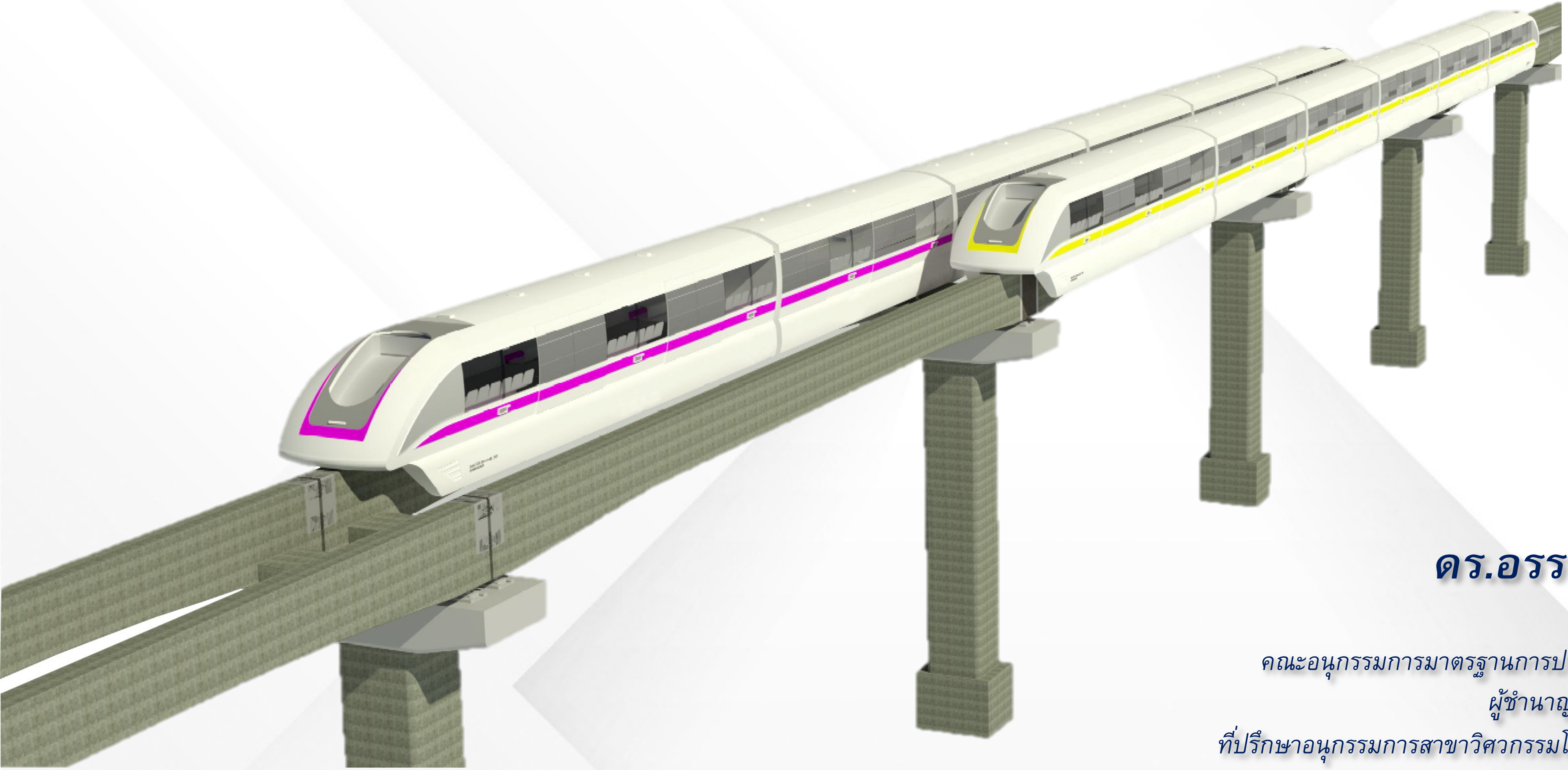
การเตรียมความพร้อมเพื่อขอรับใบอนุญาตประกอบวิชาชีพวิศวกรรมควบคุม ระดับวุฒิวิศวกร สาขาวิศวกรรมโยธา

งานออกแบบการพิจารณาตรวจสอบและการก่อสร้างโครงการรถไฟฟ้าสายสีเหลืองและสายสีชมพู



ดร.อรรถสิทธิ์ ศิริสนธิ

วุฒิวิศวกร วย.2356

คณะอนุกรรมการมาตรฐานการประกอบวิชาชีพ, สภาวิศวกร

ผู้ชำนาญการฯ สาขาวิศวกรรมโยธา

ที่ปรึกษาอนุกรรมการสาขาวิศวกรรมโครงสร้างและสะพาน, วสท.

ประธานคณะกรรมการร่างคู่มือมาตรฐานแนวทางความสามารถการทำงานแบบจำลองสารสนเทศอาคาร, วสท.

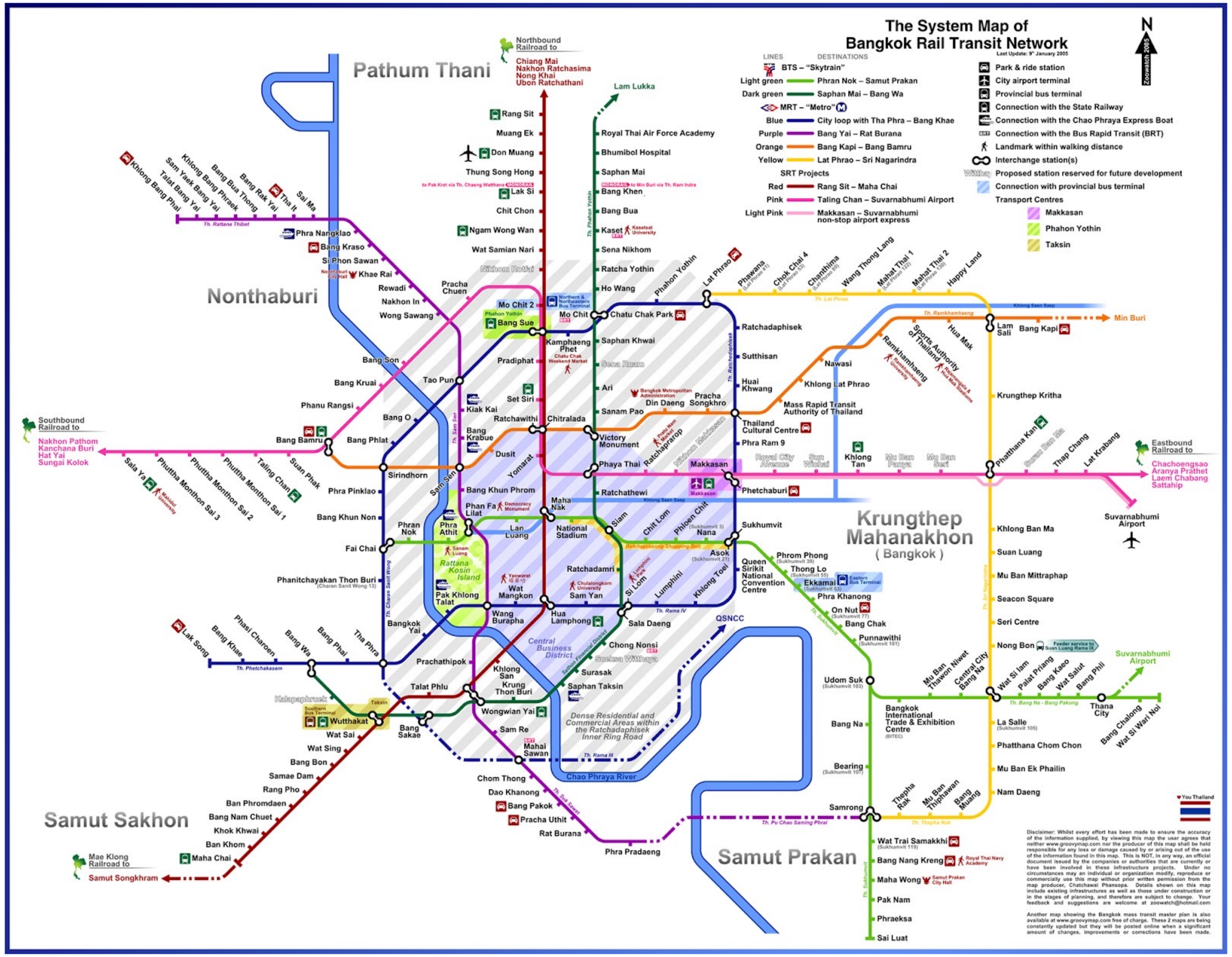
CONTENT:

INTRODUCTION

INTRODUCTION: Bangkok Mass Transit System

Bangkok is the capital and most populous city of Thailand. The city occupies 1,568.7 Square Kilometers in the Chao Phraya River delta in central Thailand, and has a population of over eight million, or 12.6% of the country's population. Over fourteen million people (22.2%) lived within the surrounding Bangkok Metropolitan Region at the 2010 census making Bangkok the nation's primate city, significantly dwarfing Thailand's other urban centers in terms of importance.

The Bangkok Mass Transit System, commonly known as the BTS or the Sky train is an elevated rapid transit system in Bangkok, Thailand. This system was beginning in 1999. In 2004, underground train system i.e., Metropolitan Rapid Transit or MRT was operated by the Bangkok Expressway and Metro Public Company Limited (BEM) under a concession granted by the Mass Rapid Transit Authority of Thailand (MRTA).



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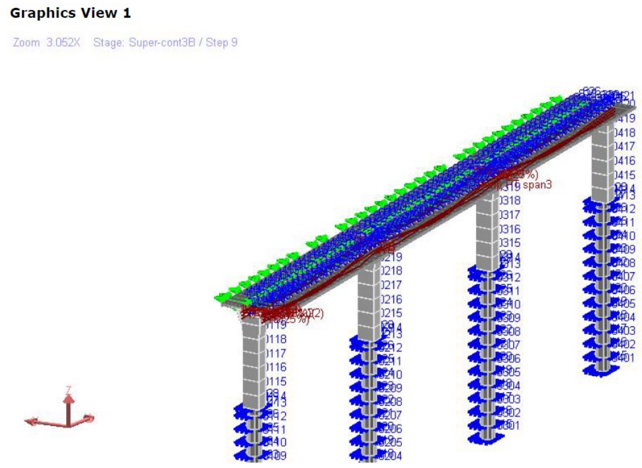
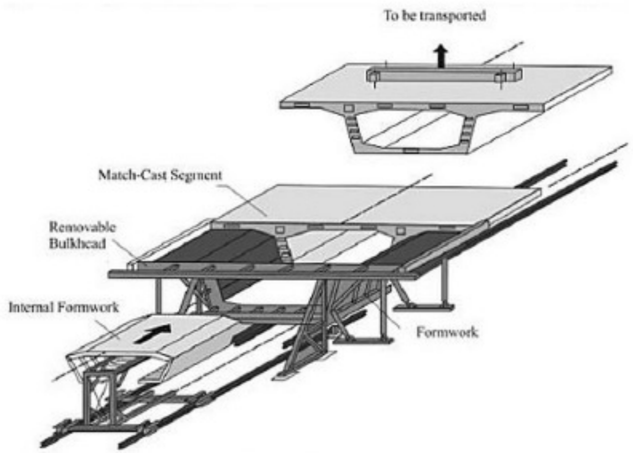
INTRODUCTION: Bangkok Mass Transit System

Elevated MRT system: Precast segmental Box girder – Span by Span construction





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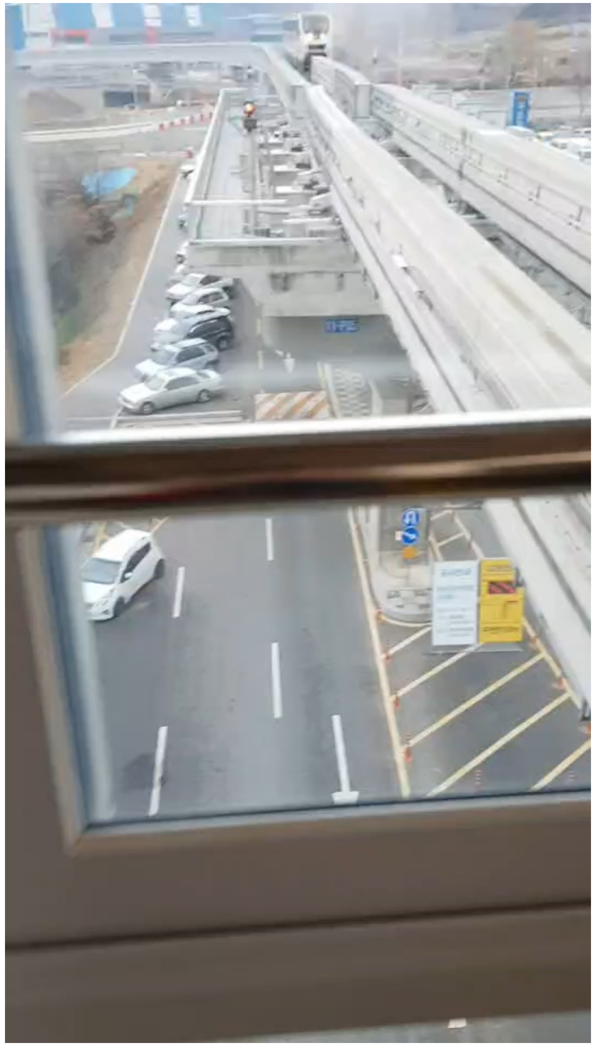
INTRODUCTION: Bangkok Mass Transit System

Elevated MRT system: Monorail system – Guideway Beam



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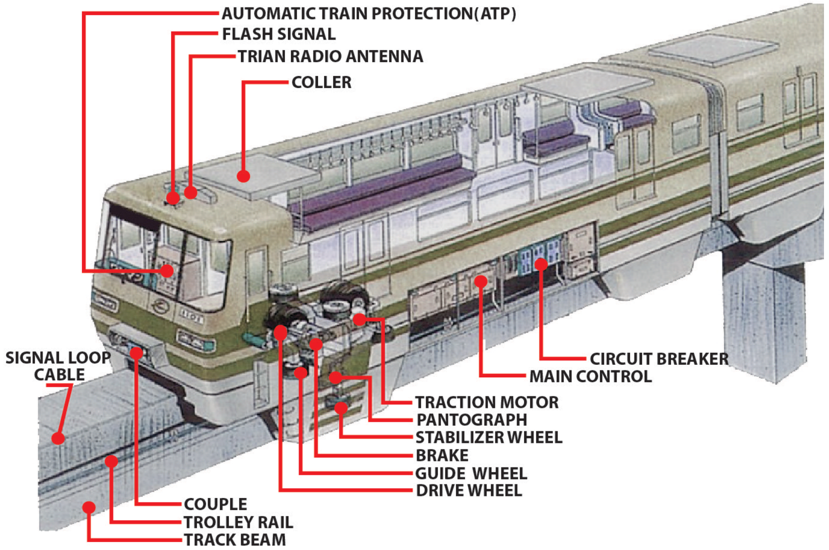
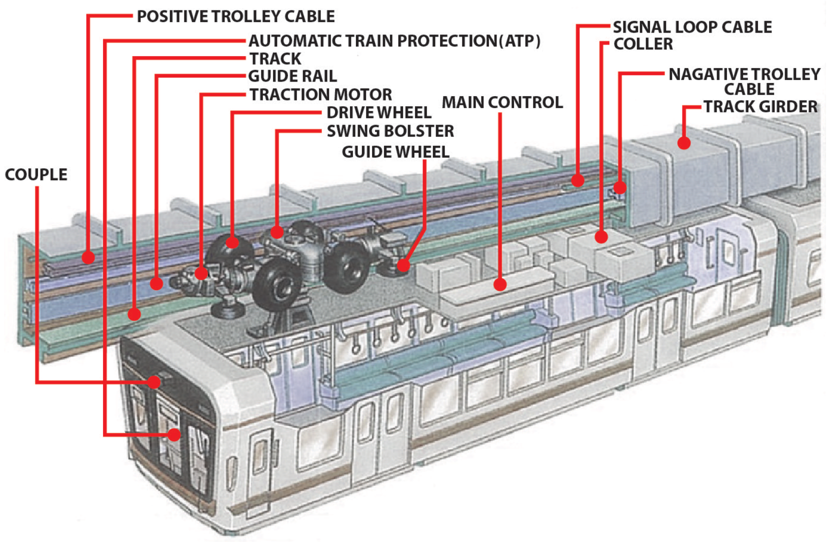
INTRODUCTION: Bangkok Monorail





Monorail transportation systems have been widely used in medium and small cities as well as hilly cities owing to their excellent climbing ability, lower noise, and shorter construction period. Monorail transportation systems can be classified into two categories:

(1) Straddle types,

(2) Suspension types,

according to how the monorail vehicle is operated. Recently, Mass Rapid Transit Authority (MRTA) Thailand has decided to adopt Monorail system in Bangkok as a rapid transit system due to the limited space, narrow roads and sharp curves in the city. The design of monorail track lines permits flexible and various alignments that include curves of small radiuses and large slopes.

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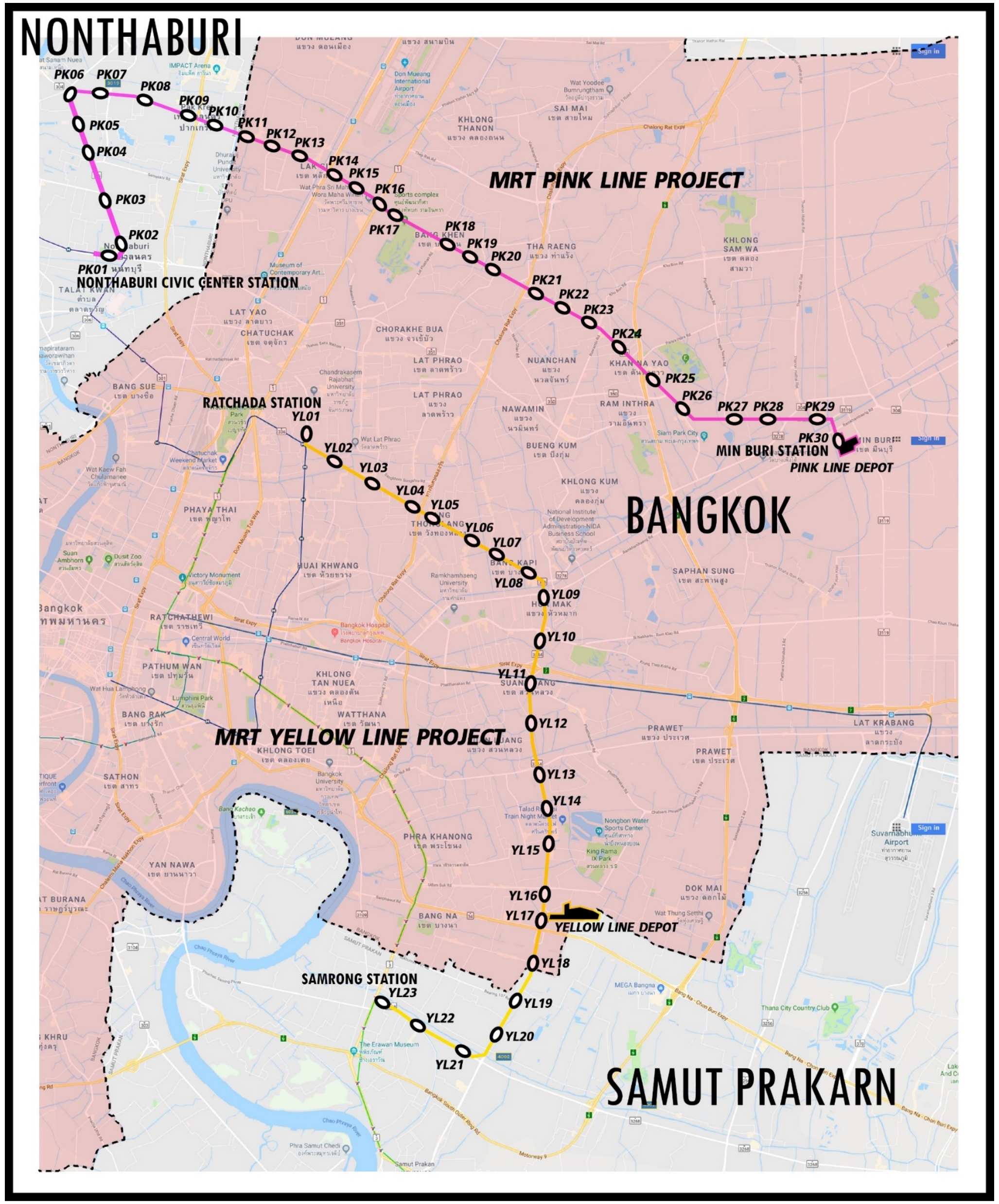
PROBLEM STATEMENT: Bangkok Monorail



Initially MRTA has approved the construction of two monorail projects i.e., ***Pink Line (PL) and Yellow Line (YL)***. The proposed duration for the both projects is 39 months. MRTA Thailand adopted bidding process for the selection of the appropriate contractors for design and construction. The bidding process was in the form called Public Private Partnership Project (PPP project).

MRTA awarded construction, operation and maintenance services of both projects to the ***BSR Joint Venture***. BSR Joint venture is a joint venture among three groups i.e., Bangkok Mass Transit System (BTS) holding Group, Sino-Thai Engineering and Construction Public Company Limited (STECON), and RATCH Group Pubic Company Limited, Thailand.

Further, BSR Joint Venture invited ***STECON as an exclusive contractor for the civil works*** and assign responsibility of complete design and construction. Since Bangkok is highly populated city with narrow roads and sharp curves in the city, the construction of the traditional sky train system may cause difficulties in construction, large construction cost and time. In contrast to the traditional monorail systems.

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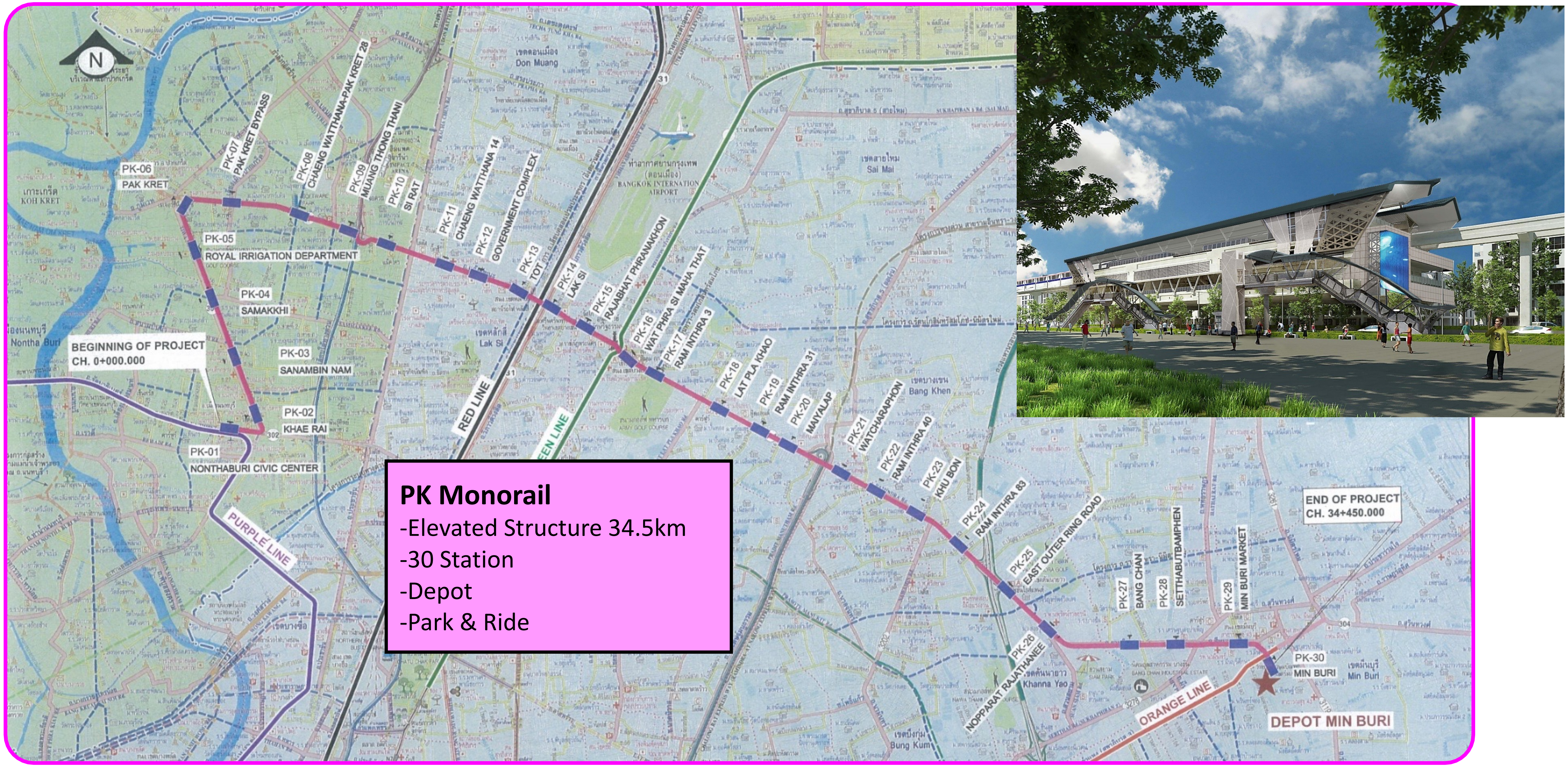
PROBLEM STATEMENT : MRT Pink Line Monorail



PK Monorail

- Elevated Structure 34.5km
- 30 Station
- Depot
- Park & Ride

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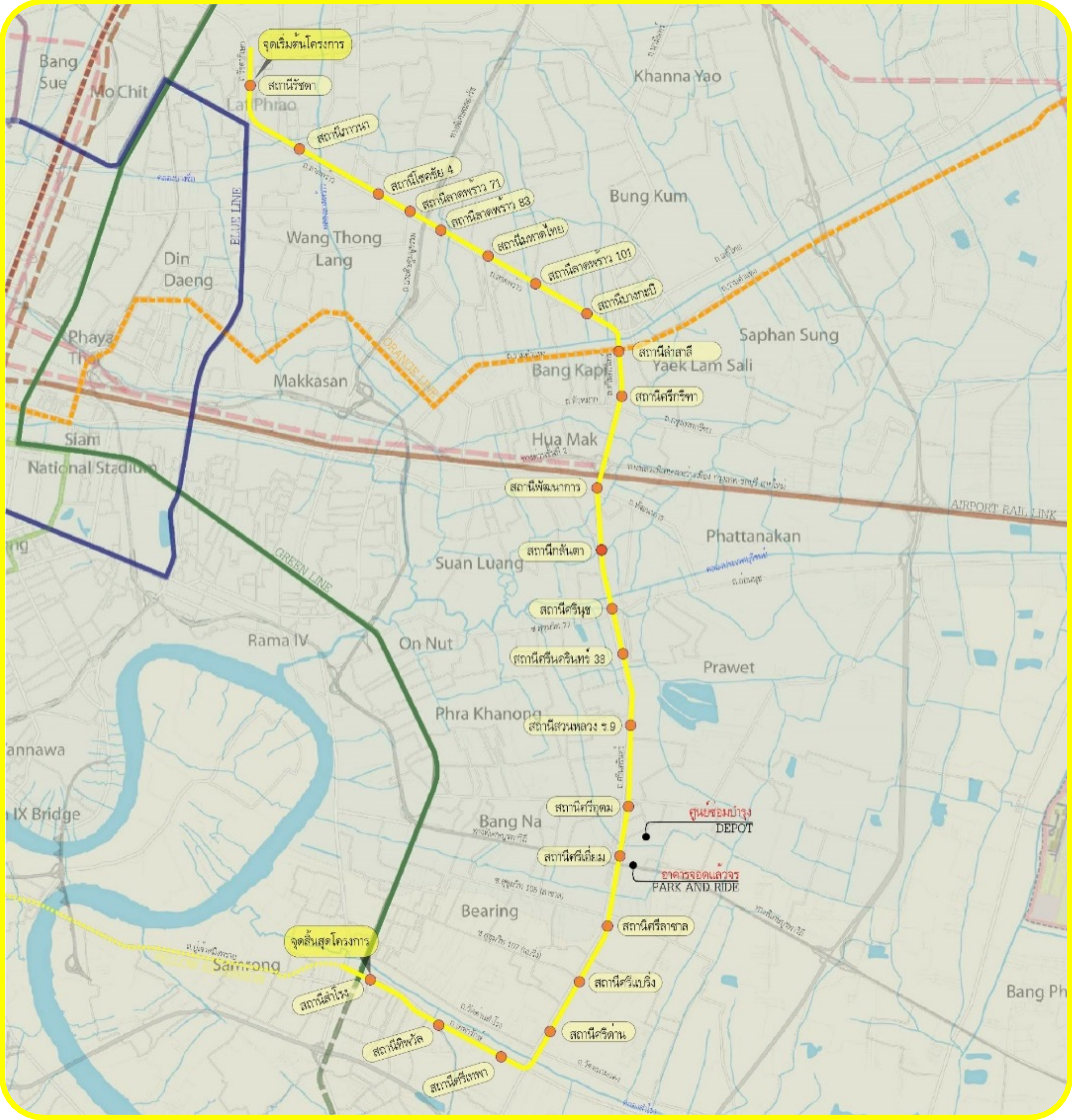
PROBLEM STATEMENT : MRT Yellow Line Monorail



YL Monorail

-Elevated Structure 30.4km

-23 Station

-Depot

-Park & Ride

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PROBLEM STATEMENT: PK-YL Monorail

Pink Line and Yellow Line Monorail; Quantitative details of different structural components for PK and YL projects are summarized in tables, within 39 months the project have must be ready for operated. The actual construction time is too short around 27-30 months, the design and construction method is the mainly reason to finished project in time

Structure	PK Line (34.50km)		YL Line(30.50)	
	Type	Qty	Type	Qty
Pier		**1,147**		**977**
Pile	Bored Pile 1.00m Dia.	40	Bored Pile 1.00m Dia.	8
	Bored Pile 1.20m Dia.	220	Bored Pile 1.50m Dia.	348
	Bored Pile 1.50m Dia.	658	Bored Pile 1.80m Dia.	549
	Bored Pile 1.80m Dia.	605	Bored Pile 2.00m Dia.	109
	Bored Pile 2.00m Dia.	9	Barrette Pile 2.50mx0.80m	18
	Barrette Pile 2.50mx0.80m	44	Barrette Pile 2.70mx0.80m	1
	Barrette Pile 3.00mx1.20m	24	Barrette Pile 3.00mx1.20m	90
	On design	41		-
	Total Pile	**1,641**	**Total Pile**	**1,123**
Guideway Beam	Straight Beam	1,563		1,448
	Curved Beam	841		602
	Total GWB	**2,404**	**Total GWB**	**2,050**

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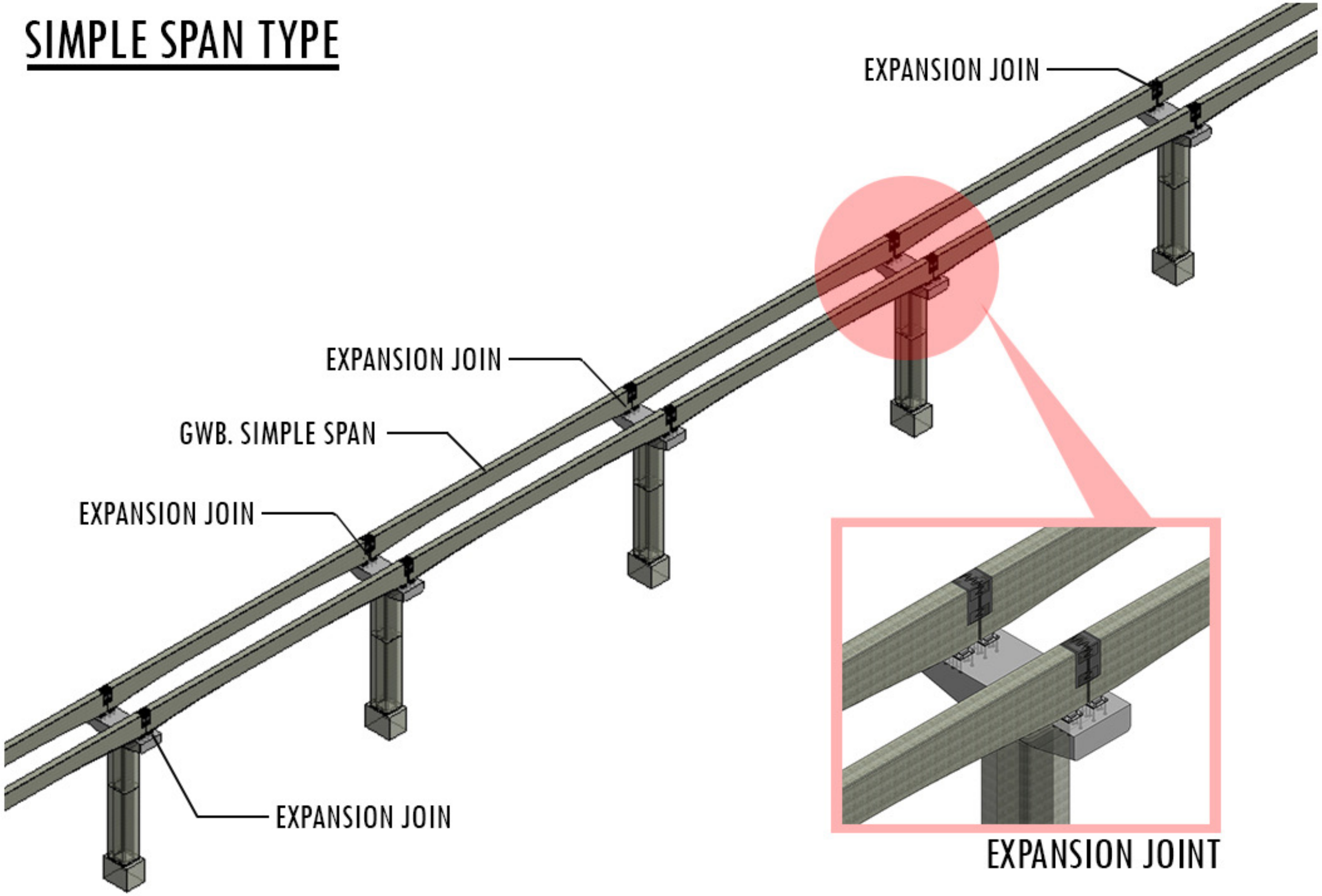
PROBLEM STATEMENT

INTRODUCTION: Monorail Structure Characteristic

SIMPLE SPAN STRUCUTRE SYSTEM; single span girders are placed on the large size columns or piers. In this type, the installation of GWB is simple and accurate. However, their performance is poor during earthquake. In addition, bearings required high initial and maintenance cost.



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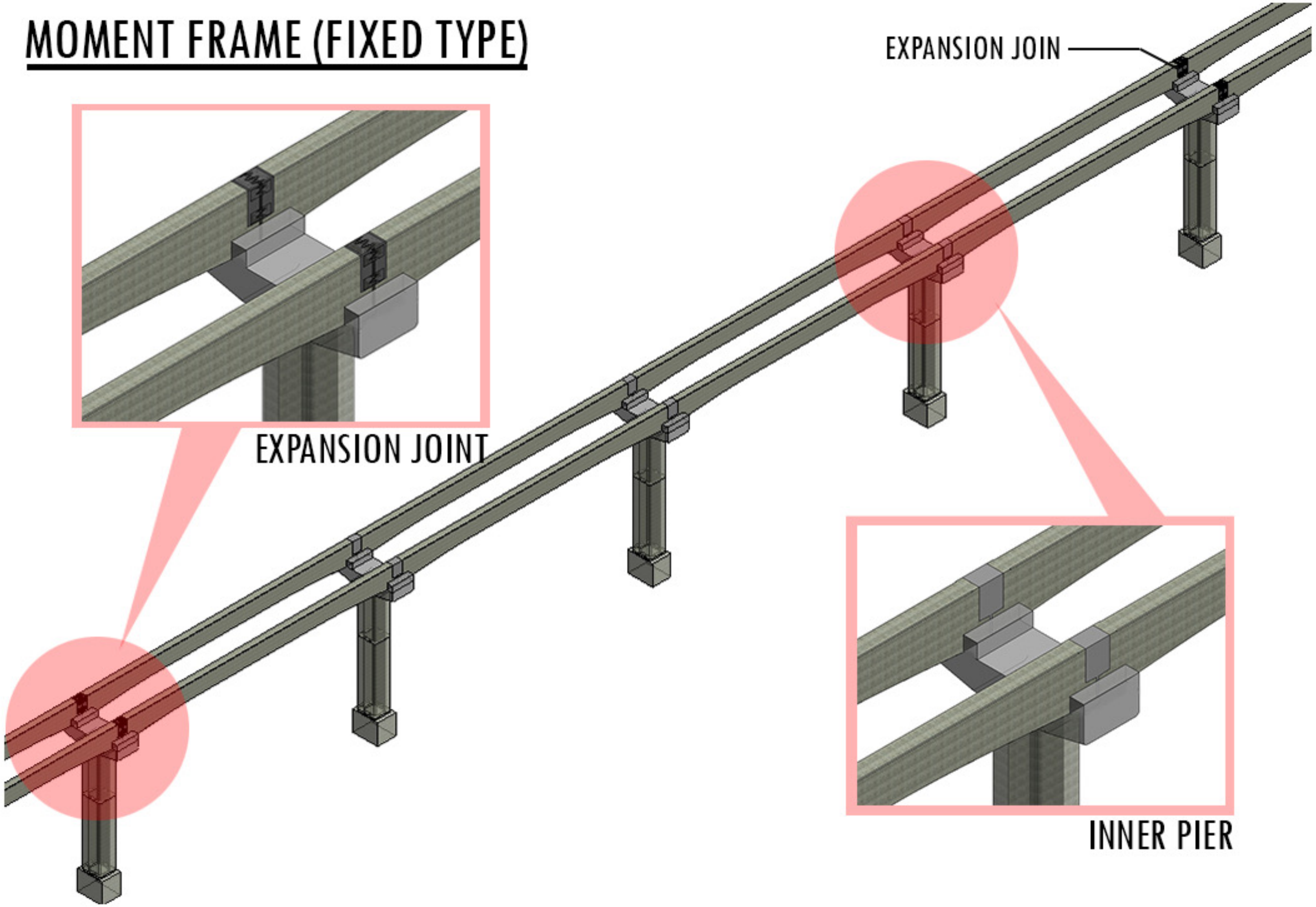
INTRODUCTION: Monorail Structure Characteristic

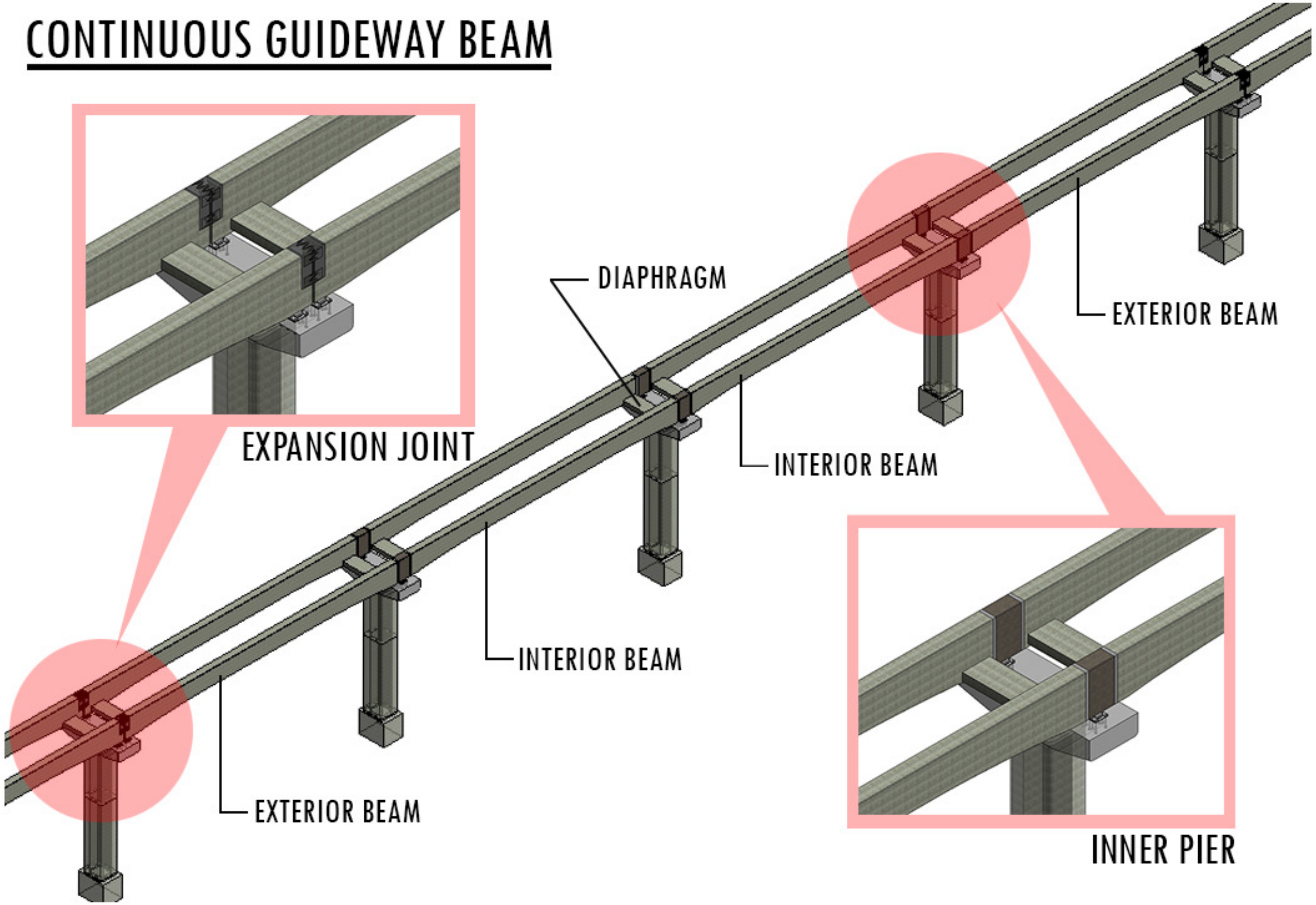
Moment Frame Structural System; is fixed-frame in which three or four span pre-tensioned girders are installed and connected with cross beams. In this system, the sizes of the supporting columns and foundations are smaller than Simple Span system



PROBLEM STATEMENT: PK-YL Monorail

CONTINUOUS GUIDEWAY BEAM SYSTEM;

Based on broad experience of design and installation of bridge girders, it was decided to propose continues Four PTGS supported at columns at 30 meter. At each support, the use of bearing was proposed to transfer load to the cross beams thus acting as continues girder system. In this system small-size GWBs are required and their installation is easy. The performance of the proposed system is much better during the earthquake as compared with the traditional systems. A computer program was employed to design the GWBs



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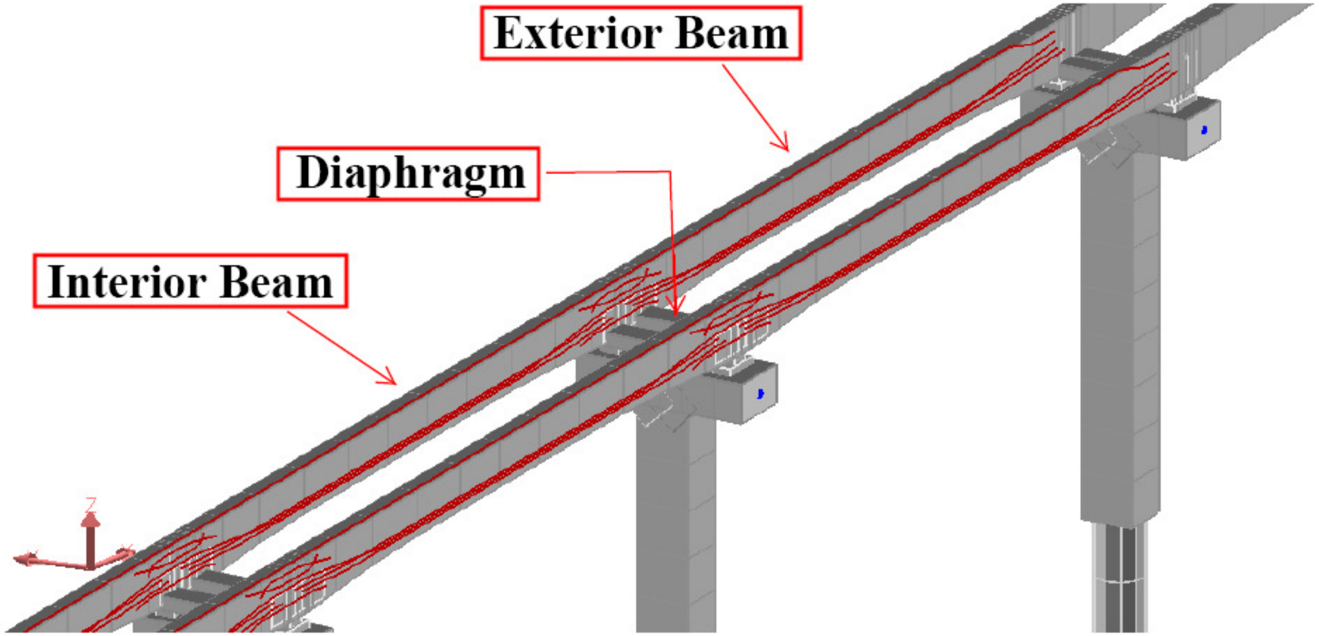
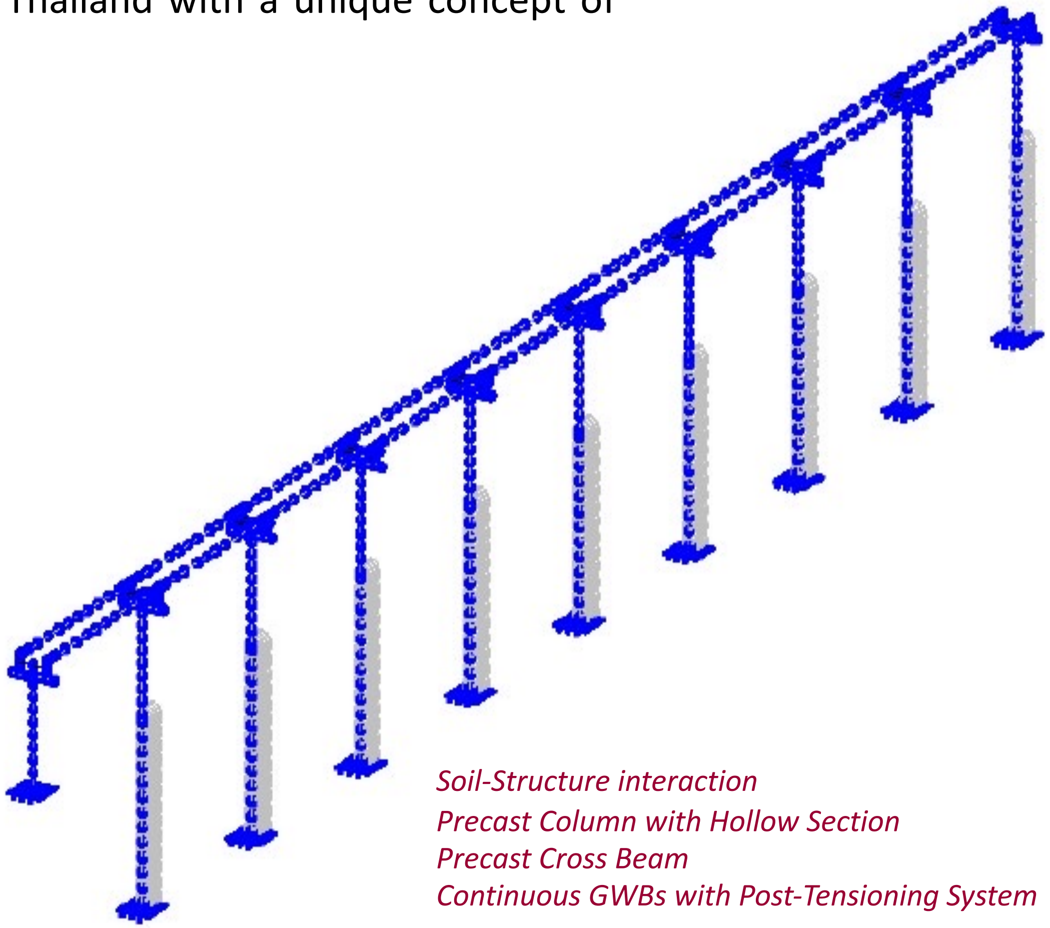
PROBLEM STATEMENT: PK-YL Monorail

CONTINUOUS GUIDEWAY BEAM SYSTEM; proposed a novel four-span post-tensioned girder system (PTGS) in which four Guideway Beams (GWBs) will be post tensioned in such a way that post-tension tendons will run through four consecutive spans. The salient features of the proposed system are low cost, safe and less construction time. The proposed monorail system is 1st monorail project in Thailand with a unique concept of design and construction.



Structural Detailing



Structural Model

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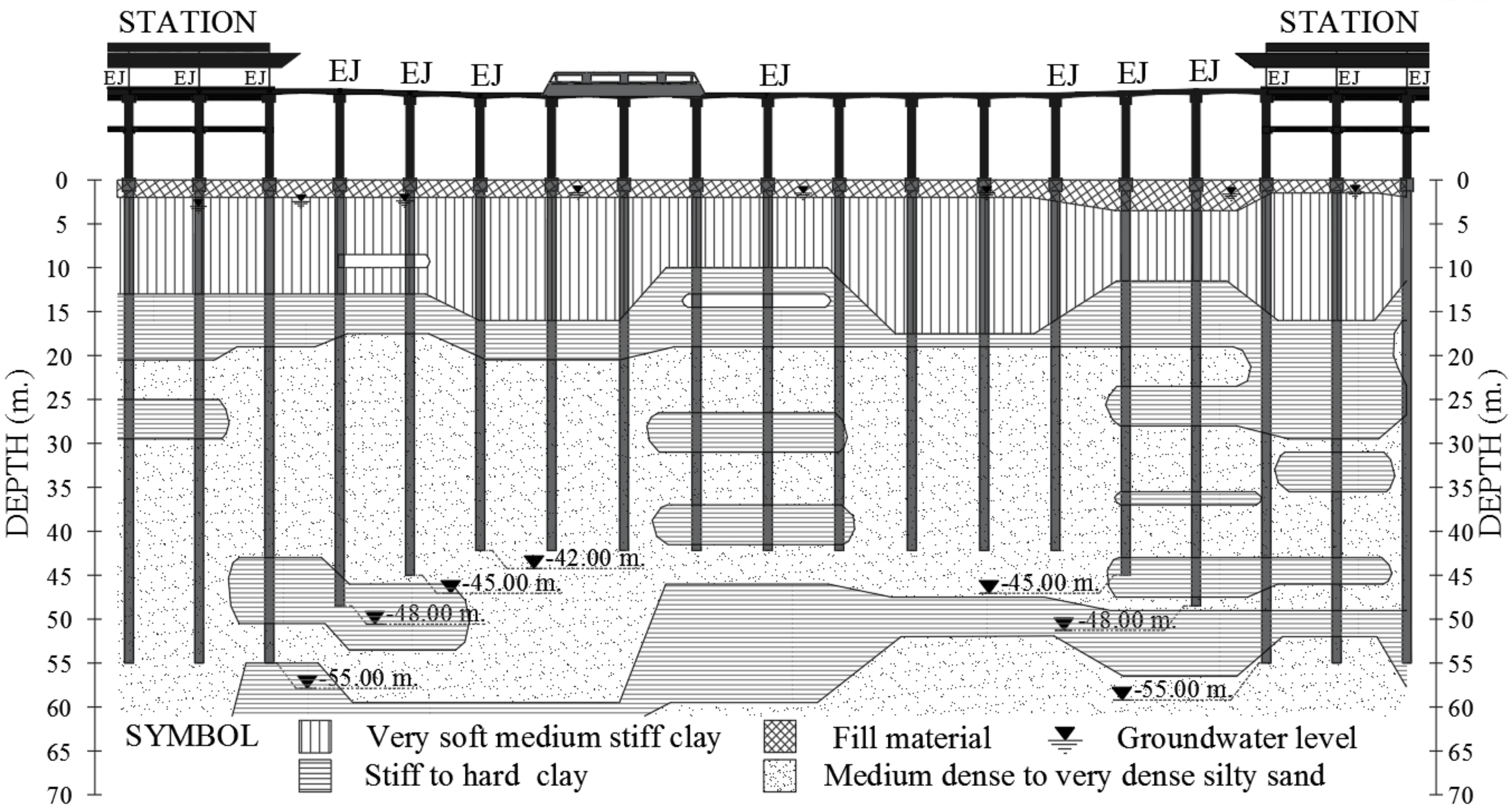
PROBLEM STATEMENT: PK-YL Monorail

ML Foundation;

Soil properties were access through the soil investigations at different locations. In these projects, mainly bored piles with wet process were designed to facilitate the loading and existing soil conditions. However, at some locations, barrette piles were recommended to accommodate the local soil conditions. The proposed system is basically a lightweight system as compared with traditional box girders thus requires piles of shorter lengths. These piles were designed to transfer load to the layers of stiff clay. The depth of the stiff clay layers is around 39-44 meter. The piles are placed on the stiff hard clay thus providing piles length around 55-60 meters.



Bangkok's soil profile for PK Line & YL Line

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PROBLEM STATEMENT: PK-YL Monorail

ML Column & CB;

The column or pier is basically comprised of three parts, 1. Transition block, 2. Box segments, and 3. Crossbeams. Construction step is as follow;

In first step, transition blocks will be constructed over the pile caps.

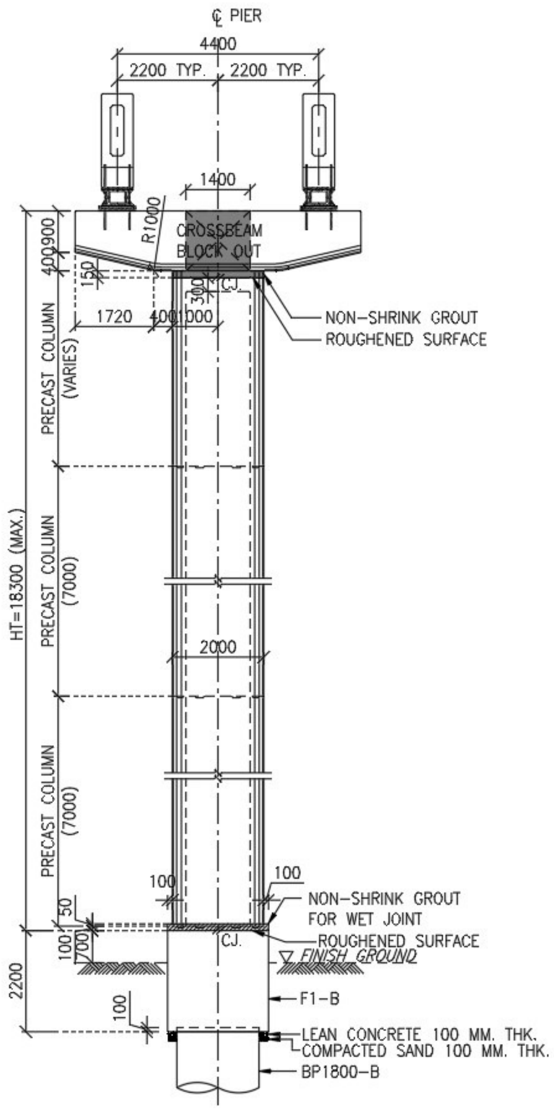
In the second step, PT tendons will be installed.

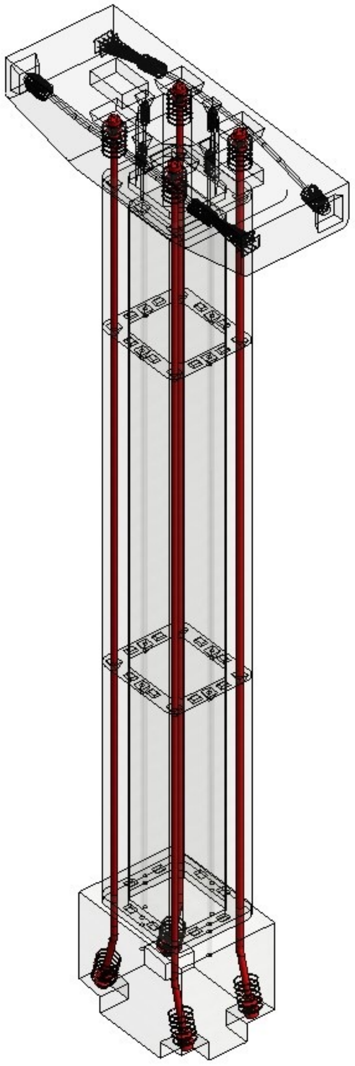
In the third step, hollow box segments will be installed.

In the fourth step crossbeams will installed and a temporary post-tension (around 15%) will be applied to hold box segments and crossbeam on right place.

In the fifth step, the opening between column and transition block will be filled by using concrete.

Finally, full pre-stressing force will be applied to the PT tendons.





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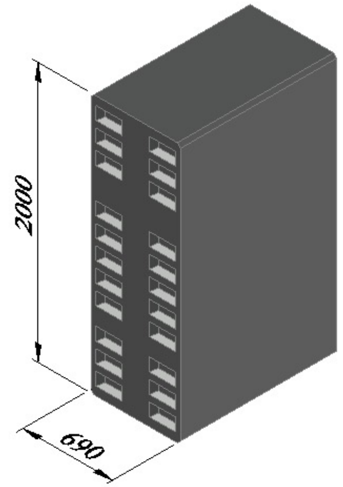
PROBLEM STATEMENT: PK-YL Monorail

Details of GWBs;

GWBs require high precision both at construction and installation stages. It is important to manage the design, construction and installation of GWBs to meet the required standards of monorail system. The proposed system will be installed in the following steps;

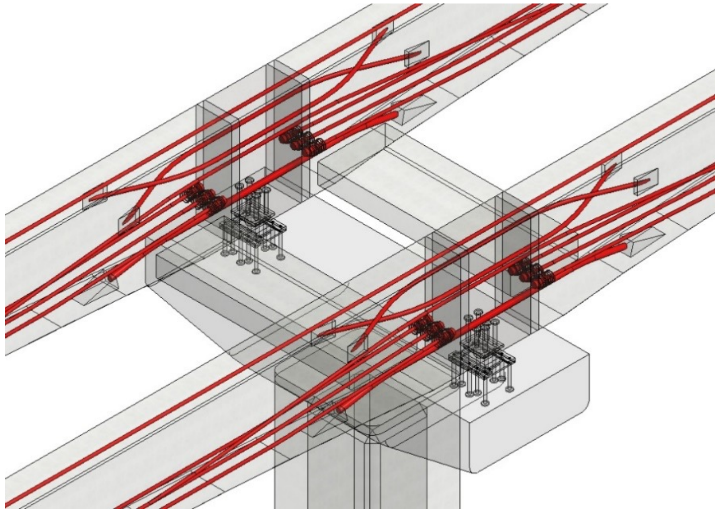
1. installation of the PGs over the cross beams with the help of some temporary arrangements, 2. PGs will be locked with cross beams after proper installation, 3. Installation of the GWBs, 4. Installation of wet joints and 5. Installation and post-tensioning of PT tendons. It is important to note that each time, a pair of GWB will be installed at the same time to avoid un-necessary load distribution. The philosophy of the PG is like the pre-cast segmental box girder. Finally, a diaphragm beam will be constructed to hold two guideway beams at the right place.

Exterior GWBs



Pier Segment (PGs)

Interior GWBs


Graphical image of PT at internal PGs

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THEORY AND PREVIOUS RESEARCH

THEORY AND PREVIOUS RESEARCH:

Theory: The structural response of the proposed pre-cast post-tensioned girder system will be investigated under two different conditions such as service load condition and ultimate load conditions. Further details of each condition are discussed in the following sections;

1) ***Service load condition:*** The main objective of this loading condition is *to verify the structural response of the proposed pre-cast post-tensioned girder system in terms of crack appearance and deflection.* From design point of view and structural safety requirements, at service load condition the maximum deflection should not be greater than span/1000 without any crack occurrence. Thus, in service load conditions maximum load will be applied up to the service state. The criterial for service state will be developed by using the tensile strain of the steel bars in the tension region. Service state will be considered onset of 50% yield stain in the steel bars. Further in order to completely evaluate the structural response of the proposed three-span pre-cast post-tensioned girder system, the service load will be applied separately both at the exterior and interior spans. On each span, two-point loading will be applied using hydraulic jacks.

2) ***Ultimate load condition:*** The main objective of ultimate load condition is *to evaluate the detailed structural response of the proposed pre-cast post-tensioned girder system up to the ultimate failure and or collapse.* In this condition, four-point loading will be applied at time. Four-point loading will be considered by applying two-point loading at each interior and exterior girder. During the loading, complete response of the three-span system will be monitored by using large number of linear variable differential transducers and strain gauges. The structural response of the wet joints will be observed through the crack gauges. The structural response of the longitudinal steel bars, vertical steel bars and post-tension tendon wires will be recorded through the strain gauges. The behavior of the bearings will also be monitored through linear variable differential transducers and strain gauges. During the test, the crack appearance and propagation will be monitored through the visual inspection and recorded using cameras.

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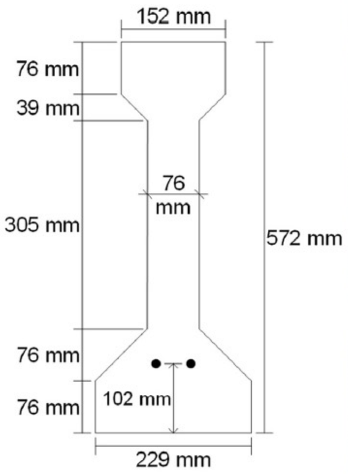
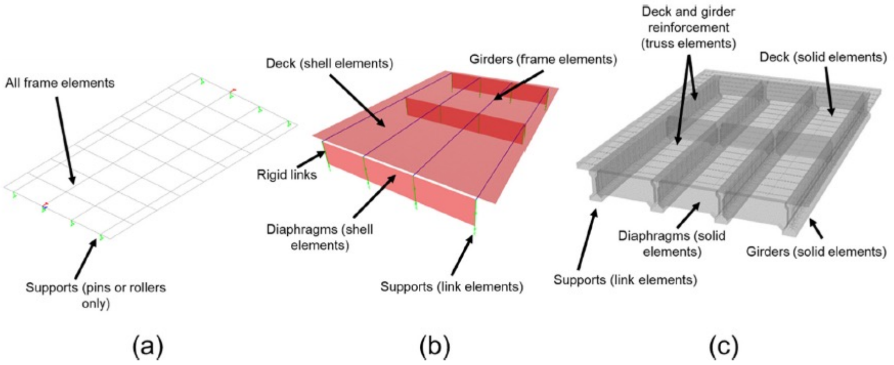
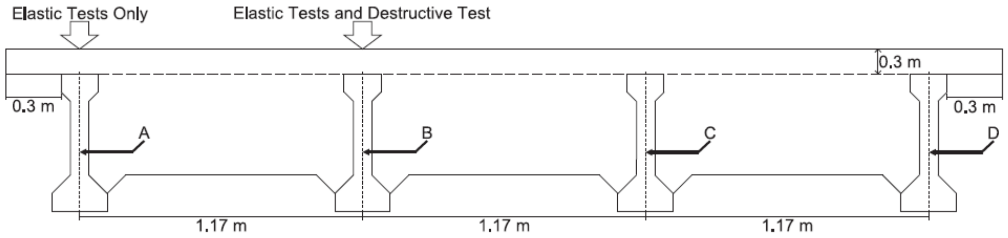
THEORY AND PREVIOUS RESEARCH:

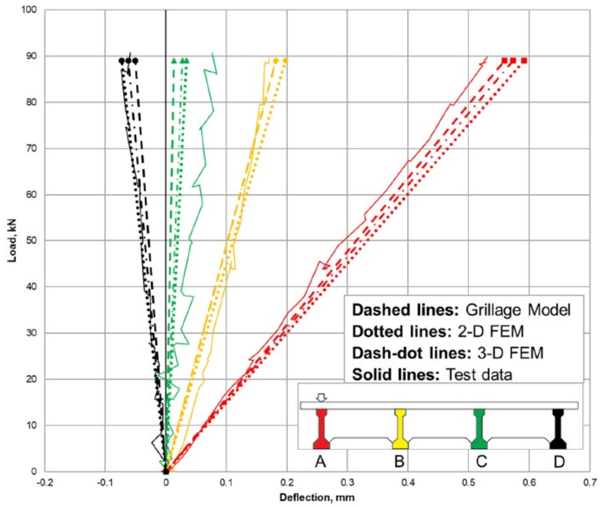
Summary of literature review: The detailed review of existing research indicated that experimental response of different types of bridges and bridge girders such as;

Pre-stressed concrete bridges, pre-stressed concrete I girder bridges and pre-stressed concrete girder bridges, have been extensively studied both in the laboratories and field environments. *Nurray et al. 2019 performed destructive testing and computer modeling of a scale pre-stressed concrete girder bridge.*









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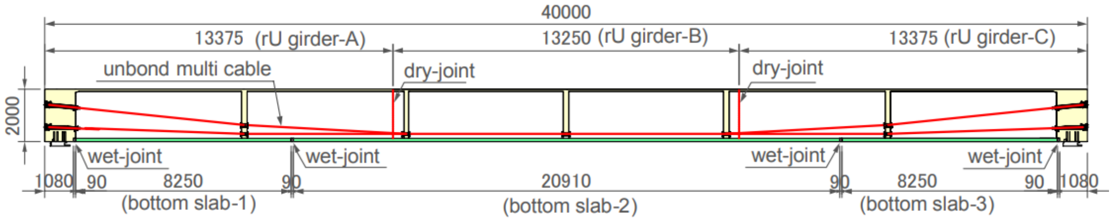
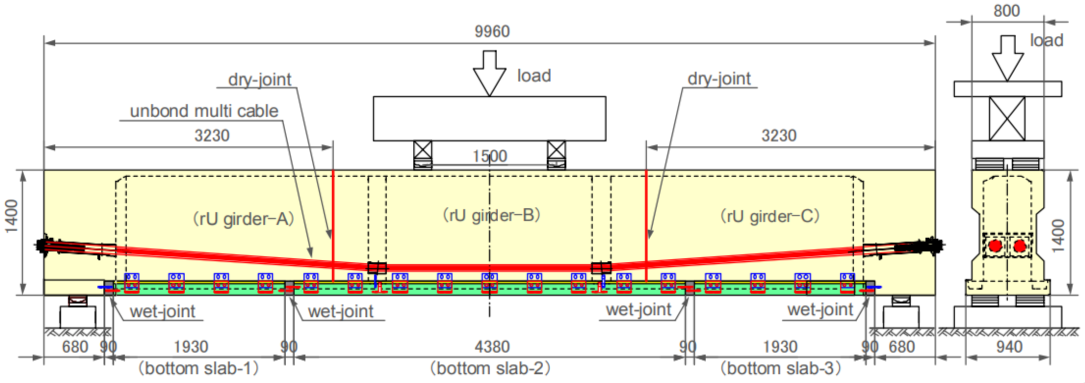
THEORY AND PREVIOUS RESEARCH:

Summary of literature review: The detailed review of existing research indicated that experimental response of different types of bridges and bridge girders such as;

A few studies have also been conducted on the application of monorail bridge girders and their structural response in Japan. For the structural response of the monorail girders, small scale girders were constructed and tested in the laboratory. *Tokyo Monorail and Taisei corporations have been carrying out the corporative technical development of a 40m long monorail girder applying the UFC that must be the longest span in the world made of concrete material.*





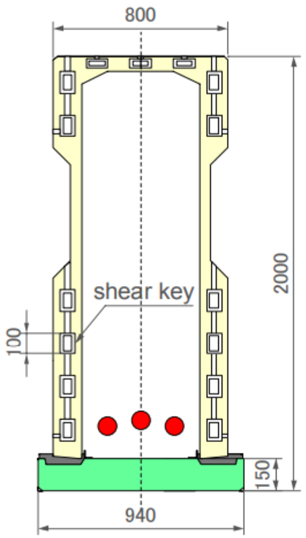


Figure 5. Dry-joint.

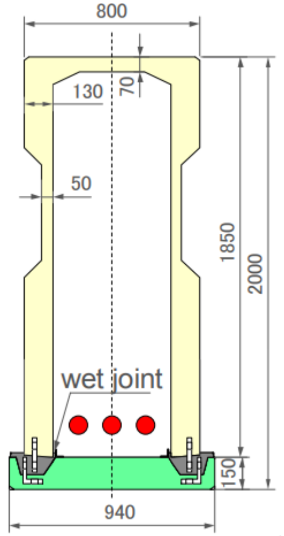
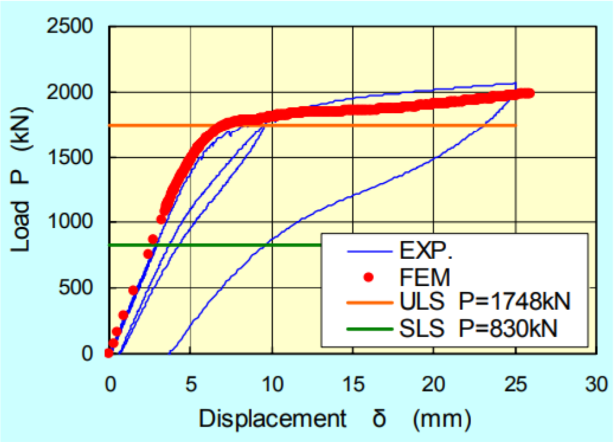


Figure 6. Wet-joint.



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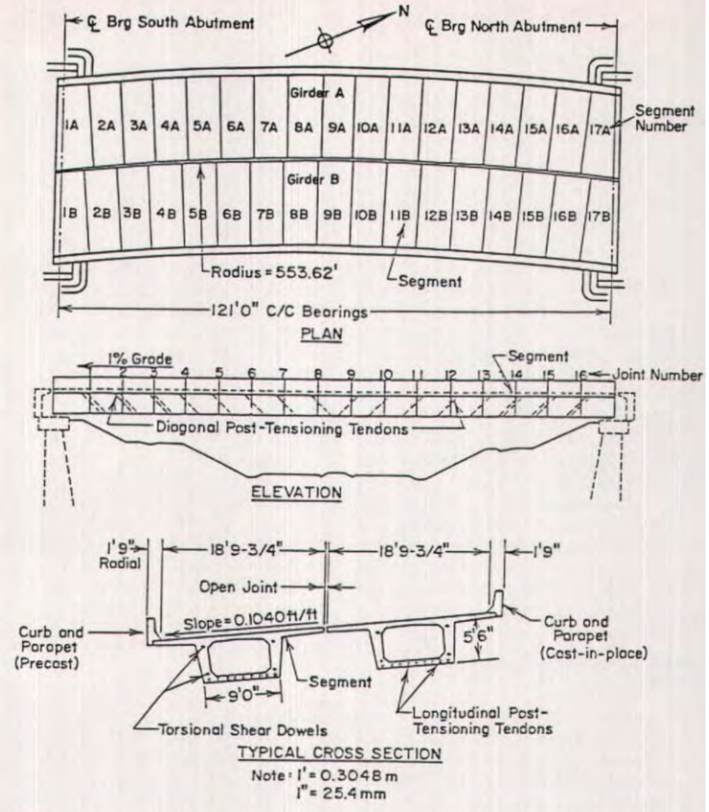
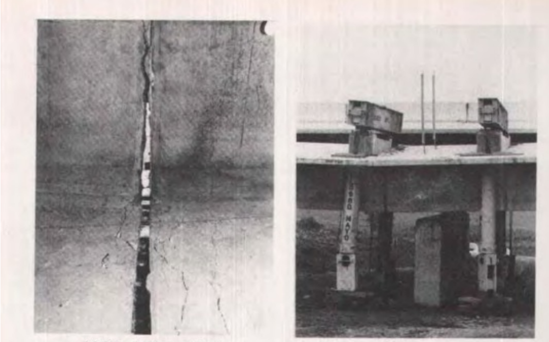
THEORY AND PREVIOUS RESEARCH:

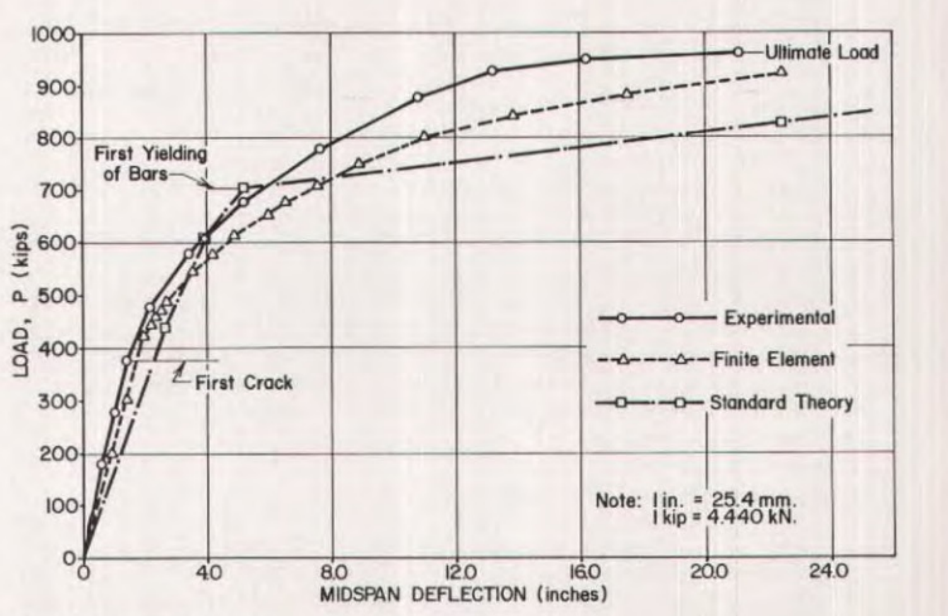
Summary of literature review: The detailed review of existing research indicated that experimental response of different types of bridges and bridge girders such as;

Some studies have also reported the performance of concrete segmental bridge technology keeping in view the sustainable bridge construction. Different researchers have also investigated the behavior of pre-stressed concrete bridges after few years of service. *Abdel-Halim et al. 1987 investigated the overload behavior of pre-cast concrete segmental girder bridge.*





(a) Plan (bottom surface) (b) Elevation



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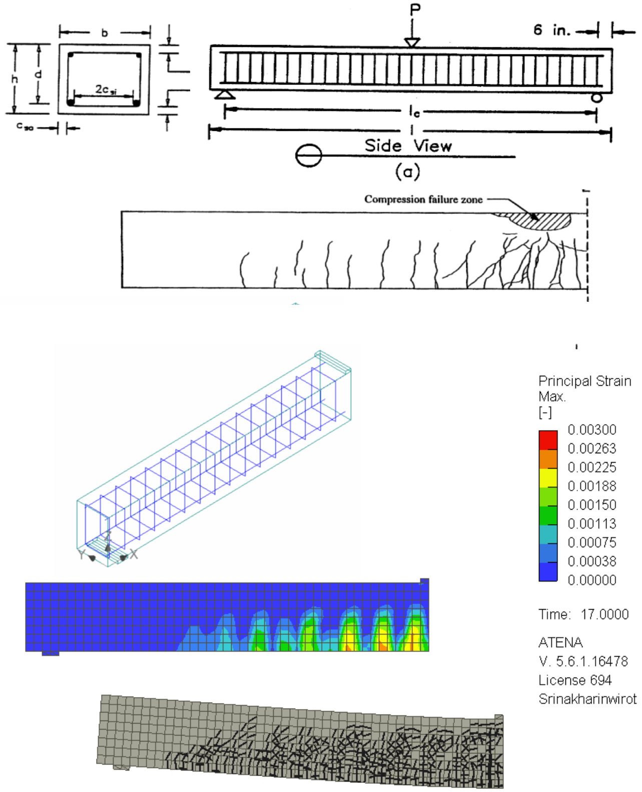
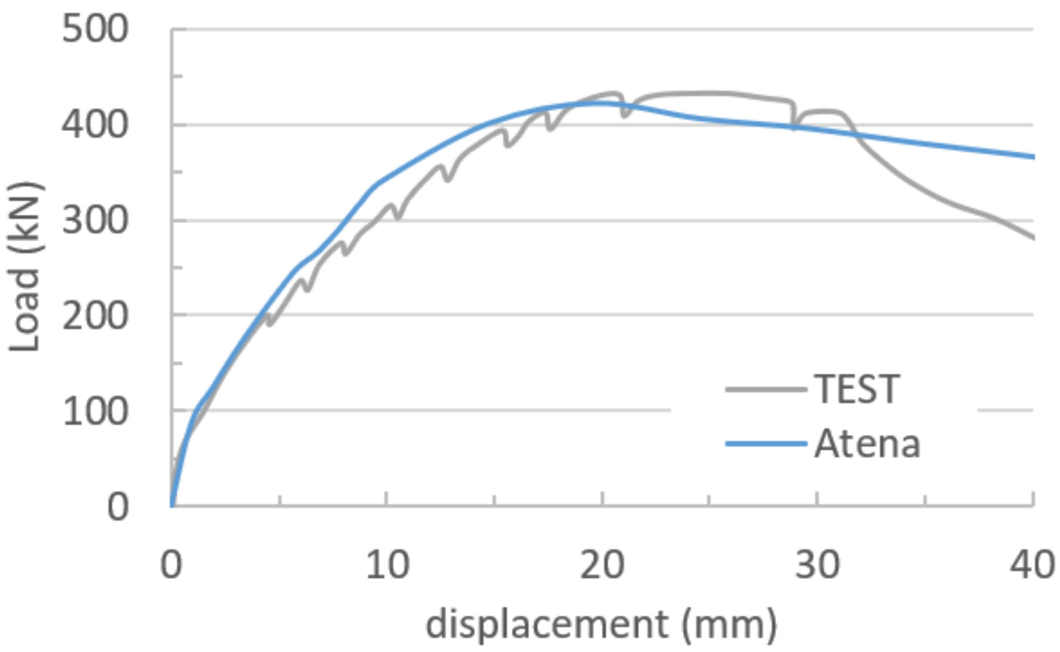
THEORY AND PREVIOUS RESEARCH:

Summary of literature review: The detailed review of existing research indicated that experimental response of different types of bridges and bridge girders such as;

Further, different studies indicate that finite element analysis program ATENA is well capable to predict the structural responses of the reinforced concrete members which can be effectively used to study the behavior of the proposed system in this study. *Panuwat J. 2019 has conducted different studies to investigate the performance of the finite element models in ATEAN and compared the experimental results with the existing studies. Results showed a good comparison among ATENA and experimental results*





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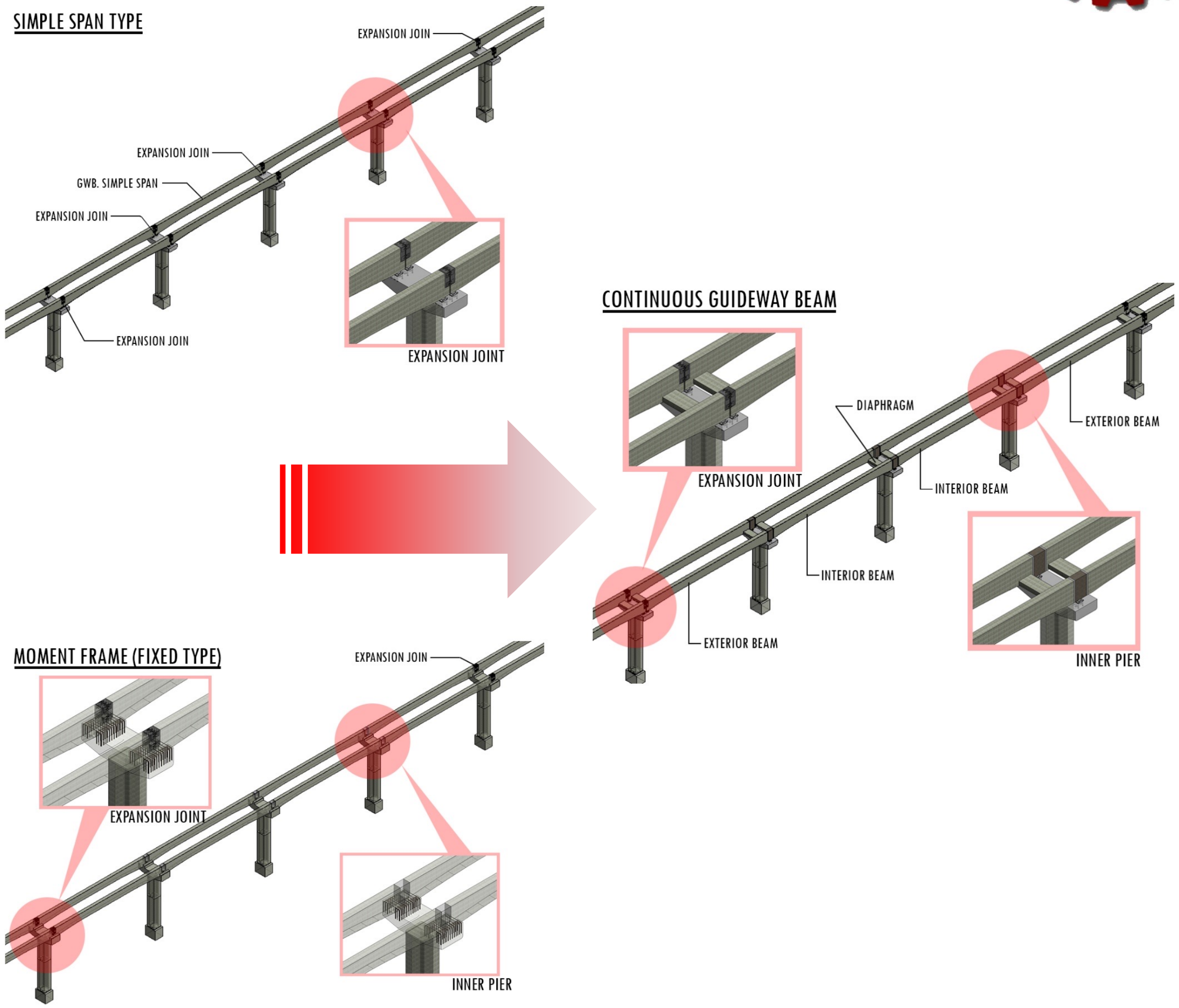
OBJECTIVE

OBJECTIVE

- The objective of the large-scale experimental study was to *investigate the elastic and plastic structural response of a Full-scale Precast Post-tensioned Continuous (FPPC) girder for straddle monorail* - a subject that has not yet been explored to ascertain the accuracy of the design.
- Another objective was to *investigate the effect of different loading conditions such as service and ultimate loads on the structural behavior of the Full-scale Precast Post-tensioned Continuous (FPPC) girder.*
- To *investigate the effect to loading conditions on different spans of the Full-scale Precast Post-tensioned Continuous (FPPC) girder such as exterior and interior spans.*
- To *develop an analytical tool which can be used to accurately predict the ultimate behaviour of the Full-scale Precast Post-tensioned Continuous (FPPC) girder.*



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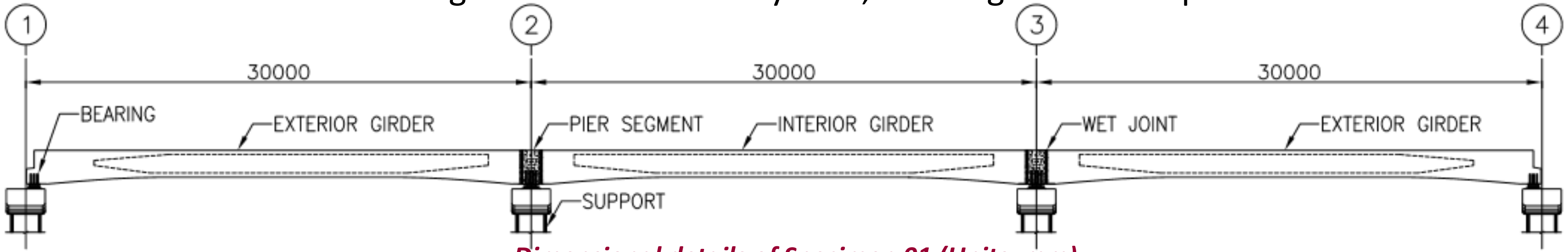
METHODOLOGY

METHODOLOGY: Scope of Test - FPPC

Scope of Test: The main scope of the current research work is to experimentally and analytically investigate the structural response of a newly proposed three-span post-tension girder system. For this purpose, full-scale three-span post-tension girder system will be constructed and tested under different loading conditions. In this system, the length of each span will be 30 meter as shown



Dimensional details of Specimen 01 (Units: mm)

The structural response of the proposed three-span post-tension girder system will be evaluated under different conditions such as service load condition and ultimate load conditions.

In service load conditions, maximum load will be applied up to the service state. The criterial for service state will be developed by using the tensile strain of the steel bars in the tension region. *Service state will be considered onset of 50% yield stain in the steel bars*. Further in order to completely evaluate the structural response of the proposed three-span pre-cast post-tensioned girder system, *the service load will be applied separately both at the exterior and interior spans*. On each span, two-point loading will be applied using hydraulic jacks.

In ultimate load condition, four-point loading will be applied at time. ***Four-point loading will be considered by applying two-point loading at each interior and exterior girder.*** During the loading, complete response of the three-span system will be monitored by using large number of linear variable differential transducers and strain gauges. *The structural response of the wet joints will be observed through the crack gauges.* The structural response of the longitudinal steel bars, vertical steel bars and post-tension tendon wires will be recorded through the strain gauges. The behavior of the bearings will also be monitored through linear variable differential transducers and strain gauges. During the test, the crack appearance and propagation will be monitored through the visual inspection and recorded using cameras.

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METHODOLOGY: Scope of Test - FPPC

Material Properties: In this research project, the material properties will be selected to represent the real construction of the post-tension three-span bridge girder system to carry on monorail system. The main material properties of concrete, steel bars and poste tension tendons are summarized in the table;

Sr. No	Description	Compressive strength (MPa)	Yield Strength (MPa)	Ultimate Strength (MPa)
1	Concrete (Pile Cap)	50	-	-
2	Concrete (Support Column)	50	-	-
3	Concrete (Girders)	60	-	-
4	Concrete (Pier segment)	60	-	-
5	Concrete (Wet Joint)	60	-	-
6	Steel Bars (DB12)	-	550	650
7	Steel Bars (DB16)	-	550	650
8	Steel Bars (DB25)	-	550	650
9	Prestressing steel ASTM Grade 270	-	1674	1860

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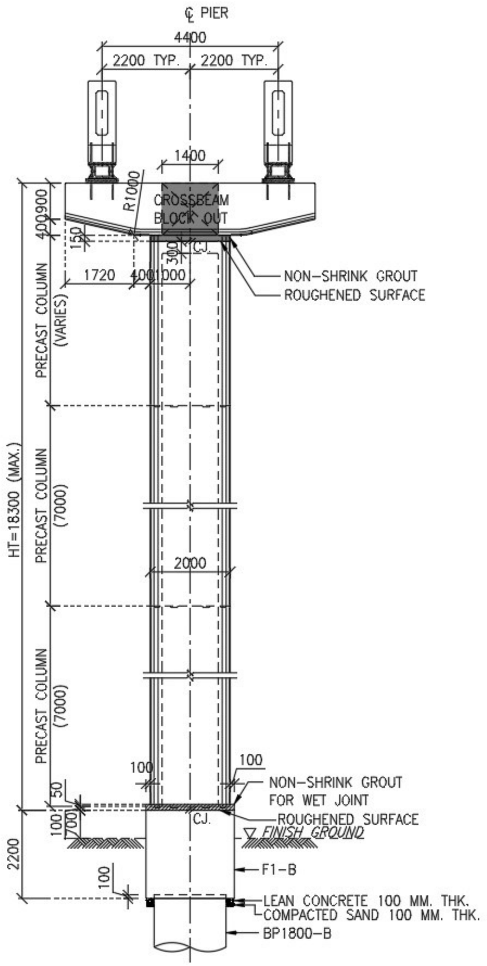
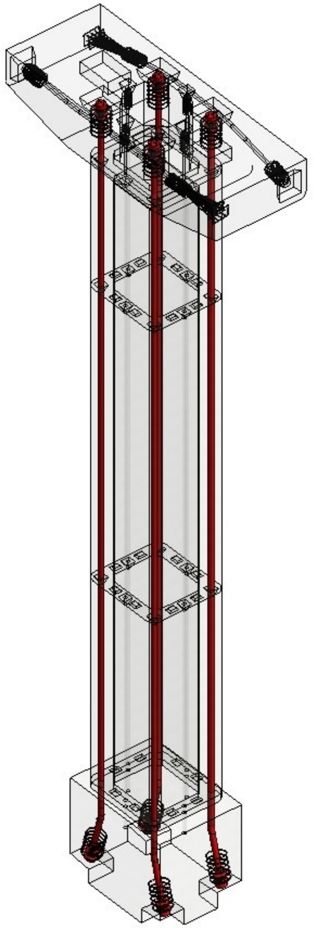
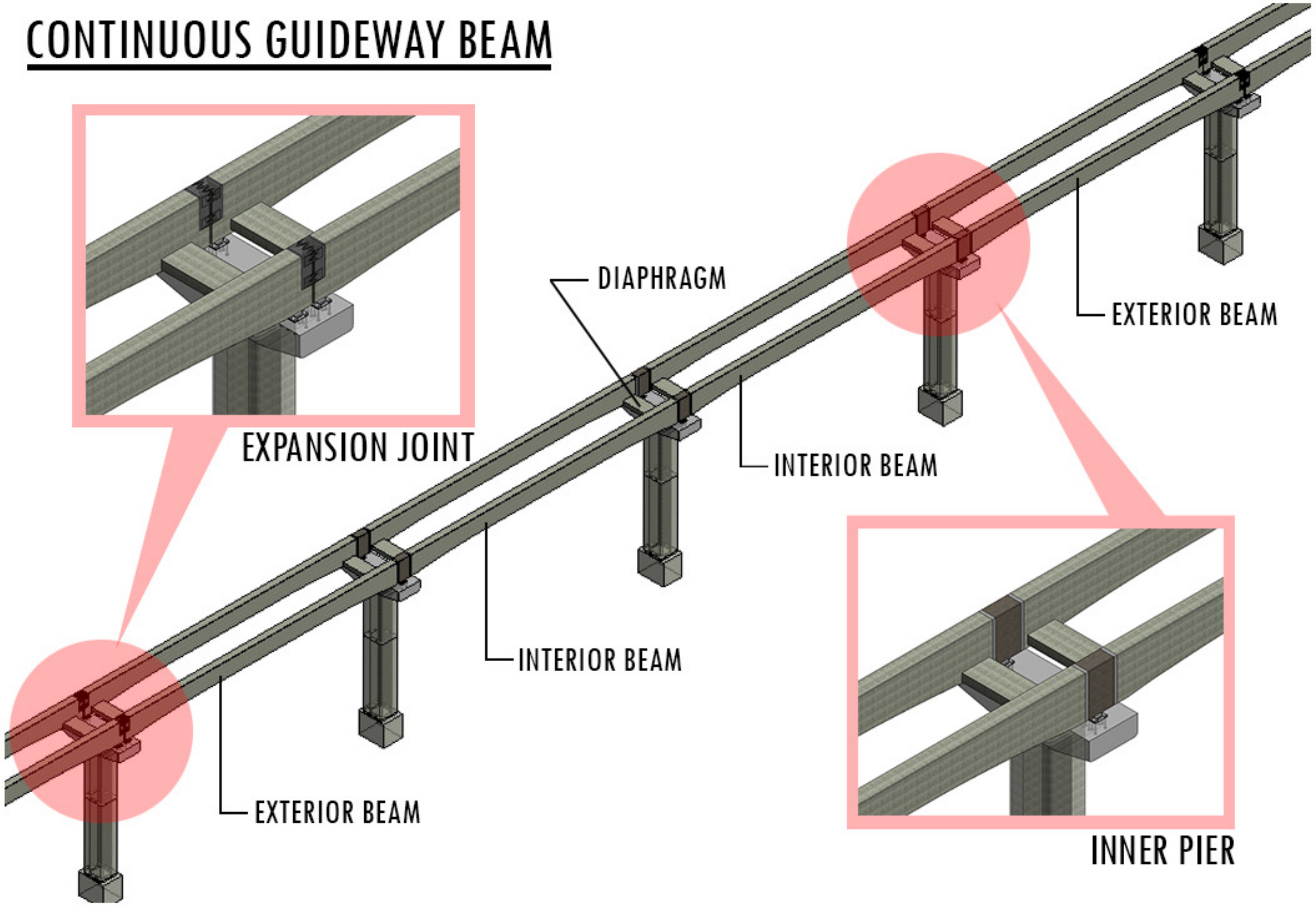
METHODOLOGY: Structure configuration







Substructure: Piling, Column & Crossbeam

Superstructure: GWB arrangement

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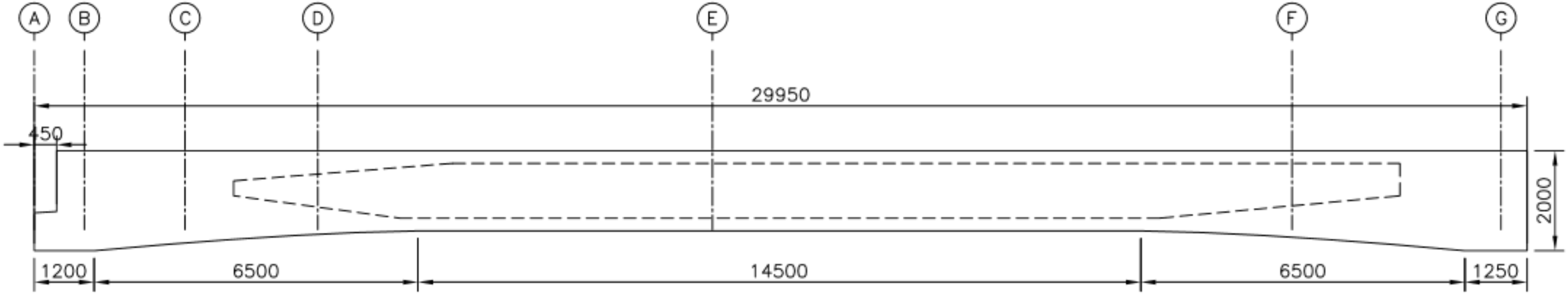
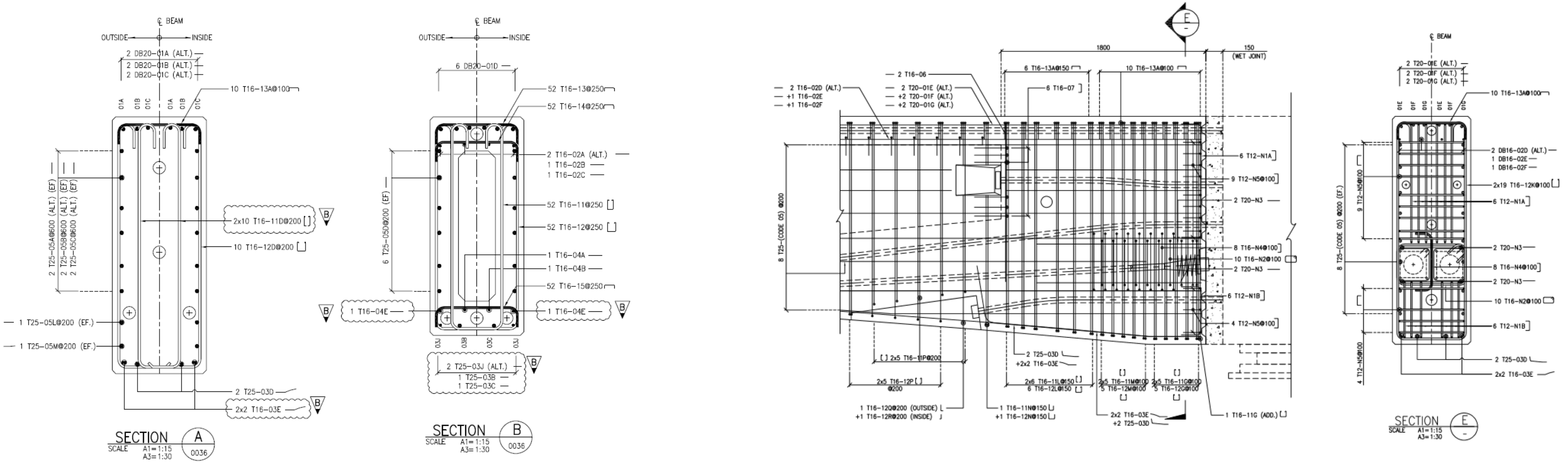
METHODOLOGY: Scope of Test, Exterior GWB





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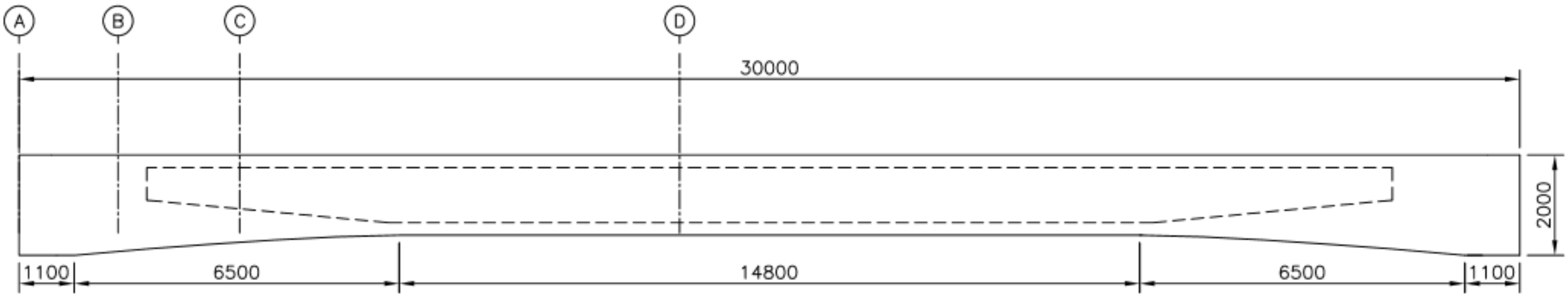
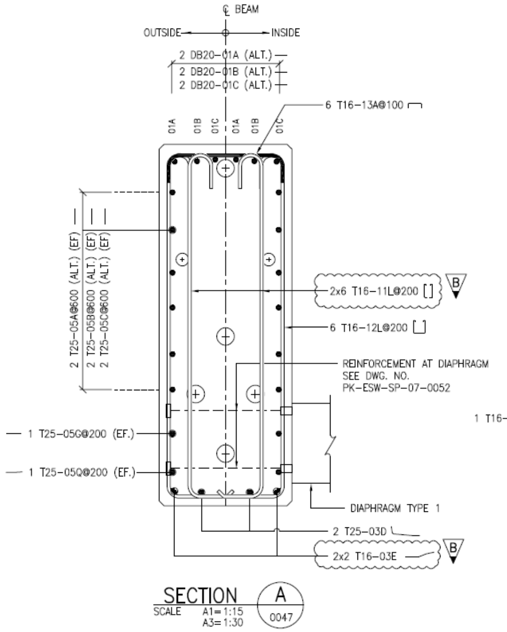
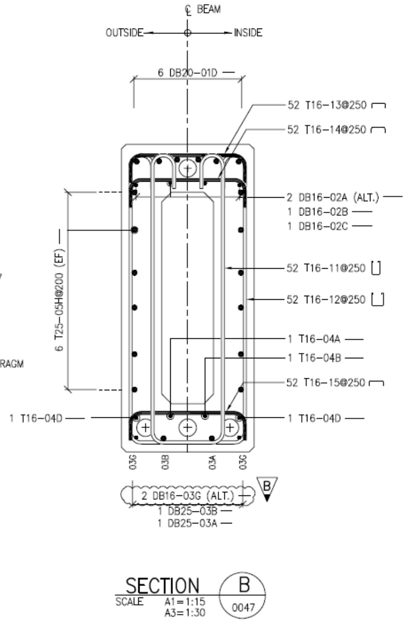
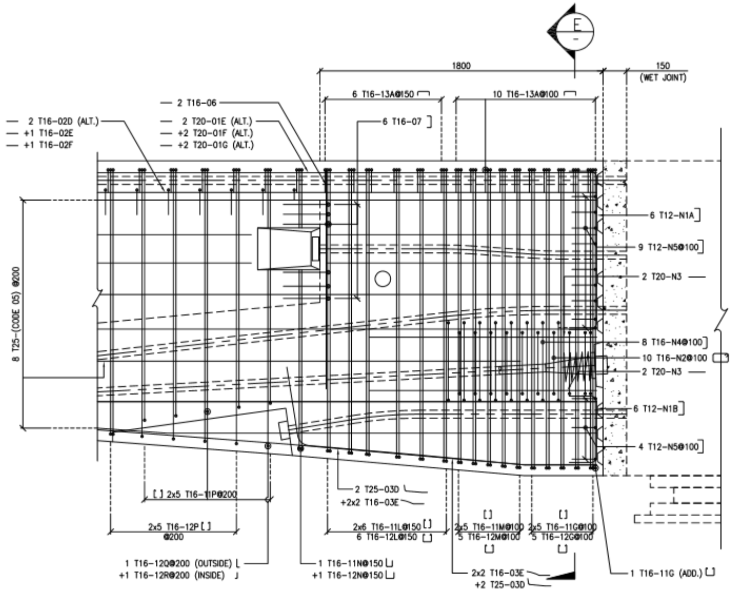
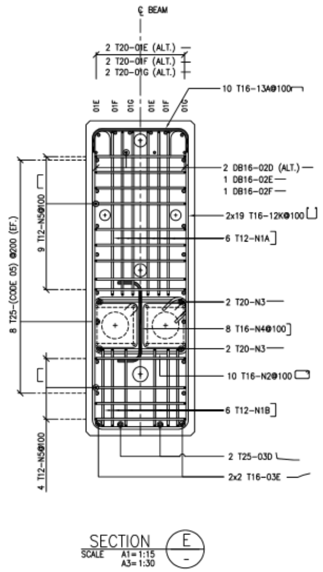
METHODOLOGY: Scope of Test, Interior GWB











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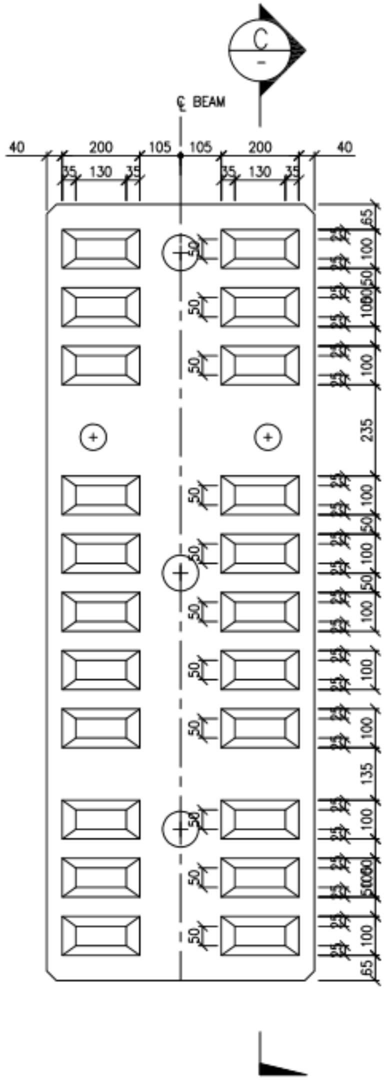
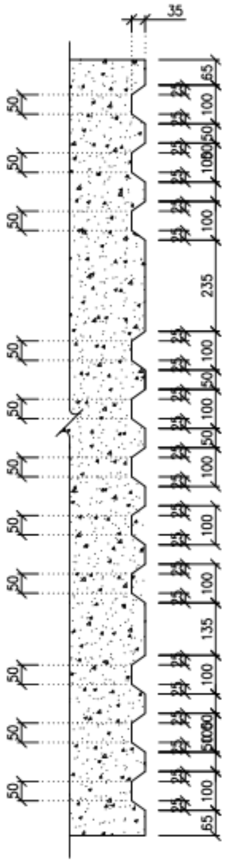
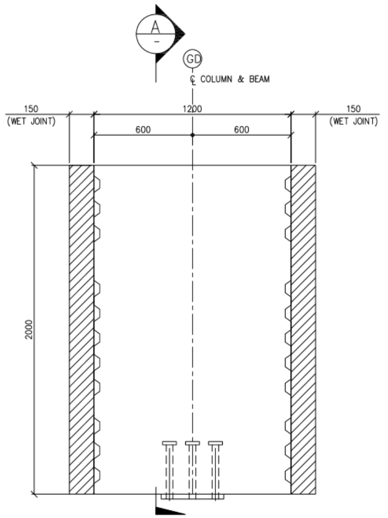
METHODOLOGY: Scope of Test, Pier Segment



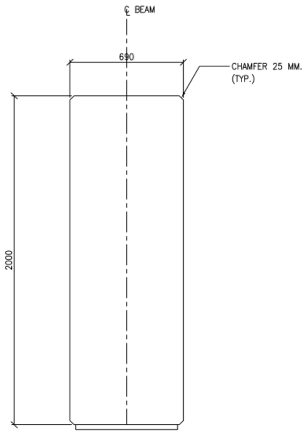
SHEAR KEY DETAIL AT PIER SEGMENT
SCALE A1=1:10 A3=1:20



SECTION C
SCALE A1=1:10 A3=1:20



ELEVATION OF PIER SEGMENT
SCALE A1=1:15 A3=1:30



SECTION A
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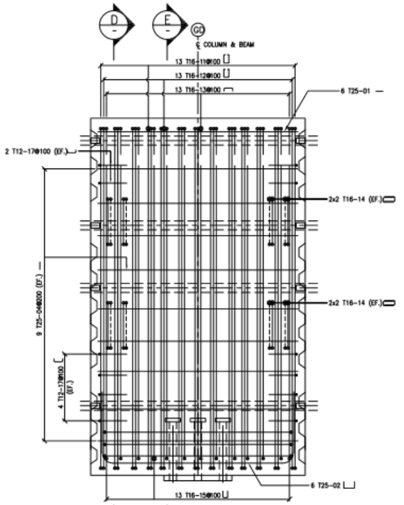
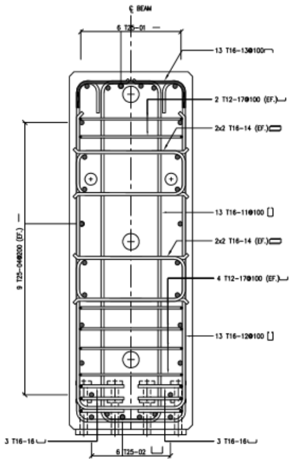
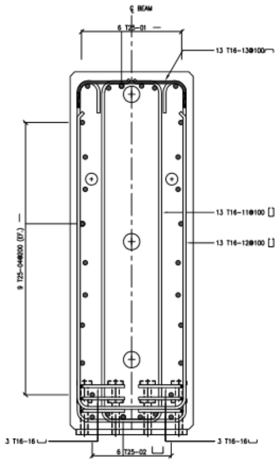


REINFORCEMENT AT CENTER OF BEAM
SCALE A1=1:10 A3=1:20



SECTION D
SCALE A1=1:10 A3=1:20



SECTION E
SCALE A1=1:10 A3=1:20

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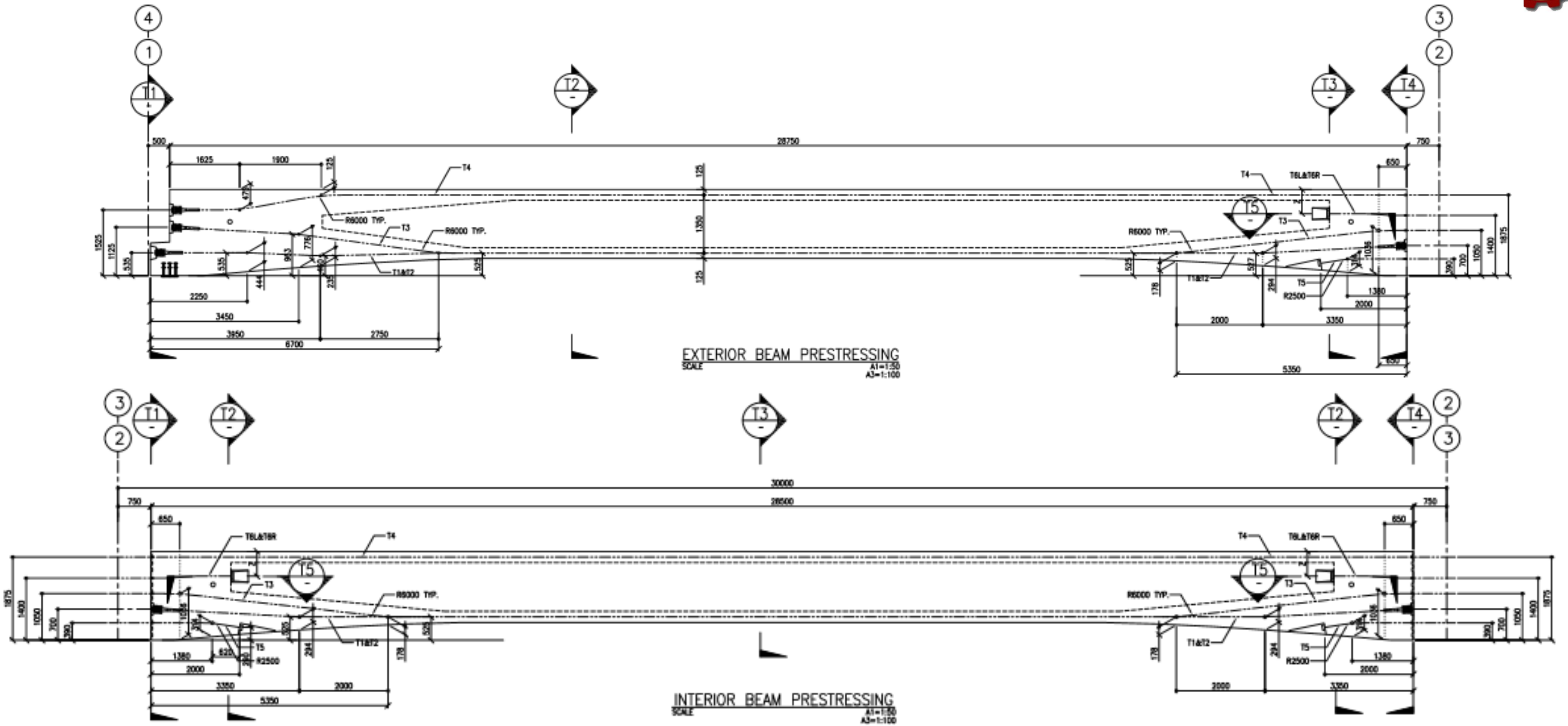
METHODOLOGY: Scope of Test, PT arrangement



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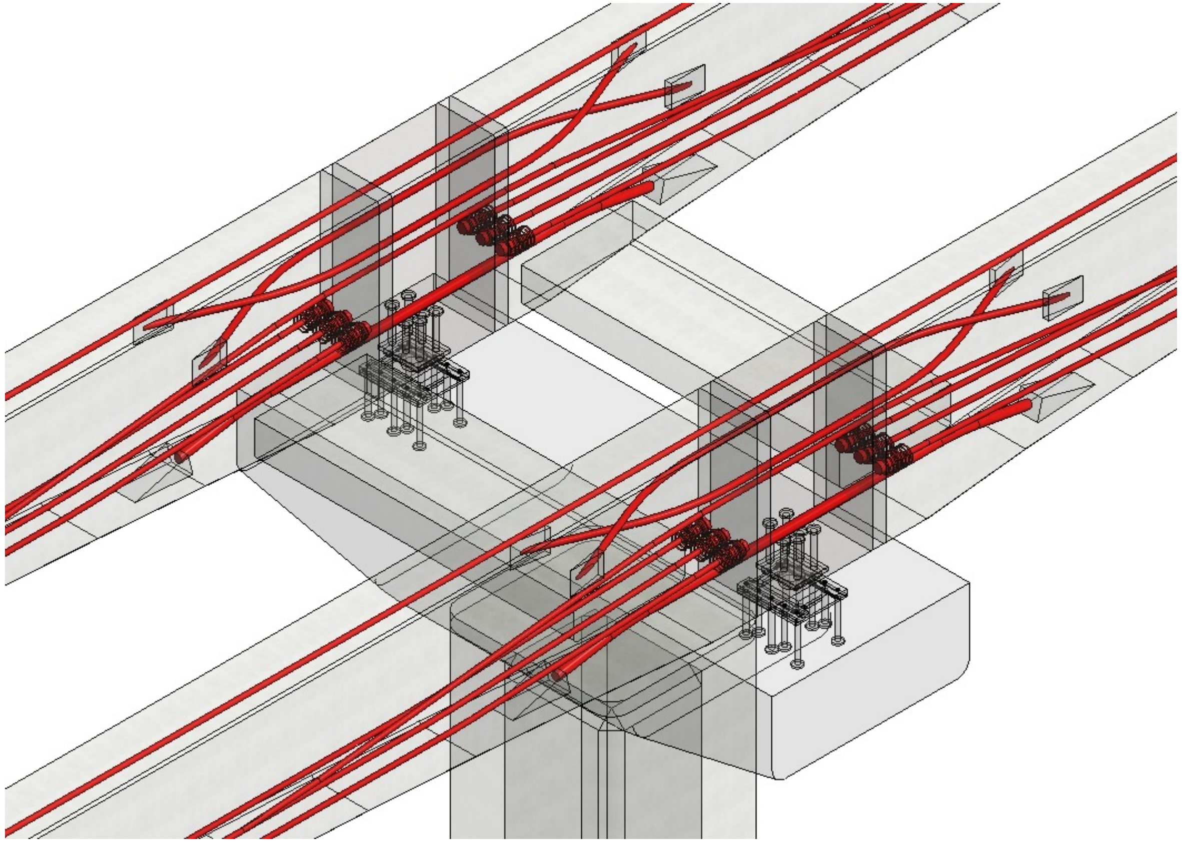
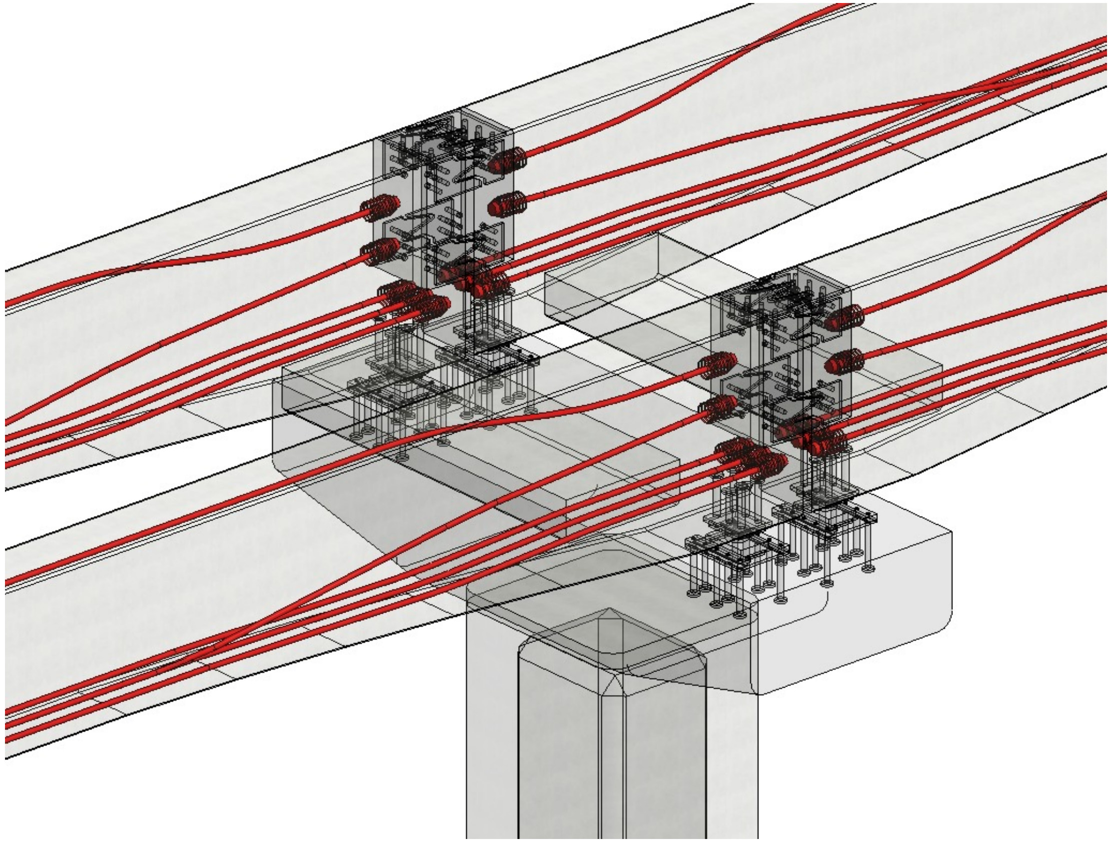
METHODOLOGY: Scope of Test, PT arrangement



3D for inner Pier: PT arrangement



3D for Expansion Joint: PT arrangement

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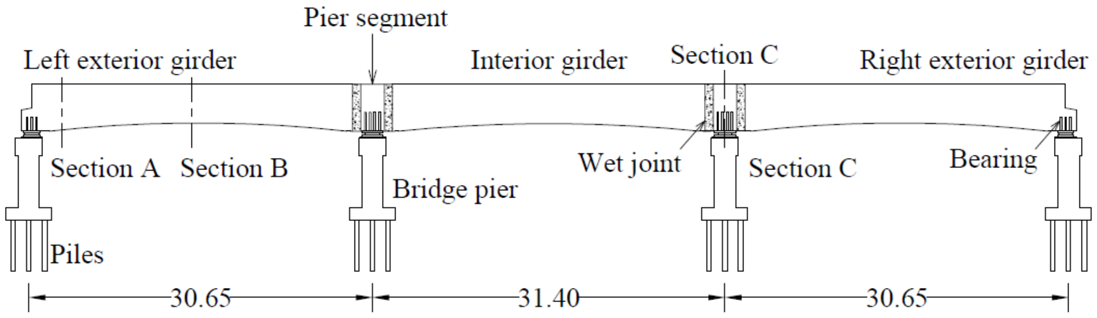
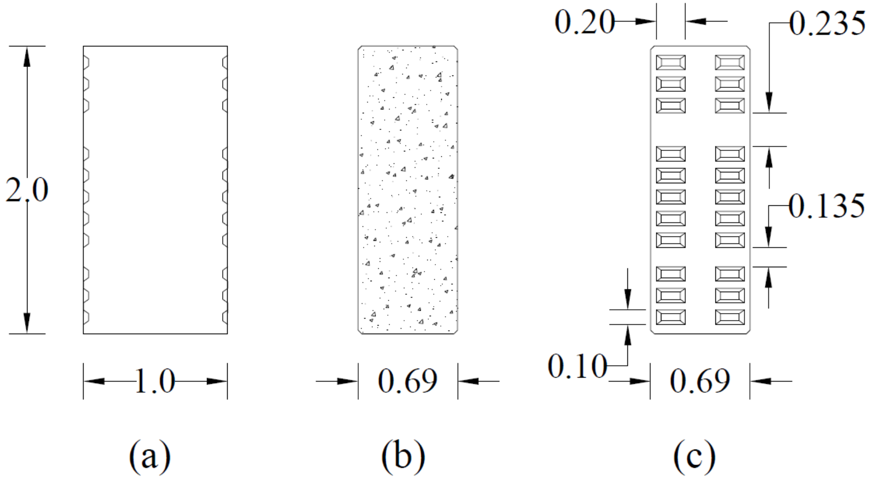
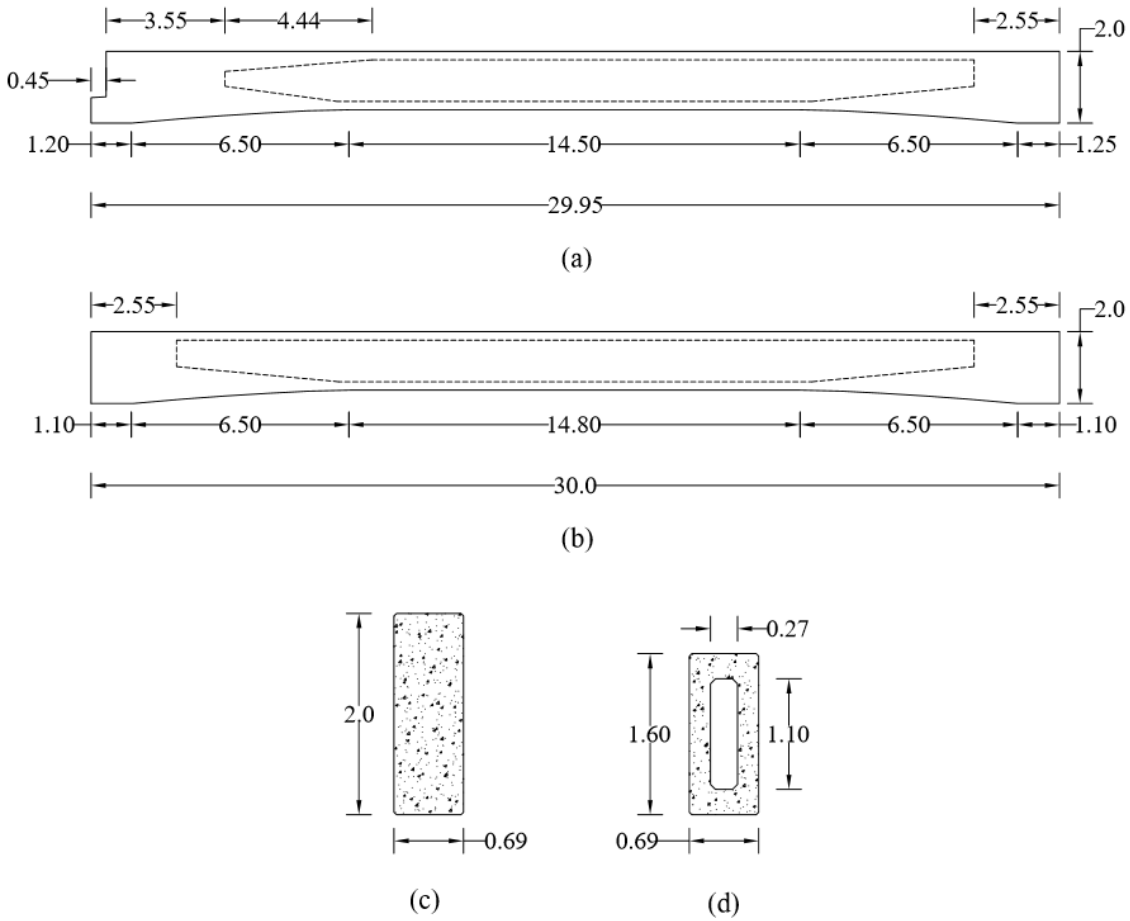
METHODOLOGY: Specimen setup - FPPC



(1) Typical details of the FPPC girder (units: meters)



(2) Details of pier segment (a) longitudinal section, (b) cross section, and (c) right\left end view (units in meters)



(3) Dimensional details of precast girders (a) exterior girder, (b) interior girder, (c) end section, and (d) middle section (units in meters)

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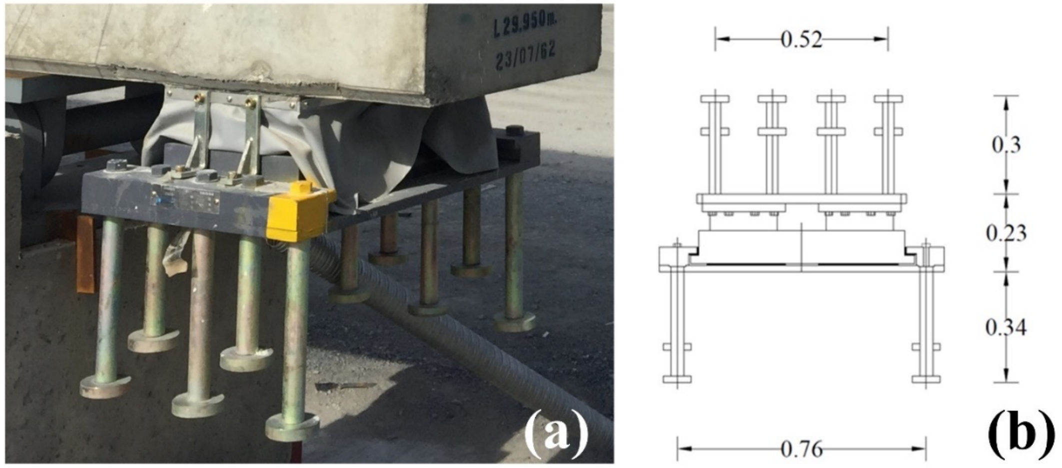
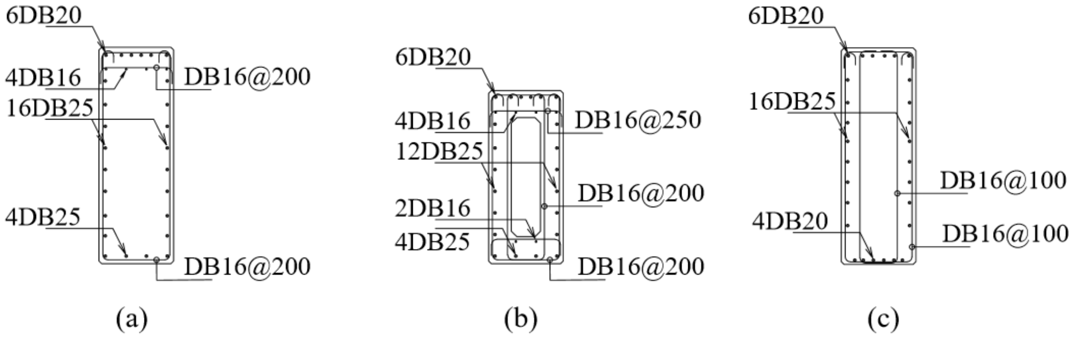
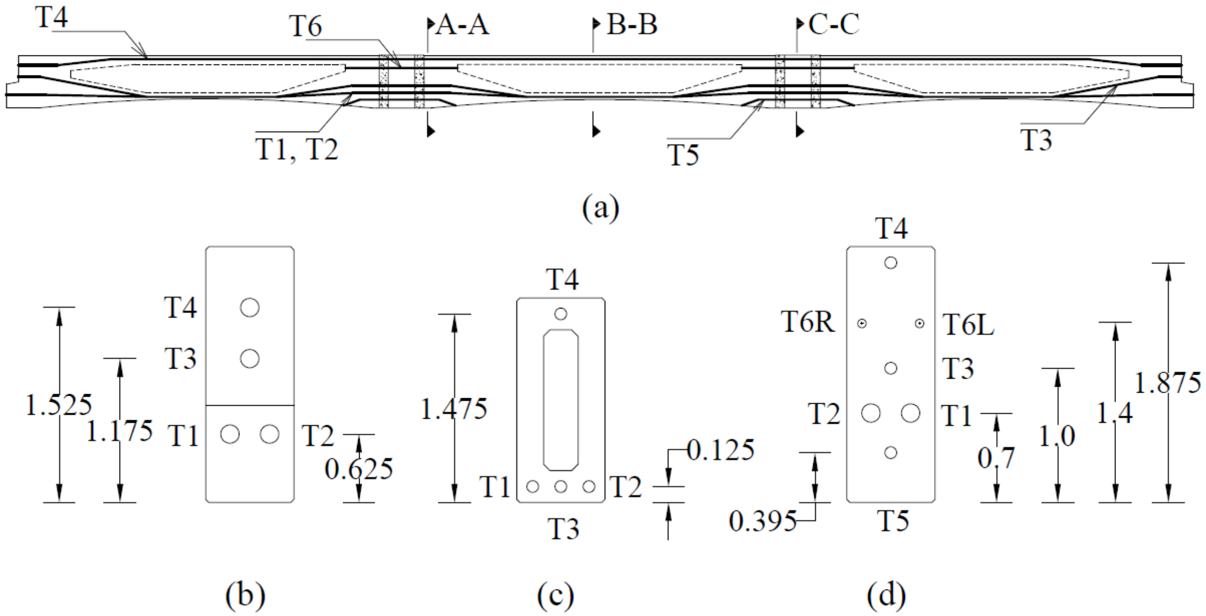
METHODOLOGY: Specimen setup - FPPC



(4) Typical details of end bearing (a) Typical view of end bearing, and (b) Typical details of end bearing.



(5) Reinforcement details (a) girder section at the end, (b) girder section at the middle, and (c) pier segment section.



(6) Details of posttension tendons: (a) geometry and reinforcement layout of the test-structures, (b) section at A-A, (c) section at B-B, and (d) section at C-C.

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METHODOLOGY: Specimen setup - FPPC

(7) Typical post-tensioning of the FPPC girder.

(a) Front view

(b) Bottom view

(8) Special purpose ducts, a) at front side and b) at bottom side

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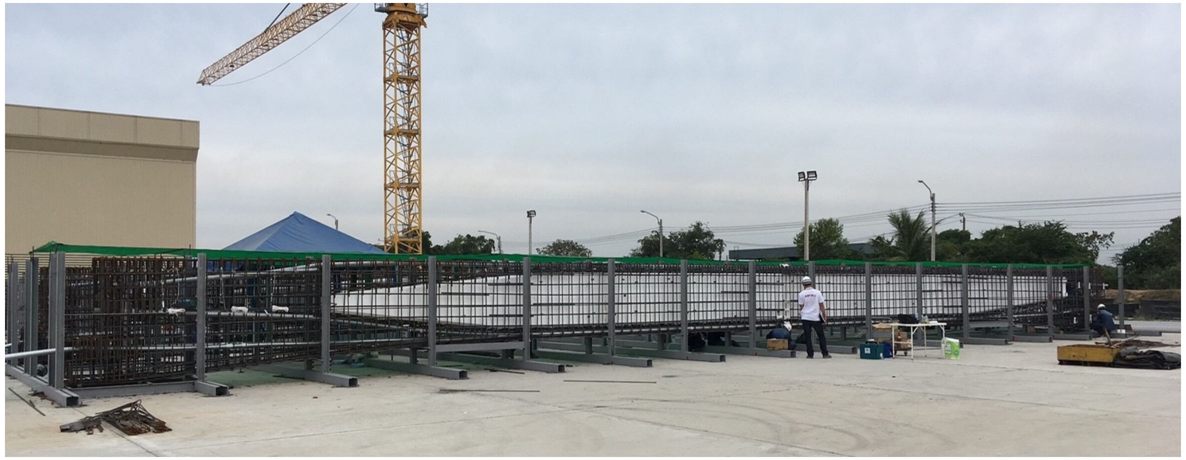
METHODOLOGY: Specimen setup - FPPC

(a) (b)

(9) Construction details of the foundations (a) pre-cast piles foundation, and (b) pile caps.

(11) Typical view of the FPPC monorail bridge girder.



(10) Rebar cage of FPPC monorail girders

(12) Typical monorail girders.

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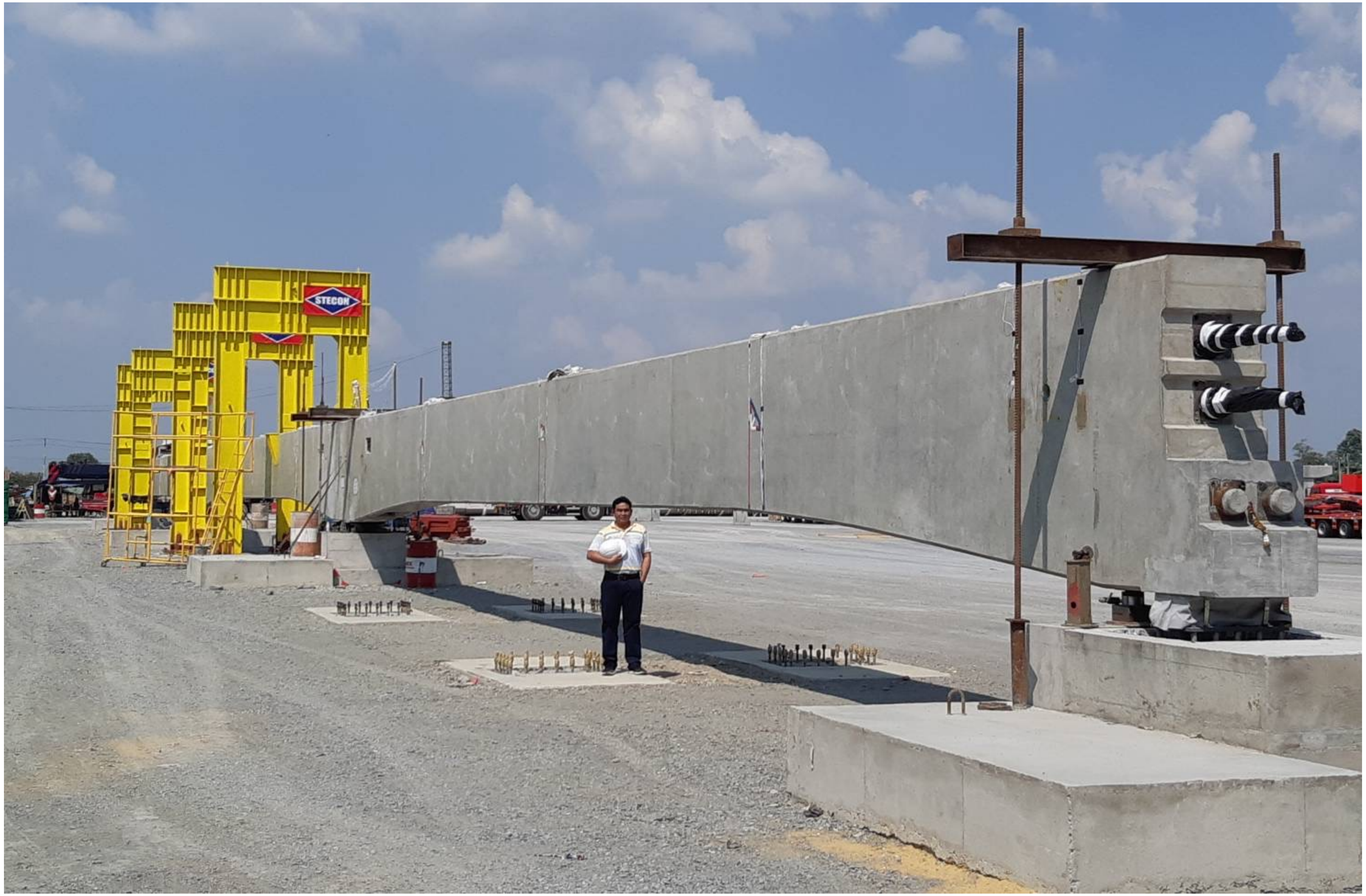
METHODOLOGY: Specimen setup - FPPC



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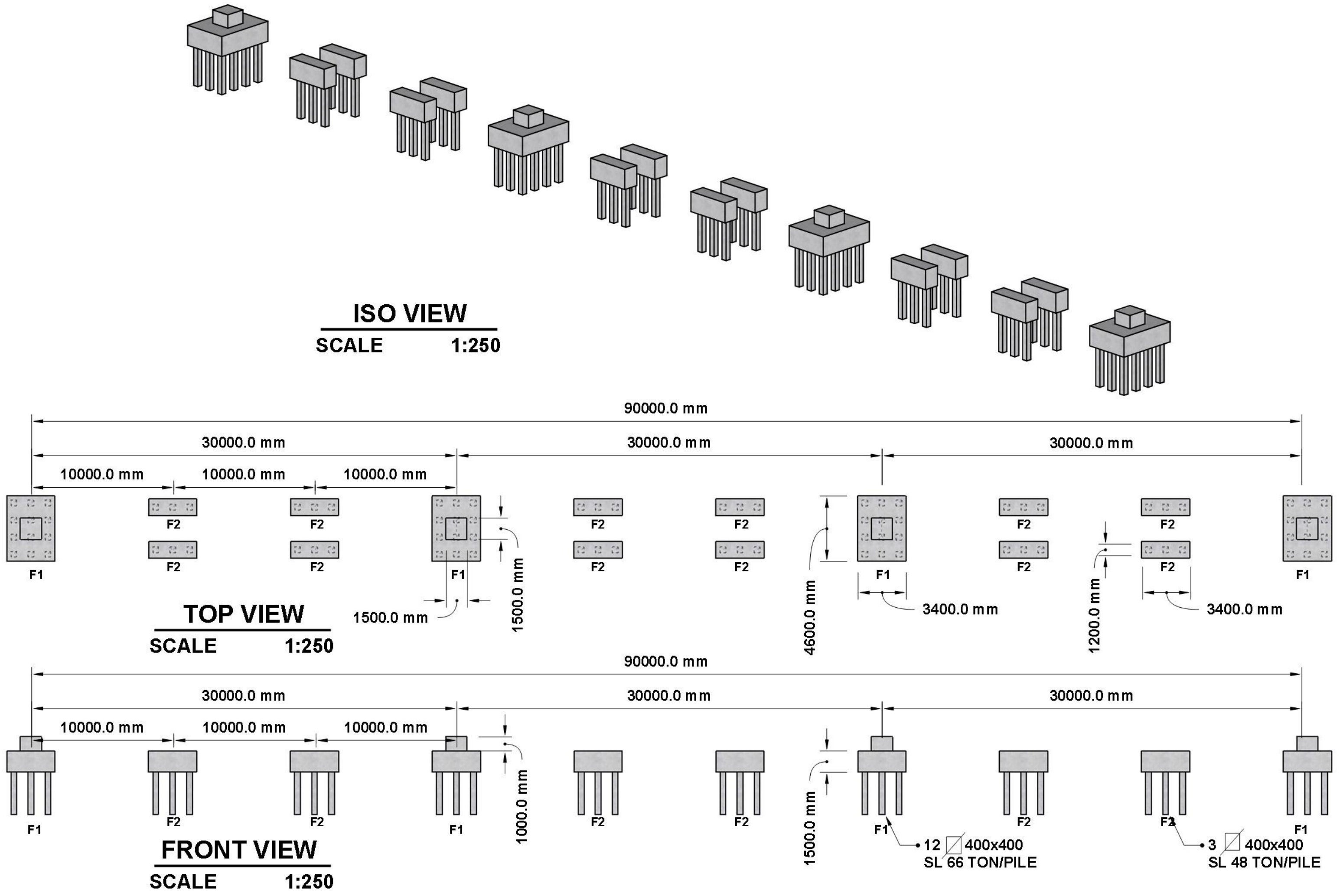
METHODOLOGY: Scope of Test - FPPC

Experimental program: Foundation layout for Test specimen has been setup at STECON's casting yard



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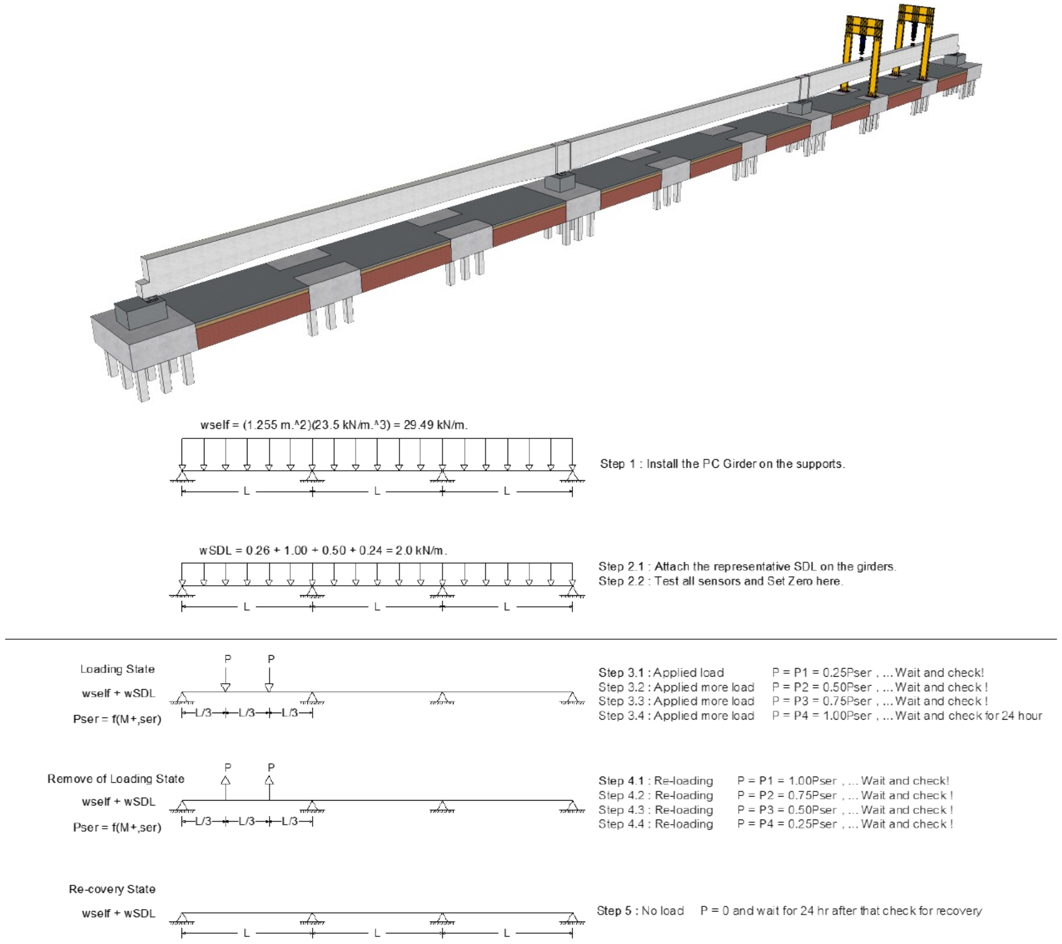
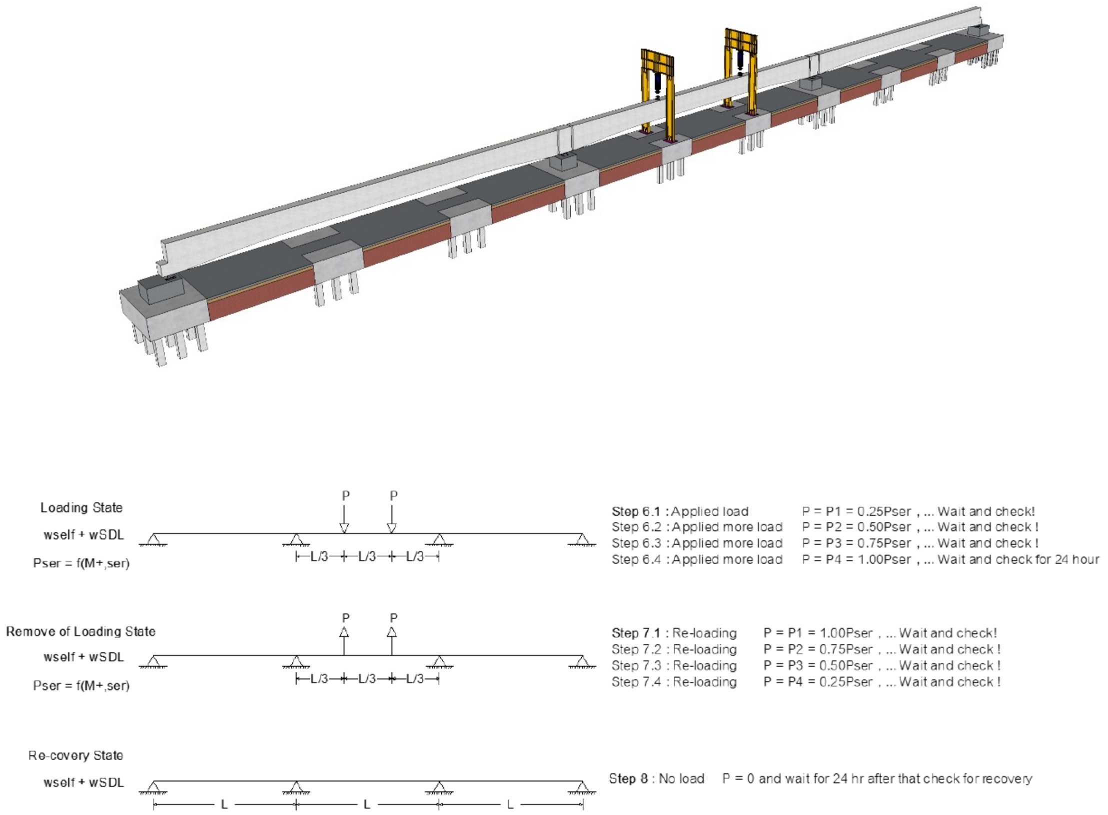
METHODOLOGY: Test scenario - FPPC

Experimental program: In order to precisely investigate the structural response of three-span post-tension girder, the loading setup and procedure for the proposed three-span post-tension girder system is proposed in following four parts;



Service axial load on right exterior span (Test 1.0)



Service axial load on interior span (Test 2.0)

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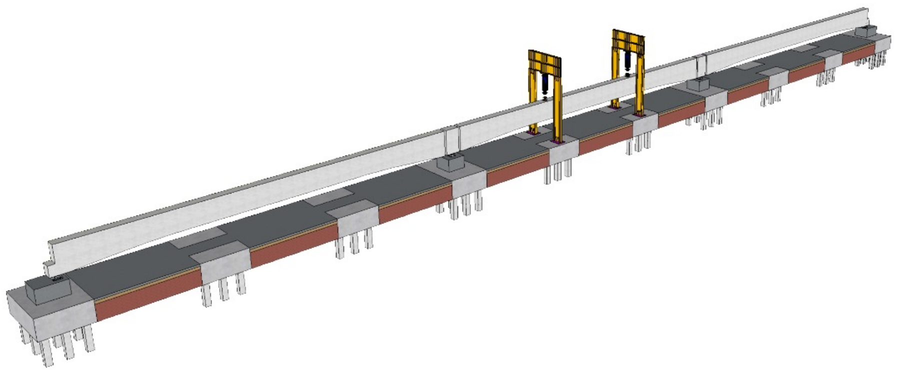
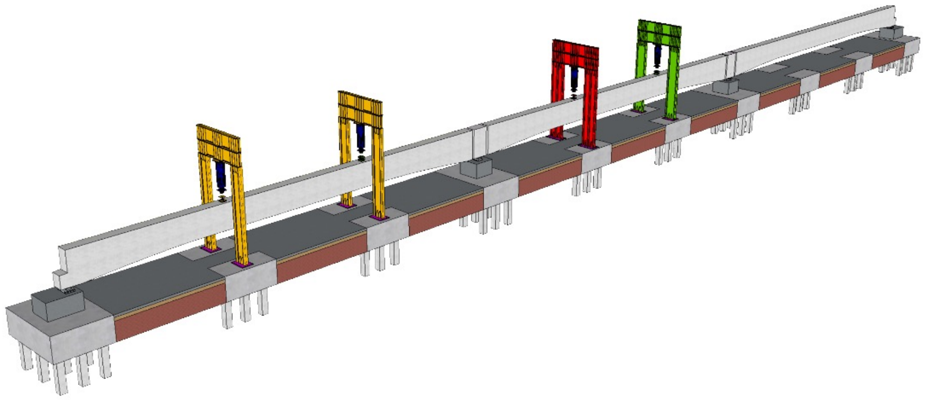
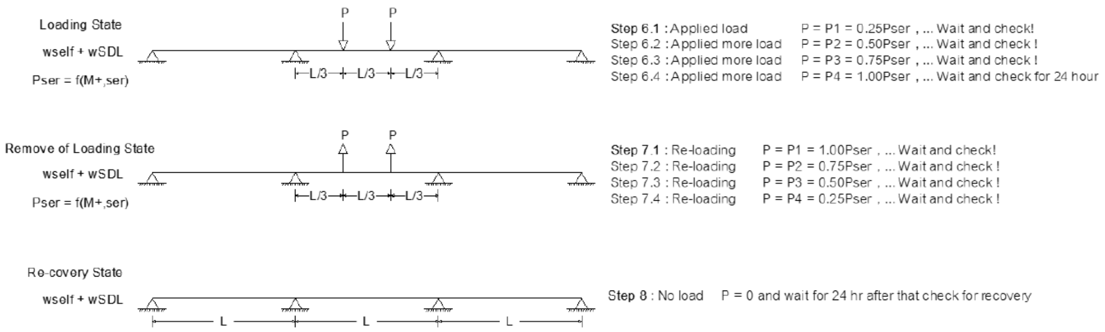
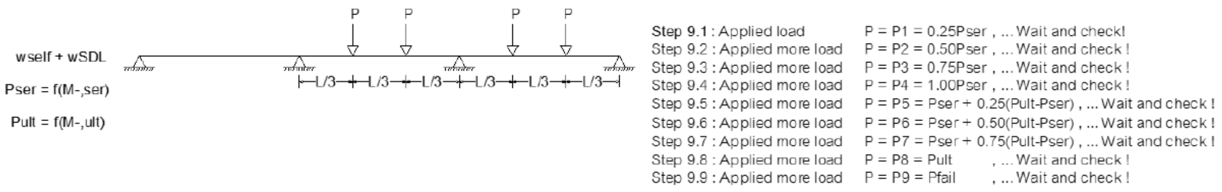
METHODOLOGY: Test scenario - FPPC

Experimental program: In order to precisely investigate the structural response of three-span post-tension girder, the loading setup and procedure for the proposed three-span post-tension girder system is proposed in following four parts;







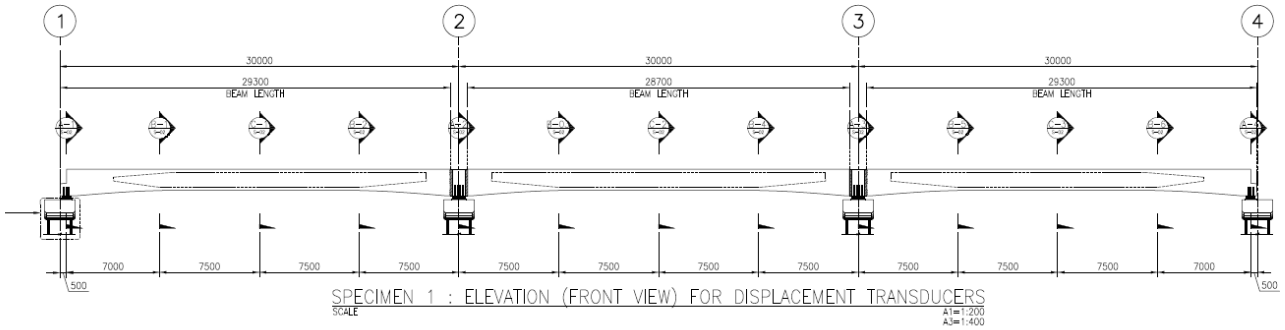


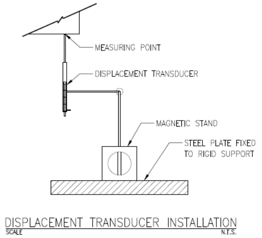
Service torsion load test on interior span (Test 3.0)

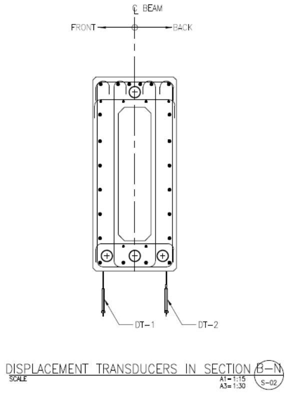
Ultimate axial load on left exterior and interior span (Test 4.0)

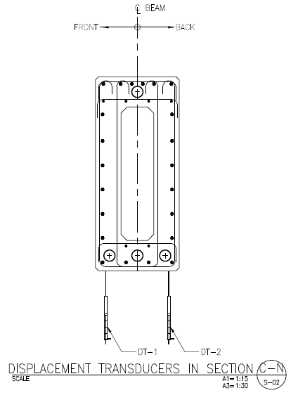
METHODOLOGY: Instrumentations

Proposed Instrumentation and Devices: A detailed and comprehensive instrumentation plan is proposed to accurately capture the load versus deflection responses of three-span real scale post-tensioned monorail girder, strain data on concrete, steel bars and tendons, rotation profile of girders and cracking pattern during the loading procedure.

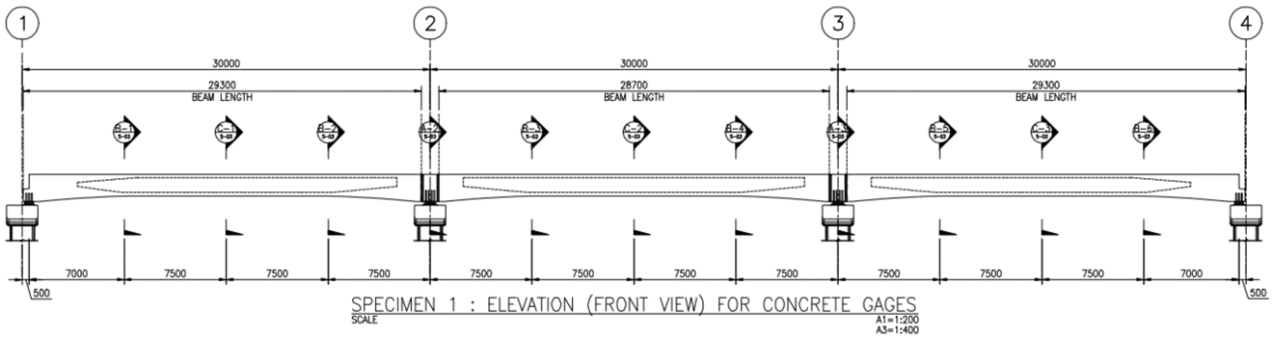


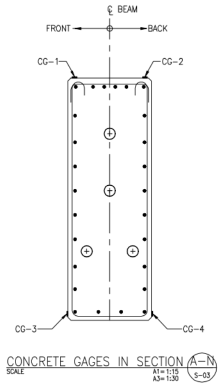


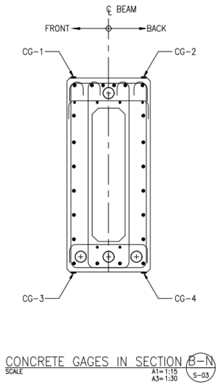


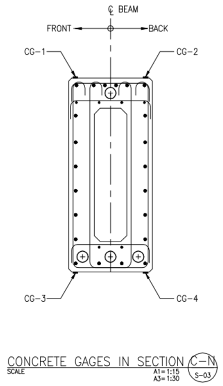


A total number of *thirty-four Linear Variable Differential Transducers (LVDTs)* will be used to capture the vertical and twisting deformation of the girders as shown in figures.









A total number of *forty-eight concrete surface strain gauges* will be used to monitor axial strain values in the concrete as shown in figures.

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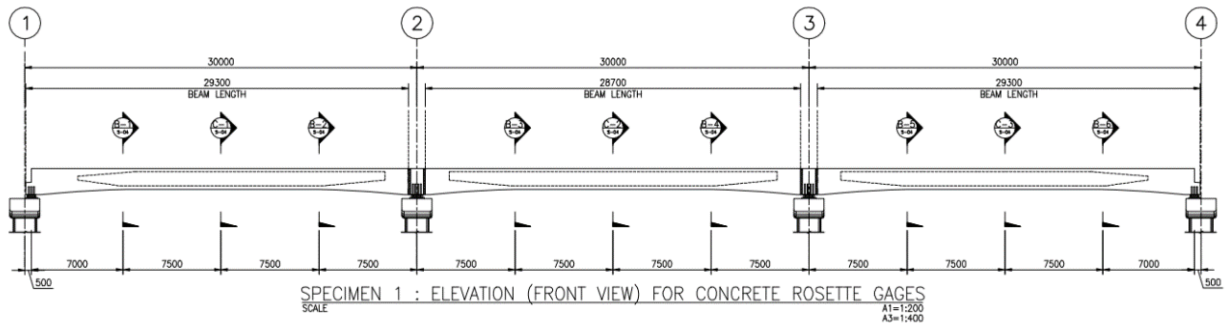
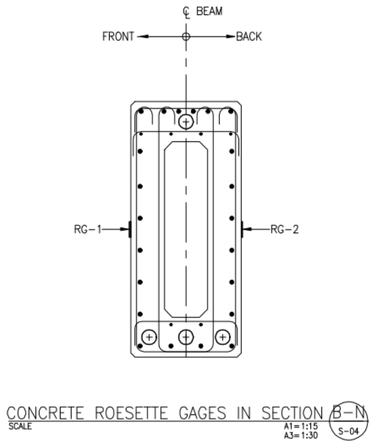
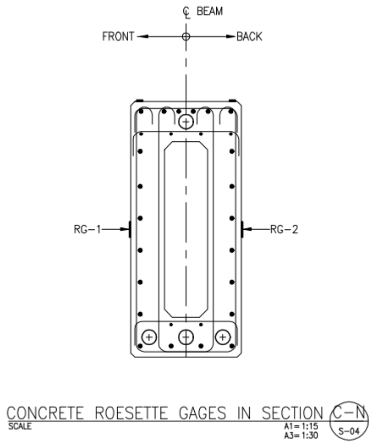
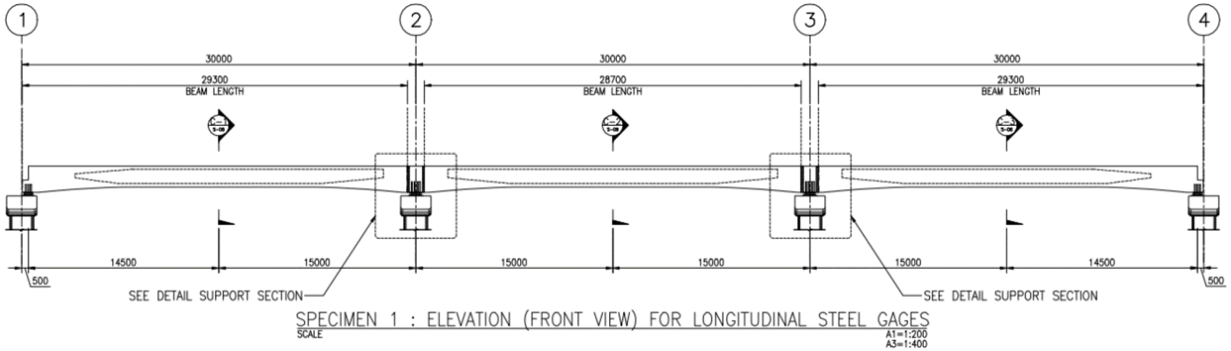
METHODOLOGY: Instrumentations

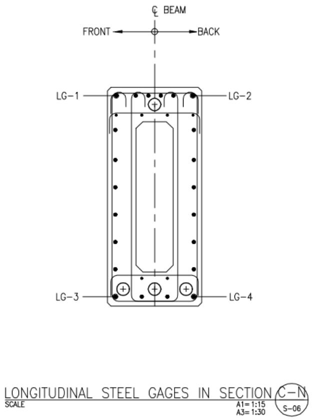


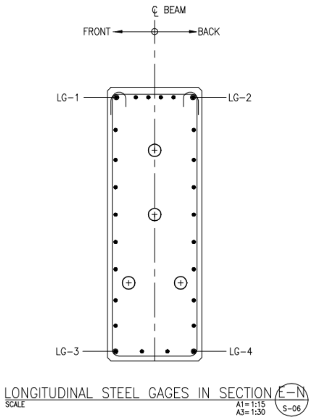




A total number of ***eighteen concrete surface rosette strain gauges*** will be used to monitor shear strain values in the concrete as shown in figures.







A total number of ***thirty-six steel strain gauges*** will be used to record tensile response of longitudinal steel bars as shown in figures.

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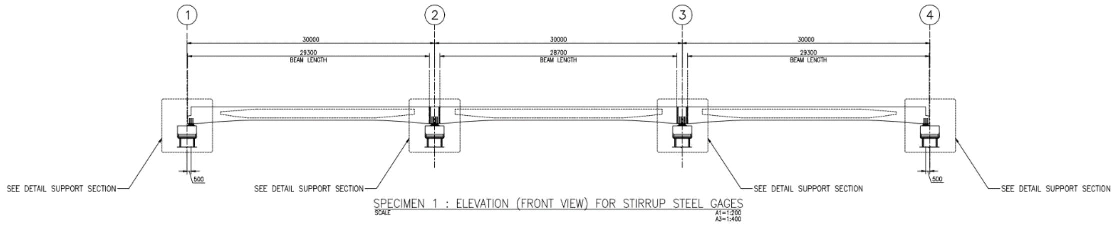
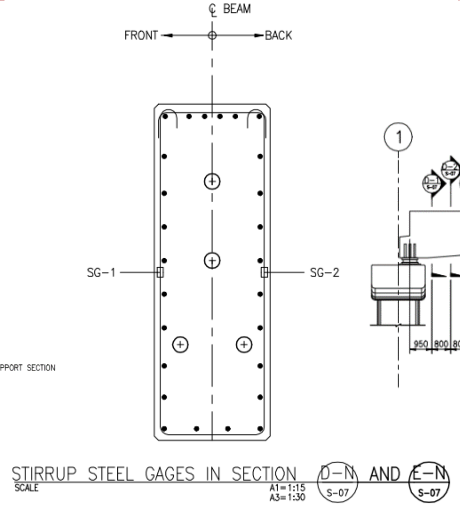
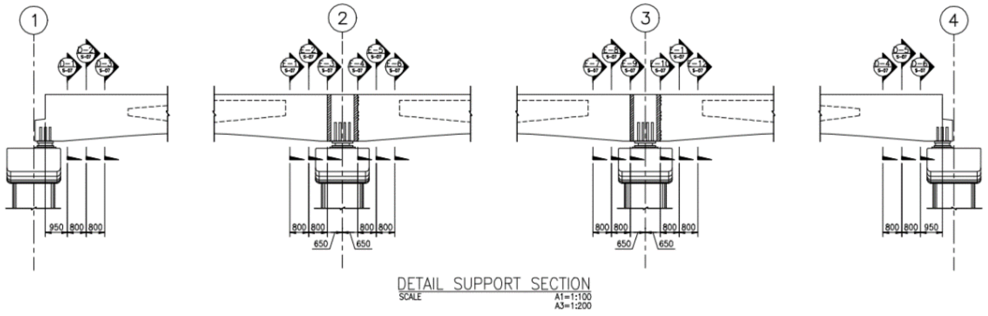
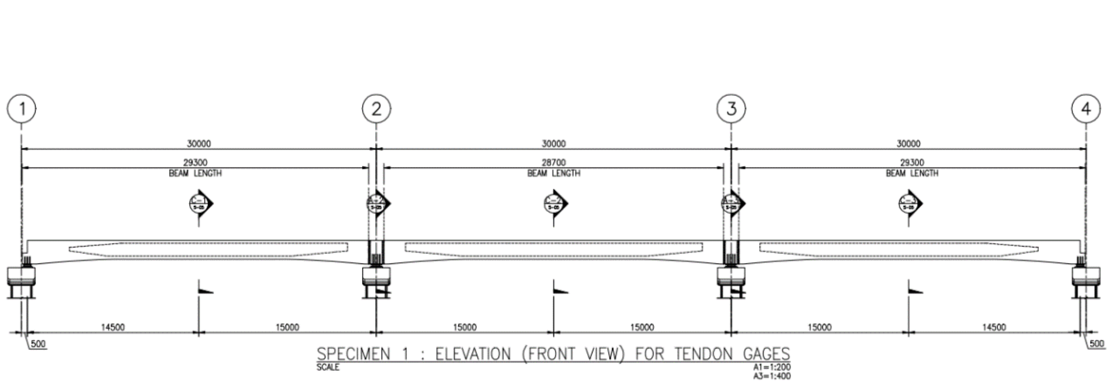
METHODOLOGY: Instrumentations

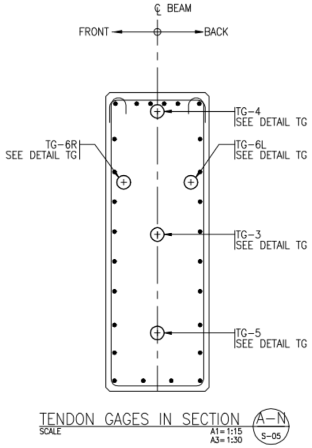


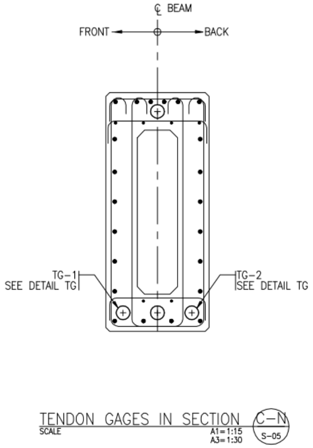


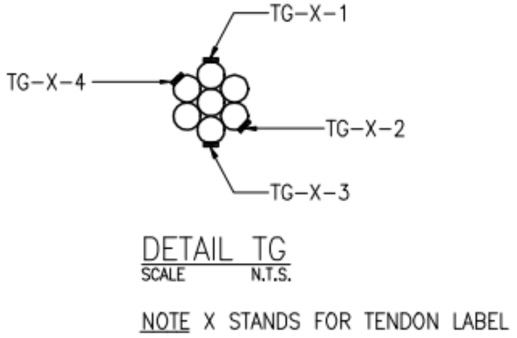


A total number of <u>*thirty-six steel strain gauges*</u> will be used to record tensile response of vertical steel bars as shown in figures.









<u>*Tensile strain in the post-tension tendons*</u> will be recorded by using <u>*48 strain gauges at the tendons*</u> at different locations as shown in figures.

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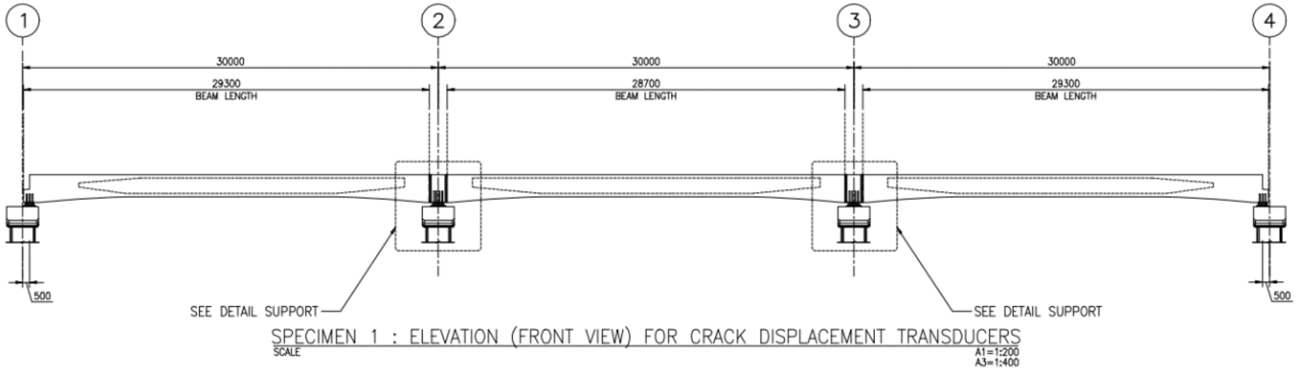
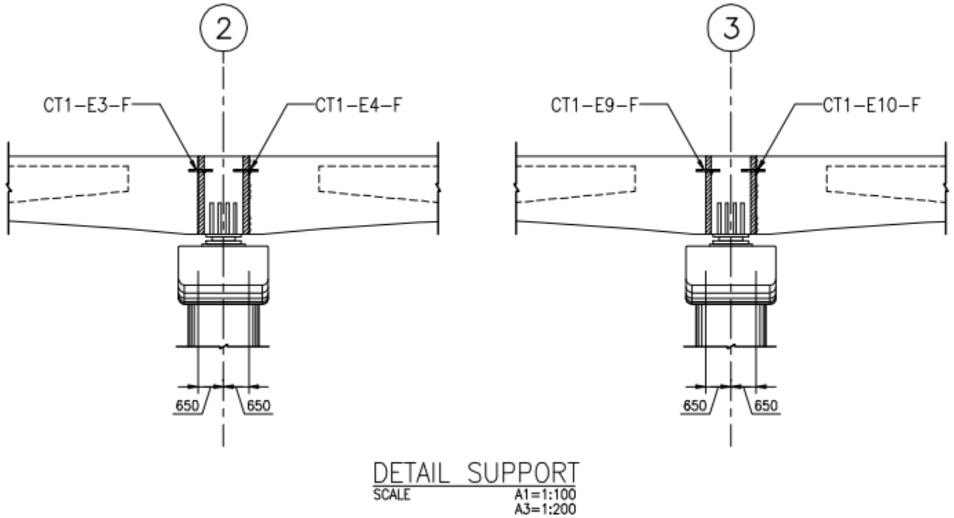
METHODOLOGY: Instrumentations





A total number of *four crack displacement transduces will be installed at the locations of wet joint to monitor crack width* as shown in figures.
A dynamic data logger will be used to continuously record the data from all instrumentations.

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METHODOLOGY: Instrumentations

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METHODOLOGY: Instrumentations

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METHODOLOGY: Finite Element Analysis

The Finite Element Analysis (FEA) is the simulation of any given physical phenomenon using the numerical technique called Finite Element Method (FEM). Engineers use it to reduce the number of physical prototypes and experiments and optimize components in their design phase to develop better products, faster.

In this research project, it is ***proposed to use computer software ATENA to simulate the structural response of three span and single span monorail bridge girders.*** ATENA is a user-friendly software for nonlinear analysis of reinforced concrete structures. ATENA user Richard Malm says in his Ph.D. thesis: "One advantage using ATENA for the finite element analyses is that it calculates all material properties based on the cube strength with equations from Model Code 2010. Another great advantage with this program is that it is specially designed for concrete, which makes it easier for the user since good default values are given. The main advantage is that, even though the analyses described severe cracking, the program never had problems finding a convergent solution. A novice user can rather easy create advanced models in ATENA."

With ATENA You can simulate real behavior of concrete and reinforced concrete structures including concrete cracking, crushing and reinforcement yielding. ATENA gives you the power to check and verify your structural design in a user-friendly graphical environment. ATENA program is proved by over 1000 installations worldwide. A typical ATENA finite element model of bridge structure is shown in figure

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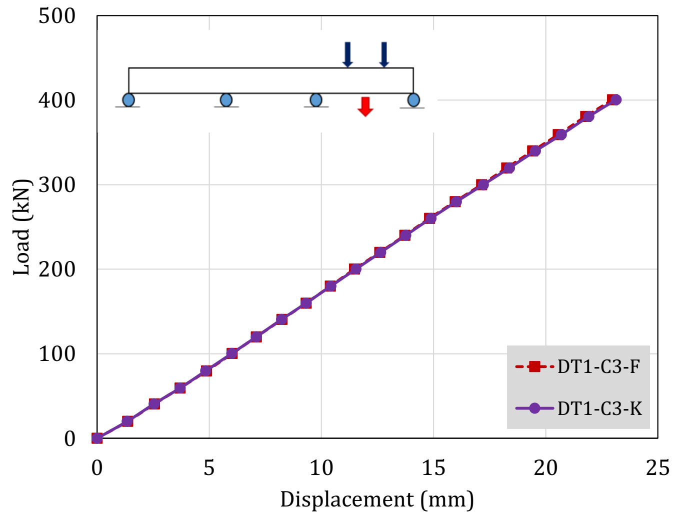
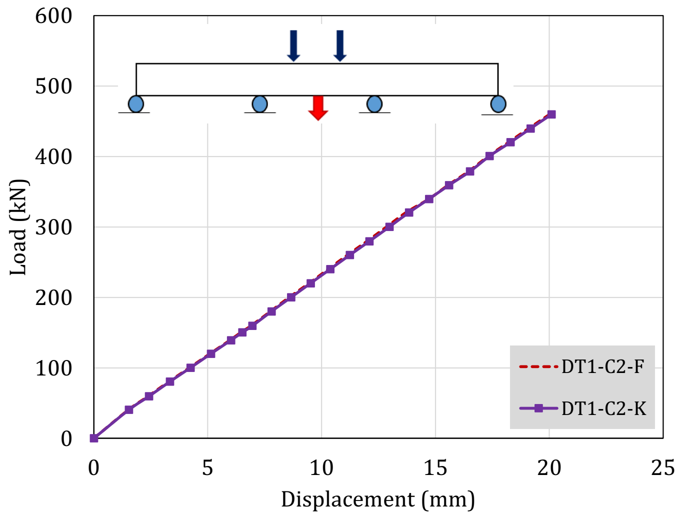
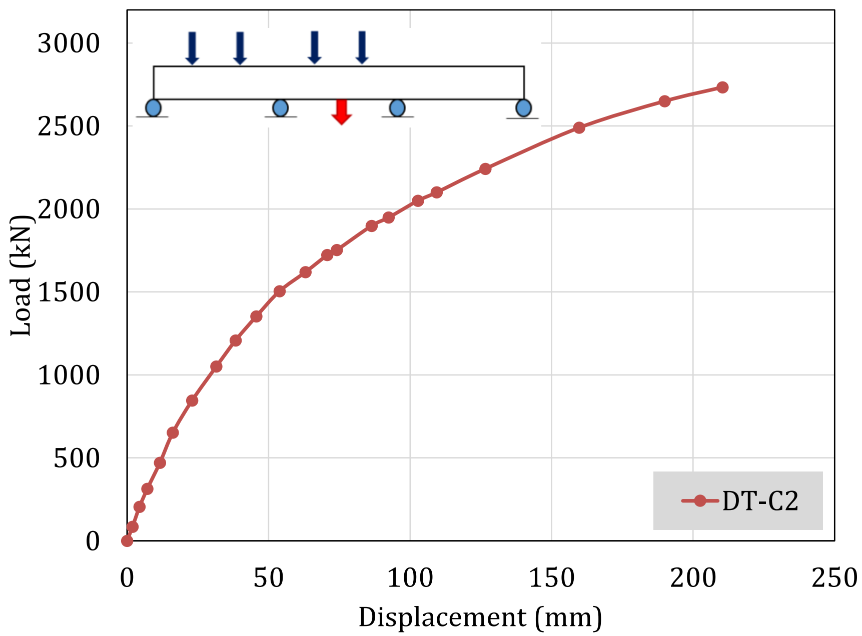
TEST RESULT

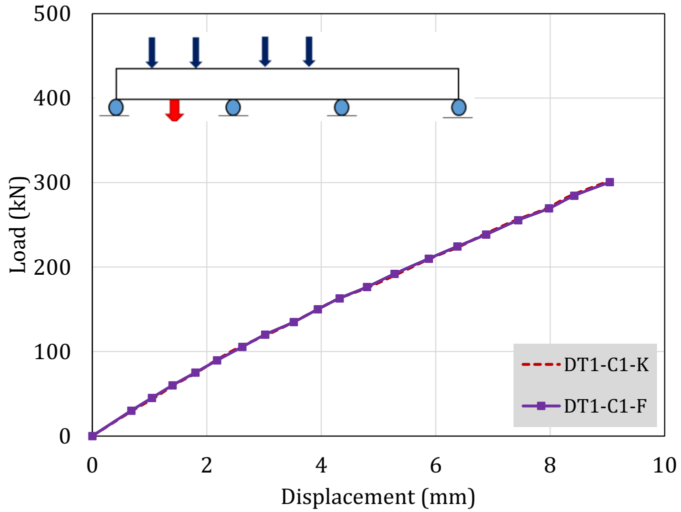
TEST RESULT: Load versus deflection responses

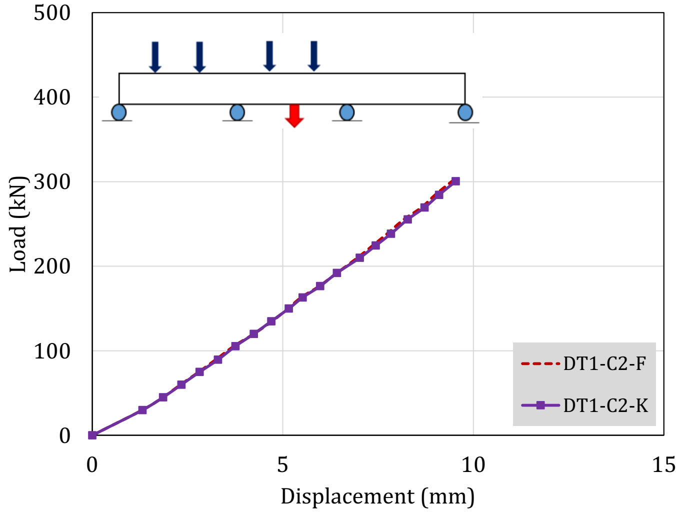






Load vs Deflection response





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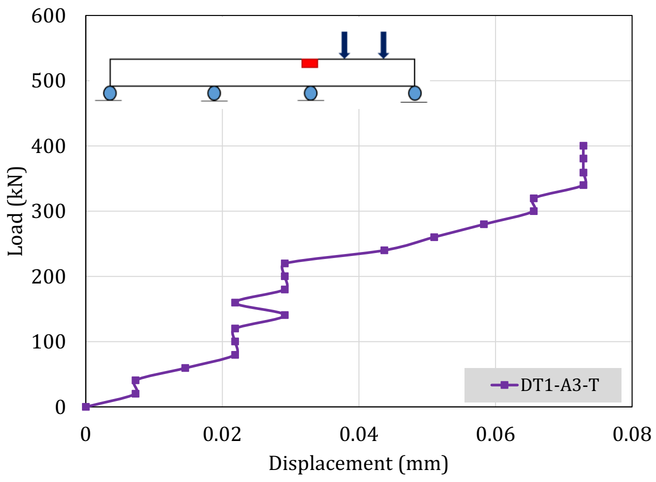
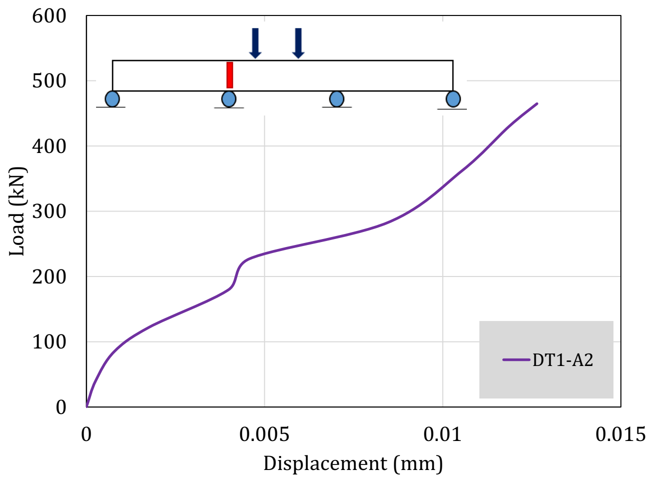
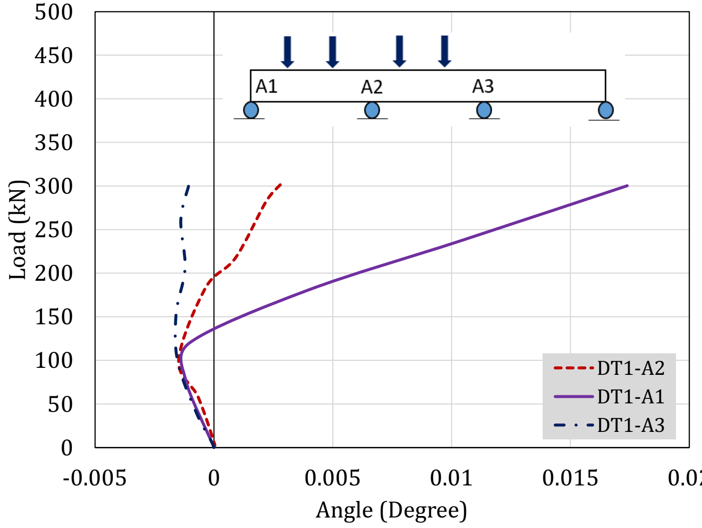
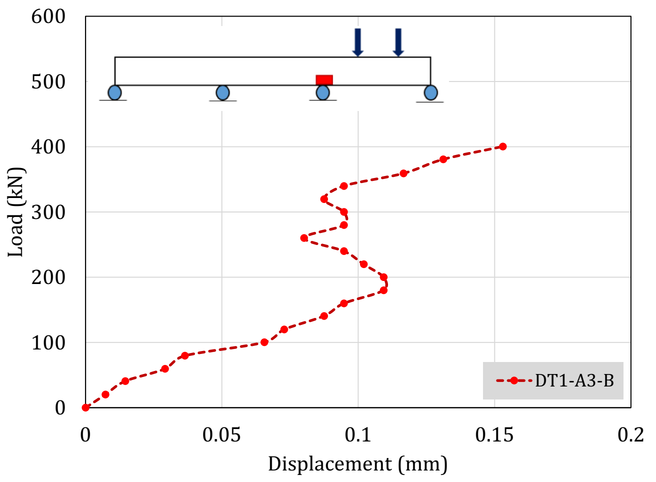
TEST RESULT: Out-of-plan movement of FPPC girder

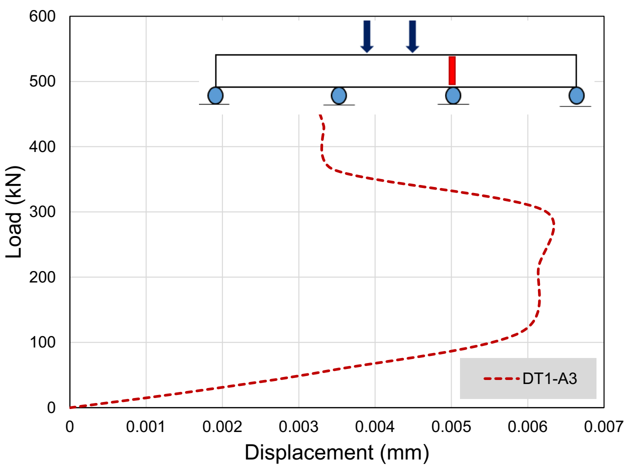






Load vs out-of-plane movement (Z direction)





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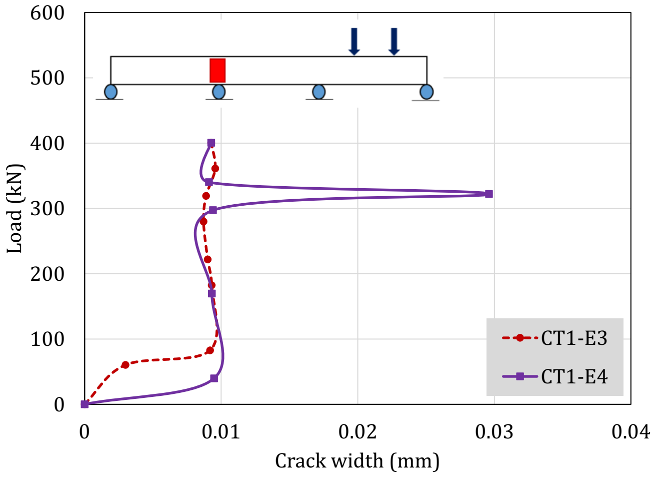
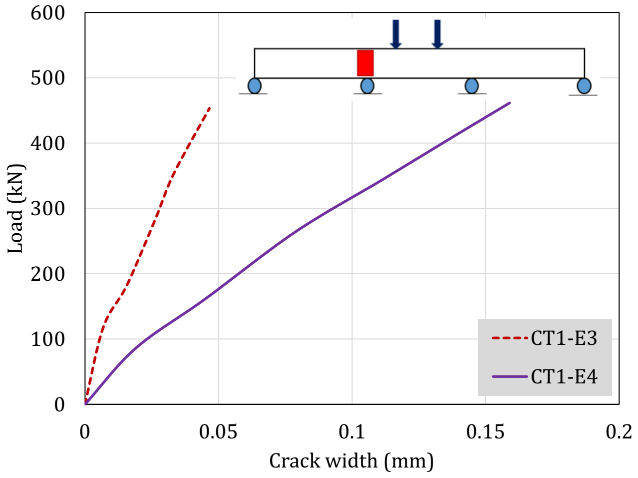
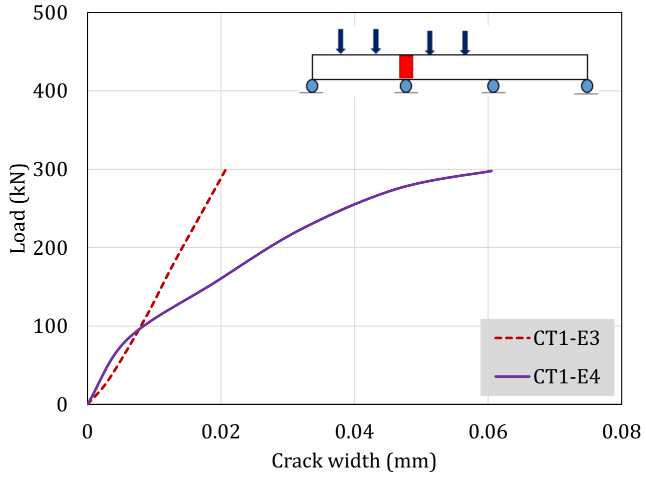
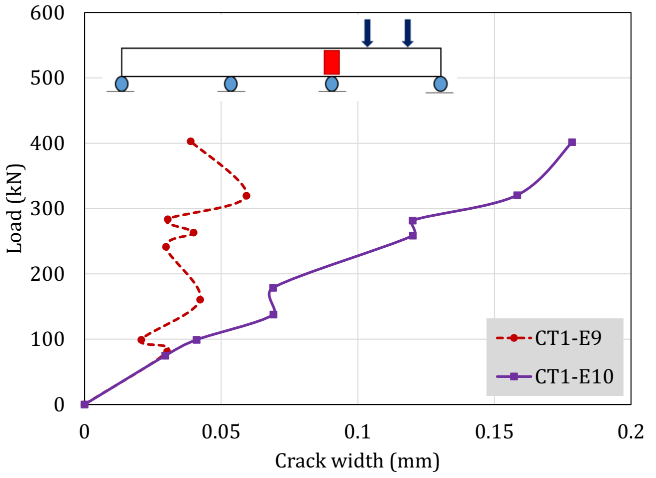
TEST RESULT: Performance of Wet Joint

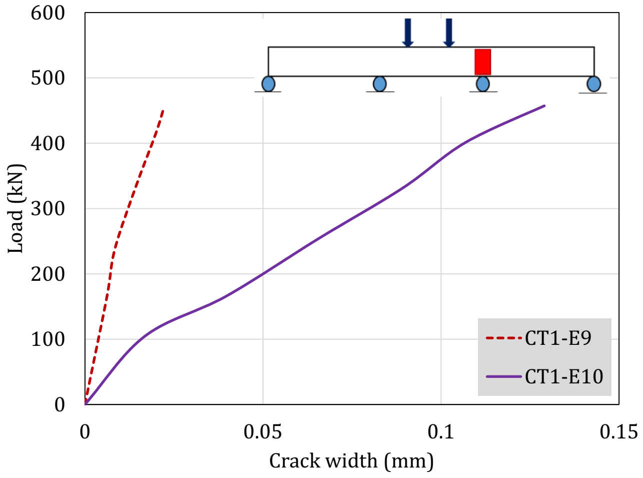


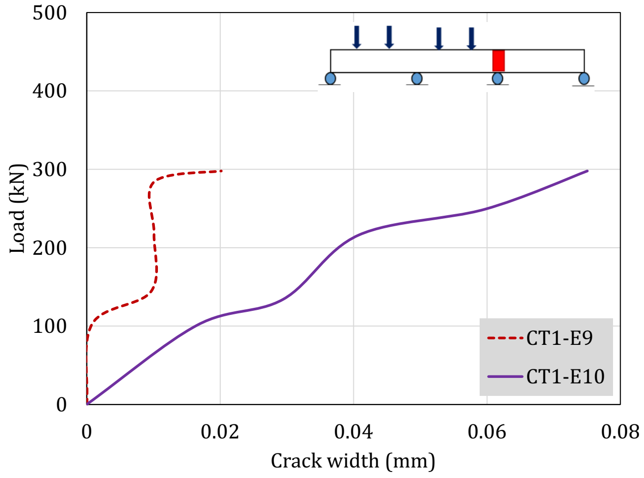




Load versus crack width







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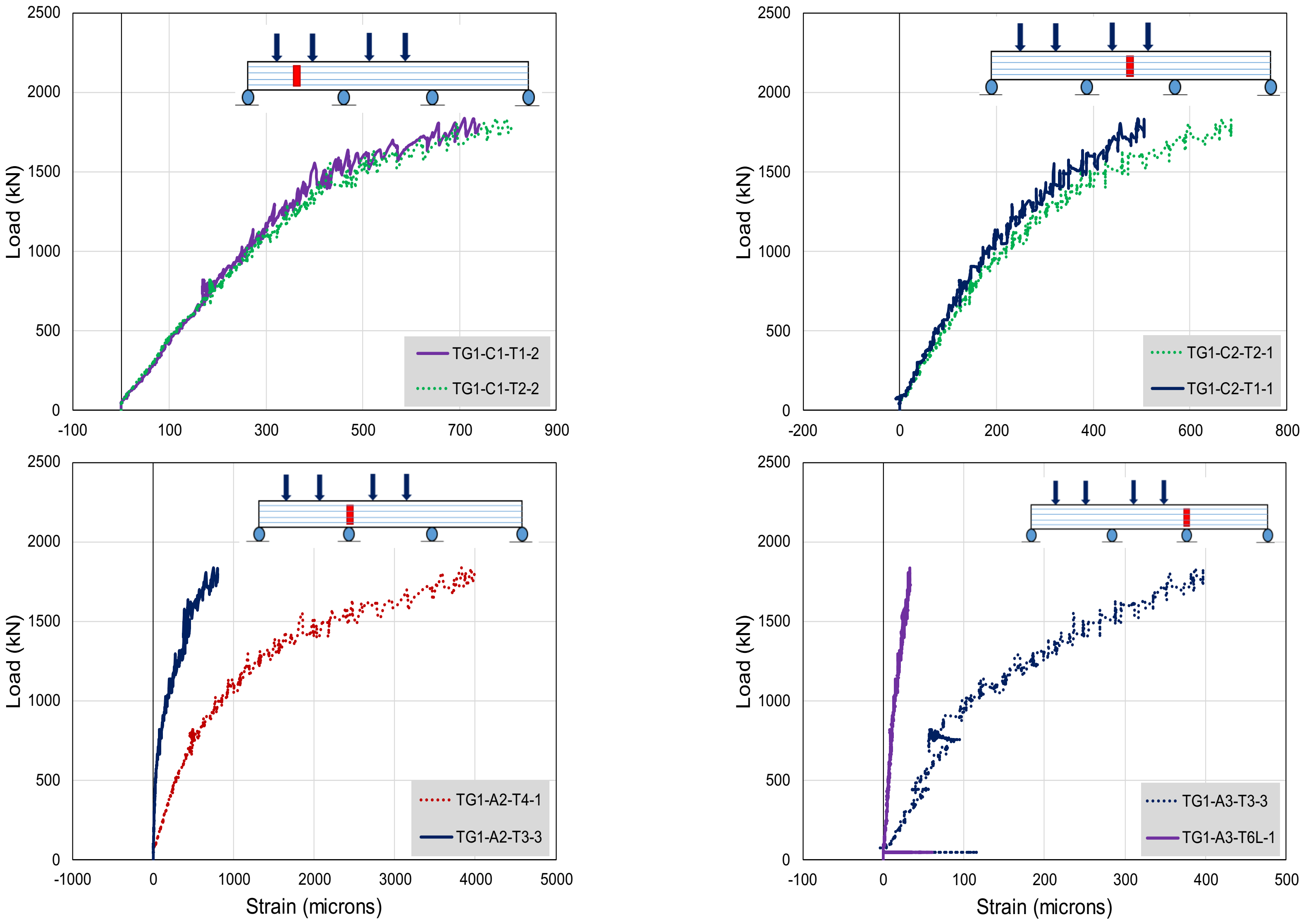
TEST RESULT: Tendon Strains – Type 4 test



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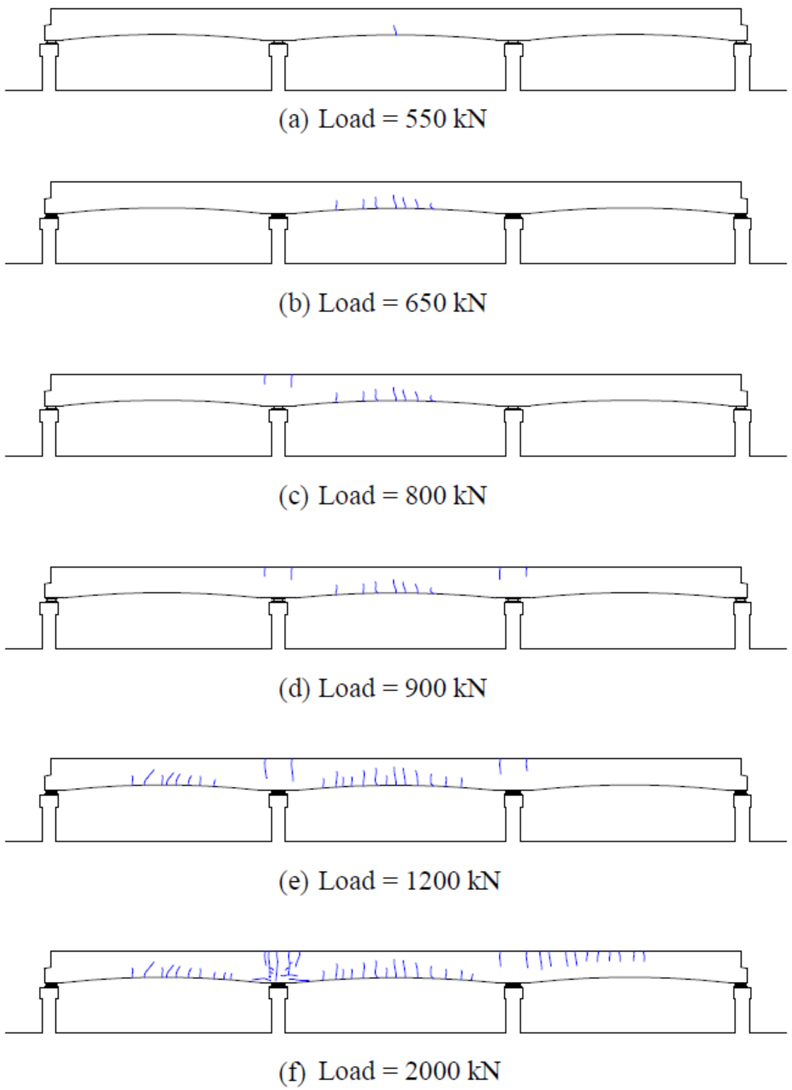
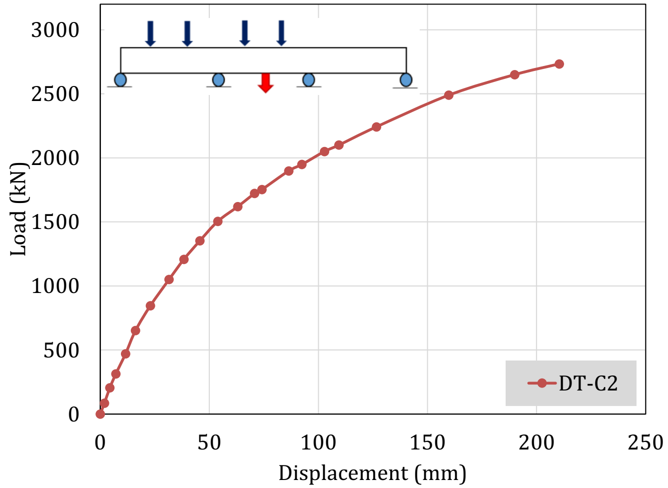
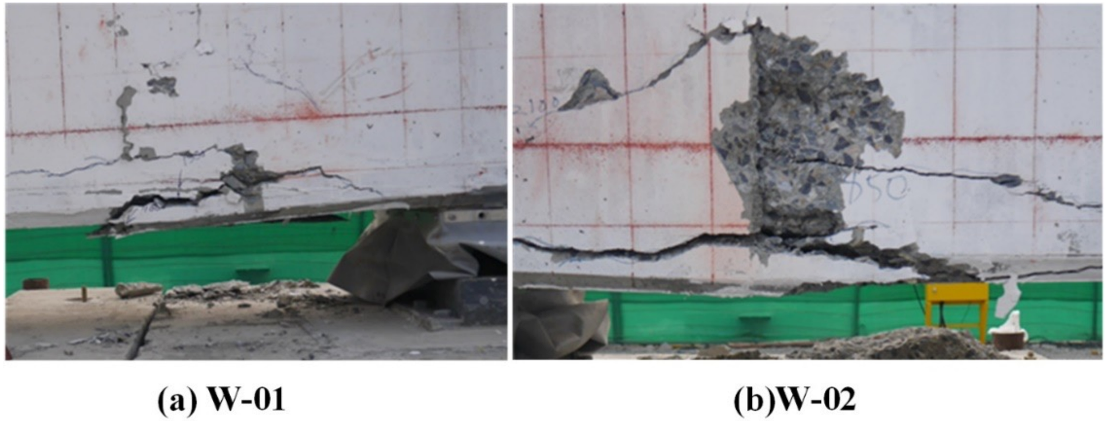
TEST RESULT: Failure Modes– Type 4 test



Cracking pattern of the FPPC girder at different loads, a) 550 kN, b) 650 kN, c) 800 kN, d) 900 kN, e) 1200 kN, and f) 2000 kN



Cracking pattern at the pier segment.



Detailed cracking pattern at the pier segment.

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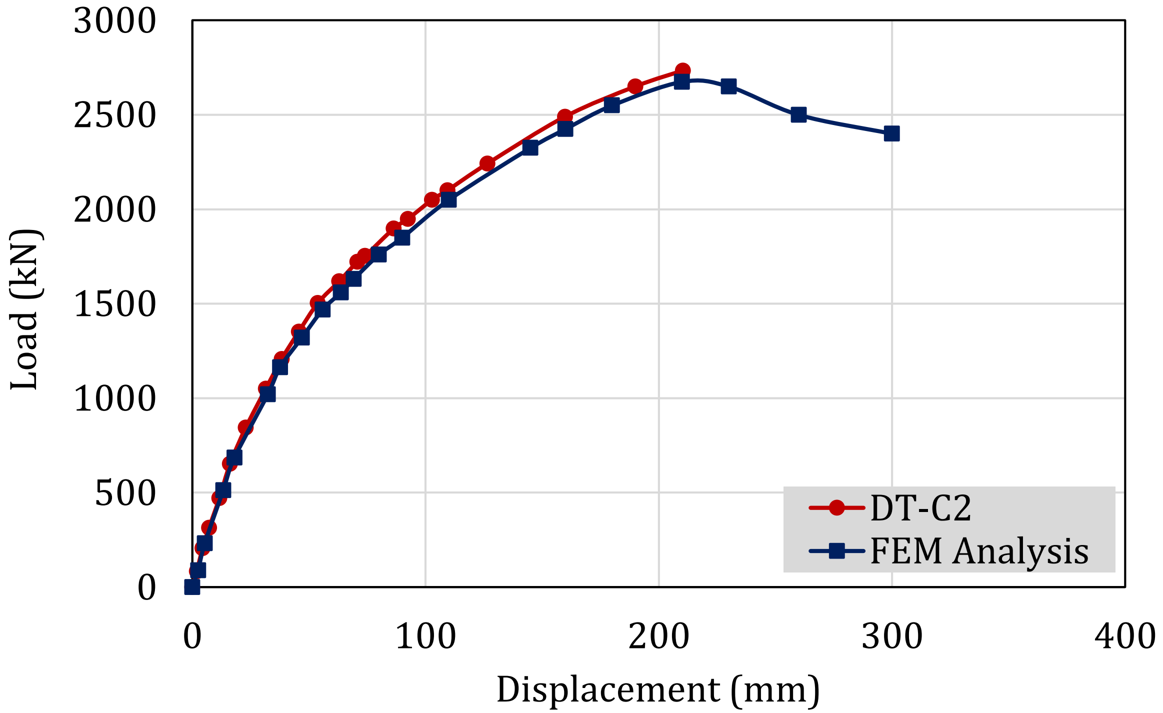
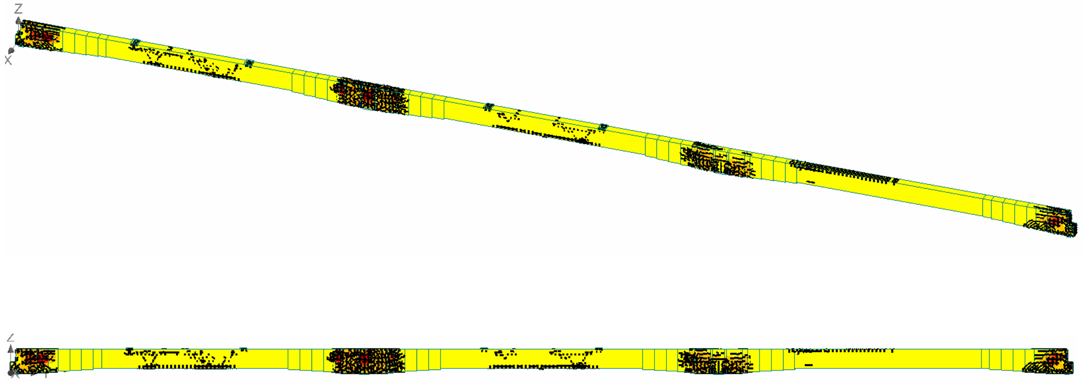
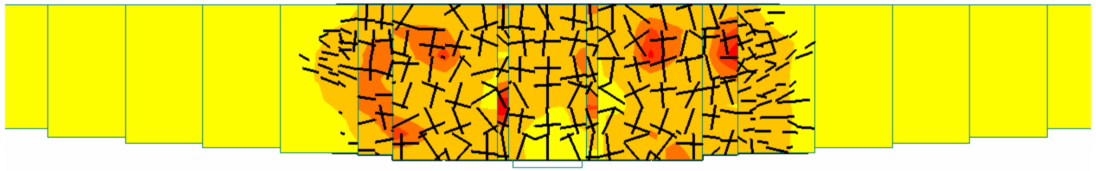
TEST RESULT: FEA result



FEM versus experimental results of interior girder – Combined ultimate Load at left exterior and middle girder



Cracking pattern observed in the finite element analysis



Cracking of pier segment as observed in finite element analysis

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CONCLUSION & DISCUSSION

CONCLUSION:

Full-scale precast post-tensioned continuous (FPPC)

• The FPPC girder was observed to be uncracked at all locations under service load conditions.

• The load versus deflection responses of the FPPC girder at all locations were observed essentially linear under service load conditions. Moreover, the maximum deflection of the FPPC girder under all load conditions was marginally less than the permissible limits.

• The ultimate load of the FPPC girder was recorded at 2600 kN and corresponding ultimate deflection was observed at 210 mm. This observed value is higher than that of the design load. The first linear relation of load and deformation was observed until 550 kN, and severe crushing and splitting of the concrete were observed at continuous supports.

• The ultimate failure of the FPPC girder was mainly due to severe damage to the bearing at the discontinuous end.

FEA – Finite Element Analysis by ATENA

• The finite element analysis results indicate that the computer program ATENA is well capable to predict the ultimate load carrying capacity, displacement and cracking patterns of FPPC girder.

CONCLUSION: Conference & Journal

The Evolving Metropolis
2019 IABSE Congress New York City
IABSE 90 YEARS

Construction Techniques and Development of 1st Monorail System in Thailand

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1 Abstract

This paper aims to present the construction techniques and development of first and unique monorail system in Bangkok, Thailand. Bangkok is the capital and most populous city of Thailand. The city occupies 1,568.7 km² and has a population of over eight million, or 12.6 percent of the country's population. In the last decade, Bangkok has attracted millions of migrants seeking economic opportunity and city is expanding quickly. Recently, Mass Rapid Transit Authority (MRTA) Thailand has decided to adopt monorail system in Bangkok as a rapid transit system due to the limited space, narrow roads and sharp curves in the city. The design of monorail track lines permits flexible and various alignments that include curves of small radiuses and large slopes. The first two projects i.e., Pink Line and Yellow Line projects consist of elevated structure around 64.9 km long, 53 stations, 2 depots and 2 park-and-ride buildings. MRTA has awarded these projects (design, test run and construction of first two lines) to the BSR Joint Venture who invited Sino-Thai Engineering &

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Case study

Experimental study of the load-deformation behaviour of the precast post-tensioned continuous girder for straddle monorail: Full-scale load test under service and ultimate loading conditions

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A R T I C L E I N F O

Keywords:
Finite element analysis
Precast concrete
Posttensioned
Girder
Straddle monorail
Pier segments
Service load

A B S T R A C T

This study presented the results of an experimental program conducted on a newly proposed Full-scale Precast Post-tensioned Continuous (FPPC) girder for straddle monorail. The investigated FPPC girder represents the actual size, design and construction details for a newly designed monorail transit system (Yellow Line and Pink Line Monorail) in Bangkok, Thailand. The salient features of the newly proposed girder system include lightweight, low-cost, easy and fast construction. The newly proposed FPPC girder is mainly comprised of three reinforced concrete (RC) hollow haunched girders, four piers or supports, two pier segments, four wet joints, and four bearings at each support. The FPPC girder was constructed at the casting yard of Sino-Thai Engineering and Construction Public Company Limited (STECON), Thailand. The FPPC girder was tested under different loading conditions (such as service and ultimate loading conditions). Both service and ultimate loads were applied as two-point loadings. Service load in a monotonic manner was applied on the right exterior span (two-point), middle span (two-point), and on the left exterior span and middle span (four-point). Meanwhile, the ultimate load in a monotonic manner was applied only on the left exterior and middle span as a four-point loading scheme. The test results indicate that the behaviour of the FPPC girder under service load conditions is elastic. Further, cracking of the concrete was not observed at any location. The observed maximum deflections under service load conditions were less than the permissible limits at all locations. Further, the maximum ultimate load-carrying capacity was observed to be much greater than the design load under ultimate loading conditions. This is an indication that the design details and construction procedure of FPPC girder are appropriate and further that this system could be used effectively to construct straddle monorail transit systems. Finite element analysis of FPPC monorail bridge girder was also performed by using a computer program ATENA which is a computational tool for nonlinear engineering analysis of bridges and culverts. The finite element analysis results indicate that the computer program ATENA is well capable to predict the ultimate load carrying capacity, displacement and cracking patterns of FPPC girder.

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polymers
MDPI

Article

Structural Behavior of Large-Scale Hollow Section RC Beams and Strength Enhancement Using Carbon Fiber Reinforced Polymer (CFRP) Composites

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Published: 31 December 2021

Abstract: An experimental program was conducted to ascertain the efficiency of Carbon Fiber Reinforced Polymer (CFRP) in enhancing the flexural response of hollow section reinforced concrete (RC) beams. Nine beams were tested under four-point bending in three groups. Beams were categorized to reflect the presence or configuration of the CFRP sheet. Each group consisted of three beams: one with a solid section, one with a square 50 × 50 mm x mm opening, and 1 with 100 × 100 mm x mm opening. Beams in 1st group were tested in as-built conditions. Beams in the 2nd group were strengthened with a single CFRP sheet bonded to their bottom sides. Configuration of CFRP sheet was altered to U-shape applied to the tension side of 3rd group beams. The inclusion of openings, regardless of their size, did not result in degradation of ultimate load and corresponding deflections. However, cracking loads were found to decline as the opening size increased. Regardless of the opening size and CFRP configuration, ultimate loads of beams increased with the application of CFRP. However, this improvement was limited to the debonding and rupture of CFRP in group 2 and 3 beams, respectively. A comparison in the behavior of group 2 and 3 beams revealed that the application of the U-shape CFRP sheet yielded better flexural performance in comparison with the flat-CFRP sheet bonded to the bottom of beams. In the end, In order to further evaluate the economic and performance benefits of these beams, the cost-benefit analysis was also performed. The analysis showed that the feasibility of the hollow section RC beams is more than the solid section RC beams.

Keywords: reinforced concrete beams; hollow section; carbon; fiber reinforced polymers; ultimate deflection; energy dissipation; strain; cost-benefit analysis

PROJECT STATUS

PROJECT STATUS:

GBWs casting yard

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PROJECT STATUS:

GBWs casting yard

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PROJECT STATUS:

GBWs casting yard

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PROJECT STATUS:

Column Erection

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PROJECT STATUS:

Crossbeam Erection

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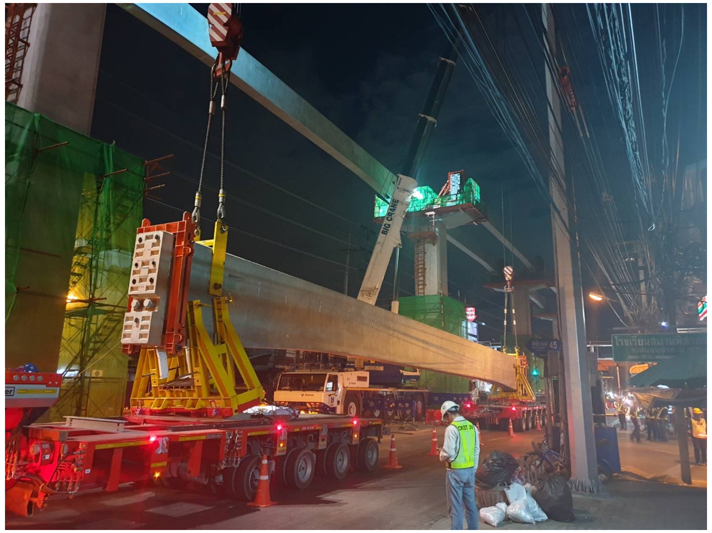
PROJECT STATUS:




PGs and GWBs Erection

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PROJECT STATUS:

	Pink Line (34.50 km)			Yellow Line (30.50 km)		
	Jun-23	Total	%Progress	Jun-23	Total	%Progress
Substructure						
Pilling	1,687	1,687	*100.00%*	1,239	1,239	*100.00%*
Transition Box	1,216	1,216	*100.00%*	1,018	1,018	*100.00%*
Column	1,216	1,216	*100.00%*	1,018	1,018	*100.00%*
Crossbeam	1,147	1,147	*100.00%*	993	993	*100.00%*
Superstructure						
GWBs Casting	2,517	2,517	*100.00%*	2,122	2,122	*100.00%*
GWBs Erection	2,517	2,517	*100.00%*	2,122	2,122	*100.00%*

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