Settlement of bridge approaches on soft soil area in Batu Pahat, Johor

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Abstract. Soft soil is well known to have low bearing capacity, high water content, high differential settlement, long term settlement and not able to sustain external loads without having large deformation. A study was conducted to measure the settlement at two bridge approaches on soft soil area in Batu Pahat, Johor. The settlements not only cause discomfort to road users but may be dangerous to road users as drivers tend to reduce speed drastically while approaching the bridges. This paper specifies and presents the settlement values of bridge approaches as well as identifies the critical areas. The result of this study indicates that the settlement value is higher in the area approaching the bridge and more critical than the settlement in the area leaving the bridge. In addition to these results, a description of the measurement technique, field data collection and procedures are presented.

1. Introduction
Due to the increasing need for regional development, it’s a challenge to find safe ways to construct the infrastructure of transportation on soft soils [1,2]. Soft soil is well known in term of geotechnical properties to have low bearing capacity, high water content, high differential settlement, long term settlement and not able to sustain external loads without having large deformation [3].

The settlements not only cause discomfort to road users but may be dangerous to road users as drivers tend to reduce speed drastically while approaching the bridges. The problem between bridge and road connections results in a different settlement or can be described as a bumpy condition. This makes road users feel uncomfortable, can be dangerous and cause traffic congestion because users suddenly had to reduce vehicle speed while crossing the bridge [4]. Also, when this problem persists, it can cause a defect within bridge structure and bridge approach. [5] had mentioned the cause contributed to this issue are the settlement of the natural soil under the embankment, the compression of the embankment backfill and the stiffness of the concrete approach slab.

[6] had categorized that the cause to these phenomena which are differential settlement, movement of the abutment and design or construction problem. Differential settlement consists of compression of natural soils, compression of embankment soils and local compression at bridge or pavement interface. Movement of the abutment involve vertical, horizontal and both vertical and horizontal directions.

In situ subgrades on a bridge approach often do not provide the support needed to achieve acceptable traffic loading and environmental demand performance. Options for dealing with soft soil of subgrade on a bridge approach include attempting to dry and compact the subgrade, reinforcing the subgrade with...
a geo-synthetic material and applying a chemical stabilizer. Practical method of repairing the problem of the settlement area is resurfacing the pavement to ensure a smooth riding surface. However, the same problem will happen again after a few months and need to be repaired again. According to [7], inspection reported from Wyoming Department of Transportation indicates bridge approach slab settlements occurred not only on existing bridges but also on newly built bridges that were recently opened to public. Several studies investigating differential settlement at bridge approach carried out show that bump is the primary indication at the end of a bridge. It is a persistent problem for highway agencies and may lead to many negative effects on the function of roads, impacts on bridge and road structures, increase in maintenance cost and time correction [7,8,9,10,11].

According to [5], generally the settlement of the natural soil under the embankment, the compression of the embankment fill, and the stiffness of the concrete approach slabs contributes to the development of such a bump problem. [12] summarised that consolidation settlements of foundation soil, poor compaction of backfill material, incorrect material specification, poor drainage, soil erosion, seasonal temperature variations and types of bridge abutments are identified the major factors contributed to the bump circumstance at bridge approaches. [13] summarised in his studies a review of other investigations that addressed this differential settlement issue. Previous authors had claimed that the main contributing factors to approach slab settlement problems are subsurface void development caused by water infiltration through unsealed expansion joints, bridge approach and abutment, collapse and erosion of the granular backfill, and poor construction practices [14,15]. There are various mitigation techniques to overcome bridge approach settlement problems such as improvement of foundation soil, improvement of backfill material, design of bridge approach, more effective drainage and erosion control methods [16]. The values of settlement of bridge approaches at two locations in the district of Batu Pahat, Johor were measured and analysed.

2. Methodology
The study was conducted to identify the area of bridge approach that experienced critical settlement either towards the bridge or outward from the bridge. The selected bridge approaches for visual inspection and settlement are as shown in figure 1 and figure 2.
In order to investigate the settlement, the equipment that had been used were 50 m and 5 m measuring tape, a whiteboard marker, a steel ruler, a digital automatic level, a levelled tripod and a barcode staff. The selected locations and points of settlement as shown schematically in figure 3. There are 24 points that had been identified on the bridge approaches; 12 points in the longitudinal direction at Bridge Approach A (A, B, C and D) and also 12 points at Bridge Approach B (H, I, J and K). Each point measured at distance of 600 mm, 1200 mm and 1800 mm from the bridge approach connection. In transverse direction, 24 selected points of measurement which is contain 12 points at Bridge Approach A (AE, AF, AG, BE, BF, BG, CE, CF, CG, DE, DF and DG) and also 12 points at Bridge Approach B (HL, HM, HN, IL, IM, IN, JL, JM, JN, KL, KM and KN). In figure 4, a researcher illustrated the measuring technique to get a value of the settlement at the point selected. Initially, every point which marked with a marker pen, and then digital automatic level tools was used to get a level value at each point that has been indicated.

**Figure 2.** Bridge Km 6.2, Jalan Parit Karjo, Batu Pahat. (GPS Coordinate 1.793250, 103.063922).

**Figure 3.** Points measuring settlement at bridge approaches.
3. Data Analysis And Discussion

Table 1 shows the results of the settlement measured at all selected locations. These settlement values show a decrease from the location of 600 mm, 1200 mm and 1800 mm distance from the bridge.

| Location          | Distance (mm) | A  | B  | C  | D  | H  | I  | J  | K  |
|-------------------|---------------|----|----|----|----|----|----|----|----|
| Bridge Km         | 600           | 39 | 38 | 32 | 34 | 32 | 30 | 36 | 38 |
| 0.4 Jalan Parit   | 1200          | 37 | 36 | 29 | 30 | 28 | 25 | 34 | 36 |
| Karjo             | 1800          | 35 | 35 | 26 | 26 | 26 | 27 | 30 | 33 |
| Bridge Km         | 600           | 36 | 34 | 31 | 32 | 35 | 35 | 34 | 37 |
| 6.2 Jalan Parit   | 1200          | 33 | 35 | 29 | 26 | 31 | 33 | 33 | 36 |
| Karjo             | 1800          | 31 | 32 | 26 | 28 | 30 | 31 | 33 | 32 |

Based on the obtained data, analysis were carried out using the minimum settlement value from the entire data at both locations as a benchmark to form a pattern of settlement area in the bridge approach. The minimum settlement value is 25 mm located at bridge Km 0.4 Jalan Parit Karjo. From observations on vehicles passing through this bridge, most vehicles especially heavy vehicles have slowed down before passing through the bridge. Most of the vehicles continued to increase the speed after passing through the bridge. Table 2 and table 3 show the settlement values taking into account 25 mm settlement as the datum.

Table 2. Data settlement at bridge km 0.4 Jalan Parit Karjo.

| Distance (mm) | To Bridge | After Bridge |
|---------------|-----------|--------------|
|               | ΔAd       | ΔBd          |
| 600           | 14        | 13           |
| 1200          | 12        | 11           |
| 1800          | 10        | 10           |

From the data in table 2, the diagram shown in figure 5 shows the bridge approach details with a high settlement value and a minimum value of 25 mm with a reference value of 0 mm. There are subsequently 3 settlement value classifications of < 5 mm (blue), ≥5 mm (green) and ≥10 mm (orange). When it comes to periodic plotting, it is easier to locate critical areas. At bridge approach A (toward the bridge) there are 6 points available, 100% readable at ≥10 mm, while at bridge approach B (outwards of the bridge) there is no point indicating reading at ≥10 mm and only 2 points have a value of 5 mm at point HL (7 mm) and IL (5 mm), while the rest is 66.67% with a value of < 5 mm. Through this analysis,
bridge approach A (toward the bridge) at km 0.4 shows a higher settlement value than bridge approach B (outwards of the bridge).

![Figure 5](image-url)

**Figure 5.** Settlement value (m) with 25 mm value as datum at bridge km 0.4 Jalan Parit Karjo.

In the opposite direction, at bridge approach B (towards the bridge), 50% indicates the value of ≥ 10 mm and 50% indicates the value of ≥ 5 mm while at bridge approach A (outwards of the bridge) there is no value of ≥ 10 mm and only the value of 5 mm (50%) and < 5 mm (50%) respectively. The critical area with a settlement value of 10 mm at bridge approach B (towards the bridge) is JL, KL and KM from this analysis.

| Distance (mm) | Settlement value (mm) with 25 mm value as datum |
|--------------|-----------------------------------------------|
|              | To Bridge | After Bridge | To Bridge | After Bridge |
|              | ΔAd | ΔBd | ΔHd | ΔId | ΔJd | ΔKd | ΔCd | ΔDd |
| 600          | 11  | 9   | 10  | 9   | 10  | 12  | 6   | 7   |
| 1200         | 8   | 10  | 6   | 8   | 11  | 9   | 4   | 1   |
| 1800         | 6   | 7   | 5   | 6   | 8   | 7   | 1   | 3   |

![Figure 6](image-url)

**Figure 6.** Settlement value (mm) with 25 mm value as datum at bridge km 6.2 Jalan Parit Karjo.

From figure 6, the settlement value appears uniformly in both bridge approaches, but when examined, 33.3% of the settlement value with a value of 10 mm at bridge approach A (towards the bridge) at point AE (11 mm) and BF (10 mm) compared to bridge approach B (outwards of the bridge) of 16.7% at point HL (10 mm). From this assessment, bridge approach A (towards the bridge) at bridge Km 6.2 has a more
critical settlement value than bridge approach B (outwards of bridge). In addition, it is found at this location that bridge approach B (towards the bridge) with a location of 50% has a value of 10 mm as opposed to 33.3% in bridge approach A (towards the bridge). The highest settlement value is at KL (12 mm) and the lowest value (1 mm) is at two points (CG and DF) where both points are at bridge approach A (outwards of the bridge).

4. Conclusion
From the analysis carried out through the measurement of the settlement value of the location, the bridge approach area that direction inward to bridge shows a high settlement pattern as it is direction outward from bridge. By comparison of the two bridge approaches that have been conducted with respect to the value of this settlement, it was found that the bridge Km 0.4 has a higher settlement value compared to the bridge Km 6.2. It shows therefore that bridge approaches in rural areas will also face the failure if many heavy vehicles use the road. In order to provide comfort to road users through the bridge, whether in urban or rural areas, complete attention must be paid to the problem in this study. Further work needs to be done to investigate the failure of the bridge approach. The advantages of this study are to provide and improve knowledge of the important approaches of the bridge.

5. References
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