Pavement Quality Concrete as Engineering and Design Alternative for Municipal Bus-Bays

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Abstract. The article presents the application of cement composite to the construction of pavement within the area of bus-bays. The influence of bus traffic on the pavement condition was discussed and most frequently occurred types of damage in case of this type of pavement were described. The suggested solution was provided on the example of bus-bays performed, according to cement concrete method located within the area of Świętokrzyskie province.

1. Introduction

Arrangement of the traffic zone within city centre should include the areas of zones with traffic ban for passenger vehicle and traffic difficulties concerning the opportunity to arrive at the selected destination. Moreover, the extension of necessary travel time influences the intensification of using municipal public means of transport. Higher ecological awareness of the society and the opportunity to reduce vehicle exhausts to the atmosphere make the city dwellers, who consider the environment protection, use public transport more willingly.

Provision of well-prepared and efficient infrastructure intended for public transport services allows quick and safe commuting. The main objective of proper municipal transport policy is the provision of well-prepared construction which provides long and failure-free service life. Means of public transport, e.g. buses, moving within the city area should be provided with places where the safe passenger transfer is available. Bus-bays serve this purpose. Location requirements and geometric parameters are included in [1] and alternatively in sec. 11.6 [11] and sec. 5.11 [12].

Within the area of Kielce, there are altogether 67 bus lines which serve the city centre bus routes and provide transport services to passengers from neighbouring areas to the city centre. Transfer of passengers takes place at 515 bus stops [9] which are diversified with regard to technical parameters (among others materials applied in structural layers) and geometric (among others the length of platform). Depending on the traffic volume of passengers who use public transport within the area of Kielce, three types of bus-stops were applied.

The most numerous group are bus-bays located within carriageway section (Figure 1). There are also bus-stops near the right edge of the traffic lane (Figure 2) and some examples of bus-bays separated from the carriageway with vegetated buffer strip (Figure 3).
Other types of bus-stops can be recognized, among others the bus island (called also anti-bus-bay), and bus-stop platform with two symmetrical platforms, which has been presented in Figure 4. The selection of the type of bus-bay has significant influence on the traffic safety and traffic flow, average speed of passage and the duration of journey.

![Figure 1. Example of bus-bay located within the area of Kielce, Klonowa Street](image1)

![Figure 2. Example of bus-stops near the right edge of the traffic lane within the area of Kielce, Sandomierska Street](image2)

![Figure 3. Example of bus-bays separated from the carriageway with vegetated buffer strip within the area of Kielce, Jesionowa Street](image3)

The contents of this article are bus-bays, which are the places, where buses (vehicles adapted to provide the transport of more than 9 people, together with the driver) may stop in order to provide safe passenger transfer. Regulation of the Minister of Transport and Marine Economy [1] specifies the location and basic geometric parameters, which these type of structures should comply with. Minimum length of edge, according to [1] should be 20m, and bus-bay width should be 3m (3,5m if a bus-bay is separated from the carriageway by median strip), while the platform width should be at least 1,5m. Due to the nature of the occurred load (Figure 5) bus-bays are particularly exposed to pavement damages.

![Figure 4. Bus-stop: a) bus-island (anti-bus-bay) [3], b) bus-stop platform with symmetrical platforms](image4)

The accepted solution each time should provide suitable load-bearing capacity in bus-bay and will be the consequence of the occurred load application. Within the area of Kielce, the traffic volume, in case of bus-bays made of cement concrete, is diversified. Monthly analysis is from 2500 to 12500. Analysing the annual traffic volume the differences are between 30000 and 150000. Service life of the structure is identified with load carrying capacity in complex circumstances and during service life. Disruptive nature is associated with the combined influence of the transferred static and dynamic load by buses in the course of braking, stopping and moving off. Static load of bus-bays is the weight of buses. Within the area of Kielce, traditional types of buses are in service, the length of which is up to...
15 m and articulated buses of allowable total weight of 18 t and 28 t. These loads are intensified by the changes of weather conditions, i.e. humidity and temperature, which may contribute to the occurrence of places of weakened surface, which may cause damage in the future. Within the area of świętokrzyskie province, there are diversified weather conditions, which is mainly related to the location of the region within Świętokrzyskie Mountains. Average annual air temperature is approx. 7°C (maximum temperature is 36,2°C, and the minimum -33,9°C). The total annual precipitation within świętokrzyskie province is approx. 600 mm. Significant temperature variations, occurred water, and snow cover and chemicals used during wintertime adversely affect the pavement condition within the area of bus-bays. Temperature at which the pavement is in service, is also the significant factor. This factor is of considerable importance in case of pavements made of asphalt-aggregate mixture, with thermoplastic properties. These properties change under the influence of temperature. In the event of the combined influence of significant static load and maximum temperatures during summertime, permanent deformations may occur on these pavements. During wintertime, the aforementioned factors may cause cracks. The material which is less susceptible to temperature variations, both on a daily and annual basis, is cement concrete. This type of composite material is the alternative to perform pavement surfacing in bus-bays, which will be deformation-resistant within the full temperature range. It should be emphasized that bus-bays pavements performed using cement concrete are of high load-bearing capacity and long service life. Pavement regularity and roughness should be distinguished as well. Fair color of this type of pavement surfacing influences the increased traffic safety, due to improved visibility conditions, and at the same time enables to identify the bus-bay area easily in comparison to the adjacent traffic lanes intended for vehicles other than buses. The authors of the article [4] recommend that in case of traffic volume exceeding 15A/h, within the area of bus-bays cement concrete should be applied. The attention should be paid to the necessity of very careful performance of expansion joints. Expansion joints in concrete bus-bays have to provide proper and safe structure operation. Their basic purpose is providing individual slabs with the change of linear dimensions being consequence of phenomena occurred during hydration. Expansion joints provide such reduction or extension of a slab under the influence of variable temperature during service life of a structure. [2] The only properly performed pourable sealant, filled and systematically exchanged ensures that the joint may perform its role. Therefore, it is extremely significant that the condition of this construction element is constantly monitored and maintained at high level starting from the structure performance until the end of the assumed operation period. Usually, the failure to replace the material which fills the joints results in the occurrence of damages, initially near slab edges and then spreading to the remaining part of slabs and deep inside the structure.

Suggestion of the method concerning the analysis of bus-bays pavement condition can be found among others in [4, 5], and the general guidelines regarding the visual analysis of pavement condition made of cement concrete in [13, 15]. Each time, the division includes the group of surface and structural damages. Within these groups, there are many types of damages, among which, in accordance with [2] longitudinal, diagonal or crosswise slab cracks can be distinguished, cracks at the edge, reinforcement damage, defective expansion joints seal, surface damages and so called “slab faulting”, which is lowering or elevation of vertical alignment of one slab in regard to the remaining slabs.

2. Scientific research

Analyses included bus-bays made of cement concrete, located within the area of Kielce. Four groups of concrete bus-bays were selected, out of 82 bus-bays which were intended for visual assessment according to [14]. Additionally, the supplementary procedure described in [5] was described. The preliminary stage was the classification of the analysed bus-bays made of concrete, according to groups. As the basic classification criterion geometrical parameters of bus-bays were assumed. Within the area of Kielce, there are 4 types of cross-sections, presented schematically in Figure 6.
Arrangement was defined and the most frequently occurring damages within the analysed bus-bays were determined, with reference to the reasons for their occurrence. The area of analyses in this case included the entire bus-bays surface within cross-section and longitudinal section. The analysis included the classification of the occurring damages, according to [14].

Cracks of minor harmfulness occurring on the surface within the current period of time, do not require any repair procedures. It is recommended to apply surface treatment in the form of soaking components. However, it should be emphasised that constant monitoring of the condition of these cracks is necessary.

According to the visual assessment of pavement condition, the influence of operation on the change of the occurred damage quantity was proved. In case of tests conducted on the first bus-bay, in total, 4 damages were classified, out of which the prevailing majority were defective sealing expansion gaps - Figure 7a. On the second bus-bay identified 10 damages were classified - crosswise cracks - Figure 7b. In case of tests conducted on the third bus-bay, in total, 2 damages were classified - defective sealing expansion gaps - Figure 7c. In case of tests conducted on the fourth bus-bay, in total, 9 damages were classified, out of which the prevailing majority were defective sealing expansion gaps - Figure 7d.

For each cross-section, three representative bus-bays were selected, on the basis of which the visual assessment of pavement condition was conducted. As the classification criterion, at this stage, the bus-bay operating time (t_{eb}) and the maximum average bus traffic load were assumed (S_{m}) annually A/year. Such criteria provided information regarding the most intensively used bus-bays (table1). Therefore, they could be the basis for drawing conclusions concerning the condition and possible durability of this type of structures.
Table 1. Average traffic load in case of selected concrete bus-bays, together with damages disclosed in the course of visual pavement assessment

Table 1 includes the division of the occurred damages in case of the analyzed bus-bays, according to division criterion in compliance with [14] and with the division of damages containing their size. The following designations were assumed: Spd, Su, Spp, Wk, Bw, Gb, Un, Wks, Ss, Pzł, W, Ł, K, which refer to longitudinal, diagonal or crosswise cracks, no sealing, the depth of sealing gap, corner damages, joint spall, interconnected cracks, flaking surface, bumps, patches and faulting.

Reliable rut depth was determined, according to [6] in case of each bus-bays on the right tire track. According to the research, the rut was defined as permanent deformation of cross-section of pavement which occurred along the road within the area of wheels’ impact. For research purposes, the method of 2-metre-patch and wedge was used. According to the determined reliable pavement rut depth it was proved that the entire research section, independent of the cross-sections, proves good condition - Figure 8.

Figure 8. Average reliable rut depth for the bus-bays

During field studies, the roughness factor was determined in case of each bus-bays in left tyre track in six measuring points, according to [7]. In case of individual measuring points, the average of 5
measurements was assumed as the value. Tests were conducted by means of Portable Skid Resistance Tester in accordance with test procedure, subject to [16].

![Figure 9. Average value of reliable friction coefficient for the bus-bays](image)

The assumed technical and operation parameters in case of concrete bus-bays are similar to [13] and each time include the assessment of cracks condition ($N_j$), occurrence of ruts ($K_j$), the assessment of pavement condition ($Sp_j$) and defining anti-skid properties ($S_j$). The assessment of the selected bus-bays was determined on the basis of the global factor according to [15], in compliance with (1).

$$G = 100 - [W_N \cdot N_j + W_K \cdot K_j + W_{Sp} \cdot Sp_j + W_S \cdot S_j]$$

(1)

In formula (1) the following symbols $W_N$, $W_K$, $W_{Sp}$, $W_S$ indicate the weight of the assumed parameters, the sum amounts to 1. While $N_j$, $K_j$, $Sp_j$, $S_j$ indicate crack rate, ruts, pavement condition factor, anti-skid properties – determined in accordance with [6, 7, 14, 15]. Due to the weight value variations, which can be dependent on the assumed strategy of road maintenance, the following assumptions were made for the article purposes:

a) priority of improvement of pavement structural condition (which assumed that $N_j + Sp_j$ are 70%)

b) priority of improvement of traffic safety condition (which assumed that $N_j + K_j + S_j$ are 70%).

**Table 2.** Assessment of the analysed bus-bays for selected cross-sections, assuming the priority of improvement of pavement structural condition (a) and the improvement of traffic safety condition (b)

| Type of cross-section | $W_N$ priority | $N_j$ | $W_K$ priority | $K_j$ | $W_{Sp}$ priority | $Sp_j$ | $W_S$ priority | $S_j$ | $G$ |
|-----------------------|----------------|------|----------------|------|------------------|-------|----------------|------|-----|
| I                     | 0.4            | 0.2  | 0.84           | 0.3  | 0.2              | 1.2   | 0.2            | 0.98 | 0.1 | 99.1 |
| II                    | 0.4            | 0.2  | 0.52           | 0.3  | 0.2              | 0.9   | 0.2            | 1.00 | 0.1 | 99.3 |
| III                   | 0.4            | 0.2  | 0.96           | 0.3  | 0.2              | 1.6   | 0.2            | 1.00 | 0.1 | 98.9 |
| IV                    | 0.4            | 0.2  | 0.94           | 0.3  | 0.2              | 2.1   | 0.2            | 1.00 | 0.1 | 98.8 |

Calculated global pavement condition factor in case of the analyzed types of bus-bays reached high values, which proves good pavement condition. The conducted analyses proved that there is no predominant parameter. None of technical and operational parameters was qualified to C or D class, which proves the warning or critical technical condition of the pavement.

### 3. Conclusions

With reference to the conducted visual assessment of pavement condition in case of bus-bays within the area of Kielce and the awareness of weather conditions in this region, the following conclusions can be drawn:
The analysed bus-bays pavements made of cement concrete are resistant to the occurrence of permanent deformations in the form of ruts, regardless of operating lifetime and weather conditions occurred within the analysed area and the applied load;

Bus-bay pavements have high performance parameters, which refers to comfortable quality and first of all, life-time safety (reliable coefficient of friction and reliable rut depth);

The presented quantity analysis failed to prove the significant damages and the global assessment of bus-bays pavement condition made of cement concrete proves good condition of these structures;

Advantages of concrete bus-bays meet the users’ expectations, however due to the nature of expansion joints during proper structure operation, it is recommended that the local sealing gaps are cleaned and then filled by means of pourable sealant;

Application of cement composite to the construction of bus-bays, in the course of operation time, will allow for the extension of failure-free pavement operation, and at the same time proves to be the promising technology in comparison to those applied so far.

References

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