Composite girder to fulfill the needs of 60 up to 80 m span bridge for toll road projects in Indonesia

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Abstract. Ministry of Public Works and Housing of Indonesia is targeting to complete the construction of 1.000 km of new toll road projects by the end of 2019. In 2015 until August 2018, 443 km new toll roads have been operated and 1.400 km are under construction. Various types of structure for elevated toll road constructions are applied to meet the geometry and safety requirements such as cast in-situ balanced cantilever, steel I-girder, and steel box are becoming type of elevated toll construction to be applied. To meet the requirements of construction methods, construction time completion, and material volume efficiency, Indonesia Toll Road Authority on behalf Ministry of Public Works and Housing gives opportunities to toll road investors to apply the new technology as the proper selection. Composite Girder technology named Sbarch is proposed for Krian Legundi Bunder Manyar toll road project to cross at SUMO Junction. Compares Sbarch among cast in situ balanced cantilever, steel I-girder and steel box, Sbarch can comply for all requirement that cannot be fulfilled by others method such as with finish grade requirement, to road geometry alignment, accessibility, workability, and steel tonnage reducing.

1 Introduction

Infrastructure development in Indonesia is undergoing accelerated, especially for toll road. Indonesian Government through Ministry of Public Works and Housing of Indonesia is targeting to complete the construction of 1.000 km of new toll road projects by the end of 2019. During 2015 - 2018, 443 km new toll road have been operated and 1.400 km are under construction. Toll road consist of not only road structure but also bridge or tunnel structure, bridge structure especially for elevated toll road. Various types of structures are applied to meet the geometry and safety requirements. For an example in a junction area, in order to cross the existing main roads, required to have bridge structure as an elevated road. Balanced cantilever, I-girder, and steel box are becoming type of elevated toll construction to be applied. To meet the requirements of construction methods, construction time completion, and material volume efficiency, Indonesia Toll Road Authority as a representative of Ministry of Public Works and Housing to regulate the Toll Roads Investors, gives opportunities to them to select the new technology that appropriate with the existing condition.

Some structures with 60 up to 80m of bridge span are installed for junction. Recently, Serpong Junction which is connected Kunciran-Serpong and Serpong-Cinere Toll Road will be installed at least 2 (two) types of steel box with span 60m an 85m. In the same time, Kunciran Junction which is connected Cengkareng-Kunciran and Kunciran-Serpong Toll Road is designed with span of 66m and using steel box structures. Below is the girder types and span for each structures.

Table 1. List of Indonesia toll roads project with 60m span of bridge

No.	Toll Roads Name	Span (m)	Method (Girder Type)
1.	Serpong Junction	16,6+60+ 40,8	I + Steel Box + I
2.	Serpong Junction (Ramp 5)	85	Steel Box
3.	Kunciran Junction	25+66+27	I + Steel Box + I

Since there are 38 toll roads underconstruction nowadays, Indonesian Toll Road will have approximately more than 10 junction which has the same requirements and offer the opportunity for new technology to be approached.

2 Literatures

Bridge structure in the toll road usually being called as elevated toll road. Refer to Keputusan Menteri PUPR No.485/2015, there are some special bridge and tunnel structure definition:

a. Bridge with a span of at least 100 m;

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b. Arch bridge with a span of at least 60 m, suspension bridge and cable stayed bridge;
c. Bridge with total length of at least 3.000 m;
d. Bridge with pier elevation above 40 m;
e. Road tunnel with a closed length of at least 200 m;
f. Road tunnel that use boring/jacking method as a construction method
g. Bridge and tunnel structure that has high structural complexity, high strategic value ,or being designed with new technology

Nowadays, there are four structure types of elevated toll road applied:

1. *Cast In-Situ Balanced Cantilever*

Free cantilevering is a method of construction where a structure is built outward from a fixed point to form a cantilever structure, without temporary support, using staged cast-in-situ construction.

This type of method has some advantages such as suitable for structure with soft soil condition and soil in the sloping area; does not require any temporary structures for support; the bridges of greater heights can also be built using balanced cantilever method without falsework. Not only some advantages but also it has some disadvantage such as heavy structure will impact to foundation design; needs more space for work area due to foundation size; needs much longer time for construction.

For example cast in-situ balanced cantilever type, shown in Fig. 1.:

Fig. 1. Cast in-situ balanced cantilever

2. *Steel I-Girder*

Steel I-girder are structure that using steel profile as its girder. The fabrication of steel profile will be customized with the dimension of girder. Then this structure will be transported to site work.

This type of method has some advantages such as needs less of work space since the fabrication is on workshop; reduces of using formwork since the material is steel; length of span is greater than cast in situ (no limitation of bending crack that exist in concrete cast in situ and has maximum span of 75m); erection stage will be faster than cast in situ. Not only some advantages but also it has some disadvantage such as the height of steel profile might be higher when the longer of span girder; needs wider road geometry alignment due to its dimension.

Steel I-girder type can be seen in Fig. 2.:

Fig. 2. Steel I-girder

3. *Steel Box Girder*

Steel box girder is used for long spans, where the self weight of the bridge needs to be minimized, and for situations where their excellent high torsional stiffness is of particular benefit. Steel box girder are custom type of steel girder, fabricated as U-shape. Then this structure will be transported to site work.

This type of method has some advantages such as needs less of work space since the fabrication is on workshop; reduces of using formwork since the material is steel; length of span is greater than cast in situ (no limitation of bending crack that exist in concrete cast in situ and has maximum span of 66m); erection stage will be faster than cast in situ. Not only some advantages but also it has some disadvantage such as the height of steel profile might be higher when the longer of span girder; needs wider road geometry alignment due to its dimension; more heavy than steel I-girder since the shape is box, needs high capacity of crane for erection stage; difficult manuver for moving steel box in stock yard or in erection stage.

For example steel box girder type, shown in Fig. 3.:

Fig. 3. Steel box girder

4. *Composite Girder*

Composite girder is girder that use 2 (two) or more different material for its structure. Most common is steel girder combines with concrete using shear connector to ensure the structure act together. One example of composite girder that using the newest technology is Sbarch.

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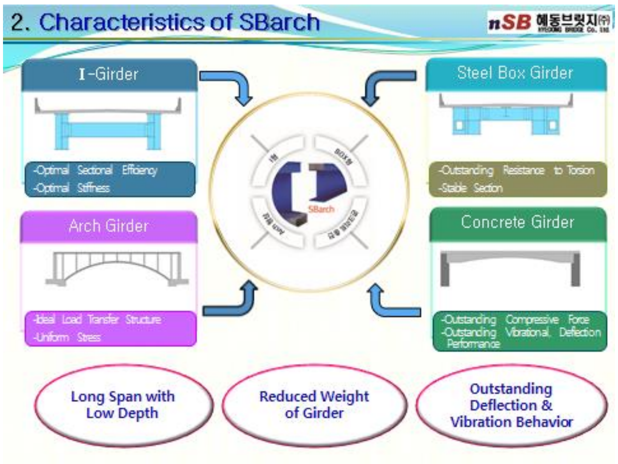

Fig. 4. SBarch characteristic

Sbarch characteristic as shown in Fig. 4., it has characteristic that are the advantages for other types of structure. Sbarch and the other types characteristic are resumed in table 1.:

Table 2. Sbarch & Other Types Structure Characteristic

Types	Characteristic
I-Girder	- Optimal sectional efficiency - Optimal stiffness
Arc girder	- Ideal load transfer - Uniform stress
Steel Box Girder	- Torsion resistance - Stable section
Concrete Girder	- Outstanding compressive force - Outstanding vibrational, deflection performance
Sbarch	- Long Span with Low Depth - Reduced Weight of Girder - Outstanding Ddeflection & Vibration Behavior

One of many implementations of Sbarch Grider are shown in Fig. 5. below:

Fig. 5. SBarch Implementation

Sbarch is composite girder with tapered section combining U-shaped section and I-shaped section in arch shape at central span. Concrete material to be filled in the U-shape section. Detail section is shown in Fig. 6. and Fig. 7.:

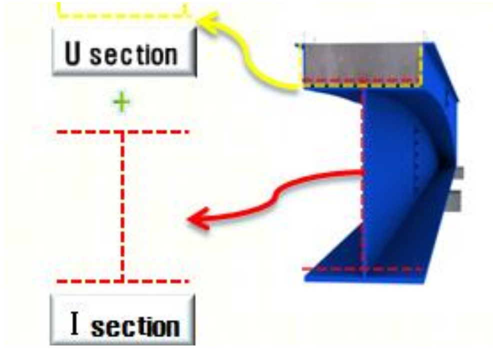

Fig. 6. SBarch profile section

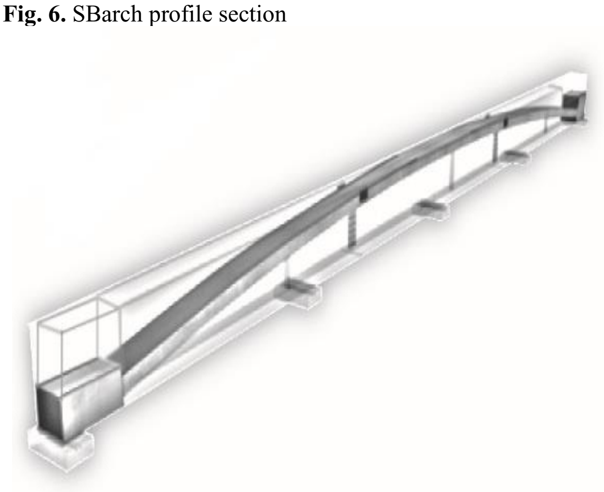

Fig. 7. SBarch profile long section

SBarch is fabricated on workshop. It ensures the homogenous of the quality to achieve the strength requirements. The production & erection phase can be seen in this flowchart below:

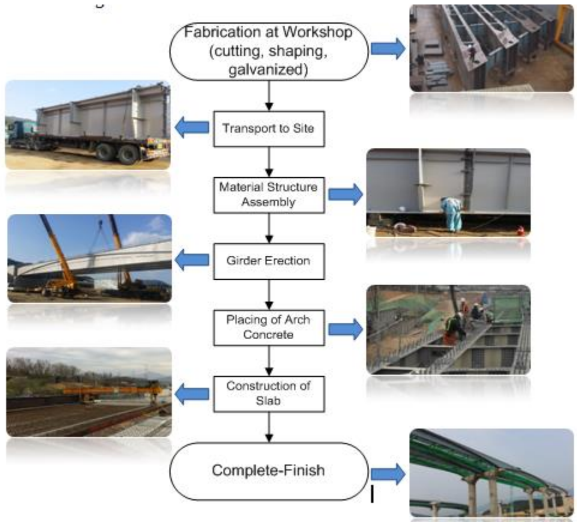

Fig. 8. Sbarch production and erection process

Fig. 9. Sbarch fabrication process at workshop

After being fabricated at workshop, then SBarch be transported to site work and be assembled. Steel section has been assembled with shear connector in the top and inside U-Section. This shear connector as a connection between steel and concrete. After being assembled then steel section be erected. Erection method can use crawler crane capacity 150 ton. With limited space of work, using crawler crane capacity 150 ton will not affected too much to the traffic.

Fig. 10. Sbarch erection process using crane lift

It might be only 1(one) or 2(two) line being closed during erection phase. Compares with another method that might be closed more line during erection phase. After being erected, concrete slab will be poured at the top of steel section.

3 Case study of SUMO junction

Krian Legundi Bunder Manyar Toll Road (KLBM Toll Road) is one of the project that being accelerated to achieve the toll road target. KLBM Toll Road is constructed to connect Kabupaten Sidoarjo with Port Area of Gresik. This road path is one of the busiest traffic in East Java Province. The purpose of KLBM Toll Road is to parse congestion and to increase economic growth in East Java Province. KLBM Toll Road has length of line about 38,29 km from By Pass Krian-Interchange Kedamean-Interchange Boboh-Interchange Bunder till Interchange Manyar. Detail line for KLBM Toll Road is described on Fig. 11. below:

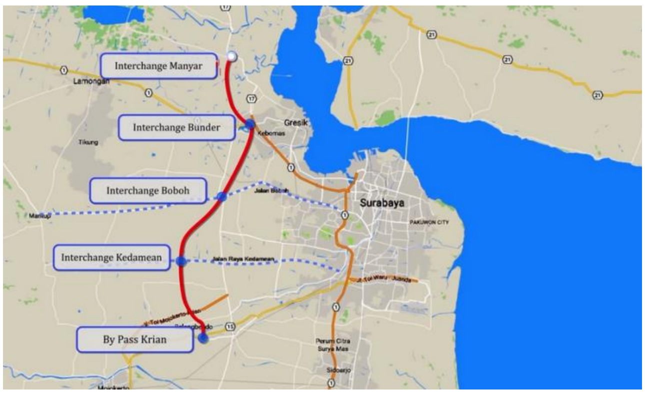

Fig. 11. KLBM toll road line route

The construction progress of KLBM Toll road now is at 41% including SUMO Junction. The elevated construction is installed as the main stucture for the main road in order to deal with the soft soil.

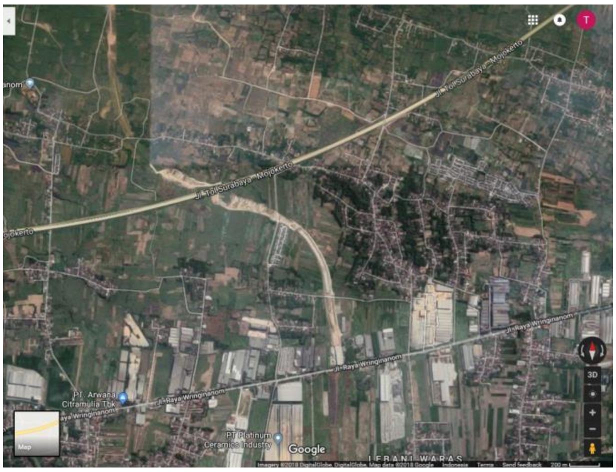

Fig. 12. The construction of Krian Legundi Bunder Manyar Toll

KLBM Toll Road also constructed in the existing area of Surabaya-Mojokerto Toll Road (SUMO Toll Road). SUMO Toll Road has Right of Way length about 78m and head vertical clearence of 5,3m. SUMO Toll Road has been operated since 2011. Therefore KLBM Toll Road needs appropriate construction method through existing SUMO Toll Road. This area also being called as SUMO Junction because the position of KLBM Toll Road passing through SUMO Toll Road. Sumo Junction is described in the Fig. 13. and Fig.14. below:

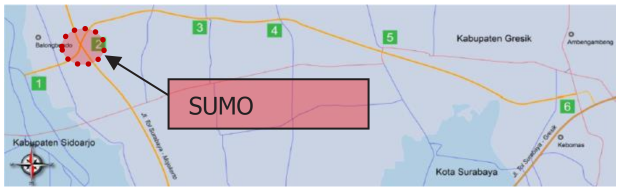

Fig. 13. SUMO junction location

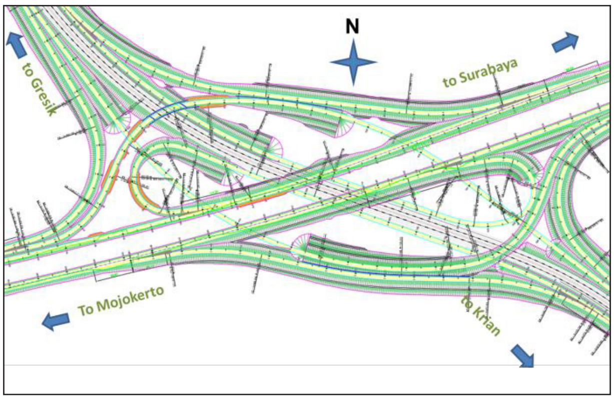

Fig. 14. SUMO junction alignment

KLBM Toll Road has Interchange and Main Road that are crossing through existing Surabaya-Mojokerto Toll Road, which are:

1. Main Road
2. Ramp No. 01
3. Ramp No. 04
4. Dedicated Line to Surabaya
5. Dedicated Line to Mojokerto

SUMO Junction has total length about 196,188 m, therefore needs an elevated structure which has the longest span is about 78m. Toll road will be constructed in the existing main road that has limited space of work and does not allowed to change the geometry alignment. In addition, SUMO Toll Road has been operated since 2011 and the traffic of these main acees cannot be affected too much due to construction of KLBM Toll Road.

4 Sbarch for SUMO Junction

Sbarch that be used in SUMO Junction has layout and dimension as Fig. 15. below:

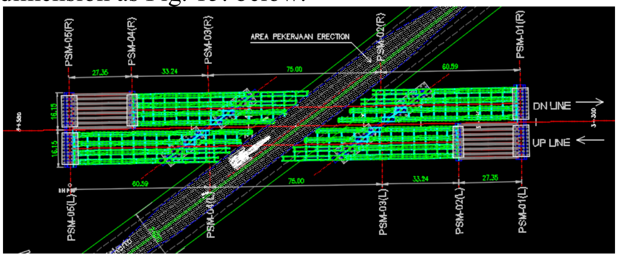

Fig. 15. SUMO junction layout and dimension

In Figure 10. can be seen that span length minimum is about 75m. Therefore, the structure type of steel box girder and cast in situ balanced cantilever cannot be used. Sbacrh can accomodate the span length of 78m.

Sbarch has method of load distribution as Fig. 16. below:

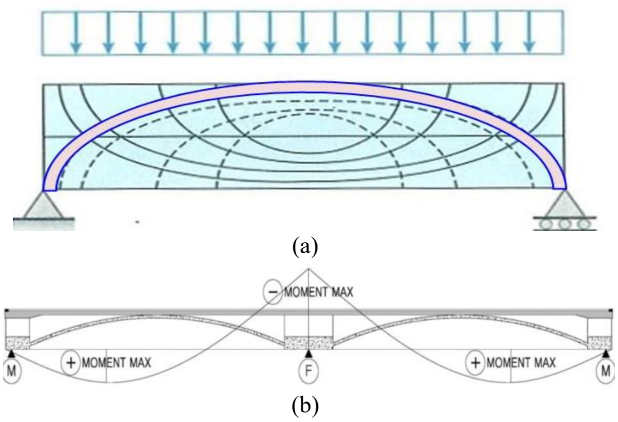

Fig. 16. (a) Load distribution; (b) Moment diagram

Firstly, concrete to be placing along the principal stress line (arch) for beam. Placing concrete in maximum compression zone for negative moment (about 1/3 of depth). It will impact to the load distribution that is maximizing concrete function as compressive strength in negative moment and steel as tension strength in positive moment. And the result is achieved effective sectional stiffness.

Technical concept of Sbacrh, compares to others method are:

- Maximize sectional efficiency which is the advantage of I-Girder
- Outstanding resistance of torsion which is the advantage of Steel Box Girder
- High damping and low deflection which are the advantages of Cast In Situ Concrete

From expalanation above, using Sbacrh which are summarize of other method. From Sbacrh, it can be obtained all advantage for I-girder, steel box girder and cast in situ concrete.

Herewith, the comparation among 4 methods, shown in Table 3.:

Table 3. Comparation 4 Method for SUMO Junction

Methods / Requirement	Cast In-Situ Balanced Cantilever	Steel I-Girder	Steel Box Girder	Composite Girder (Sbarch)
Max. Span **(78m)**	**120~180 m**	75 m	60 m	**50-120 m**
Head of Clearance **(5,3 m)**	2,95	4,926 m	No data	**6,1 m**
Steel Tonnage	-	2.948 ton	No data	**1.830 ton**
Time Completion **(6 months)**	8 months	**6 months**	No data	**6 months**
Erection Crane	No data	**2 x crane 150 T**	2 x crane 400 ton	**2x crane 150 ton**

From Table. 3. above, obtained information that:

- Max.span is complied by 2 methods (Cast in Situ Balanced Cantilever &Composite Girder)
- Head of Clearance is complied only by Composite Girder
- Steel Tonnage can be reduced approximately 60% from using Steel I-Girder
- Time completion is complied by 2 methods (Steel I-Girder & Composite Girder)
- Erection crane is complied by lower capacity due to traffic impact (Steel I-Girder & Composite Girder)

5 Conclusion

It can be concluded that Sbarch comply with length of span about 78m, finish grade requirement that has minimum height of 5.1m, possible to adjust to road geometry alignment, reduces price by saving approximately 60% of steel tonnage, reduces time of completion project (8 month to 6 month) and has ease access and workability since it only needs of using crawler crane capacity 150 ton.

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