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THE IMPACT OF ROAD BUMPS ON HIGHWAY MACROSCOPIC TRAFFIC FLOW PROPERTIES

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Abstract: Any vertical undulation of the road surface like road bumps or humps tends to affect the traffic flow properties. Bida – Minna road is a highway which serves through traffic movement between Minna; the state capital of Niger State to Bida. Towards the tail end of this road en route to Minna a series of bumps were installed, thus having an impact on traffic flow properties especially during peak hours. This study is focused on assessing the effect of road bumps on highway traffic flow properties. Two distinct sections were taken: Section A; "free section" and Section B; "bump section". At both sections, volume and speed studies were conducted simultaneously during peak hours. A significant reduction in mean speed of vehicles were observed, from 42.11 km/h at free section to 9.21 km/h at bump section was observed. Whereas the traffic flow increased from 1,160 Pcu/h/l to 1,546 Pcu/h/l with density increasing significantly from 28 Pcu/km/l at free section to 170 Pcu/km/l at the bump section and a corresponding rise in operational capacity from 1,270 Pcu/h/l to 1,776 Pcu/h/l. The road levels of service changed from the best flow condition 'A' at free section to the near worst condition 'E' at bump sections. In conclusion, road bumps are best suited for low-speed facilities like parking lots because of its effectiveness in slowing vehicles down to a minimal speed; for this study a 77% loss in mean speed was observed from free section to the bump section, while volume flow rate increased by 4.68% and consequently increasing traffic density by 530% which causes a near congestion condition. Thus, road bumps are not suitable on highways.

Keywords: Speed, Flow, Density, Road Bumps.

INTRODUCTION

Vertical deflections on road surfaces be it road pavement distress or designed can be an effective measure in controlling traffic especially in terms of speed reduction. Speed humps and bumps are traffic calming features used to slow down traffic through vertical deflections [3]. Road humps can be made of recycled plastic, metal, asphalt, concrete or rubber but the most commonly found in Nigeria are those made of Asphalt. Road bumps of various sizes can be placed on a road, from using a six foot device with a space on either side for drainage and designed such that cars cannot avoid the bump on one side of the car. It may also be connected across the entire road surface.

The use of vertical deflections is common and has gained wide acceptance in the world today [5]. They are mostly found were vehicle speeds are very much needed to be low usually 30 km/h or less in the case of road humps, or even about 8 to 16 km/h in car parks in the case of road bumps. Although, they are very effective in keeping vehicle speeds down, their use is sometimes controversial as they can cause an increase in traffic volume, increase in noise and possibly vehicle damage when not installed properly [6].

Speed Humps and Bumps are installed to serve same purpose of speed reduction on the road. Speed humps and bumps should not be confused as they are used at varying locations. Speed humps are known to be a raised area in the road's pavement surface which extends transversely across the roadway. Humps are mostly installed with heights of 3 to 3.5 inches (76 to 90 mm) with a travel length of 10 to 14 feet (3.0 to 4.3m) and are generally used on residential local streets and are recommended to be used on highways when the need arises because they have evolved from an extensive testing and research and designed to achieve a specific outcome from vehicular operations, without imposing an unnecessary safety risk on vehicles. Vehicles tend to slow to about 20 mph (32 km/h) on streets with properly spaced speed humps. On the other hand, a speed bump causes vehicles to slow to 5 mph (8 km/h) or less at every installation. They are mostly used on private roads and parking lots. They generally have a height of 3 to 6 inches (76 to 152 mm) and a travel length of 1 to 3 feet (0.3 to 1.0 m). They also do not exhibit a consistent design parameter from one installation to another. Bumps are usually constructed with heights ranging between 4 and 6 inches (10 to 15 cm) of evaluation is normally done using speed, volume and collision data [6]. Speed humps are usually wider than the wheel base of a car with gentle slopes while road bumps are more aggressive with steeper slopes and narrow which causes major discomfort to the motorists [1]. Three important parameters like: road hump heights, spacing and road hierarchy are important when considering road hump as a road safety control device [3].

Rural residential streets normally experiences low traffic volumes and of course, high operational speeds against this background , a research work carried out by ITE in 2005 on the effectiveness of speed hump in traffic calming shows that speed humps decreases the posted speed limit. It also concluded that, more than one speed hump on a short roadway section does not yield more benefits. [7]

Towards the tail end of the highway linking Bida a major town and Minna; the capital city of Niger state, Nigeria, there exist speed bumps which tend to slow down significantly the speed of approaching vehicles as they try to move slowly through the bump section. This sudden decrease in speed has been hypothesized to bring about a decrease in speed add flow rate while an increase in the density of the traffic which often leads to a near congestion problem and hence, the impact of road bumps of traffic flow properties.

The Relationship between Traffic Flow Rate, Speed and Density

The traffic flow, *q*, a measure of the volume of traffic on a highway, is defined as the number of vehicles, *n*, passing some given point on the highway in a given time interval, *t*, i.e.

$$q = \frac{n}{t} \qquad (1)$$

In general terms, *q* is expressed in vehicles per unit time. The number of vehicles on a given section of highway can also be computed in terms of the density or concentration of traffic as follows:

$$k = \frac{n}{l} \qquad (2)$$

Where the traffic density, *k*, is a measure of the number of vehicles, *n*, occupying a length of roadway, *l*. For a given section of road containing *k* vehicles per unit length *l*, the average speed of the *k* vehicles is termed the space mean speed *u* (the average speed for all vehicles in a given space at a given discrete point in time).

Therefore:

$$u = \frac{(\frac{1}{n})\sum_{i}^{n} li}{2a} \quad (3)$$

Where "*li*" is the length of road used for measuring the speed of the *i*th vehicle. It can be seen that if the expression for *q* is divided by the expression for "*k*", the expression for *u* is obtained by:

$$q \div k = (n|t) \div (n|l) = (n|t) \times (l|n) = u$$

Thus, the three parameters *u*, *k* and *q* are directly related under stable traffic conditions:

$$q = uk \quad (4)$$

This constitutes the basic relationship between traffic flow, space mean speed and density

Level of Service

One the most important measure of quality is the level of service concept. Quality of service requires quantitative measures to characterize operational conditions within a traffic stream [8]. Level of Service (LOS) is a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience. Six LOS are defined with letters designate each level, from A to F, with LOS A representing the best operating conditions and LOS F the worst. Each level of service represents a range of operating conditions and the driver's perception of those conditions [2].

1. **Level of Service A:** This is a condition of free flow accompanied by low volumes and high speeds while traffic density will be low.

2. **Level of Service B:** This occurs in the zone of stable flow, with operating speeds beginning to be restricted somewhat by traffic conditions. Drivers still have reasonable freedom to select their speed and lane of operation. Reductions in speed are not reasonable, with a low probability of traffic flow being restricted.

3. **Level of Service C:** This is still in the zone of stable flow, but speeds and manoeuvrability are more closely controlled by the higher volumes. Most of the drivers are restricted in their freedom to select their own speed, change lanes or pass.

4. **Level of Service D:** This level of service approaches unstable flow, with tolerable operating speeds being maintained, though considerably affected by changes in operating conditions. Fluctuations in volume and temporary restrictions to flow may cause substantial drops in operating speeds. Drivers have little freedom to manoeuvre, and comfort and convenience are low. These conditions can be tolerated, however, for short periods of time.

5. **Level of Service E:** This cannot be described by speed alone, but represents operations at lower operating speeds. Flow is unstable, and there may be stoppages of momentary duration. This level of service is associated with operation of a facility at capacity flows.

6. **Level of Service F:** This describes a forced-flow operation at low speeds, where volumes are below capacity. In the extreme, both speed and volume can drop to zero. These conditions usually result from queues of vehicles backing up for a restriction downstream. See table I below for level of service classification.

Table I: Level of Service

LOS Rating	Arterial Travel Speeds KMPH (MPH)
A	≥ (25)
B	(19 - 25)
C	(13 - 19)
D	(9 - 13)
E	(7 - 9)
F	≤ (7)

Source: Highway Capacity Manual (HCM, 2000).

METHODOLOGY

Site Description

The site used for case study is the Bida- Minna road towards the tail end of this road located at Kpakungu area of Niger state. Two sections of the road were used for the study comprising section A; free sections and section B; bump section. Section A is taken to be by Kpakungu Bridge, just before College of Arts and Islamic Studies 900 meters before the bump section with a trap distance of 100 m. The trap distance is determined due to the presumed speed of vehicles at the sections. While the bump section is also at Kpakungu, and has its trap length determined to be 50 m. In taking the time at this section, the distance between two consecutive bumps were used as the trap markers.

Spot speed studies and traffic volume counts were conducted simultaneously at both sections on Tuesdays, Wednesdays and Thursday in morning and evening peak hours. Mondays and Friday were excluded because they present extremely high traffic volumes and those not represent the true state and traffic flow properties of the road.

DISCUSSION AND RESULTS

Results

Geometric Properties of the Bumps

The geometric properties of the bump has an average height of 120 mm, its width 700mm and its length is 12.5 m. from literatures this is classified as bump.

Traffic Flow Properties

Traffic volume measured was converted to passenger equivalent unit since the traffic is mixed traffic. Also spot speed studies were conducted simultaneously and traffic density was computed. The summary of the results are tabulated below in tables I and II for bump and free section respectively.

Table II: Macroscopic Traffic Flow Properties (Bump Section)

	Flow Rate Pcu/Hr/Lane	Speed Km/Hr	Density Pcu/Km	LOS
	1448	11	130	E
	1479	12	123	E
	1511	9.5	160	F
	1552	11	140	E
	1602	6.5	244	F
	1681	7.6	220	F
Mean	1546	10	170	
Std. Dev.	103	2	21	

Table III: Macroscopic Traffic Flow Properties (Free Section)

	Flow Rate Pcu/Hr/Lane	Speed Km/Hr	Density Pcu/Km	LOS
	1772	41	27	A
	1568	46	24	A
	1726	39	29	A
	1542	44	25	A
	1643	40	31	A
	1479	43	28	A
Mean	1622	42	27	
Std. Dev.	113	3	3	

The summary of findings is shown in tables II and III but the estimation of the impact is given below;

1. The average percentage decrease in flow from free section to bump section
   $= \frac{1622-1546}{1622} \times 100 = 4.68\%$

2. The average percentage decrease in speed from free section to bump section
   $= \frac{42.17-9.6}{42.17} \times 100 = 77\%$

3. The average percentage increase in density from free section to bump section

   $= \frac{27-170}{27} \times 100 = -530\%$

The negative sign shows a sharp increase in density from 27 Pcu/km/lane to 170Pcu/km/lane

Comparative Assessment

The geometric properties of the vertical deflection measured on site matches the properties of a bump given in the literatures. [1].

Generally speaking, any alterations in the pavement like potholes, bumps, humps etc. will affect the traffic flow properties. From preliminary studies, during the off peak periods, flow properties do not experience any alarming changes in traffic flow properties with the exception of speed of the vehicles which experiences sharp decrease. While during the peak hours, the average speed decreases from 42.17 Km/Hr. at the free section to 9.6 Km/Hr. at the bump section; this represents an average percentage decrease of about 77%. Similarly, flow rate decreases from 1622 Pcu/Hr./lane at the free section to 1542 pcu/hr/lane at the bumps section which represents a percentage loss of 4.68% and unlike the other properties, traffic density which had a sharp increase from 27 Pcu/km/lane to 170 Pcu/km/lane which represents 530% increase. The free section is generally operating at a level of service “A“, which represents a stable flow; best quality flow condition while the bump section is operating on a level of service “E” representing forced flow, near congestion.

These results coincide with different researchers like Johnnie Ben-Edigbe and Nordiana Bint Mashros., their work concludes that speed humps reduce speed and also their loss in capacity. Also, Raj V. *et al,* 2005 also concluded from their studies that traffic humps reduces cut through traffic and increases the rate of flow and decreases the posted speed limit. Speed bumps reduce the speed of the traffic to about 8 Km/Hr.

Although most of these researchers worked on speed humps as speed humps are better suited for higher class facility than road bumps, road bumps are better suited for parking lots and facilities. In the case of research work an undulation which has the characteristics of speed bumps were used on an arterial highway which explains the sharp loss in traffic speed and traffic density.

CONCLUSION

Installation of road bumps on a highway affects the traffic flow properties immensely; as a sharp decrease in speed and flow rate and an increase in traffic density. While road bumps might be good in residential streets where traffic volume is low and tendencies for high speeds; it should be strongly discouraged in the case of highways and expressways where high traffic volume and speed are experienced to avoid congestion especially during peak hours.

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