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Determination of OCS Mast Offset in Johore Bahru Sentral for Gemas-Johor Electrified Double Track Project

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ABSTRACT

The Gemas – Johor Bahru Electrified Double Track Project (GJBEDTP) is the most recent railway electrification. GJBEDTP runs from Gemas Railway Station to Johore Bahru (JB) Sentral. Since the JB Sentral station platform track is existing, it cannot achieve the minimal offset in the client's Statement of Needs (SON). The station canopy's acting load capacity is limited, so it cannot support the Overhead Line Equipment (OLE). Malaysia's standard offset value was 3.0 m, while the KTMB guideline's maximum offset value is 3.60 m and the minimum is 2.60 m. Thus, this research investigates the concrete mast offset that should be used when track separation is lower than standard. JB Sentral architecture data was collected to evaluate the mast offset. Sicat Master simulation and a cross-sectional diagram can be used to determine the proper minimum offset from the data collected. The results show that the mast at the centre of the two tracks can achieve clearances with the minimum offset of 1.80 m from the track centreline to the concrete mast face. These results also show that tangent track alignment allows a minimum offset of 1.80 m at a lower train speed.

1. Introduction

Nowadays, electricity is widely used to move trains on modern railways. It can be done via overhead wire or via a third or fourth rail on the ground. The overhead wire is frequently used in the development of high-speed train or intercity train operations. The Overhead Catenary System (OCS) comprises Overhead Line Equipment (OHLE) and Traction Power Supply System (TPSS) [1,2]. Almost all railway lines in Malaysia are electrified, and some are being upgraded to the electrified system. Only a few lines, such as those on the east coast, continue to use diesel trains. The most recent

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project to upgrade a non-electrified railway system to an electrified railway system is the Gemas - Johor Bahru Electrified Double Track Project (GJBEDTP). The project spans 192 kilometres, from Gemas to Johor Bharu, and includes 11 stations worth a total of RM7.5 billion [3]. This figure includes the cost of consultation as well as rolling stock acquisition. This section will be built exactly to the specifications of the Seremban-Gemas Electrified Double Track Project (SGEDTP), which was completed on October 30, 2013. The system will be powered by a 25kV AC supply, 50 Hz single-phase supplied by an OCS [4,5]. Figure 1 depicts the proposed GJBEDTP route.

Fig. 1. Gemas - Johor Bahru EDTP route [3]

Johor Bahru Sentral (JB Sentral) is a transportation hub located in Bukit Chagar, Johor Bahru. On October 21, 2010, this infrastructure was inaugurated, replacing the old Johor Bahru Railway Station, which is now a KTM Museum. It is a Customs, Immigration, and Quarantine (CIQ) building that is part of the Southern Integrated Gateway. Figure 2 depicts the JB Sentral's location in Google Maps. This station serves as one of the modes of transportation that connects Malaysia and Singapore via the railway network. JB Sentral is a transportation hub with a train station and a bus station, similar to KL Sentral in Kuala Lumpur. For passengers traveling southbound by train towards the Woodlands, JB Sentral serves as the Malaysian immigration checkpoint. Northbound rail passengers from Woodlands are checked by Malaysian immigration and customs officers at the Woodlands Train Check Point before boarding.

Fig. 2. JB Sentral Railway Station Location via Google Map

On a straight alignment, the terminal is designed to operate six rail lines and four island platforms. This building's ticketing counter, passenger hall, and upper level are designed to fit the narrow site of the railway lines, which is similar to KL Sentral. This is due to the existing rail line from the old Johor Bharu Railway Station, which creates a site constraint for the development of a new structure near the track. Figure 3 depicts the platforms at JB Sentral, along with the six (6) existing rail lines.

Fig. 3. Six numbers of rail lines in JB Sentral

In terms of the issue description, because the station is already operational, all upgrading works for JB Sentral under the GJBEDTP project must be carried out with care, while considering all existing structures on the site. Since the track at the station platform is an existing track, obtaining the minimum offset specified in the client's Statement of Needs (SON) is impossible. The station canopy cannot be used to provide support for the OLE because the canopy's ability to withstand the acting load of the OLE support is limited. Because of these shortcomings, this project proposes a study on the mast offset value that is most suitable for use while taking into account JB Sentral's existing structure.

The following are the objective for this study: -

i. To determine the parameter that affects the OCS mast offset in the JB Sentral Platform area for GJBEDTP.
ii. To investigate the mast strength due to applied loads using STAAD.Pro software and run clearance simulation using Sicat Master as an OCS designing tool.
iii. To validate the design of OCS mast offset through the cross-sectional diagram using computer-aided-design software, AutoCAD, by determining the minimum mast offset.

1.1 Mast

A mast is a vertical concrete or steel pole used to support cables along a railway network's alignment [6-9]. It can be found along the track's edge. Concrete and steel masts are used for GJBEDTP. GJBEDTP uses pre-stressed concrete poles that meet the requirements of J.I.S. A 5309. Poles made of concrete need to be designed differently depending on the weight they'll be supporting. Pole bends will be used to connect the Cantilever and other assemblies to the poles, or they can be fastened directly to the mast through prefabricated ferrules/holes. An earth rod will be installed inside the masts and extended to the ground or concrete during setup. This will serve as the building's earth connection. The rod will then be linked to the masts' ferrules, allowing for easier earthing to the masts' steel components that support the OHLE. Concrete poles are commonly used for locating open routes at ground level. On the other hand, steel masts (H-beams) are employed in places like bridges and viaducts. Portal and Twin Track Cantilever, both of which use steel mast as its primary building material, are two other examples (TTC). Figure 4 depicts a concrete mast example from the GJBEDTP.

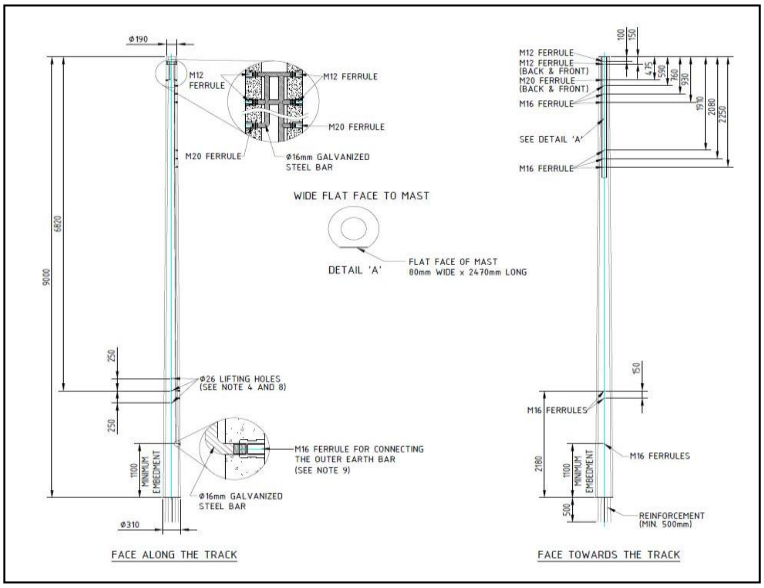


Fig. 4. Concrete Mast used in GJBEDTP

1.2 Mast Offset

Offset refers to the distance between the centre track to the mast's outside surface. Several nations use identical terminology, with just a select few preferring to use something else. The distance from the centre track to the mast's face is called "implantation" in India. In contrast, the rail edge is the only point of measurement in the United Kingdom (UK), where the word offset is also known as REFOS (Rail Edge to Face of Mast).

The minimum and maximum offset amounts vary per country. In Malaysia, for instance, the default offset value was maintained at 3.0 m; the KTMB guideline specifies a maximum offset value of 3.60m and a minimum offset value of 2.60 m [10-13]. India, like Malaysia, uses a standard offset value of 3.0m, however its minimum offset value is lower, at 2.80 m. The fundamental configuration for mast offset in GJBEDTP is depicted in Figure 5.

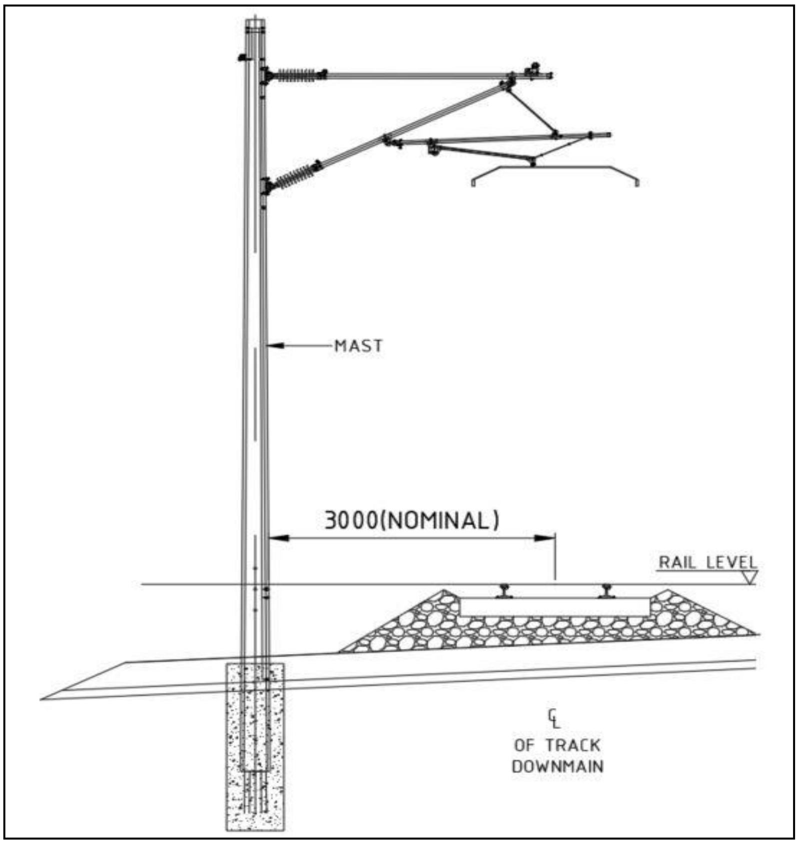


Fig. 5. Standard mast offset in for GJBEDTP

2. Methodology

Figure 6 is a flowchart that served as the basis for this investigation. The procedures were organised and carried out in a methodical fashion. Sicat Master was used as a design tool, and AutoCAD was used to create a cross-sectional diagram (CSD) to verify the OCS mast offset design. In addition, the Sicat Master will make it easier to show off all the weight that will be hoisted up the mast.

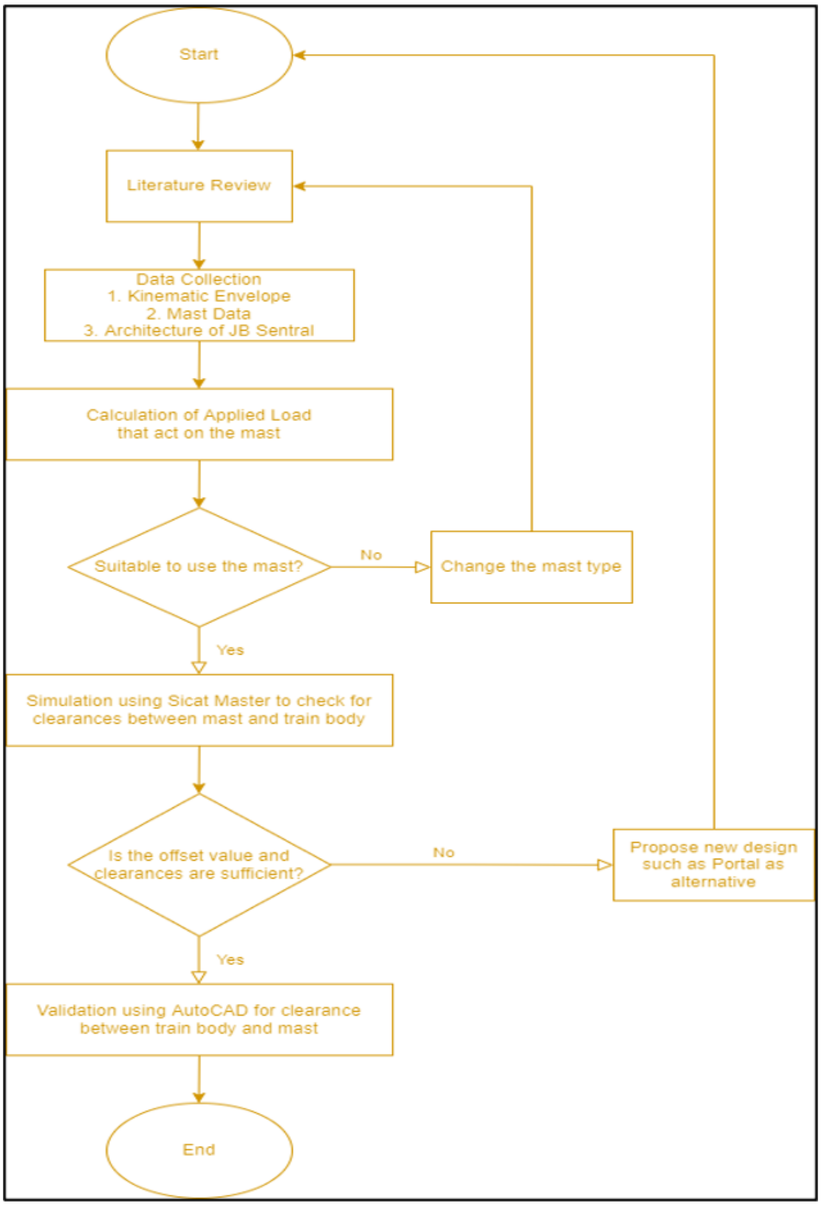


Fig. 6. Project Flowchart

2.1 Data Collection

The mast offset parameter is based on the KTMB railways project, GJBEDTP. These data were gathered from a variety of sources, including the JB Sentral station's as-built architectural drawing, the KTMB Permanent Way Manual, Series Drawing for GJBEDTP, Statement of Needs (SON), Electrification Design Brief for GJBEDTP, research papers, and standards. All project-related sources are accessible via the construction management software Aconex, which is shared by the Client, Main Contractor, and Sub-Contractor involved in this project [14].

A site visits to JB Sentral (Figure 7) was also used to collect data. According to Chapter 11: Loading Gauge, Kinematic Envelope, and Minimum Structure Gauge of the KTMB Permanent Way Manual [6,7], the loading gauge is kept at 3905mm and 2820mm, respectively.

Fig. 7. View from Down Mainline facing south towards Singapore

The kinematic envelope mentioned in the manual is already calculated and fixed because the KTMB uses a metre gauge in all of its networks. Since the kinematic envelope already considers the outhrow of the train body at curve areas, the kinematic envelope used in the study is more than adequate for analysing the minimum offset of the OCS mast. The width of the mast is critical in determining the offset of the mast from the centre of the track. The lower the mast offset, the larger the mast. The mast width for the Gemas-Johor Bahru Electrified Double Track Project ranges from 190 mm to 350 mm for all sizes. The concrete mast used in GJBEDTP is the same mast used by the KTMB on all of their railway networks. Because the study's focus location has two (2) tracks that must be catered for, the mast type 102B is an ideal type to use, as shown in Figure 8.

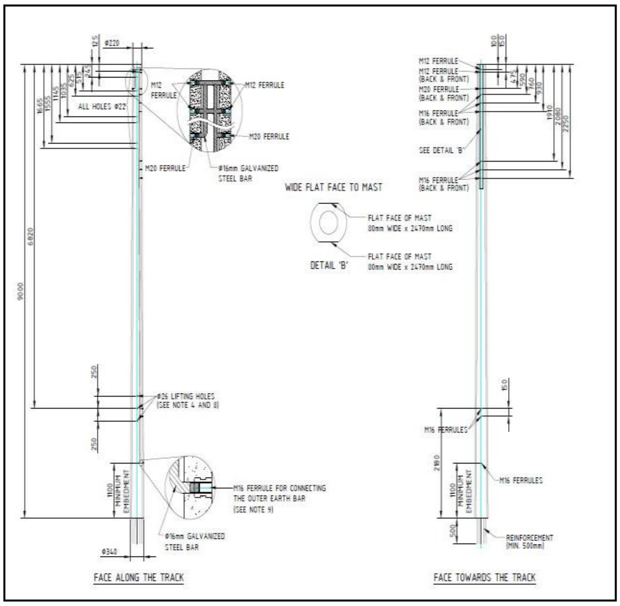


Fig. 8. Mast 102B details

The 102B mast is commonly used for back-to-back cantilever assemblies, which are masts with cantilevers supported on both sides. Mast 102B has a top diameter of 220 mm and a bottom diameter of 347 mm. The mast's length is 9000 mm, and the maximum bending moment is 75 kN. As a result, the 102B can bear 9.806 kN and has two (2) wide flat faces to the mast. The offset is also affected by track separation. According to the KTMB Permanent Way Handbook, the standard track separation is 4.20 m. As a result, if the structure is positioned in the middle of the separation, a lower mast offset will be adopted when the track separation between two tracks is lower [10,11]. JB Sentral is experiencing mast offset issues at the station platform. The track spacing between platforms 2 and 3 and 4 and 5 is less than 4.20 m, at 3.927 m and 3.987 m, respectively. Because the alignment at JB Sentral is tangent, all of the analysed locations at 757.105 D, 757.160 D, and 757.215 D have the same track separation value as Platforms 4 and 5. Meanwhile, 757.105 U1 and 757.160 U1 have the same track separation value as 757.045 U1 because they are located on Platforms 2 and 3. The cross-sectional diagram from the survey at the JB Sentral at chainages 745.045,757.105,757.160, and 757.215 is shown in the figures below. Figure 9 and Figure 10 illustrate that the track spacing between the two tracks is near to each other and does not meet the KTMB standard of 4.20m. These figures were obtained from the JB Sentral as-built architecture drawing in AutoCAD and softcopy format. The data were used to create a cross-sectional diagram to validate the OCS minimum offset at the location.

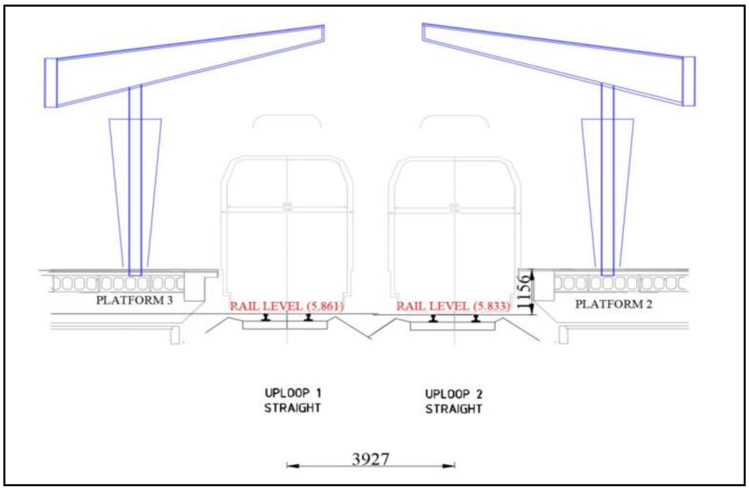


Fig. 9. Cross-Sectional Diagram of Platform 2 & 3 at JB Sentral at CH: 757.045, 757.105, 757.160 and 757.215 facing Singapore

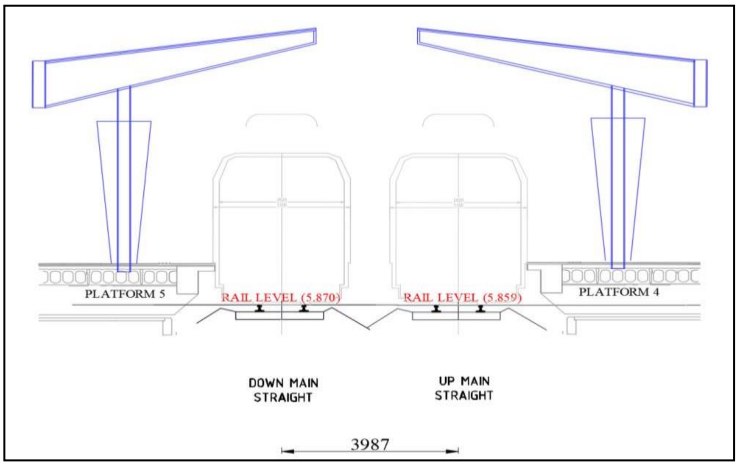


Fig. 10. Cross-Sectional Diagram of Platform 4 & 5 at JB Sentral at CH: 757.045, 757.105, and 757.160 facing Singapore

2.2 Calculation of the Minimum Offset

The plan view for the studied area in JB Sentral is shown in Figure 11. The red marked in the sketched plan view is the location where the studies were done. These locations are 757.045 D, 757.105 D, 757.160 D, 757.215 D, 757.045 U1, 757.105 U1 and 757.160 U1.

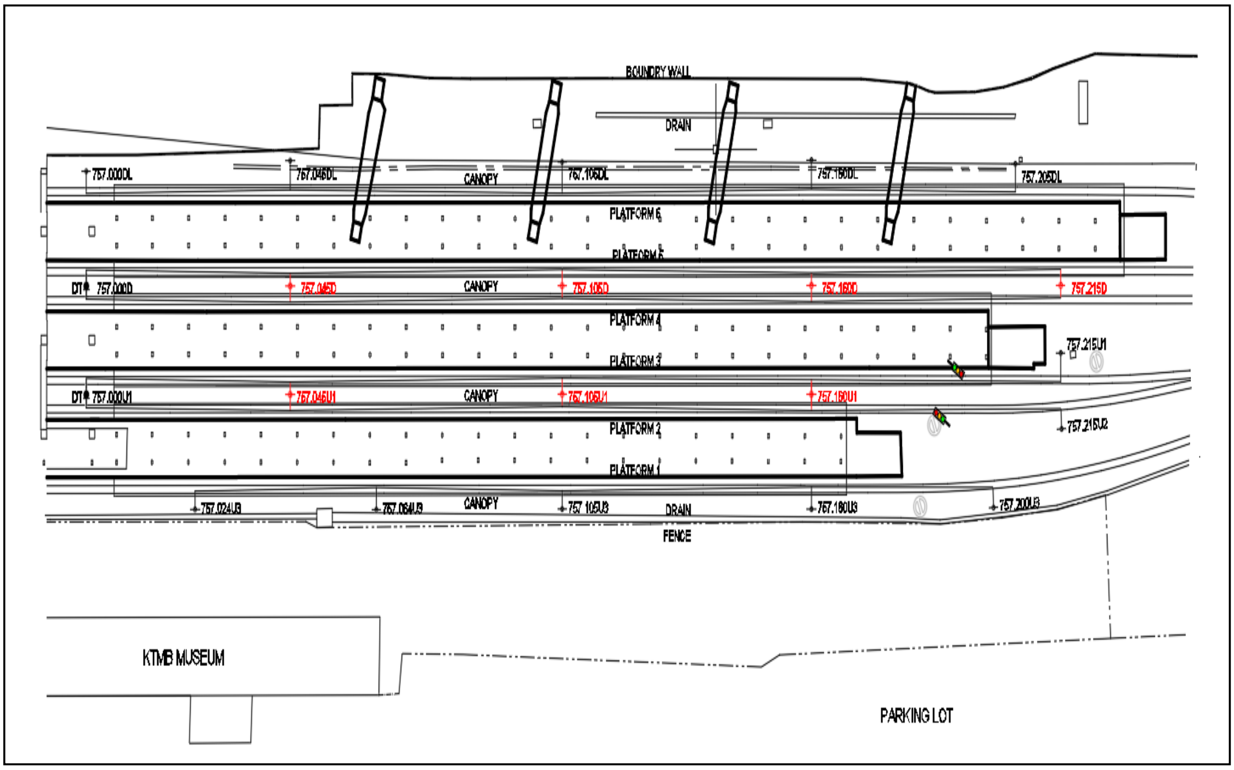


Fig. 11. The plan view for the JB Sentral studied area

Since the alignment in JB Sentral is tangent, thus all the studied locations at 757.105 D, 757.160 D, 757.215 D have the same track separation value for location 757.045 D, which is located at Platform 2 & 3. Meanwhile, 757.105 U1 and 757.160 U1 have the same track separation value as 757.045 U1 because it is located at Platform 4 & 5.

To get the centre of the track separation,

$$X = \frac{TS_x}{2} \tag{1}$$

where X is the centre value between two tracks at Mainline/Loopline

Since the Mainline track has two (2) tracks, Down Main and Up Main, the mast width at the bottom is Ø345 mm, and it is divided by 2 to get the value for half side of the mast.

Then, to get the minimum offset value:

$$\text{Min Offset} = X - 172.5 \text{ mm} \tag{2}$$

Since the track separation for Mainline track separation (TS1) is 3987 mm, then by using Eq. (1) and Eq. (2):

X =3987/2; X = 1993.5 mm

Min Offset; 1993.5 mm – 172.5 mm = 1821 mm
As for the Loop Line track separation (TS2) is 3927 mm, then by using Eq. (1) and Eq. (2):

X =3927/2; X = 1963.5 mm
Min Offset; 1963.5 mm – 172.5 mm = 1791 mm

The minimum offset for both Mainline and Upline will later be used as an input to the Sicat Master software and during the validation using AutoCAD.

3. Result and Analysis

The Research employing this way of gathering information reveals that the mast offset is affected by three (3) factors: kinematic envelope, mast width, and track spacing. The KTMB railway network uses a standard offset of 3.0 m from the centre of the track to the face of the mast. While the KTMB Guideline specifies a minimum offset of 2.60 m, this may be waived in some places where KTMB is the network owner. Unfortunately, the 2.60 m offset may not be possible in some places due to lack of space. This includes the current area in JB Sentral. The maximum bending moment of the concrete mast is 22.866 kN/m at any tangent region with a wind speed of 30 m/s, while the maximum designed moment for a concrete mast at a windspeed of 30 m/s is 40 kN/m, as shown in the static calculation report [24]. This demonstrates that the mast is able to withstand the load applied at the location under investigation. A better design is provided by the use of concrete mast 102B with a maximum bending moment of 75 kN at the investigated site. Table 1 shows the summary of applied load that acts on the mast.

Table 1
Summary of Applied Load

Wind Load Cases	**30 m/s**	
Radius	Tangent (∞)	mm
Mast Type	102B	
APPLIED LOAD		
SELF WEIGHT		kN
MW+CW	1.0930	kN
REW	0.5161	kN
ADSS	0.0600	kN
Mast	Default	kN
Cantilever	Default	kN
RADIAL LOAD		
MW	0.1752	kN
CW	0.1752	kN
REW	0	kN
ADSS	0	kN
WIND LOAD ACROSS TRACK		
Mast	0.1080	kNm
MW	0.3125	kN
CW	0.3661	kN
REW	0.6281	kN
ADSS	0.3066	kN
WIND LOAD ALONG TRACK		
Mast	0.1080	kNm

Cantilever	0.0382	kNm
CONSTRUCTION		
Man	0.56	kN
RESULT		
(a) Max Bending Moment	25.396	kNm
(b) Max Designed Moment	75	kNm
if (a) ≤ (b) then OK	OK	

Maximum bending moment of the mast have been studied using STAAD software from Bentley. Figure 12 shows the maximum bending moment of the mast is 25.396 kN/m which is lower than the maximum specified moment that mast 102B can withstand. It may be stated that the strength of the mast is more than enough to be used at the studied area.

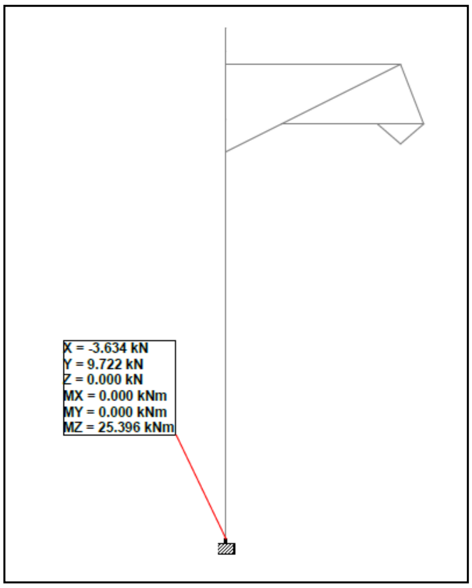
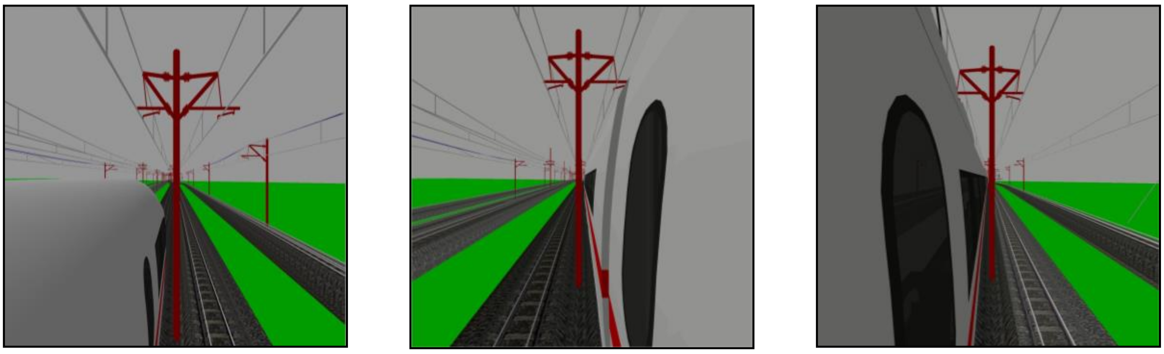


Fig. 12. Maximum Bending Moment for Mast 102B

3.1 Clearance Simulation from Sicat Master

Sicat Master created a 3D view for the designers to check clearances and the compatibility of the parameters they selected. Because the programme lacks the KTMB Class 91,92, and 93 models, the train model Inter City Express 3 (ICE 3) was used as a model. The train was travelling at 30km/h [17-18] in this simulation, which is the maximum allowed speed in the station area. The clearances between the train body and the mast locations are shown in Figure 13.



(a) (b) (c)

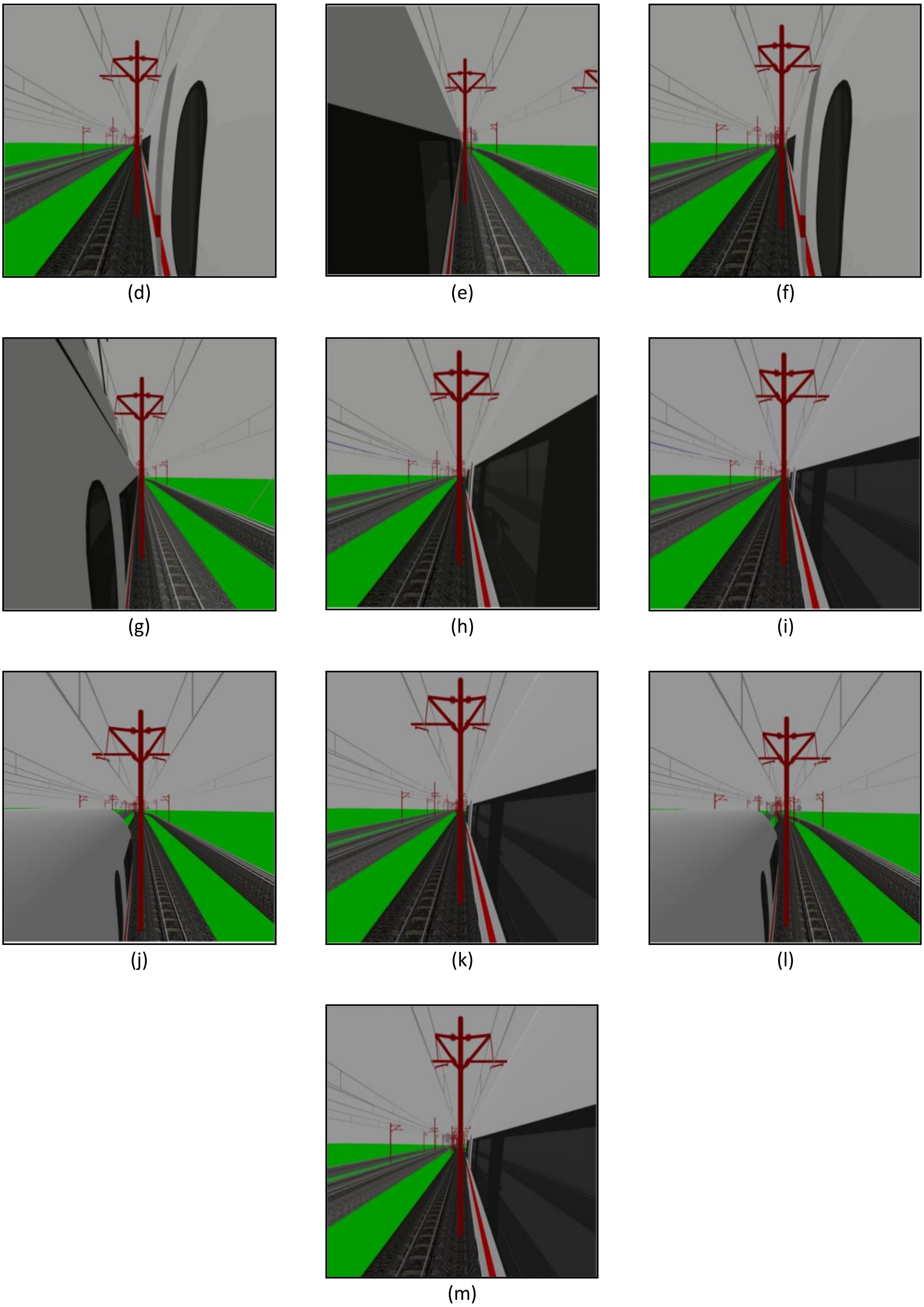


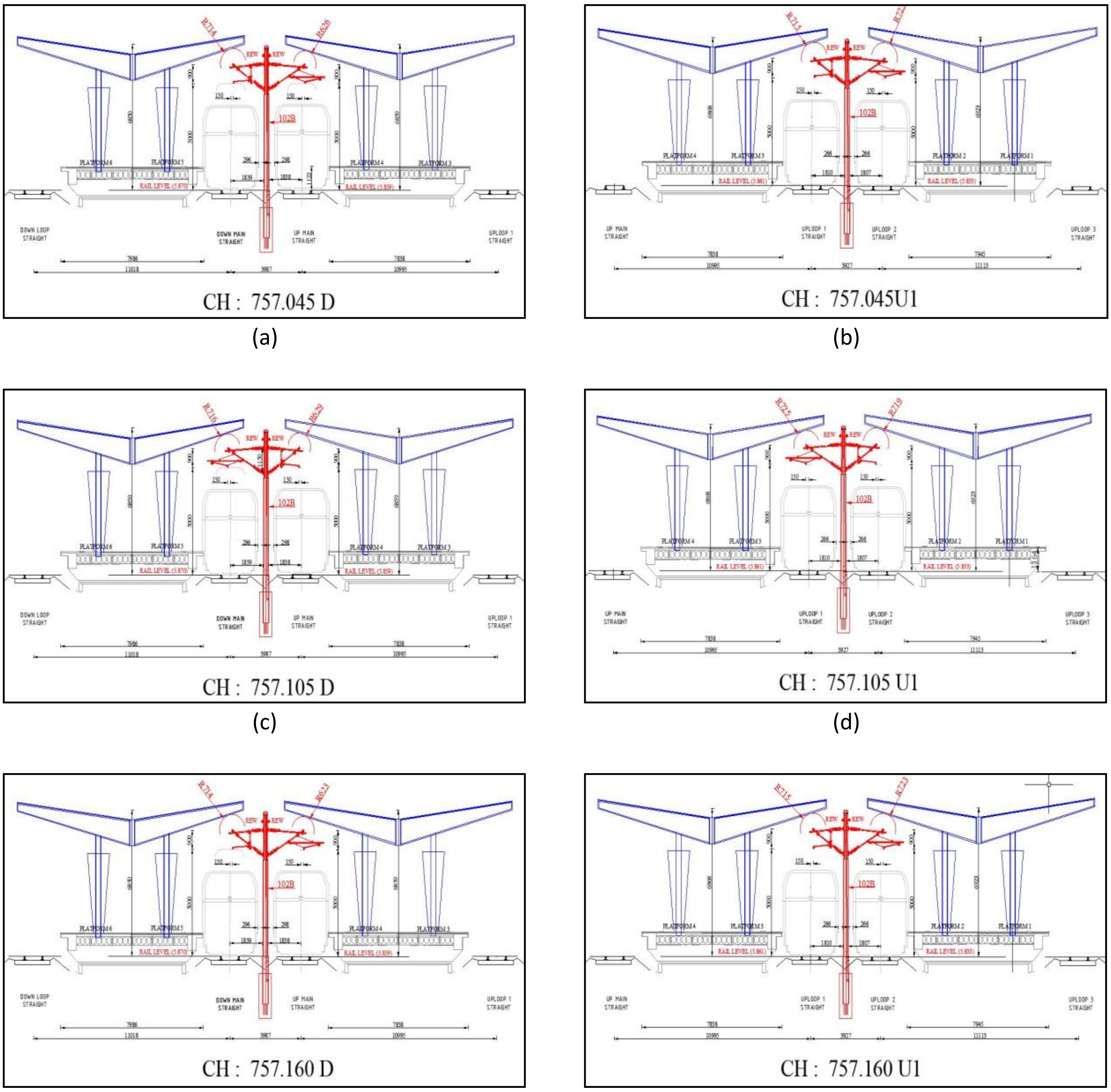
Fig. 13. Clearances between train body and mast at chainage a. 757.045 D (Down Main), b. 757.045 D (Up Main), c. 757.105 D (Down Main), d. 757.105 D (Up Main), e. 757.160 D (Down Main), f. 757.160 D (Up Main), g. 757.215 D (Down Main), h. 757.215 D (Up Main), i. 757.045 U1 (Up Loop 2), j. 757.105 U1 (Up Loop 1), k. 757.105 U1 (Up Loop 2), l. 757.160 U1 (Up Loop 1) & m. 757.160 U1 (Up Loop 2)

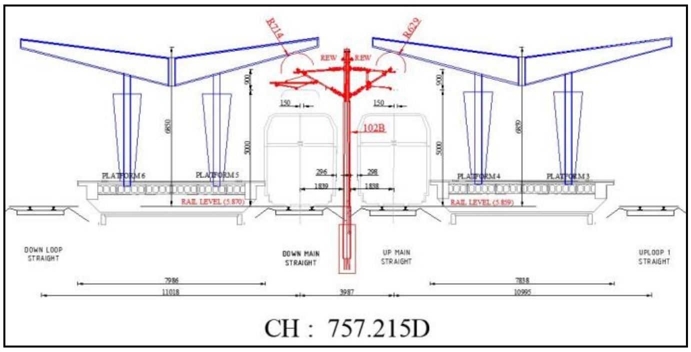
ICE 3 trains are used because their 2950 mm width is an improvement over the 2750 mm width of KTMB Class 91, 92, and 93 trains. The standard gauge track that the ICE 3 utilises is 1435 mm. The ICE 3 train used in the simulation has a larger clearance between the train's gauge and the mast. The simulations show that at the maximum allowed speed in the station area, the train body will not collide with the mast at these locations.

3.2 Validation of OCS Design Offset using AutoCAD

With the designated offset of 1839 mm for Down Main, 1838mm for Up Main, 1810 mm for Up Loop 1 line, and 1807 mm for Up Loop 2 line, the simulation [19,20] using Sicat Master demonstrates that there is sufficient clearance for the train to operate in the station area, as shown in Figure 13.

This is less than the minimum standard offset as stated in the KTMB Permanent Way Manual. The station's cross-section diagram and canopy are displayed in AutoCAD as part of the validation process. The cross-sectional diagram for the locations under study is depicted in Figure 14.





(g)

Fig. 14. Cross-Sectional Diagram for Location a. 757.045 D, b. 757.045 U1, c. 757.105 D, d. 757.105 U1, e. 757.160 D, f. 757.160 U1 & g. 757.215 D

The offset of 1839 mm at Down Main and 1838 mm at Up Main is adequate for a train to operate with extra clearance of 296 mm at Down Main and 298 mm at Up Main at stations 757.045 D, 757.105 D, 757.160 D, and 757.215 D, respectively. There are sufficient extra clearances of 266 mm for the train to run in the station area at points 757.045U1, 757.105U1, and 757.160U1 where the offset is 1810 mm on Up Loop 1 and 1807 mm on Up Loop 2.

4. Conclusions

The estimated minimum offset indicates the amount of clearance that can be achieved between the train body and the mast. Furthermore, the proposed mast is sturdy enough to withstand the given load. The study proposed a remedy to the problem that arose in JB Sentral. Considering JB Sentral is an existing and operational station, all GJBEDTP upgrades must take into account and be carried out properly. The study began with the collection of related data, followed by the calculation of the minimum offset that can be used, simulation using Sicat Master to test the suitability of the mast offset, and finally validation of the minimum offset calculated using AutoCAD through the development of the cross-sectional diagram. These reports have described the approvals that may be obtained at JB Sentral. According to the analysis, the mast offset for GJBEDTP can be as low as 1800 mm and can be deployed at JB Sentral. The usage of the minimum offset may help the client acquire a less expensive solution as well as a simple design. This design, on the other hand, can help to protect the station's architecture because no changes will be made to the station buildings, which is especially significant when the station is a heritage station. If the same conditions and restrictions exist as in JB Sentral, the current design can be modified and improved. Furthermore, using the drop arm as an element of the Overhead Catenary System will bring various benefits in terms of clearances and restricted area.

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