment in 10 years since it was built.
- In the Second Penang Bridge, aquatic life such as algae, oysters, fishes are found abundantly around the newly driven piles.
- They become food for fish like the Longfin Bannerfish (Heniochus acumiratus), Rock Grouper (Epinephelus fasciatomaculosus) and White Cheeked Monocle Bream (Scolopsis vosmeri) and the local "udang lipan" (Stomatopod Crustacean).
- It has been recorded that towards the end of the project, the number of fish and invertebrate species also found to increased from 9 to 23 and 4 to 12 respectively for four years of monitoring. As such, it has been proven that the construction of Second Penang Bridge does not affect the marine environment of the surrounding area.



View of Bandar Cassia Toll Plaza at Night

Green Building Technology

Toll Plaza & Administrative Building Complex

- **The design is based on requirements of :-**
  - ✓ **80% of IBS**
  - ✓ **88% (Platinum) for PB2X Toll Plaza Green Building Index (GBI).**
  - ✓ **80% (Gold) for PLUS Toll Plaza GBI.**

- **The details of the target score as follows :-**

ITEM	MAXIMUM POINTS	TARGETED SCORE
Energy Efficient (EE)	35	32
Indoor Environment Quality (EQ)	21	20
Sustainable Site Planning & Management (SM)	16	11
Materials & Resources (MR)	11	8
Water Efficiency (WE)	10	10
Innovations (IN)	7	7
Total Score	100	88 (PLATINUM)

PB2X Toll Plaza

PLUS Toll Plaza

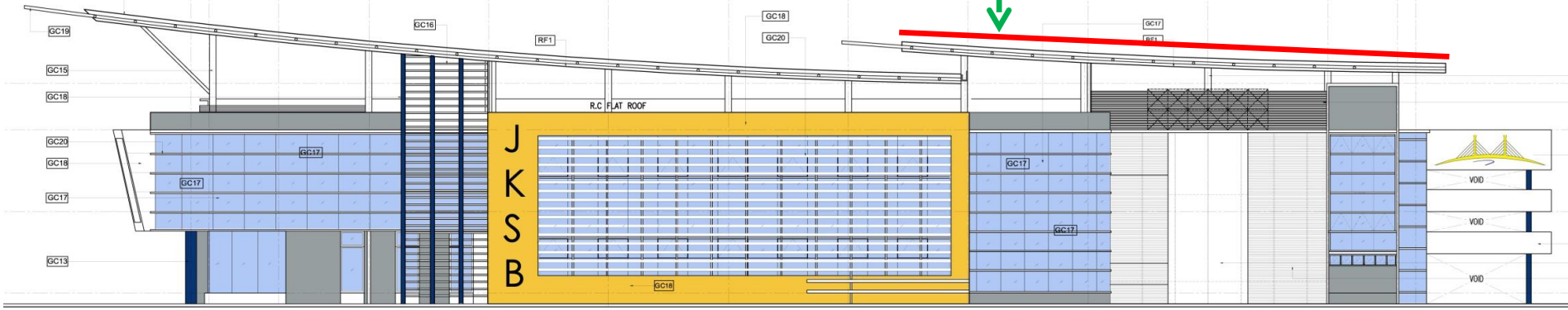
Proposed Toll Plaza & Administrative Building Complex

- **A green building concept is introduced to save water, energy and material.**
- **The landscaping and the exterior look of the Toll Plaza are designed in such a way that the trespassing light is eliminated by plants and shaded area.**
- **Rain water from the roof of the building is harvested to supplement the conventional water supply. The natural light is maximized for the intermediate floors to minimize the usage of electricity. High efficiency windows and insulation in walls, ceilings and floors are used for the benefit of better temperature control.**

Renewable Energy

SOLAR THERMAL COOLING
& PHOTOVOLTAIC

ADMINISTRATION BUILDING

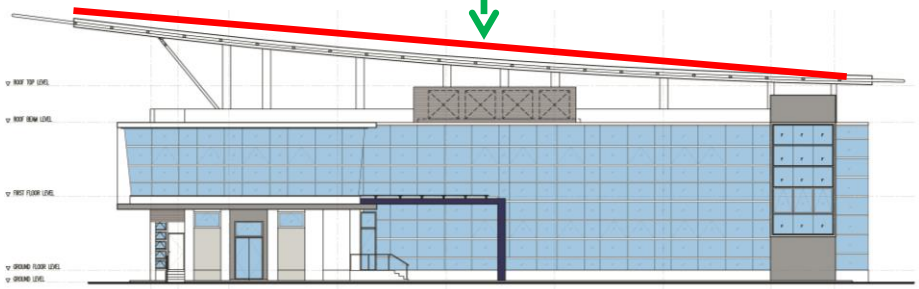


FRONT ELEVATION

SURAU

WIND TURBINE
AT SURAU

PHOTOVOLTAIC



FRONT ELEVATION

SUPERVISION BUILDING

PB2X Complex

❖ OPERATION AND MAINTENANCE

- **All systems are integrated with synergy between Asset Management (ISO 55000), Risk (ISO 31000), Quality (ISO 9000), Environmental (ISO 14000) and Safety (ISO 18000) Systems.**

Lloyd's Register LRQA

CERTIFICATE OF APPROVAL

This is to certify that the Quality Management System of:

Jambatan Kedua Sdn. Bhd. (824573-U)
Tingkat 4 & 10, Bangunan Setia 1
15, Lorong Dungun, Bukit Damansara
50490 Kuala Lumpur
Malaysia

has been approved by Lloyd's Register Quality Assurance to the following Quality Management System Standards:

ISO 9001:2008
EN ISO 9001:2008
BS EN ISO 9001:2008
MS ISO 9001:2008

The Quality Management System is applicable to:

Provision of project management services in engineering, procurement and construction of Jambatan Sultan Abdul Halim Mu'adzam Shah. Provision of toll collection for Jambatan Sultan Abdul Halim Mu'adzam Shah. Management of highway and facilities operation and maintenance and asset management for Jambatan Sultan Abdul Halim Mu'adzam Shah.

Approval Certificate No: KLR 6011500

Original Approval: 18 July 2011
Current Certificate: 04 February 2015
Certificate Expiry: 17 July 2017

Issued by: Lloyd's Register of Shipping (M) Bhd
for and on behalf of Lloyd's Register Quality Assurance Ltd.

UKAS MANAGEMENT SYSTEMS 001

Suite 21-04, Level 21, Menara Tan & Tan, 207 Jln Tun Razak, 50400 Kuala Lumpur, Malaysia. Registered Number 111008-K
For and on behalf of Hiramford Middlemarch Office Village, Siskin Drive, Coventry, CV3 4FJ, United Kingdom
This approval is carried out in accordance with the LRQA assessment and certification procedures and monitored by LRQA.
The use of the UKAS Accreditation Mark indicates Accreditation in respect of those activities covered by the Accreditation Certificate Number 001

LRQA Business Assurance

CERTIFICATE OF APPROVAL

This is to certify that the Environmental Management System of:

Jambatan Kedua Sdn. Bhd. (824573-U)
Tingkat 4, Bangunan Setia 1
15, Lorong Dungun, Bukit Damansara
50490 Kuala Lumpur
Malaysia

has been approved by Lloyd's Register Quality Assurance to the following Environmental Management System Standard:

ISO 14001:2004
EN ISO 14001:2004
BS EN ISO 14001:2004
MS ISO 14001:2004

The Environmental Management System is applicable to:

Provision of project management services in engineering, procurement and construction of Second Penang Bridge.

Approval Certificate No: KLR 6013661

Original Approval: 26 July 2012
Current Certificate: 26 July 2012
Certificate Expiry: 25 July 2015

Issued by: Lloyd's Register of Shipping (M) Bhd
for and on behalf of Lloyd's Register Quality Assurance Ltd.

UKAS MANAGEMENT SYSTEMS 001

This document is subject to the provision on the reverse
Suite 21-04, Level 21, Menara Tan & Tan, 207 Jln Tun Razak, 50400 Kuala Lumpur, Malaysia. Registered Number 111008-K
For and on behalf of 71 Fenchurch Street, London EC3M 4BS, United Kingdom
This approval is carried out in accordance with the LRQA assessment and certification procedures and monitored by LRQA.
The use of the UKAS Accreditation Mark indicates Accreditation in respect of those activities covered by the Accreditation Certificate Number 001

LRQA Business Assurance

CERTIFICATE OF APPROVAL

This is to certify that the Occupational Health & Safety Management System of:

Jambatan Kedua Sdn. Bhd. (824573-U)
Tingkat 4, Bangunan Setia 1
15, Lorong Dungun, Bukit Damansara
50490 Kuala Lumpur
Malaysia

has been approved by Lloyd's Register Quality Assurance to the following specification:

OHSAS 18001:2007

The Occupational Health & Safety Management System is applicable to:

Provision of project management services in engineering, procurement and construction of Second Penang Bridge.

Approval Certificate No: KLR 6013663

Original Approval: 19 September 2012
Current Certificate: 19 September 2012
Certificate Expiry: 18 September 2015

Issued by: Lloyd's Register of Shipping (M) Bhd
for and on behalf of Lloyd's Register Quality Assurance Ltd.

UKAS MANAGEMENT SYSTEMS 001

This document is subject to the provision on the reverse
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Integrated Asset Management System

Definitions:

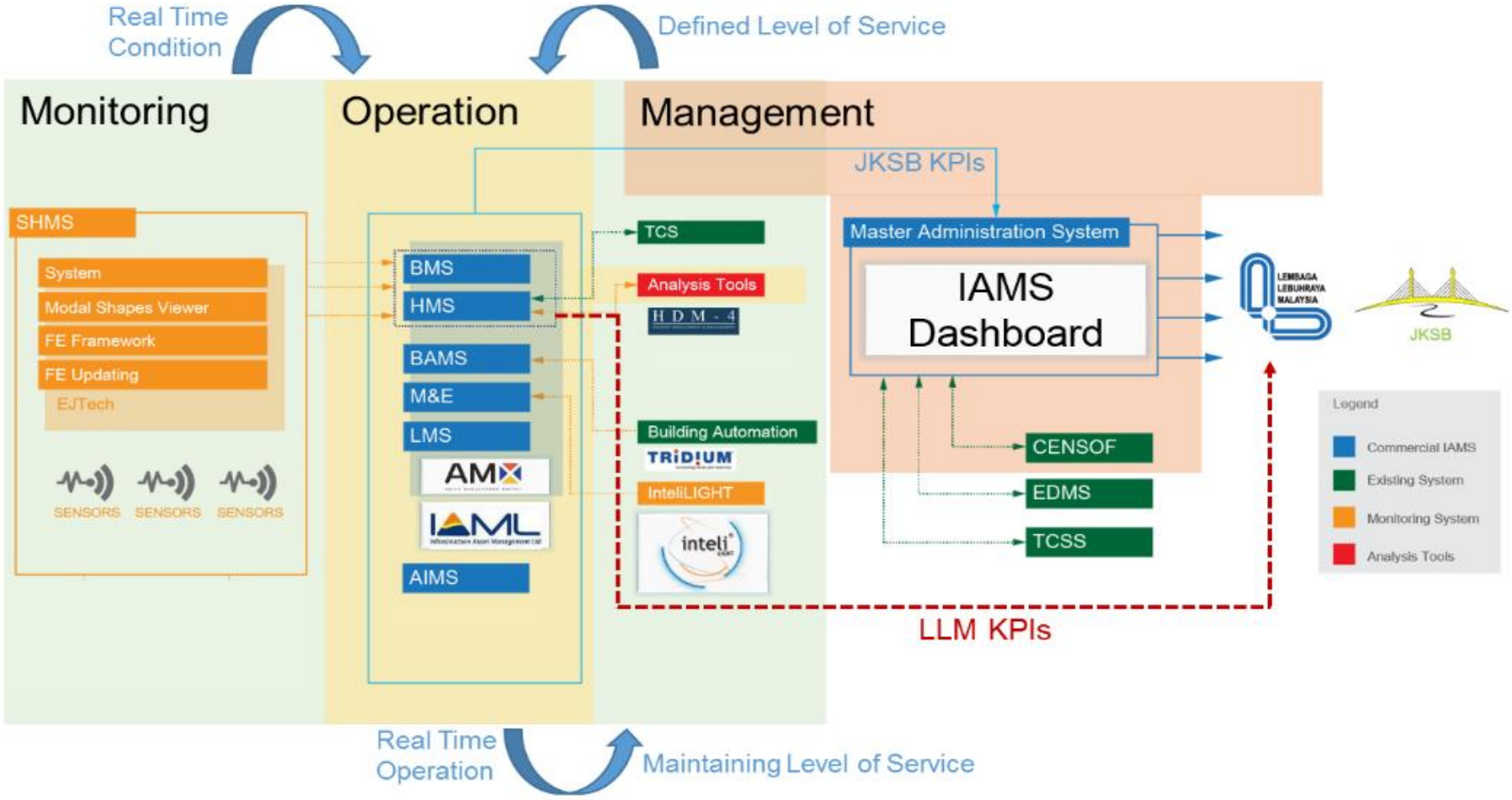
"Coordinated activity of an organization to realize value from assets"
(ISO55000:2014 – Asset Management)

"the combination of management, financial, engineering, economic and other practices applied to physical assets with the objective of providing the required level of service in the most effective manner" *(AS/ISO 55000)*

ASSET MANAGEMENT ISO 55001 PROGRAMME

No.	Programme	2015					2016											Remarks
		Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	Training, GAP and Brainstorming																		12 days
	Strategic Asset Management Plan (Policy, Objective, LOS, Management Std, Risk and Lifecycle)																		106 days
3	Asset Management Plan (Bridge, Buildings, Highway, Landscape, MEE)																		106 days
4	Procedures, Work Instruction, SOP																		106 days
5	Implementation (Internal & External Audit, Management Review)																		274 days

Integrated Module Overview



Performance Based Contract (PBC)

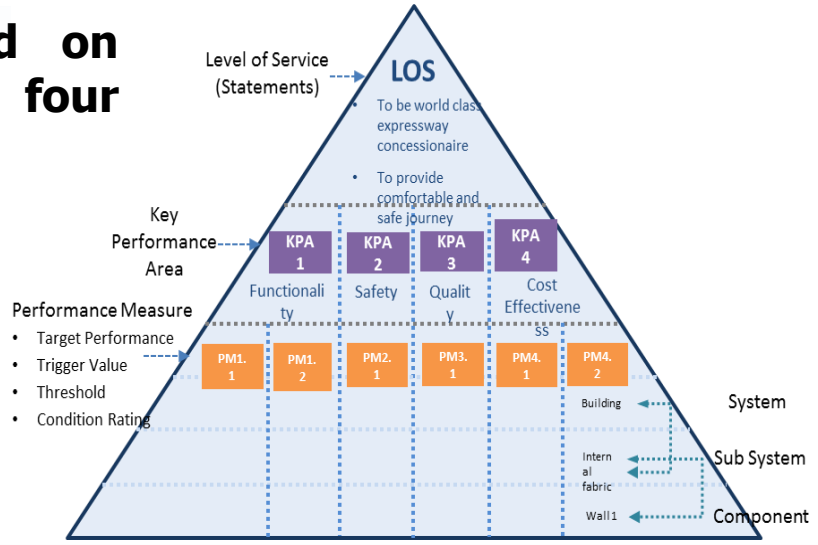
Definition:

A type of contract in which payment for the deliverable is explicitly linked to the contractor successfully meeting or exceeding certain clearly defined performance indicators

World Bank Transport Note

Maintenance contractors appointed based on Performance Based Contract divided into four packages:

- **Mainline**
- **Building and Toll Plaza Complex**
- **Mechanical and Electrical Installation**
- **Turfed and Landscape Areas**

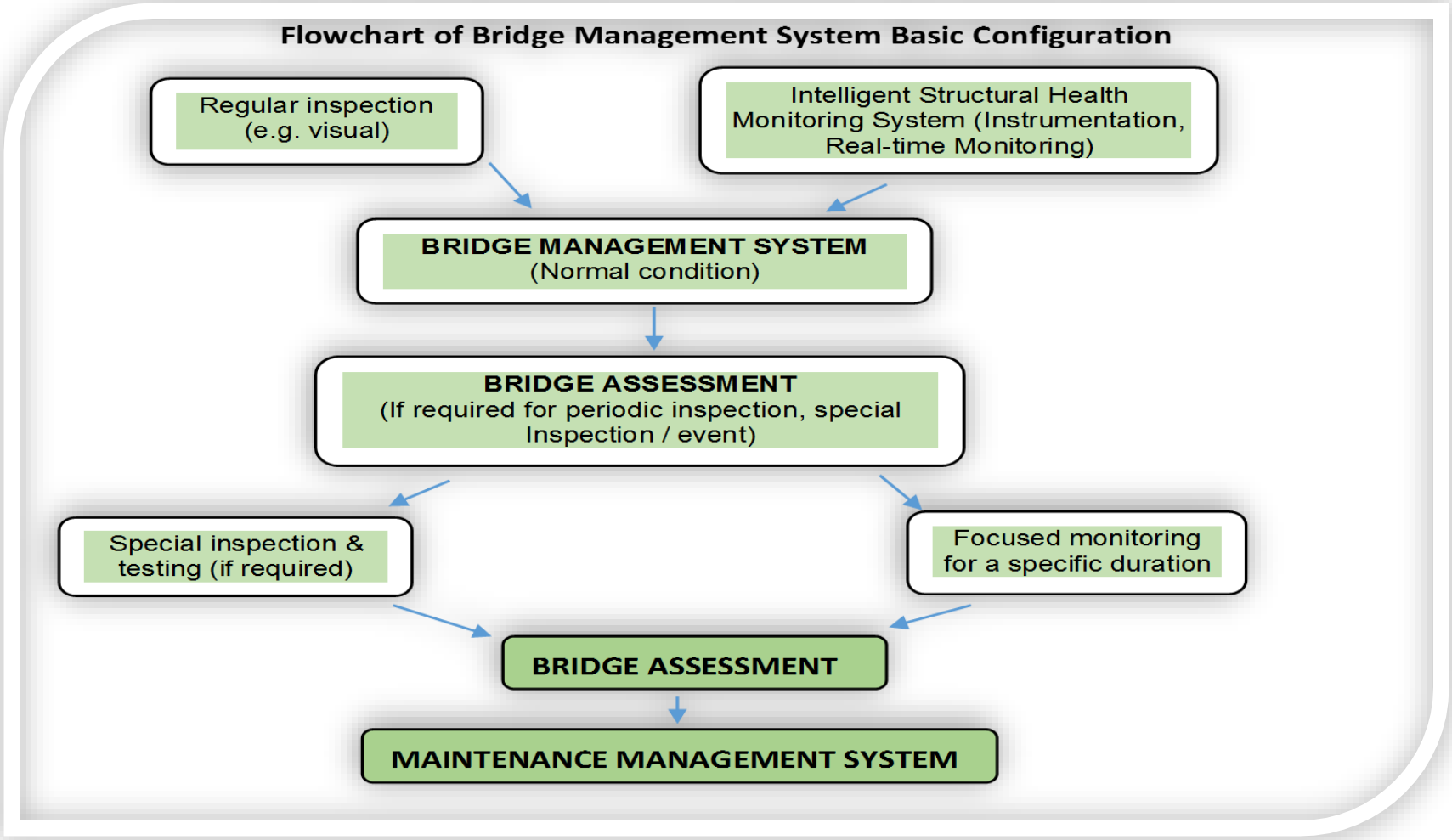


Benefit of Performance Based Contract (PBC)

- **The benefit of PBC are:-**
  - **More consistent outcomes**
  - **Budget certainty**
  - **Cost saving**
  - **Improved safety outcomes**
  - **Transparent governance**
  - **Contractor carry the consequences of their workmanship**
  - **Focus is on intervention at the appropriate time and preventive maintenance**

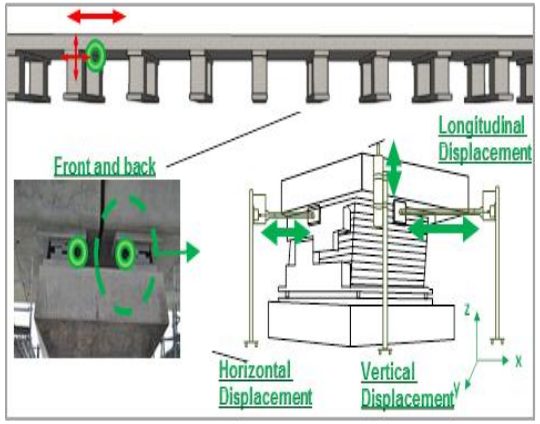
- **With implementation of PBC for building and road asset management, the JKSB's aim is to get the best value-of–money and obtain innovative solutions in maintaining its JSAHMS assets in order to meet increasing expectations of the public.**

- **The Bridge Management System (BMS) shall be supplemented with information from the bridge inspection, as well as the Structural Health Monitoring System (SHMS) to give detailed assessment and more realistic maintenance/repair programme for assets.**



SHMS Sensor System

- The system should be designed and serviced consistently to eliminate failure of data acquisition.
- The system shall be such that the following monitoring data are collected for analysis:-
  - Anemometer
  - Accelerometers
  - Temperature sensors
  - Dynamic & static strain gauges
  - GPS
  - Displacement transducers
  - Buffer sensors
  - Bearing sensors
  - Electromagnetic sensors
  - Barometers, rainfall gauges and hygrometers
  - Corrosion cells
  - Digital video cameras
  - Dynamic weigh-in-motion station
  - Automatic prisms
  - Wave height, water level
  - Embankment settlement and/or lateral movement
  - Speed radar
  - Photo cells
  - Inclinometers
- More than 500 nos. sensors to be installed.



Development and Establishment of the BMS

System Components

- **The components of the BMS shall consist of, but not limited to the following:-**
  - ❖ **Bridge Inventory**
  - ❖ **Bridge Inspection**
  - ❖ **Structural Assessment and Analysis**
  - ❖ **Monitoring of post-construction**
  - ❖ **Maintenance Program Analysis & Work Planning**
  - ❖ **Development Work**

Bridge Inspection

- **Below are the minimum requirements for bridge inspection works:-**

Type of Inspection	Frequency of Inspection
Routine inspection	Every 6 months
Periodic inspection	Every 2 years
Principal inspection	Every 5 years (on all bridge elements, including those that are difficult to access – may require special bridge equipment)
Underwater inspection	Every 5 years (to inspect and monitor any environmental problems or impact)
Special inspection	e.g. after a major event, expiration of anticipated service of life or warranty period, exceptional high loading

Highway Management System (HMS)

- **The main purpose of the HMS is to maintain the adopted highway network for the safe use of motorists.**
- **The HMS shall be a decision-making tool to provide a method for road management and programming road works to achieve the stated objective.**
- **The HMS shall consist of the following components:**
  - **Pavement**
  - **Embankment / slope**
  - **Drainage**
  - **Road Furniture**
- **A condition-based 10 years maintenance plan and trend analysis is used to maintain every asset and element of the highway.**

The asset inventory shall include the following assets:-

- **Pavement (asphalt and concrete)**
- **Signage (regulatory, warning and information)**
- **Supports and structures for signs, signals and lighting**
- **Pavement markings and treatments**
- **Lamp post**
- ***Variable Message Signs (VMS)***
- ***Vehicle Incident Detection System (VIDS)***
- ***Dynamic Road Information System (DRIS)***
- ***Emergency Telephone System (ETS)***
- **Longitudinal barriers (guardrail, NJB, New Jersey Parapet, crash cushion and wire rope)**
- **Etc.**

System Components

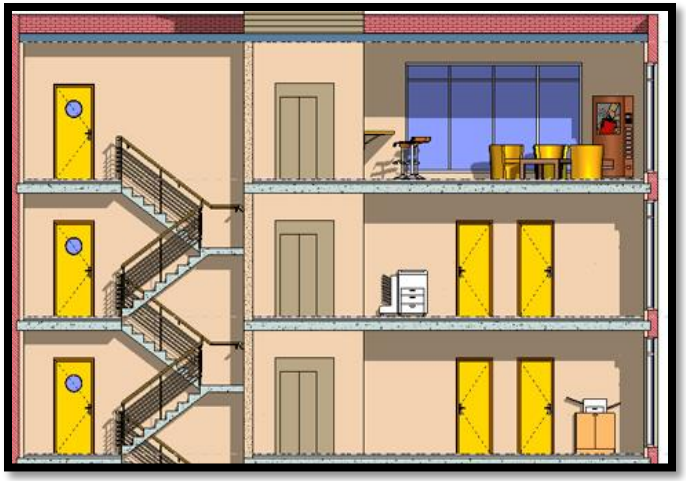
- **The components of the HMS shall consist of, but not limited to the following:-**
  - **Pavement Inventory**
  - **Pavement Inspection**
  - **Condition Assessment and Analysis**
  - **Monitoring of Post-construction**
  - **Maintenance Program Analysis & Work Planning**
  - **Development Work**

Highway Inspection

- **Three key objectives of a highway maintenance strategy:-**
  - **Network Safety - Safety Inspections/Ad-hoc inspections**
  - **Network Serviceability - Inspection of Utility/Licensees Works**
  - **Network Sustainability - Structural Condition Surveys**

The minimum requirements on the highway condition surveys to be carried out as follows:

No.	Survey Type	Expressway	Motorcycle Lane	Service Road
1.	SCANNER (TTS) survey - Machine Based Condition Survey	100% of network annually	-	-
2.	Coarse Visual Inspection survey	-	-	100% of network annually
3.	Detailed Visual Inspection surveys	-	50% of network annually	-
4.	Visual Categorization	100% of network annually	4 times annually	100% of network annually
5.	Skidding Resistance survey (SCRIM or equivalent)	100% of network annually	-	-
6.	Road Maintenance Condition Surveys – Visual condition survey	15 times annually	-	15 sites annually
7.	Deflectograph Survey	Every 5 years	-	-
8.	IRI	Every 5 years	-	-



Building Asset Management System (BAMS)

- **It shall include the assessment of the current condition of all building systems, review of operational costs, development of maintenance plans, determination and analysis costs, depreciation reports and assistance in the implementation of maintenance programs.**

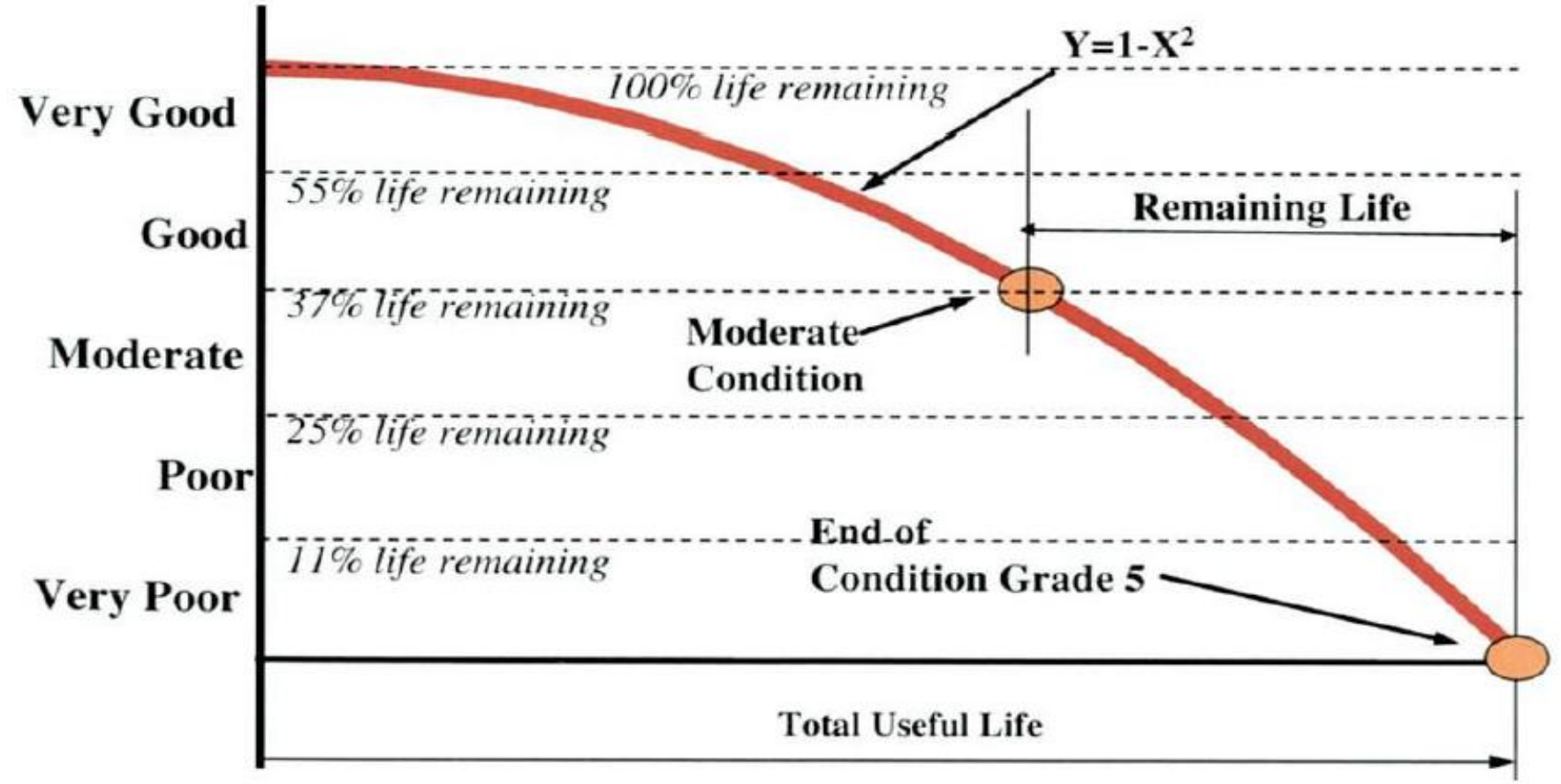
- **The software provide dynamic tracking of service life prediction, future cost estimates and reserve fund balances and examine multiple funding models.**

Markov Chain Deterioration Model

- **Most common stochastic technique used in modeling deterioration of infrastructure facilities.**
- **Analyze the probability of deterioration from a better condition level to a poorer condition level.**
  - **Achieved by establishing Markov Chain probability transition matrix**
- **Requires adequate consecutive data collection from actual site to construct an accurate transition matrix (empirical model)**

Markov Chain Deterioration Model – Deterioration Trend Assumption

An assumption in creating the deterioration trend curve graph can be based on NAMS 2009, Building Condition & Performance Assessment Guidelines

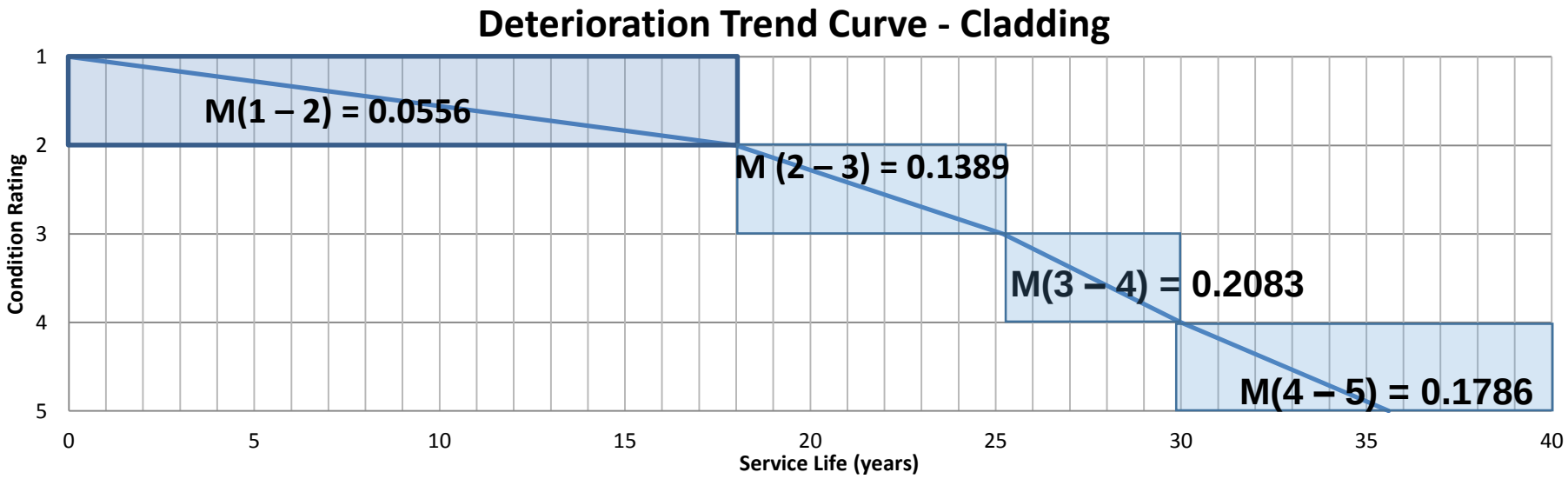


Markov Chain Deterioration Model – Deterioration Trend Assumption

Example: Cladding Finishes

Assumption of Cladding Service Life: 40 years(Extract from BS 7543 & NAMS 2009)

Condition Rating	Life Remaining (years)	Service Life (years)	Gradient of Line Trend, M
1	100% - 40 years	0 years	0.0556
2	55% - 22 years	18 years	0.1389
3	37% - 14.8 years	25.2 years	0.2083
4	25% - 10 years	30 years	0.1786
5	11% - 4.4 years	35.6 years	-



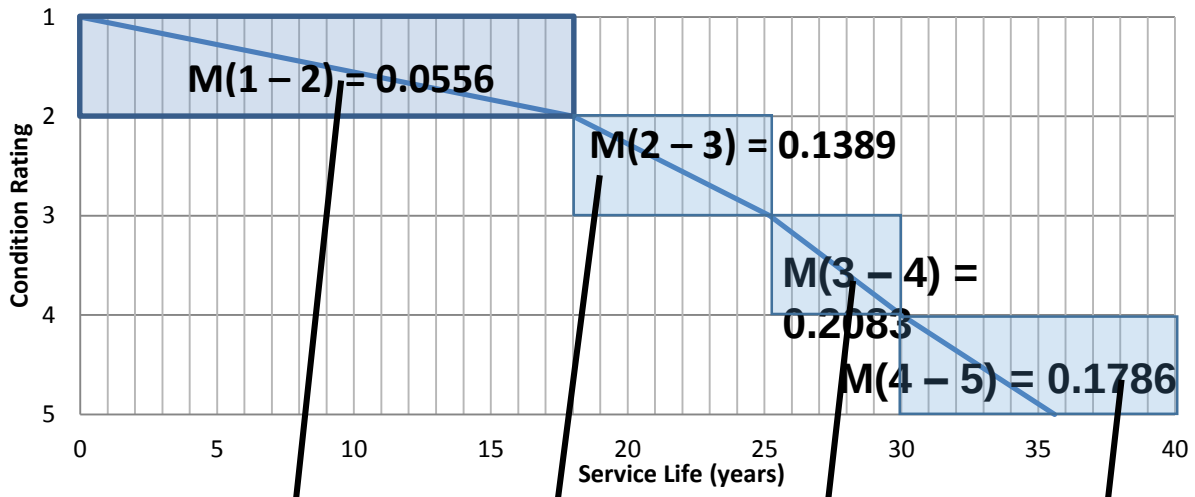
Markov Chain Deterioration Model – Forming of Transition Matrix

Example: Cladding Finishes

Assumption of Cladding Service Life: 40 years (Extract from BS 7543 & NAMS 2009)

Condition Rating	Gradient of Line Trend, M
1	0.0556
2	0.1389
3	0.2083
4	0.1786
5	-

Deterioration Trend Curve - Cladding



Transition Matrix

Condition	1	2	3	4	5
1	0.0000	0.0556	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.1389	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.2083	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.1786
5	0.0000	0.0000	0.0000	0.0000	0.0000

Markov Chain Deterioration Model – Forming of Transition Matrix

Example: Cladding Finishes

Transition Matrix

Condition	1	2	3	4	5
1	0.9444	0.0556	0.0000	0.0000	0.0000
2	0.0000	0.8611	0.1389	0.0000	0.0000
3	0.0000	0.0000	0.7917	0.2083	0.0000
4	0.0000	0.0000	0.0000	0.8214	0.1786
5	0.0000	0.0000	0.0000	0.0000	1.0000

1 – M(1 – 2) = 0.9444

1 – M(2 – 3) = 0.8611

1 - M(3 – 4) = 0.7917

1 - M(3 – 4) = 0.8214

Usually 1; As condition 5 assets will remain at condition 5

Markov Chain Deterioration Model – Transition Matrix multiply Condition Vector

Example: Cladding Finishes (time step: year 1)

Transition Matrix, P

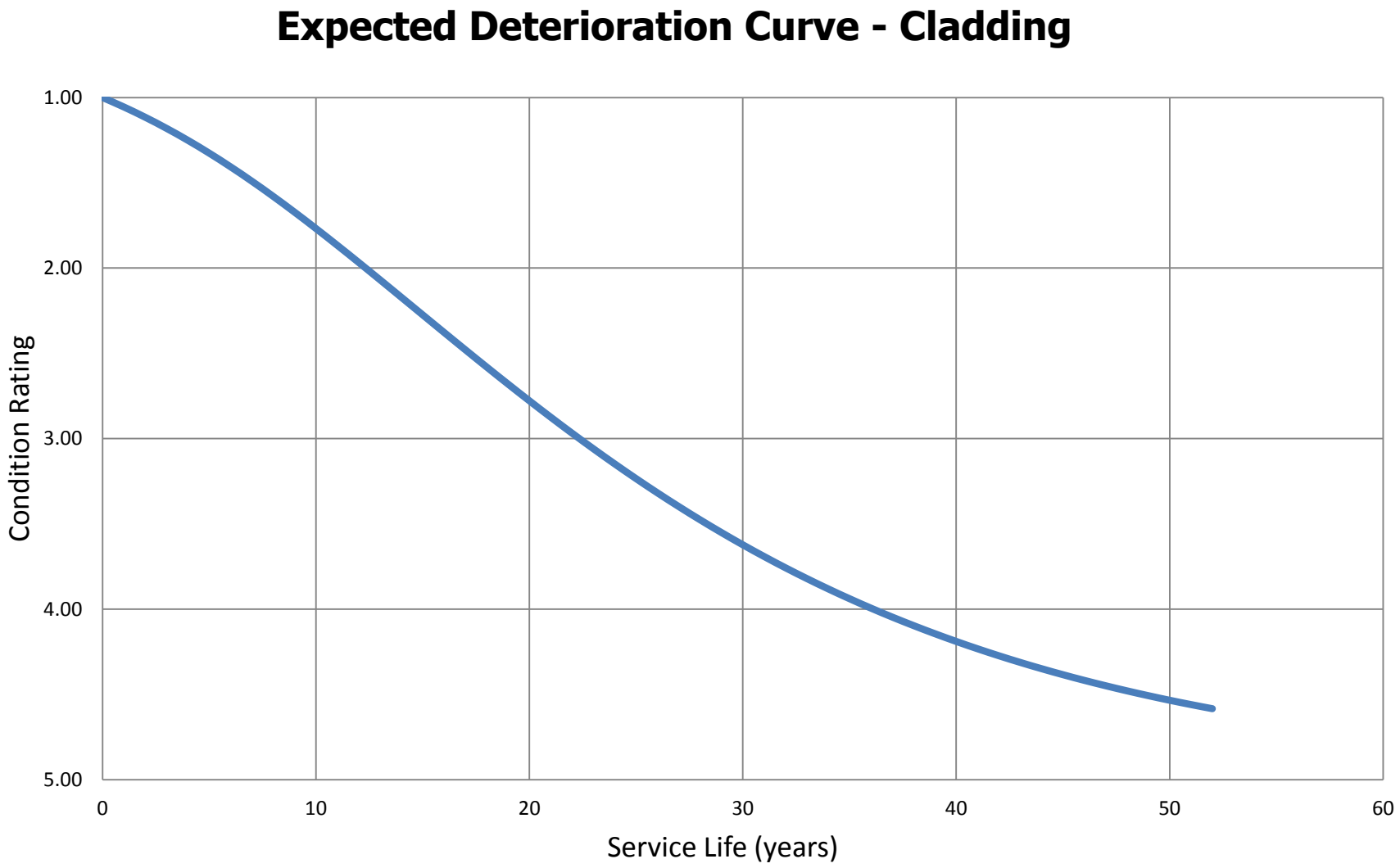
Condition	1	2	3	4	5
1	0.9444	0.0556	0.0000	0.0000	0.0000
2	0.0000	0.8611	0.1389	0.0000	0.0000
3	0.0000	0.0000	0.7917	0.2083	0.0000
4	0.0000	0.0000	0.0000	0.8214	0.1786
5	0.0000	0.0000	0.0000	0.0000	1.0000

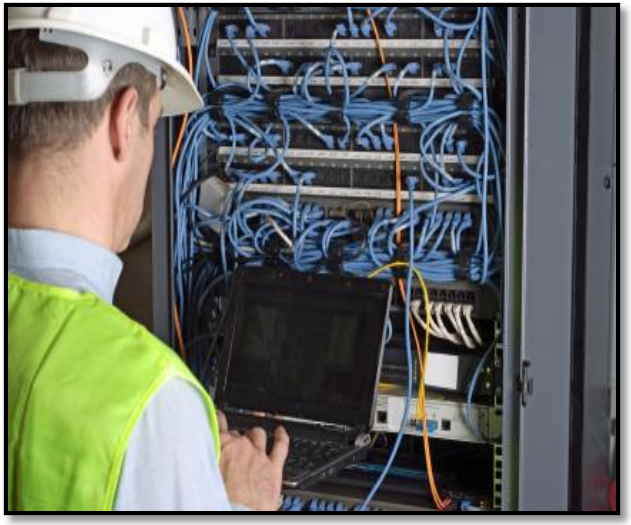
Initial Condition Vector, v

	1	0	0	0	0

Condition	1	2	3	4	5	Expected Condition Rating
Year 1	0.94 x 1 = 0.94	0.06 x 1 = 0.06	0	0	0	0.94 (1) + 0.06 (2) = 1.06

Example: Cladding Finishes – End Product of the Matrix Multiplication



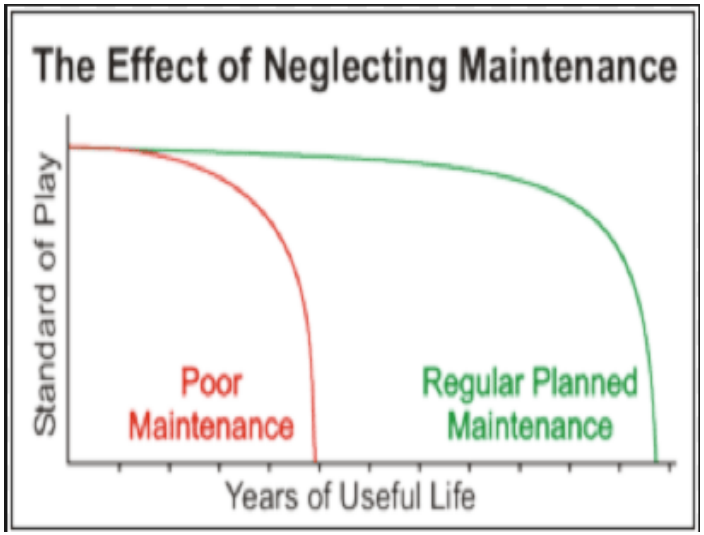


M&E Management System (MMS)

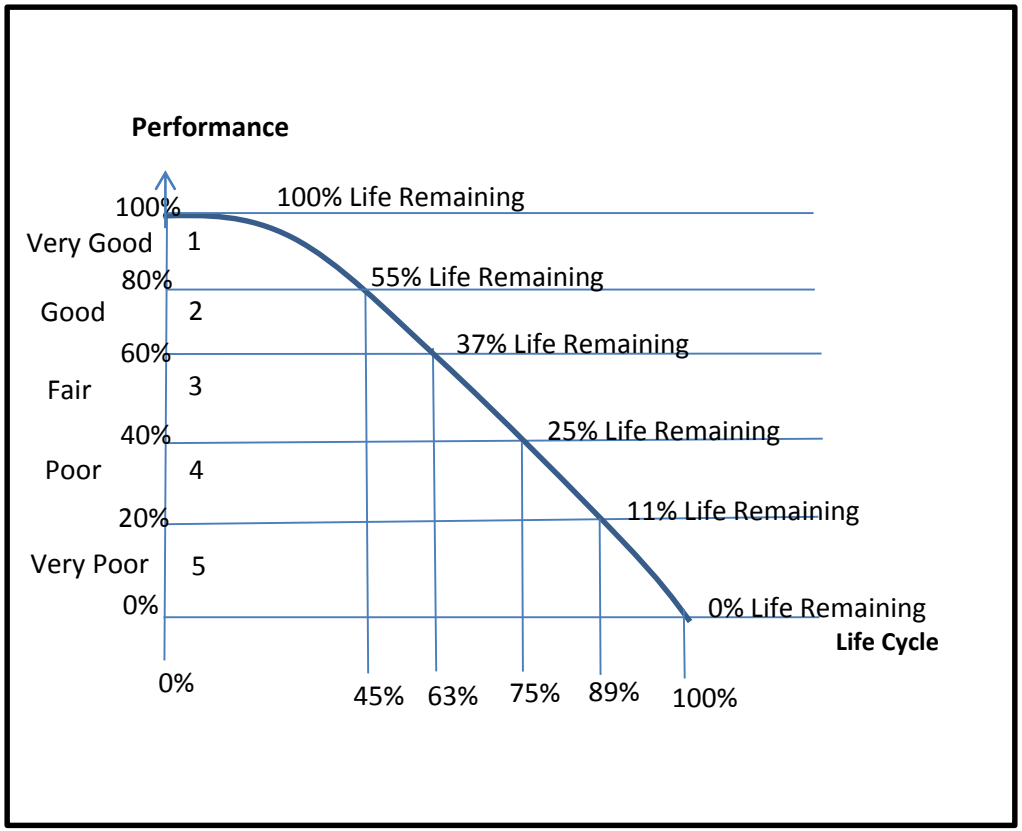
- The main objectives of the MMS are as follows:-
  - Manage and maintain the M&E asset and inventory information
  - Maintain the defect information
  - Schedule and maintain inspection and maintenance works

- MMS shall cover the establishment, installation operation and maintenance of M&E equipment such as:-
  - Street lighting
  - Decorative lighting
  - Aviation lighting
  - Navigation lighting
  - Highmast lighting
  - M&E cables
  - Telco cables
  - Building Automation System (BAS)
  - Other electrical components

M&E Deterioration Model



Graph 1: Impact of Maintenance Activity on Asset Performance and Useful Life Span

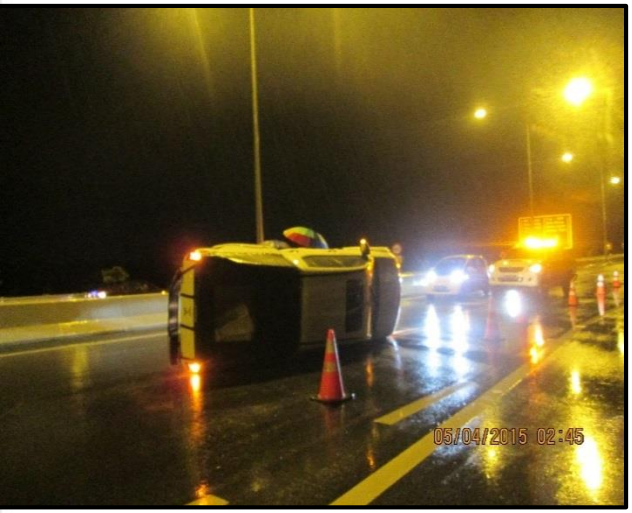


Graph 2: Remaining Life Chart (NAMS 2009) for Replaceable Assets

***NAMS 2009 = National Asset Management Strategies**

Landscape Management System (LMS)

- The LMS for perennial plans integrates the information, geographic information, growth decisions support systems and other applications landscape management.
- Maintenance of highway landscaping aims to vegetation control practices and optimize the life and value of vegetation on the expressway.
- Rather than deterioration, LMS use the "Growth describe the growing stage of the plants and shrubs.
- The landscape system components as follows:-
  - ❖ Landscape inventory
  - ❖ Landscape inspection
  - ❖ Resource inventories
  - ❖ Monitoring of post-construction
  - ❖ Maintenance program analysis & work planning

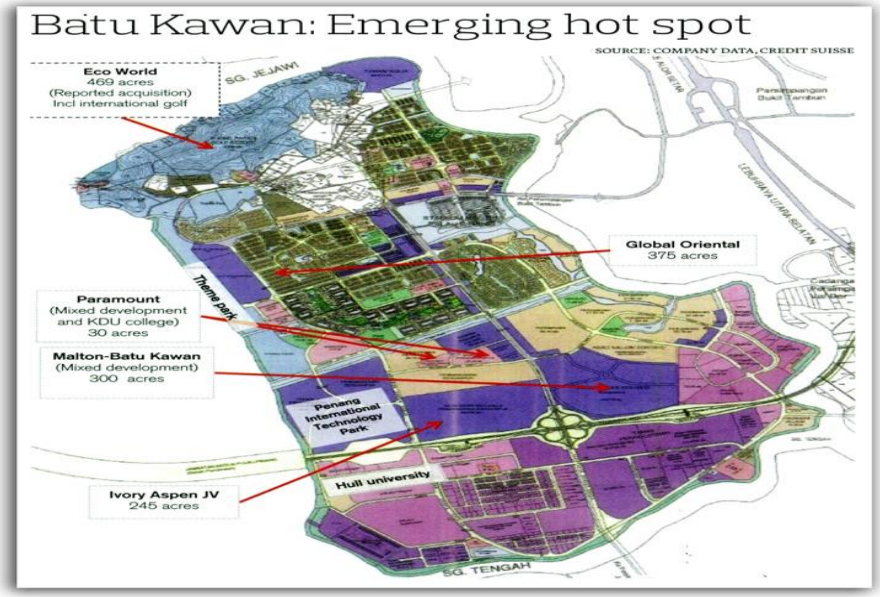


Accident Information Management System (AMX)

- **Its primary aim is to collect all information related to an accident incident, where the analytical tool will present the data with which the JKSB can use for traffic safety improvements.**
- **The AIMS shall be able to produce an improvement proposal based on the statistical and analytical data gathered to reduce and completely eliminate any accidents.**
- **The major functions shall includes the following:**
  - **Crash record management**
  - **Query and sorting**
  - **3-D plot of crash frequency and its location on GIS map**
  - **Crash analysis**
  - **Graphics display of results**
  - **Collision diagram drawing**
  - **Accident rate computation**
  - **Report generation**

Regional Economic Development

- **The bridge has reduce traffic volume on the First Penang Bridge by 8%**
- **The bridge is a catalyst for development at the northern corridor and also position the state as a transportation hub for the northern region.**
- **Spur the economic growth at Batu Kawan and surrounding area, GVD > 50 billion**
- **The route will become major passage for the movement of goods to Penang ports and the international airport in which will facilitate economic activity and also promote regional tourism industry.**
- **It will also contribute to accelerate economic transformation under the Indonesia, Malaysia & Thailand Growth Triangle programme (IMTGT).**



❖ AWARDS AND RECOGNITIONS

- **The International Green Apple Awards; for the Built Environment & Architectural Heritage 2013 – 24 June 2013**

  The award is giving by The Green Organization which recognize and reward those who are making a positive contribution to their built environment and architectural heritage. JKSB also became the Green World Ambassador for year 2014.

- **Platinum Building Award (Design Assessment) – Green Building Index (GBI) – 27 February 2014**

  The benefits of GBI are; Save energy and resources, minimize the emission of toxic substances throughout its life cycle, harmony with the local climate, traditions, culture and the surrounding environment and increase workplace activities.

- **Geneva International Star Award for Quality (ISAQ) 2014 - International Star Quality Convention in Geneva, 2014 – 21 September 2014**

The objective of the International Star Award for Quality (ISAQ) is to recognize the commitment to quality in the top areas of business, services and industry from diverse sectors all around the world.

Jambatan Kedua Sdn Bhd (JKSB), the concessionaire for the Sultan Abdul Halim Mu'adzam Shah Bridge or Penang Second Bridge, won a gold award at the International Star Award for Quality (ISAQ) during the International Quality Convention in Geneva.

- **Road Engineering Excellence Award 2014 - Road Engineering Association Of Malaysia (REAM)**
  – 10 November 2014

  This award was introduced to confer recognition to the most outstanding road engineering project built within Malaysia.

- **Special Project Award (Silver Awardee) -Prime Minister's Hibiscus Award 2014/2015**
  – 15 November 2015

  Prime Minister's Award 2014/2015 presents an opportunity for public recognition of business, industry's environmental accomplishment, leadership and serves to create environmental awareness amongst enterprises that have yet to demonstrate environmental stewardship. JKSB was the first construction company/ concessionaire to participate and achieve the Special Project Award.

- **The Brunel Medal Awards 2015 - ICE (Institution of Civil Engineers), UK – 9 October 2015**

ICE's Annual Awards are designed to recognize both outstanding civil engineering achievements and contribution to the profession and the institution. The Brunel Medal is awarded to a project or individual that represents excellence within civil engineering.

Jambatan Kedua Sdn Bhd (JKSB), has carved Malaysia name on the 'Civil Engineering Wall of Fame' after being the first Southeast Asian country and the third country outside the United Kingdom to be honored with the prestigious Brunel Medal award.

The ICE Awards Ceremony was held at ICE Headquarters, One Great George Street, Westminster, London.

❖ CONCLUSION

Despite its implementation in a fast track manner, the Jambatan Sultan Abdul Halim Mu'adzam Shah project was constructed to the highest quality, considering health, safety, cost, sustainability and environmental conservation.

Thank You
For Your Kind Attention