IMPACT OF HIGHWAY ALIGNMENT ON URBAN FLOODING IN MINNA, NIGERIA

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ABSTRACT

This paper examines the causes of urban flooding along main road junctions in Minna. The hydraulic capacity of the drainage channels along the carriageway, as well, as the highway alignment were assessed. It was found that the hydraulic capacity of the drainage channels is adequate. The traverse slopes of roads approaching the junctions are lower than the highway standard. This results in retention of water on road surface and weakening the pavement structure. The longitudinal profile of roads shows that the junctions form a valley, without the provision of collectors at the junction. Thus, the flooding experienced at the junction are attributed to poor highway alignment,
Key words: urban flooding, highway alignment, drainage facility

INTRODUCTION

Urban flooding is the washing away of built-up areas due to a number of reasons such as climatic (high intensity rainfall), socio-environmental (poor maintenance culture, land use pattern) and inappropriate hydraulic structures. Jimoh (1999) showed that urban flooding in Niger State is not only due to high intensity rainfall, but also as a result of poor maintenance culture and inappropriate land development policy. Whelans and Palmer (1993) had earlier shown that flooding is also as a result of poor management of storm water and runoff. They stated that there is the need to manage storm water. This management would involve looking at storm water as a resource rather than a burden. They argued that management of urban runoff in a water sensitive manner does not only resolve problems related to storm water, but it enhances the social and environmental amenity of the landscape. The Land Systems EBC (1993) took a more critical look at the effect of road layout on flooding. It stated that a water sensitive road layout incorporates the natural features and topography of the site and that if the practice of locating roads beside public open spaces is implemented, this would enhance visual and recreational amenity, temporary storage, infiltration and minimize the extent of impervious road surfaces which allows for water to stay longer on the surfaces, causing floods. A short-duration and intense burst rainfall usually do not cause widespread flooding, but can cause debris flows, which flows downhill and clog drain inlets, causing substantial flood damage (Rogers, 2003). The National Capital Planning Authority (1993) suggested that a good road alignment should ensure that local collector roads run parallel to contours. Access places and road cross falls are required to direct runoff to local collection/detention measures. It also suggested a decrease in the length and width of low traffic local roads, as well as design of shorter urban road networks. The effect of highway alignment on flooding of an area cannot be over emphasized. Singh and Quiroga (1996) showed that interstate highway I-49 in the United States was partly responsible for the floods that occurred in Northwest Louisiana in 1989. The combinations of vertical grade and traverse roadway slopes that might inhibit drainage are of concern to planners and managers. (Highway Design Manual, 2003 and Drainage Manual for Roads and Bridges, 1998, 2004). Minna, the capital of Niger State is growing due to its nearness to the Federal Capital City. Mobil junction (Fig. 1) is at the centre of the town, and connects the major commercial places in the town. The roundabout is often flooded, especially at the Hospital -Keteren Gwari and Bosso axes, even during a moderately high rainfall. Plate 1 shows one of the flooding situations in September 2004. The State Government through her various ministries and units often (at least yearly) carry out routing maintenance of the failed section of the road, especially the Keteren Gwari axis. The mode of failure at these sections suggests inadequate control of water in the pavement. Previous maintenance activities include: (i) patching of potholes, (ii) asphalt over-lay, and (iii) reconstruction of base and sub-base courses. The maintenance exercises have not been able to address the persistent failure of these sections of the highway in the town. A similar phenomenon was observed on the Paiko Police station roundabout to the old Post Office road. This paper is aimed at identifying the effect of the highway alignment on the flooding at these locations.

MATERIALS AND METHOD

Minna lies within Latitude 9º 30’N and Longitude 6º 30’E, and is located in the upper part of the Guinea Savannah region of Nigeria. Two distinct (rainy and dry seasons) are experienced in the region, which is due to the seasonal movement of the Inter Tropical Convergence Zone. The rainy season is between April

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and October with the peak rainfall in August or September. The dry season is between November and March. The hourly rainfall data of Minna was obtained from the Federal Department of Meteorological Services, Oshodi, Lagos. The data (15 years) was then analysed to produce the design storm equation. The street layout map of the town was obtained from the Town Planning authority, while a detailed topographical survey of the two main roundabouts was carried out to determine the longitudinal and transverse profiles of the roads. The profiles were compared with design standard of highway, while the hydraulic capacity of the drainage facilities was compared with flood volumes of typical storms.

DESIGN STORM EQUATION

An intensity-frequency-duration curve of the form (eqn. 1) was developed.

$$i = \frac{aT^b}{t^c} \tag{1}$$

where i is the rain intensity in mm/hr, T is the return period in years, t is the duration in hour, a, b and c are constants depending on locality. It was found that a, b and c are respectively 1.02, 0.75 and 0.279 for Minna. The storm equation was then used to determine the critical rain intensity (for 5 years return period, and 0.2 hour duration). The peak runoff was then estimated based on the rational formula. It was found that the hydraulic capacity of existing channel along the dual-carriage road is adequate. This agrees with Jimoh (1999) that stated that the hydraulic capacities of most of the drainage channels in the town are adequate. Jimoh (1999) further stated that urban flooding in the town could be attributed to inadequate maintenance of the channels, lack of coordination of development and indiscriminate dumping of refuse on the channels. It was however, found that drainage channel along main highway like the Bosso-Paiko road is properly maintained and there is no indiscriminate dumping of refuse on the channel. Areas that are prone to indiscriminate dumping of refuse include drainage channels within streets, roads that serve as arteries or collectors.

ROAD ALIGNMENT

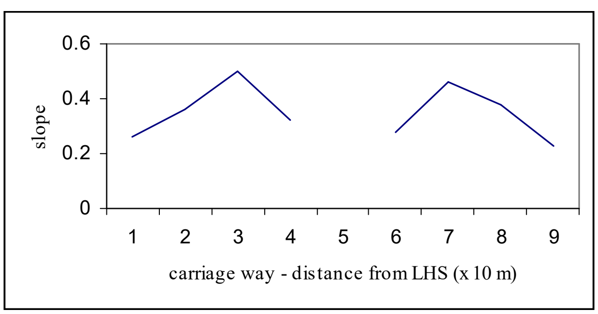
The traverse profile of the Mobil roundabout is presented in Fig. 2. The Bosso – Paiko arterial is a dual-carriage road while the other roads are single-lane road. The surface of the roads is bitumen with drainage facility. Figure 2 shows the transverse profile of each road at different sections. The streets and roads are arranged in grid form. This generally follows the topography of the area. The roads are generally meant to follow the contours. The road surfaces are impervious with relatively flat cross-falls as shown in the figure. There are cull de sacs also. The buildings/street interface have uniform set backs, which create monotonous street spaces, there are no verge allocations, which limits the scope for planting of trees. The figure shows that that transverse slopes at most sections considered on the Keteren-Gwari axis, as well as Bosso axis ranged between 0.23 and 1.0%. These values are low since the minimum slope recommended (Nigerian Highway Manual, 1973) for bituminous concrete surface is 1.5. The traverse slopes are inadequate, resulting in pool water remaining on road surface a long time after the rain has ceased. This results in increase in percolation of water to the base, and weakening the various strata. A similar observation was obtained in the Paiko Police station roundabout. Figure 3 shows longitudinal profile of Mobil roundabout at the four different axes. The figure shows that for the Bosso-Paiko road, the roundabout is at the lowest point, without a drain to transfer the runoff from the roundabout. Water flows from the Paiko axis into the roundabout at a high velocity due to the steep slope. This results in water build-up at the roundabout and a backflow into the Bosso axis, which is at a same level as the roundabout. The transverse profile of this section is however, inadequate for draining off the excess water. See Plate 1, which shows flooding of the Bosso axis in September 2004. In addition, the longitudinal profile towards the Keteren Gwari axis is lower than the level of the roundabout. Water drains from the roundabout to the road, but the water is retained over the road surface for a long time because the longitudinal and transverse slopes are inadequate (Fig. 2d and 3d). In particular, this section is the worst spot on the roundabout. Similarly, the traverse slope of the section of the Bosso road, about 300m from the roundabout, is not sufficient to drain off runoff. This finding agrees with the findings in Design Manual for Roads and Bridges (2004). One way of solving this problem is the use of surface and subsurface drainage systems at the roundabout. Keteren-Gwari axis is the lowest area within the area. A subsurface drain should be constructed from the left hand side of Bosso axis (at the lowest spot on the axis) to the right hand side of the road. Then, a surface drainage should be constructed from the right hand side of Bosso axis to the Ketren-Gwari axis. Similarly, a subsurface drain from the roundabout to Keteren-Gwari axis will remove excess water from the market and Paiko road axes. The surface drainage on the Keteren-Gwari axis should then be re-designed to accommodate the excess water from Bosso, market and Paiko axes of the roundabout.

CONCLUSION

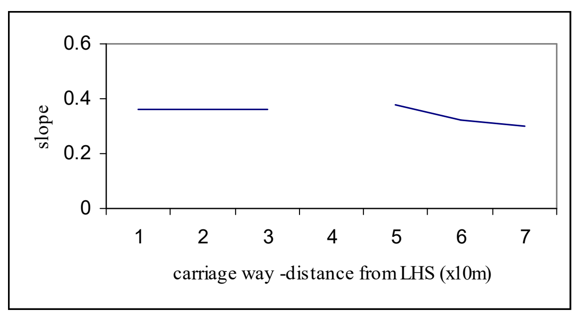
The study has shown that urban flooding along the main road in Minna is due to inadequate highway alignment. It was found that the longitudinal and transverse slopes of the road approaching the roundabout are not within the designed limits. In addition, there are no drains to remove excess water at lowest point on the road network. It is recommended that a network of surface and subsurface drainage systems be provided as a means of draining the excess water from the road surface.

REFERENCE

1. Design Manual for Roads and Bridges (1998). The effects of flooding of highway construction on flood plains. Vol. 4 Geotechnics and Drainage, Section 2, drainage, part 1. The Highway Agency, UK.
2. Design Manual for Roads and Bridges (2002). Drainage of runoff from natural catchment. Vol. 4 Geotechnics and Drainage, Section 2, drainage, part 1. The Highway Agency, UK.
3. Highway Design Manual (2003). Highway drainage, Chapter 8 (Limited Revision) Revision 41. New York Department of Transportation.
4. Jimoh, O. D. (1999). Causes of urban flooding in Niger state: a case study of Bida and Minna towns. Journal of National Association of Technological Teachers, Vol . 3, no. 1: 231 - 241.
5. Land Systems EBC Pty Ltd (1993). Better drainage: Guidelines for the multiple use of drainage systems. Sydney: Department of Planning.
6. National Capital Planning Authority (1993). *Designing subdivisions to save and manage water,* Occasional Paper Series 1: Paper 3, Report prepared by National Capital Planning Authority for the Better Cities Program, AGPS, Canberra.
7. Nigerian Highway Manual (1973). Part I – Design, Federal Ministry of Works and Housing, Federal Republic of Nigeria.
8. Rogers, J. D. (2003). Say, what is 100-year flood and why do we have so many of them? http://web.umr.edu/~rogersda/flood_hazards/What%20Is%20a%20100%20Year%20Flood.htm Accessed on 20 September 2004.
9. Singh, V. P. and Quiroga, C. A. (1996). Effect of highway alignment on flooding. A case study. Journal of Environmental Hydrology, vol. 4,: 1 – 17.
10. Whelans, H. G. M. and Palmer, T. (1993). Water sensitive urban (residential) design guidelines for the Perth Metropolitan Region. Institute for Science and Technology Policy Paper, Murdoch University. Department of Planning and Urban Development of WA

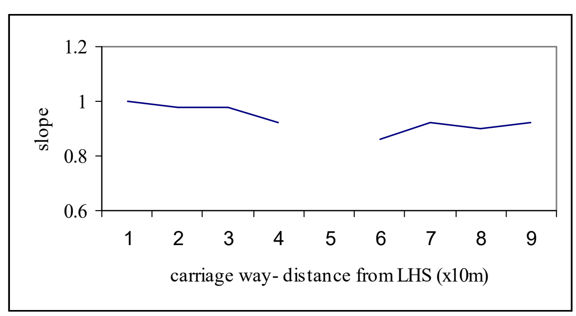


(a) Bosso road (Mobil round-about to Paiko axis)

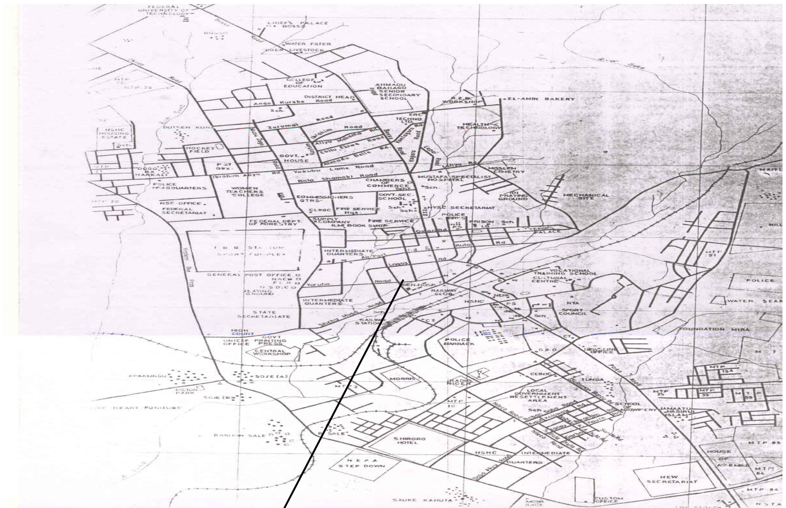


(b) Bosso Road (Mobil roundabout to Bosso axis)

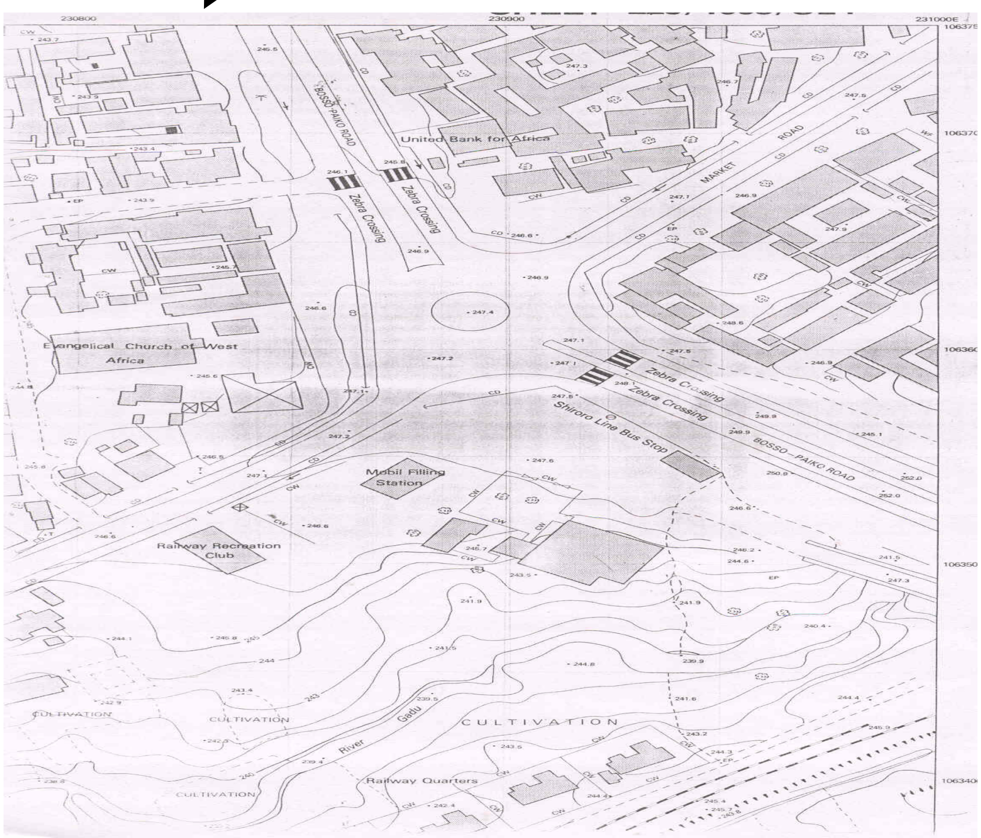
Fig. 2: Traverse sections of roads



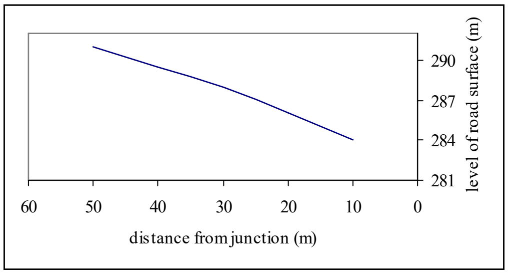
(c) Keteren-Gwari road (Mobil roundabout to hospital axis)



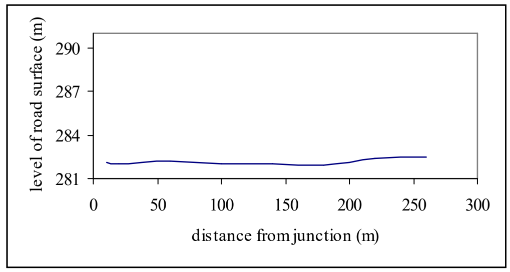
(a) Minna street map



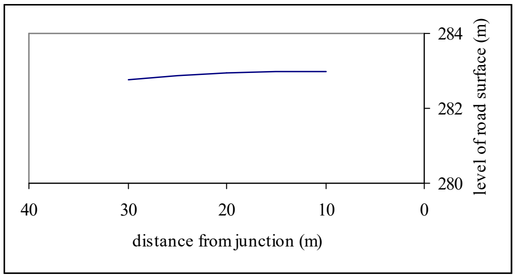
(b) Mobil roundabout
Fig. 1: Street layout of Minna



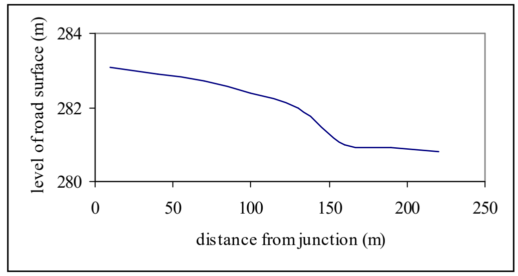
(a) Mobil roundabout to Paiko axis



(b) Mobil roundabout to Bosso axis



(c) Mobil round-about to Market axis



(d) Mobil round-about to Keteren Gwari axis

Fig. 3: Longitudinal profile of Mobil round-about

(a) Left hand side (by Fototek house)

(b) Right hand side of the road

Plate 1: Flooding of Booso Road – approaching Mobil roundabout in September 2004