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The Study on The Mechanical Properties and Performance Concrete of Precast Segmental Box Girder in Klang Valley Light Railway Transit Line Three (KVLRT3) for Package GS10

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Abstract: To generate a better outcome of the precast product, the raw material used for casting the product is important due to implement the safety, long-lasting and trustworthy precast product. The constructions of high rises and superstructures using a high strength concrete that can take the load of the active load or passive load onto the segments. Thus, the precast segmental box girder of Klang Valley Light Rail Transit Line 3 package GS10 is using the high strength concrete (HSC) of design mixed concrete which is required as standard specification from the consultant. There are 79 number of precast segments that has been casted by AlKauthar Kinematics Sdn. Bhd. at casting yard Batang Kali. This research is using five number of segments as reference to conduct the research which is to specify the concrete grade that used for precast segmental box girder at KVLRT3 package GS10, analyzing the compressive strength test that using the test laboratory result and monitoring the performance of the segmental box girder according to the defects appear on segments. In this finding, the compressive test result can be used as the reference for specifying the grade concrete used for the precast segmental box girder and comparing to the requirement of casting the precast segment by the consultant. The workability of the concrete also can be determined by the fresh concrete test which is flow table test because the concrete cast into the steel mold of segmental box girder. These results suggest that the potential of the concrete with the high workability and the great curing method can avoid the major defects of the precast segment.

Keywords: Concrete, Segmental Box Girder, Precast Segment, LRT3

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1. Introduction

The use of box girders is becoming more widespread. A trapezoidal box form with cantilevered top flange extensions combines mild steel reinforcement and high strength post-tensioning tendons into a cross section large enough to accommodate the whole width of the highway. There are both segmental and monolithic box girders in use. Segmental box girder in KVLRT3 project used for the long span deck which is needed to cross an active traffic roadway, KESAS roadway.

Precast construction entails prefabricating bridge members or segments in a place other than the site, transporting them to the site, and installing them there. According to Mathivat (1983), the maximum economical span of precast segment bridges is roughly 150 m, because the cost of installation equipment increases significantly as the span lengthens. Precast segmental bridge construction provides various benefits overcast-in-place segmental bridge construction. The segments can be cast in a controlled, plant-like environment at the precasting yard. Therefore, the method used by AlKauthar Kinematics SDN. BHD. is the precast segmental box girder method for the long span of KVLRT3 package GS10.

This industrialized approach provides for simple quality monitoring of segments before they are placed in the superstructure and saves money by reusing the precast formwork. Texturing, sandblasting, painting, and coating can be done on the ground level without scaffolding if the segments are still accessible from all sides before installation in the superstructure.

Precast construction lends itself nicely to repeated procedures and the efficiencies that come with them. Fabrication plant methods also tend to provide greater levels of quality control than cast-in-place construction field activities. Precast construction must be monitored and supervised to guarantee good vertical and horizontal alignment in the field. Match casting is commonly used to control this problem. To achieve accurate matching segments, match casting uses the previous segment as part of the formwork for the next section.

This research develops the mechanical properties and concrete performance of the segmental box girder in Klang Valley Light Railway Transit Three (KVLRT3) for package GS10. This research study is starting with the determination and study of the concrete used for the precast Segmental Box Girder for the Klang Valley Light Railway Transit Three (KVLRT3) for package GS10. The research of the mechanical properties and performance concrete of Precast Segmental Box Girder in Klang Valley Light Railway Transit Three (KVLRT3) for package GS10 shall be determine by the laboratory test and the record of defects that occur on the segmental box girder that casted at Batang Kali AlKauthar casting yard. The analysis of the concrete performance used for the precast segmental box girder for KVLRT3 package GS10 which is provided by AlKauthar Kinematics SDN. BHD.

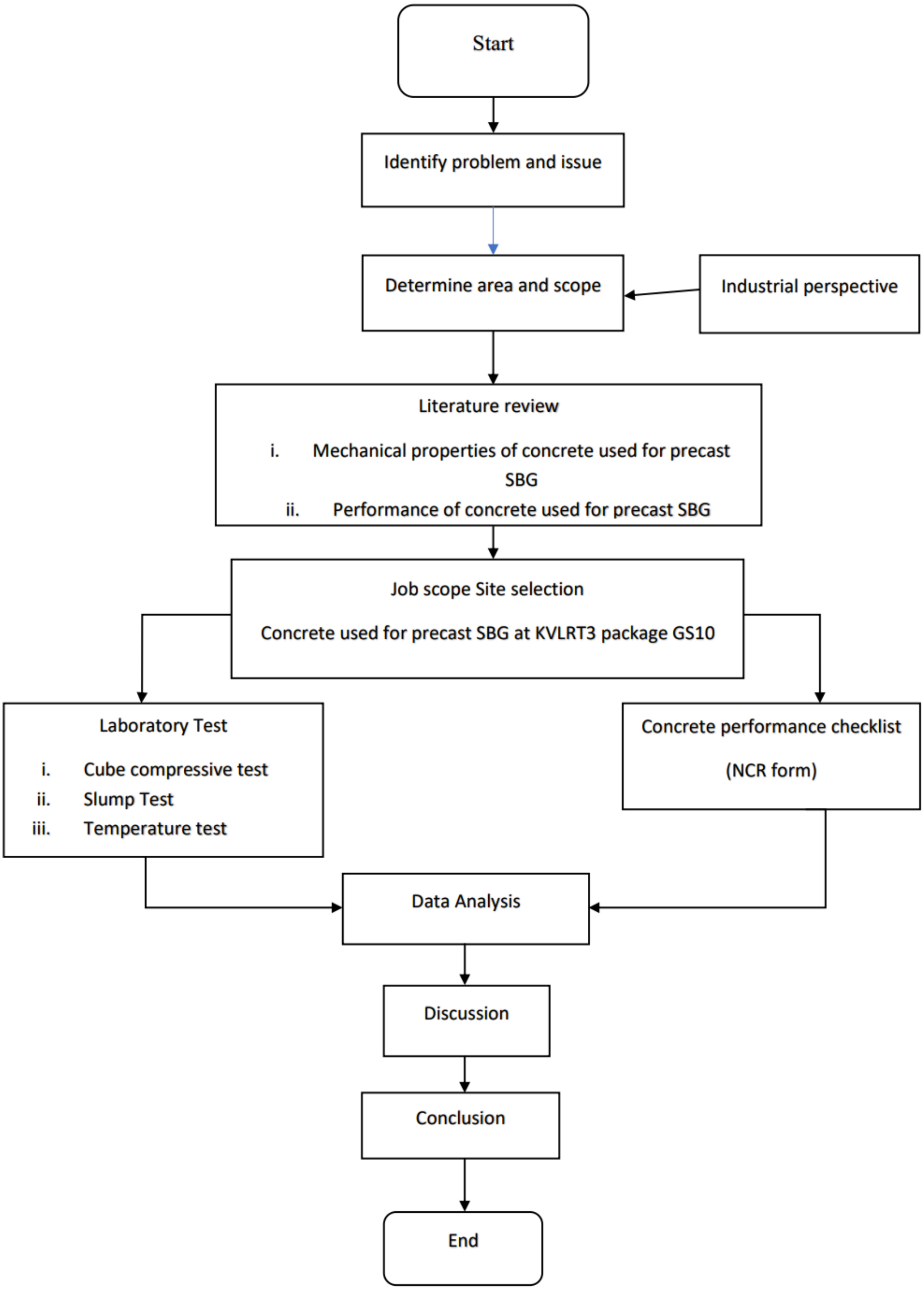

Figure 1: The flow chart of methodology

2. Klang Valley Light Rail Transit Line 3 (KVLRT3) Package GS10

This case study used to analyze the mechanical properties and performance of the concrete used for the precast segmental box girder at Klang Valley Light Rail Transport Three (KVLRT3) package GS10, which is provided and casted at AlKauthar Kinematics SDN BHD Casting Yard, Batang Kali. The data that needed for this research is from the laboratory test for the concrete used for precast segmental box girder. The laboratory test that required is the compressive cube test, slump test and temperature test.

This test purpose is to analyze the mechanical properties of the concrete used to cast the segmental box girder. The data acquire from the laboratory test can be established to acknowledge the workability of the concrete through the data accumulation in graphical method.

Then, the performance of the concrete used for the precast segmental box girder can be determined through the post concrete pour result checklist. In this field, it shows the performance of the concrete after completing the casting and curing process. From the performance of the concrete result, it can intercorrelated to the mechanical properties of the concrete before casting process. This chapter was also discussed the sequences from the flow chart methodology in detail.

2.1 Laboratory test for the concrete used for precast segmental box girder

High strength concrete made such projects feasible due to enhance load carrying capacity in which the segmental box girder used for the KVLRT3 designed to carry the load on the elevated track on the deck. Lowering dead loads reduces the loads associated with foundation design. Furthermore, the end user benefits financially because the amount of rentable floor space increases as the space occupied by the columns decreases [6].

Before the casting process of the segmental box girder, the concrete arrival at casting yard needed to be inspected according to the specification of the concrete arrived. This inspection called the pre pour inspection and recorded into the concrete pour order checklist.

- Temperature test
- Slump test
- Cube sample for compressive strength test

The laboratory test will be conducted after the casting process in which the cube specimens will be hand over to the laboratory to run the compressive cube test which is for the early strength (1-4 days), 7 days and 28 days.

The concrete sample collections were divided into multiple compressive strength ranges so that the influence of strength level on the relationships between material qualities and their statistical parameters could be assessed.

2.2 Cube Compressive test

The laboratory test will be conducted after the casting process in which the cube specimens will be hand over to the laboratory to run the compressive cube test which is for the early strength (1-4 days), 7 days and 28 days.

The concrete sample collections were divided into multiple compressive strength ranges so that the influence of strength level on the relationships between material qualities and their statistical parameters could be assessed [9].

2.3 Calculations of Concrete Strength

Generally, the compressive strength test required the specific calculation for determine the strength of the concrete that used for the precast segmental box girder for KVLRT3 package GS10. This calculation is the manual method to determine the strength of the concrete. Usually, the machine for the concrete test cube is fully set with the calculated result. The data that need for the determine the strength of the concrete is the size of the cube, concrete grade as specified for the design mix, maximum load applied to the cube and characteristic of the compressive strength of the concrete according to the expected strength for the concrete grade [4].

Table 1: Expected strength of concrete within ages

Age in days	Percentage of strength

1 day	16%
3 days	40%
7 days	65%
14 days	90%
21 days	94%
28 days	99%

$$Expected\ strength\ of\ compressive\ strength\ for\ 7-days = 65\%\ x\ 60$$
$$= 39.00\ N/mm2$$

$$Expected\ strength\ of\ compressive\ strength\ for\ 28-days = 99\%\ x\ 60$$
$$= 59.40\ N/mm2$$

$$\text{Standard deviation of concrete, } s = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$$

$$\text{Current margin} = \text{k x s}$$

k = 1.64 (based on 95% confidence limit BS 8110)

s = standard deviation of concrete batch

n = number of batches

Thus, the concrete used for precast segmental box girder for KVLRT3 package GS10 is exceed the grade specified by the batching plan which is preferable for the superstructure to take load from the light rail transit.

2.4 Concrete performance

High-strength concrete and high-performance concrete are not synonymous because strength and performance of concrete are different properties of concrete. High-strength concrete is defined based on its compressive strength at a given age whereas high-performance concrete is defined based on performance criteria namely: high durability, high strength, and high workability [1]. High-performance concrete is defined as a concrete that meets special combination of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practice. However, high strength concrete is defined as concrete that has a compressive strength of 55 MPa or higher.

The economic advantages of using HSC in bridges have been demonstrated on several projects and comparison studies. These bridge projects have led the way in the use of HSC. As more bridges are built with HSC, it is anticipated that the short-term and long-term economic benefits will become more apparent [2].

Cracking, crazing, blistering, delamination, dusting, curling, efflorescence, scaling, and spalling are examples of flaws in concrete structures. These flaws might be caused by a variety of factors. This study is primarily concerned with the concrete performance that resulted in segmental or structural faults.

Caused of defects in concrete structure:

(i) Structural deficiency resulting from errors in design, loading criteria, unexpected overloading

(ii) Structural deficiency due to construction defects.

(iii) Damage due to fire, floods, earthquakes, cyclones etc.

(iv) Damage due to chemical attack.

(v) Damage due to marine environments.

(vi) Damage due to abrasion of granular materials.

(vii) Movement of concrete due to physical characteristics.

3. Results and Discussion

This study of this research was conducted at Klang Valley Light Rail Transit Line 3 (KVLRT3) package GS10 at Bandar Utama to Johan Setia in order to obtain the laboratory test and the performance of the Segmental Box Girder that has been cast at AlKauthar Kinematics Casting Yard, Batang Kali. This research is started with the search data of the concrete that used for precast Segmental Box Girder for KVLRT3 in AlKauthar Kinematics records for precast segment. this record for the segmental box girder known as the Birth Certificate of the Precast Segment. data collection has been started since March 2022. this record contained document of pre-pour, post-pour, final inspection, concrete pour record with the fresh concrete test as flow and temperature, alignment control, as -built dimension, NCR inspection form, rectification form, concrete compressive strength early, 7-days and 28-days, concrete delivery order and segments handbook.

The related records for my research are the concrete pour record, NCR inspection form and concrete compressive test from the laboratory test from Reliable Testing Laboratory Sdn. Bhd.

3.1 Results

Table 2: Compressive test for each segment according to Laboratory and expected strength

segment id	Laboratory		expected	
	7 days	28days	7 days	28days
P25-08-U08	65.85	71.15	39.00	59.40
P25-10-U01	60.50	75.50	39.00	59.40
P25-10-U02	64.05	72.15	39.00	59.40
P25-10-U03	63.85	73.95	39.00	59.40
P25-10-U05	63.60	76.10	39.00	59.40

Table 3: Calculation of mean strength of concrete

segment id	exact	calculation		
	28days	(x-mean)	(mean-x)	(x-mean)^2
P25-08-U08	71.15	(2.62)	2.62	6.86
P25-10-U01	75.50	1.73	(1.73)	2.99
P25-10-U02	72.15	(1.62)	1.62	2.62
P25-10-U03	73.95	0.18	(0.18)	0.03
P25-10-U05	76.10	2.33	(2.33)	5.43
∑	368.85	0.00	(0.00)	17.94
mean:	73.77			

$$standard\ deviation, s = \sqrt{\frac{17.94}{5-1}}$$

$$standard\ deviation, s \approx 2.12\ N/mm^2$$

$$current\ margin, C_m = 1.64x2.12$$

$$current\ margin, C_m \approx 3.5\ N/mm$$

$$concrete\ grade, f_c = mean\ compressive\ strength\ -\ C_m$$

$$concrete\ grade, f_c = 73.77 - 3.5$$
$$concrete\ grade, f_c = 70.27\ N/mm^2$$
$$concrete\ grade, f_c \approx 70\ N/mm^2$$

Table 3: Defects appear on each Segments

Segment id	Defects
P25-08-U08	Honeycomb
P25-10-U01	Major cracks
P25-10-U02	Shrinkage cracks
P25-10-U03	Concrete spalling
P25-10-U05	Concrete spalling

3.2 Discussions

In this research, the specification of the grade used for the segmental box girder determined by the calculation of the strength of the concrete which is from the chapter 4.1.5 which is the concrete grade, fc is 70 N/mm^2. This result shown that the concrete used is exceed the specified concrete grade by the batching plant. Thus, the concrete used for the long span of KVLRT3 package GS10 is casted according to the requirement by the Main Contractor and allowed to continue the casting works. This research conduct with the product that used as superstructure for KVLRT3, which means the concrete mechanical properties should be determine as specified for concrete strength of 7-days and 28-days. As for this research, the compressive strength was exceeding the expected result of the concrete grade G60 for 28-days. In which, the concrete compressive strength used for precast segmental box girder of KVLRT3 package GS10 for P25-08-U08-SCD2, P25-10-U01-SC4, P25-10-U02-SC3, P25-10-U03-SC2, and P25-10- U05-SC1 is 71.15 N/mm^2, 75.50 N/mm^2, 72.15 N/mm^2, 73.95mN/mm^2 and 76.10 N/mm^2 respectively.

The expected concrete compressive strength of 28-days for G60 as theoretically is 99.00 % of the concrete specified grade which is 59.40 N/mm^2. According to the comparison of the expected and the laboratory test, it shown that the concrete that used for precast segmental box girder for KVLRT3 Package GS10 has higher strength than the requirement of concrete grade.

The defect appear as the honeycomb on the segments is caused by detailing or placement of the reinforcement compounds the effect of inadequate compaction. Thus, the compaction is related to the workability of the concrete into the steel mold. As for the major or shrinkage cracks, the external force that can cause the segment to overload with the force such as the tendon stressing that used for post tension of the balance cantilever. Lastly, for the concrete spalling that appear on P25-10-U03-SC3 and P25-10-U05-SC1. The reason some concrete structures exhibit widespread spalling whilst other appear to be in a sound condition is down to a combination of age, maintenance, concrete quality, the depth of concrete cover and local environmental conditions [8].

4. Conclusion

This research is the case study of the concrete used for the precast segmental box girder for KVLRT3 package GS10 according to the concrete specification, mechanical properties and performance of the concrete. All the objective of this research is successfully achieved and concluded this research is that some recommendation of improving the concrete workability to ensure the defects as honeycomb that can cause major factor of delay in construction work. This research is the case study of the concrete used for the precast segmental box girder for KVLRT3 package GS10 according to the concrete specification, mechanical properties and performance of the concrete. All the objective of this research is successfully achieved and concluded this research is that some recommendation of improving the concrete workability to ensure the defects as honeycomb that can cause major factor of delay in construction work.

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