International Journal of Civil Engineering and Technology (IJCIET)
Volume 15, Issue 6, Nov-Dec 2024, pp. 1-8, Article ID: IJCIET_15_06_001
Available online at https://iaeme.com/Home/issue/IJCIET?Volume=15&Issue=6
ISSN Print: 0976-6308 and ISSN Online: 0976-6316
DOI: https://doi.org/10.5281/zenodo.14282888

Impact Factor (2024): 21.69 (Based on Google Scholar citation)

SIMULATION OF TRAFFIC WITH DIFFERENT AXLE CONFIGURATIONS ON THE VIADUCTS OF N'DJAMENA - CHAD : THE CASES OF DEMBÉ AND DIGUEL

Annouar Djidda Mahamat,
Department of Technology / University of N'Djamena, P. O. Box 1117 N'Djamena -Chad

INTRODUCTION

This mission involves conducting a study of peak periods on the Dembé and Diguel viaducts. The focus of the study is based on the traffic flow of public transport and heavy vehicles, which play a significant role in the damage to major structures (viaducts, paved roads, etc.). Viaducts are long-distance bridges used for the passage of railways or roads. It is important to note that these two viaducts are each 168 meters long. The Dembé and Diguel viaducts are constructed with beams, meaning the decks are supported by 10 reinforced concrete piers. Beam viaducts can only exert a vertical reaction on their intermediate supports, and the forces generated within the structure are flexural forces. These structures were built to facilitate traffic flow and contribute to resolving issues of traffic congestion and numerous accidents recorded on these routes. Indeed, the viaducts undergo repeated load effects due to the action of axles.

Cite this Article: Mahamat, A. D. (2024). Simulation of Traffic with Different Axle Configurations on the Viaducts of N'Djamena - Chad: The Cases of Dembé and Diguel. *International Journal of Civil Engineering and Technology (IJCIET)*, *15*(6), 1–8. https://doi.org/10.5281/zenodo.14282888

https://iaeme.com/MasterAdmin/Journal_uploads/IJCIET/VOLUME_15_ISSUE_5/IJCIET_15_05_002.pdf

Characteristics of the Dembé and Diguel Viaducts

The Dembé and Diguel viaducts, like the other three viaducts in the city of N'Djamena, were constructed under the same design and specifications as beam viaducts. On Monday, December 31, 2013, the Ministry of Infrastructure and Transport, in collaboration with the N'Djamena City Hall, opened four of the five viaducts built in the city to traffic, referring to them as "ouvrages d'art" or OA for short. These structures were implemented to improve traffic flow and ensure greater road safety for users. The viaducts consist of elevated sections 168 meters in length, two access ramps each 152 meters long, two lanes each 3.50 meters wide, and a roundabout at the lower level. The opening of these viaducts to traffic was timely, as they helped improve traffic conditions in these urban areas. It was a great relief for all road users who remember the nightmare these intersections used to be, where traffic jams were nearly constant.

Decree N°: 045/MIT/MISP/2013, signed by the Minister of Infrastructure and Transport and the Minister of the Interior and Security, reserves the upper passage of the viaducts exclusively for motorists. Pedestrians, motorcyclists, and cart drivers are not permitted to use the viaducts and must instead use the cycle paths bordering the ground-level roads. Trucks exceeding 3.5 tons are not allowed to drive on these structures. However, the reality on the ground is different. Although intended exclusively for automobiles, these viaducts are primarily composed of prestressed concrete deck followed by asphalt. The deck, also bordered with prestressed concrete, is designed to support a maximum load of 35 tons. The Dembé viaduct, like all the others, shares the same construction material characteristics.

Image 1: The Dembé and Diguel viaducts

Data Collection

The monitoring of traffic on the viaducts is conducted by recording data at peak traffic points.

Counting Methods

Viaducts are structures subjected to complex loads with varying levels of stress. For each of the two counting methods (permanent and temporary), there are different approaches to counting :

- **Manual Counting** : This involves placing an observer at the roadside who records the number of vehicles passing by using a counter or a computer.
- **Automatic Counting** : This involves installing a temporary periodic counter on the road to estimate the average daily traffic. The average traffic estimated this way is usually slightly overestimated (by about 2%) compared to the Annual Average Daily Traffic (AADT) because the counted weeks should not include holidays. Therefore, a reduction coefficient of 0.98 is applied to approximate the annual average.

The case study is based on a data collection method (manual counting) that involves creating a counting sheet on paper.

Paper Counting Sheet

The simplest method implemented involves using a paper sheet that describes the types of vehicles to be counted (heavy vehicles according to their number of axles). For each heavy vehicle recorded, the observer marks a tally in the corresponding box. The counting system used to identify the different types of axles is relatively standard in the context of passage measurements. The selected sites had interurban traffic with a significant proportion of 2-axle trucks and especially heavy vehicles with more than 5 axles. Vehicles with 3 and 4 axles were mainly construction vehicles.

Load Periods of the Viaducts

Traffic represents a series of moving loads, and the internal forces within the viaducts depend on the position of the vehicles. For the simulations in this study, the goal is to use these results to estimate the structure's lifespan and determine the traffic volume. The only traffic that significantly contributes to the deterioration of pavement structures is that of heavy vehicles. Therefore, this traffic needs to be characterized by both the number of heavy vehicles that will pass over the pavement during its design lifespan and their impact on the structure.

- **Data Collection and Peak Traffic Periods**

  Based on daily loads recorded over 30 days, data was summarized using a counting sheet. Vehicles with different axles were recorded at 15-minute intervals for 4 hours each day. After a full day of counting, it was observed that peak hours (6:00 AM - 8:00 AM, 11:30 AM - 1:30 PM, and 3:00 PM - 4:30 PM) were when the viaducts were most heavily loaded. To streamline the counting process, only these peak hours were used to count the various types of trucks with different axles over the 30 days on both viaducts.

- **Load Simulation**

  The simulations involve running $\boldsymbol{x}$ number of $\boldsymbol{N}$ vehicles with different axles across the viaduct and recording the peak loads each time. A static distribution of these maximum values is then established to calculate the load's lifespan. The number of axles to be simulated is derived from the viaduct's expected usage duration, the proportion of traffic under the simulated conditions, and the average traffic allowed. This calculation is done using the following formula:

$$N = n.Psat_{\square}.T._{\square}\,Ppl_{\square\square}$$

N: The number of vehicles (including light vehicles) to be simulated.

n [veh. / year]: The average annual traffic that passes over the studied structure.

$Psat_{\square}$: The proportion of traffic operating under saturated or stationary conditions.

T[year] : The planned usage duration in years.

$Ppl_{\square}$: The proportion of traffic consisting of heavy vehicles.

Dembé Viaduct

The results of the vehicle axle count on the Dembé viaduct (direction 1: from the 15th January Palace towards the Chagoua viaduct) over the course of a month are as follows:

Table 1: Dembé Viaduct Counting Sheet

Viaduct	**Directions**	**Date**	**Tourists**	**2-Axle Trucks**	**4-Axle Trucks**	**5+ Axle Trucks**	**Coaches**
	1	One Month	6482	101	72	27	74
		One Year	77784	1212	846	324	888

Dembé	2	One Month	4558	59	30	24	61
		One Year	54696	708	360	288	732

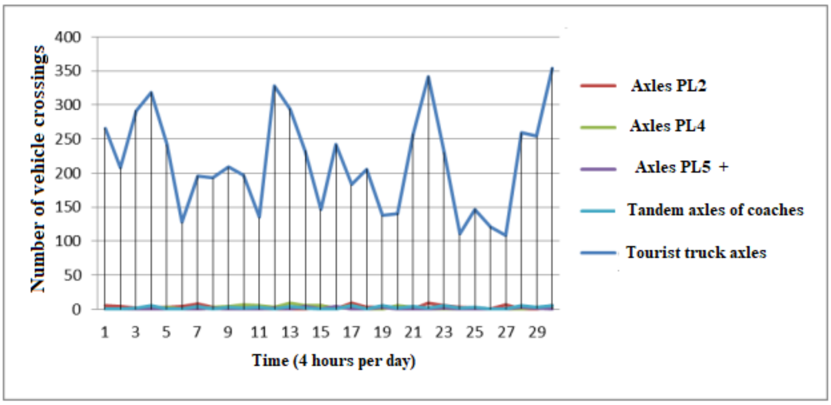

Figure 1: Dembé Viaduct (Direction 1)

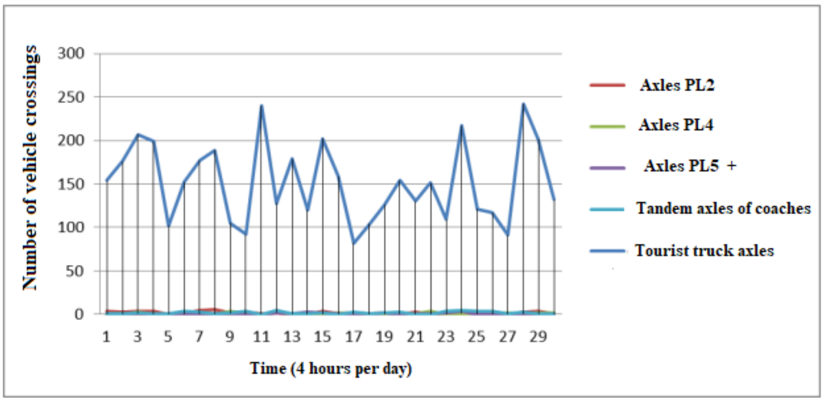

Figure 2 : Dembé Viaduct (Direction 2)

The results show very slight variations between the different traffic lane cases studied. It is therefore reasonable to conclude that the repeated passage of construction vehicles degrades the viaduct in an exponential manner, suggesting that the lifespan provided by the manufacturer may never be reached.

Diguel Viaduct

Table 2: Diguel Viaduct Counting Sheet

Viaduct	**Directions**	**Date**	**Tourists**	**2-Axle Trucks**	**4-Axle Trucks**	**5+ Axle Trucks**	**Coaches**
Diguel	1	One Month	9528	110	116	252	99
		Un An	114336	1320	1392	3024	1188
		One Year	8100	106	105	136	169

	2	Un An	97200	1272	1260	1632	2028

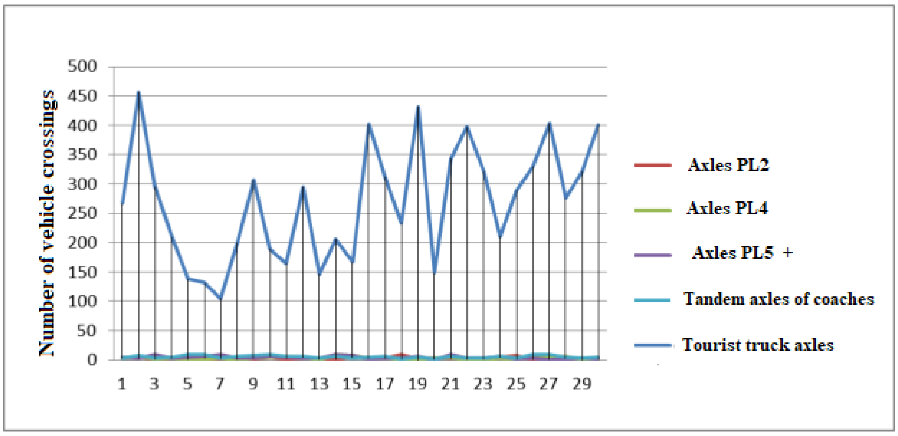

Figure 3 : Diguel Viaduct (Direction 1)

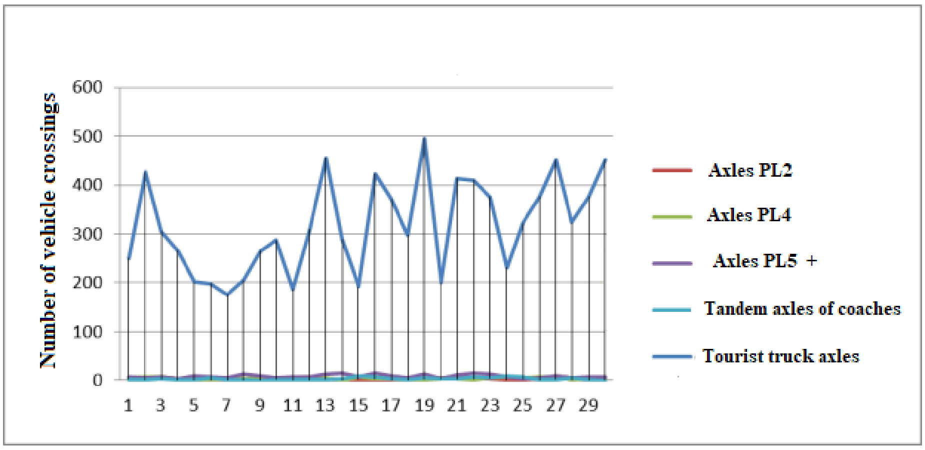

Figure 4 : Diguel Viaduct (Direction 2)

The inspection we conducted midway through our counting on the viaducts confirms our concerns: fresh cracks are present on almost all the wearing layers of the viaducts, measuring a few millimeters. In light of these findings, exceptional measures must be taken; otherwise, the lifespan of the viaducts as projected by the manufacturer may not be achieved. Knowing the total weights or axle weights and dimensions of the heavy goods vehicles allows public authorities and infrastructure managers to regulate traffic, ensure compliance with regulations, and optimize the design and maintenance.

Viaduct Lifespan

The lifespan is expressed by the number of heavy vehicle passages or the number of load repetition cycles. Implementing this principle allows for the calculation of the number of admissible passages. The lifespan is given by the following equation:

$$N_f = 11{,}542 * \varepsilon_t^{-3{,}291} * E^{0{,}854}$$

where ε_t is the deformation of the asphalt and E is the modulus of the asphalt.

Impact on Ascending and Descending Slopes of the Dembé and Diguel Viaducts

The study related to these viaducts has shown significant degradation on the ascending and descending sections of each lane. When a vehicle moves, its weight is transmitted to the ground in the form of pressure through the tires.

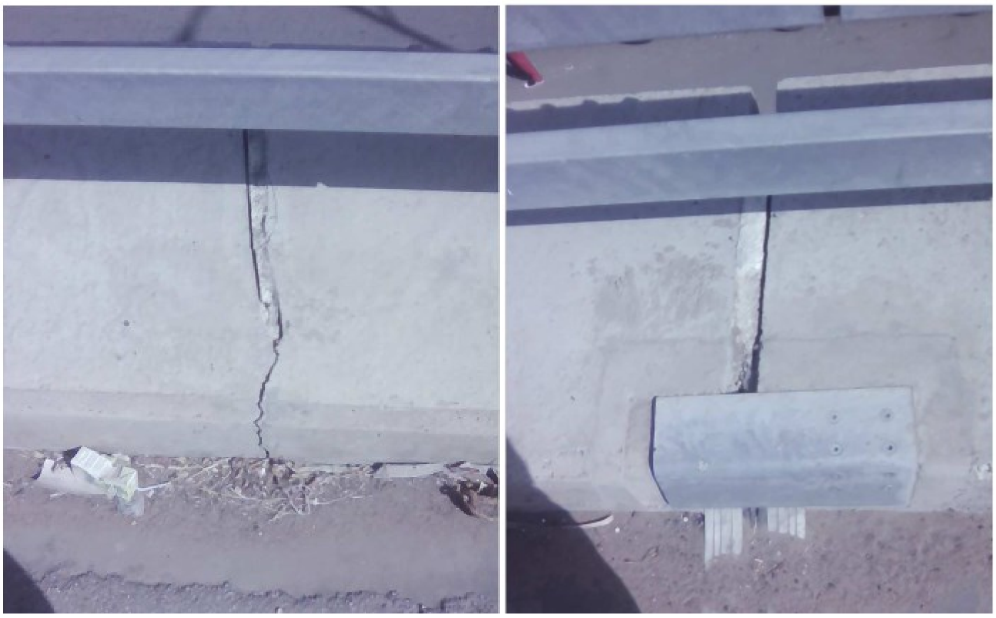

Figure 5: Prestress Cracking

Figure 6: Edge Cracking during Viaduct Elevation.

Phenomenon of Degradation and Cracking Observed on the Dembé and Diguel Viaducts

Under the influence of loads and stresses experienced by these viaducts (vehicle loads, climatic phenomena, etc.), we have observed and recorded some forms of degradation on these two viaducts. The images captured of the Dembé and Diguel viaducts show significant degradation on the ascending and descending sections of both viaducts, as well as damage to the prestressing tendons constituting the borders.

These phenomena can be explained in various ways. The first reason is that N'Djamena is located in the lake region. This means that the soil properties are somewhat difficult to control, as there can be modifications to the soil layers in this area due to climatic changes.

Figure 7: Cracks on Both Viaducts

On the other hand, these phenomena can be explained by the poor quality of the materials used for prestressing and for the asphalt:

- **Quality of the Platform:** One of the causes of these degradations is the poor quality of the platform. The soil that makes up the platform should be as stable as possible, within the limits of water content variation. If the platform undergoes significant swelling and shrinkage, it could lead to substantial degradation.
- **Quality of Implementation:** In many cases, these degradations result from insufficient compaction, separation of crushed aggregates, and failure to adhere to cement dosage.
- **Road Design:** Design errors can lead to the premature deterioration of the road. These include: undersizing, poor drainage, improper ditch design, bathtub pavements, and inadequate drainage.
- **Traffic:** Traffic is also one of the most threatening factors for viaducts and roads. It is the main cause of aggregate erosion in the wearing course, intergranular friction within the pavement body (producing fines), the appearance of longitudinal and transverse cracks in the wearing course, and the formation of ruts at certain points.

Conclusion

In light of all the above and based on the data and experiences gathered in this study, we affirm that the study of these viaducts shows that despite their complex structure designed to withstand various loads, the Dembé and Diguel viaducts are exposed to and undergoing transformations in their structure, as evidenced by significant cracking on the ascending and descending sections of these viaducts. Designed as long structures to address the issue of traffic congestion at city intersections and to reduce accidents along their routes, the viaducts were initially given a lifespan of 50 years by the constructor. However, in practice, we find that these viaducts exhibit significant and surprising cracks, suggesting that they may only be usable for half of their intended lifespan.

These degradations could be classified as premature, given their duration of use and the loads they are subjected to. It is early to observe such cracking since the loads applied to these viaducts are within the defined weight range, except for some types of unauthorized axles that exceed the limit. This has led us to consider the quality of the materials used in the construction of these structures. Designed to support loads of up to 13.5 tonnes with a maximum load of 35 tonnes, we observe that vehicles weighing more than 35 tonnes are using these roads due to a lack of control by the relevant authorities.

Although the causes of the cracking are largely due to the quality of the materials used, we must also highlight the behavior of the soils and the fact that N'Djamena is located in the lake basin, which makes the soil properties too complex to control.

REFERENCE

[1] AASHTO. (2018). AASHTO LRFD Bridge Design Specifications (8th ed.). American Association of State Highway and Transportation Officials. Retrieved from https://www.transportation.org/

[2] Chen, W. F., & Duan, L. (2014). Bridge Engineering Handbook, Second Edition: Construction and Maintenance. CRC Press. DOI: 10.1201/b17066

[3] Huang, Y. H. (2004). Pavement Analysis and Design (2nd ed.). Pearson Prentice Hall.

[4] Li, Z., & Ma, J. (2018). Influence of Axle Loads on Fatigue Damage in Prestressed Concrete Bridges. Journal of Bridge Engineering, 23(10), 04018088. DOI: 10.1061/(ASCE)BE.1943-5592.0001302

[5] Ministry of Infrastructure and Transport (MIT), Chad. (2013). Decree No. 045/MIT/MISP/2013 on Viaduct Use Regulations. Government of Chad.

Citation: Mahamat, A. D. (2024). Simulation of Traffic with Different Axle Configurations on the Viaducts of N'Djamena - Chad: The Cases of Dembé and Diguel. *International Journal of Civil Engineering and Technology (IJCIET)*, *15*(6), 1–8. https://doi.org/10.5281/zenodo.14282888

Abstract Link: https://iaeme.com/Home/article_id/IJCIET_15_06_001

Article Link:
https://iaeme.com/MasterAdmin/Journal_uploads/IJCIET/VOLUME_15_ISSUE_6/IJCIET_15_06_001.pdf

✉ **editor@iaeme.com**