Low-Level Stream Crossings in Developing Areas

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Lack of funds has delayed the provision of stream crossings in the developing rural areas of South Africa. A fund to promote labor-intensive construction and the realization that design standards could be reduced to allow for a 1-in-2-year flood flowing 300 mm (1 ft) deep across the road provided an opportunity to meet some of the community needs. The Roads Department accepted that floods bigger than a 1-in-2-year flood would overtop the structures and cause damage requiring maintenance. Designs were simplified to ensure labor-intensive construction. Three typical designs were used: a concrete slab or causeway so that the water would flow over the road, a concrete slab with one or more openings to accommodate the base flow while floods flow over the road, and a bridge or culvert with several openings, usually with a simply supported concrete deck. Liberal use was made of gabions and cut-off walls in all three designs to reduce erosion damage at the inlets and outlets. After calling for bids, the Roads Department awarded five separate contracts during 1992 to construct 17 low-level stream crossings. Special conditions in the contract documentation were necessary to ensure labor-intensive construction. The use of labor-intensive construction techniques for low-level crossings designed to reduced standards was very successful. These stream crossings met both technical and social needs in a developing area. The program will be continued and additional funds will be provided.

In the relatively arid developing rural areas of the northern Transvaal in South Africa, stream crossings on gravel roads carrying less than 50 to 100 vehicles per day generally had very vew drainage structures. As these streams have a relatively limited flow, are usually dry for fairly long periods during the year, and have relatively low traffic volumes, the public in general accepted the situation. However, during the rainy season, vehicles often got stuck in the natural streambed. The Roads Department was aware of the problem, but because funds were very limited, other projects usually took precedence. When the central government made funds available for job creation and the promotion of labor-intensive construction methods in the rural areas, the opportunity was seized (*1*).

This paper does not report on original research findings. It is a practical paper about reduced design requirements for drainage structures to provide an engineering solution using labor-intensive construction methods. All the work had to be executed within the constraints of limited available funds and such local conditions as general lack of skilled labor.

Design Standards

The flood recurrence interval for the design of drainage structures usually depends on the level of service, traffic volume on the road, and the magnitude of the expected flood (2). For example, a bridge over a river on a major road may be designed to accommodate a 1-in-50-year flood, whereas a culvert [for example, with one or two 600-mm (2-ft) diameter stormwater pipes] across a small stream on a minor road may be designed to accommodate only a 1-in-5-year flood. Bigger floods would overtop the road and probably cause erosion damage that would require maintenance.

Prevailing conditions (needs, funds, traffic) in the area demanded reduced construction costs. It was subsequently decided to reduce the design standards by accepting that the flow depth of the 1-in-2-year flood would be less than 300 mm (1 ft) and that bigger floods would overtop the structure for a maximum period of 24 hr (*1*). A corollary was reduced construction costs but increased maintenance costs, for example, for repairing the approaches after severe storms. Maintenance costs and the waiting cost for the traveling public because of flooding were included in the economic analysis to establish a priority rating for the different structures.

A substantial saving is possible if crossings are constructed for one-lane traffic only, but the prevailing traffic conditions (buses, speed, and dust) required designs for two-lane traffic. The clearance width among the guide blocks on the edges of the structure was generally 8 m (26 ft 3 in.). To reduce costs, no guardrails were provided, and guide blocks 300 mm (1 ft) high were provided at 4-m (13-ft) intervals. While the guide blocks are still visible, that is, when the water depth is less than 300 mm, vehicles would be able to negotiate the crossing safely. A disadvantage of guide blocks is the adverse effect on the self-cleaning properties of the structure after a flood with subsequent silt deposits on the road. This disadvantage had to be accepted because guide blocks are a necessary safety feature.

The traffice loading used in the design of the bridge decks was also adjusted downward. The normal loading code of the Roads Department was applied, but the abnormal heavy vehicle [i.e., 36 kN/m^2 (5.2 lbf/in.^{2})] was omitted. The decks were designed to withstand a uniformly distributed load of 10.5 kN/m^2 (1.52 lbf/in.^{2}) with a single knife-edge load of 39 kN/m (2,670 lbf/ft) and a 16-wheel heavy vehicle with four axle loadings of 320 kN (72,000 lb) each, that is, 80 kN (18,000 lb) per wheel.

Labor-Intensive Construction

One objective of labor-intensive construction is to provide job opportunities for the unemployed. This objective can be achieved through manual labor but with due regard to technical quality and efficiency of construction (*3*). The type and size of the low-level structures decided upon were ideally suited to labor-intensive construction. The fact that the financier wanted to create job opportunities and promote labor-intensive construction was additional motivation for adopting this construction method.

Typical Structures

For the purposes of labor-intensive construction and in order to accommodate the experience and ability of the labor force, the structure design had to be simplified. Based on both the hydraulic (e.g., design flood) and the geometric (e.g., vertical curve) requirements, three typical designs were accepted:

1. A concrete slab or causeway in which all the water would flow over the road. The length of the concrete slab and the vertical curvature (i.e., the *k*-value) were selected to ensure a flow depth of less than 300 mm (1 ft) during the 1-in-2-year flood (Figure 1).
2. A concrete slab with one or more openings at the bottom to accommodate the base flow and to increase the hydraulic capacity to ensure compliance with the design standards (Figure 2).
3. A bridge or culvert with several openings to accommodate an extensive flood. These structures were generally built with stone masonry walls and a simply supported cast in situ concrete deck (Figure 3).

In all instances, potential flood damage had to be minimized. Liberal use was therefore made of gabions for protection. Gabions 3 m (10 ft) and 5 m (16 ft 6 in.) wide were provided upstream and downstream of virtually all the structures. If the structure was built on rock or special conditions prevailed, the gabions were omitted. Cut-off walls were constructed at all the structures, both upstream and downstream, down to bedrock or to at least 800 mm (2 ft 6 in.) below the streambed. These precautions were taken to minimize scour damage.

These designs were deemed labor-intensive because the major components were excavating, building stone masonry walls, mixing and placing concrete, and packing gabions. The bids and the outcome of the project actually confirmed this assumption. None of the bidders decided to hand-mix the concrete; they all elected to use relatively small mechanical concrete mixers.

Contract Requirements

This particular program was one of the first for which bids were obtained to perform labor-intensive construc-

FIGURE 1 Concrete slab constructed so that water could flow over structure.

FIGURE 2 Concrete slab with three openings.

FIGURE 3 Stone masonry bridge (note guide blocks on deck and gabions and cut-off wall in foreground).

tion. This program presented the construction industry with a new requirement—a number of job opportunities had to be created during the execution of the contract.

The contract documentation was compiled to ensure labor-intensive construction, and bidders had to both bid an amount of money and undertake to create a certain number of job opportunities. Both aspects were considered in awarding the contract.

The bidder had to plan properly when bidding because detailed information had to be provided on the number of laborers who would be employed. The supervising engineer had to check on the numbers regularly, and, if fewer laborers than those bid were on site, a substantial penalty was assessed. This penalty was considered necessary to ensure that the specified number of job opportunities was provided. There were no difficulties with this "new" requirement, and it was not necessary to enforce the penalty.

Program Details

On the basis of the available funds, a cost-benefit study, and the needs of the area, 17 stream crossings were constructed in early 1992 as five separate contracts. The bid amounts varied from $100,000 to $300,000, and on average the cost of a job opportunity (i.e., labor cost, provision of materials, and professional fees) varied between $330 and $500 per month.

Discussion and Recommendation

Reduced design standards and labor-intensive construction availed the Roads Department of an opportunity to provide stream crossings in developing areas where it would otherwise not have been possible. It is accepted that these crossings are not perfect in all respects, but they are considered adequate.

The traveling public accepted the structures enthusiastically. Due to the success of this program, the Roads Department decided to continue with the provision of low-level crossings; more funds will be made available to construct crossings based on the reduced standards.

The combination of reduced design standards and labor-intensive construction presented an economic solution to an urgent technical and social problem. It is recommended that this program be implemented elsewhere in the developing world where similar circumstances prevail.

ACKNOWLEDGMENT

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REFERENCES

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