- Infrastructure development public- private partnering is required in the identification and development of crushing sites to capture and process builders' rubble to supply good quality material satisfying market demand.
- Quality best practice guidelines for the crushing industry and specifications material standards for road building aggregates that are inclusive of secondary materials.

Best practice guidelines for the secondary material industry in builders' rubble are especially needed to stimulate demand for processed builders' rubble within the public sector. These guidelines are needed for both the processing and application segments of the value chain.

In the long term, consistent demand for processed builders' rubble is dependent on the development of material specifications that are inclusive of secondary materials for roads. At a recent Road Pavement Forum, a resolution was passed to constitute a working group to develop guidelines for the inclusion of secondary materials in roads. This process will build on current research into secondary material performance in South Africa as informed by international experience. Consensus in the road industry is that for application in the most critical roads in terms of traffic volumes and loading, further performance tests are required to consider long term performance in the South Africa context.

CONCLUSION

It is estimated, based on the amount of builders' rubble available and the number of jobs currently provided by the crushing industry, that there is the potential to create at least 500 new jobs, and divert ~2.3 million tons from landfill over the next four years within the CCT as a result of the growing market in builders' rubble.

In order for the City to realise economic growth in this area, the demand side opportunities need to be unlocked, with road construction the largest market identified in the region. Key to market growth is the quality of material available, which must start with proper segregation of waste at source, followed by crushing operations subject to strict quality controls, such that high value products are available to the market.

The benefits of such development, will not only be felt in job creation and growth in the crushing industry, but also in less steep increases in disposal tariffs due to the conservation of landfill airspace, which will benefit all citizens and industries in CCT. In terms of municipal services, cost savings in road building aggregate and landfill operations, will allow re-allocation of this budget to other much-needed areas.

Possibly the best question to be asked is 'What are the consequences of not using the available resource that is builders' rubble?'

REFERENCES

1. Abrahams E 2016 pers. comm. City of Cape Town, Area Cleaning.
Cameron DA, Rahman HH, Azam AM, Gabr AG, Andrews R and Michell PW 2013. The use of recycled aggregates in unbound road pavements. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris 2013
2. CCT 2016. Municipal Budget 2016/2017
3. CCT Solid Waste Management Department 2015
4. Cement Concrete and Aggregates Australia (CCAA) 2008. Use of recycled aggregates in construction
5. Leeftink R 2015. Pers. comm. Construction and demolition waste expert through the Agentschap NL and the Dutch Ministry of Infrastructure and the Environment
6. Paige-Green P 2010. A preliminary evaluation of the reuse of cementitious materials. Proceedings of the 29th Southern African Transport Conference (SATC), Pretoria 2010
7. Rudman C and Jenkins K 2015. Self-cementing mechanisms of recycled concrete and masonry aggregate. Proceedings of the 11th Conference on Asphalt Pavements for Southern Africa (CAPSA), North West Province 2015
8. Semugaza G 2016. Comparative Shrinkage Properties of Pavement Materials Including Recycled Concrete Aggregates With and Without Cement Stabilisation. MEng Thesis, Stellenbosch University 2016
9. Van de Ven M 2015. Construction and demolition waste: a high quality (sub) base material for road construction. Presentation to CCT Roads department
10. Windapo AO and Cattell K 2013. The South African construction industry: Perceptions of key challenges facing its performance, development and growth. Journal of Construction in Developing Countries 18(2): 65-79

DEBRIS WALLS – LEARNINGS AND SUCCESSES OF ETHEKWINI MUNICIPALITY

GEOFF TOOLEY
eThekwini Municipality, Durban, KwaZulu-Natal, South Africa, 4001

ABSTRACT

Historically river culverts were sized using purely hydraulic calculations with little or no thought given to the debris being carried by these rivers during storm events. The combination of multicellular culverts and an increase in alien vegetation and litter being carried by flood waters, has meant an increase in the occurrence of blockages of these culverts with the associated damage to infrastructure and hardship for the adjacent community. This paper will present the lessons and successes of eThekwini Municipality in dealing with this problem, will highlight the innovative approach in dealing with this issue and will cover some of the science behind as to why this approach is working.

The study will provide a guide to other municipalities facing the same issues as well as the key risks which need to be checked and taken into account when adopting this approach. Results have shown that the risk to infrastructure and communities caused by debris blockages can be significantly reduced with relatively small expenditure.

INTRODUCTION

The topography of eThekwini Municipality coupled with the 4000km of valley lines means that streams and river crossings by roads are numerous. These pipes and culverts are generally sized for a 1 in 10 year storm flow within residential areas and under lower order roads. Higher order roads, such as freeways, require culverts which cater for larger storm flows. The nature of the crossings and size of the rivers often means that multicellular culverts or pipes are installed.

Historically culverts were sized using purely hydraulic capacity calculations with little or no thought was given to the debris being carried by these rivers during storm events.

The proliferation of alien vegetation with shallow root systems and the increase in the volume of litter being dumped in these rivers has meant that the frequency of blockages has increased. These blockages lead to overtopping of the roads with damage to the road and services within the road way such as sewers, cables, water mains etc. and flooding of the upstream properties adjacent to the stream.

FIGURE 1 Typical blockage of a multicellular pipe culvert after a storm event

FIGURE 2 The downstream view of the multicellular pipe culvert in Fig.1 during a flood flow showing the reduced flow capacity due to the blockage of the culvert

The primary reason for these blockages occurring at multicellular culverts is the nature of flow past the centre walls of these multicellular culverts and the debris which is caught on the centre walls thereby reducing the effective flow area and the capacity of the culvert crossing. This debris can only be cleared once the flow in the river has subsided and by then the damage is done.

Culvert blockage has plagued the city for many years with a number of different attempts being made to reduce this risk.

The blockage material is normally litter in the form of plastics, paper, fridges, tyres, mattresses as well as a lot of vegetation which is normally alien vegetation eroded out of the banks of the streams. See figures 1, 2 and 3.

The alien vegetation is particularly problematic for a number of reasons viz:

Alien vegetation generally grows quicker than indigenous vegetation which often means that indigenous vegetation is displaced by the alien vegetation.

Alien vegetation has a shallower root system in contrast to the deep rooted indigenous vegetation.

During large storm flows the shallow root systems cannot hold in the alluvial soils and are ripped out by the flow. This adds large clumps of debris into the storm flow which head downstream and assist to block downstream culverts.

In addition to the blockage problem, these clumps of alien plants ripped out by the flow leave large areas of the banks exposed to erosion which threatens adjacent infrastructure and adds large amounts of silt to the flows.

The extra silt in the river leads to siltation upstream of road crossings and siltation in certain cells of the culvert crossing.The problems faced in an urban area require a multidimensional approach solution. These approaches would include social interventions such as education programs, municipal service interventions such as systematic programs within these streams aimed at removing litter and alien vegetation and municipal engineering interventions such as debris wall installations or alterations to the culvert configuration.

Consequences of the culvert blockage problem

The blockages result in damage to the roads and associated infrastructure as well as the houses situated upstream and downstream of the road crossings as seen in figures 4 and 5. The flooding and damage of the road crossings also causes disruption to traffic and thereby to the communities using these roads as seen in figures 6 and 7. This often results in increased transport costs for communities which can be critical to those living on the breadline.

The impact of debris on multicellular culverts

The previous pictures illustrate the consequences of the blockages

FIGURE 3 Typical blockages of multicellular box culvert crossings - notice the large amount of alien vegetation forming the blockages

FIGURE 4 This house is situated upstream of a crossing that blocked and the upstream depth of water caused the house wall to fall inwards

FIGURE 5 The debris deposited upstream of a blocked culvert crossing

FIGURE 6 The overtopping of the culvert crossing due to a blockage caused damage to the road and services

however it is also important to understand the relationship between the extent of the blockages and associated impact on the water level at the culvert crossing.

In these circumstances of possible overtopping it is the ultimate capacity of the culvert in relation to the upstream water head that needs to be checked. In essence it is the failure flood calculation that is required and therefore the formula used to assess this would be the orifice flow calculation (see equation 1).

1 $$Q = Cdbd\sqrt{(2gh)}$$

Where **Q** is flow in cubic metres per second (m^3/s)

Cd is the coefficient for contraction for sharp-edged orifices (normally about 0.66)

b is the width of the opening in metres (m)

d is the depth of the culvert in metres (m)

g is the gravitational force of 9.81 m/s^2

h is the height of water measured to the centre of the culvert depth in metres (m).

Using equation (1), the relationship between the reduction in culvert opening and the subsequent increase in upstream water head required to maintain the same flow through the culvert is determined and depicted in figure 9.

The curve in Fig 9 gives an approximate of the change in height of the upstream water level should debris get caught on the centre walls of the culvert crossing and reduce the effective area of the culvert. For example, assuming the flow rate remains the same, if the culvert

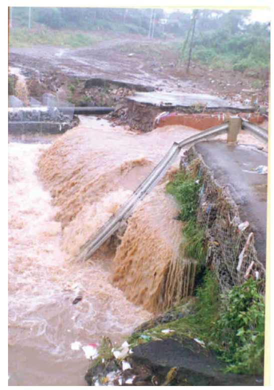


FIGURE 7 Blockages and overtopping can mean that the road is impassable

opening is reduced to 60%, the height of water upstream of the culvert will need to increase to 1.9 times the original height when the culvert was clear i.e. If the clear culvert flow height was 2m then the water height would rise to 3.8m above the invert of the culvert. If the height of the road crossing over the culvert was less than this height it would mean that the road would be overtopped and damage would occur.

THE LESSONS AND SUCCESSES OF METHODS IMPLEMENTED WITHIN ETHEKWINI MUNICIPALITY

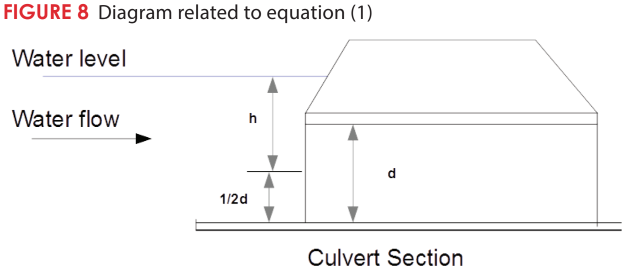
As the city has grown the number of these multiple barrel culvert crossings has increased. The blockage problem has become more apparent and there have been a number of attempts to find a solution.

Reduction in the number of cells

The most obvious solution where the capacity of the crossing has also needed to be increased or where the culvert has reach the end of its service life, has been to eliminate the centre walls by the construction of a larger single cell culvert or at least to reduce the number of cells for the crossing. This is not always possible due to the prohibitive cost of rebuilding culvert crossings.

In most cases the clean culvert has the required capacity as prescribed by the minimum level of service provided by the eThekwini Municipality and the structural integrity to last many more years. This removes the option of rebuilding the culvert and so alternative

FIGURE 8 Diagram related to equation (1)



methods of debris control needed to be investigated. A number of different solutions have been tried over the years with varying degrees of success.

Sloped debris walls

These crossings have sloping debris walls installed which abutted the centre walls of the culvert. (See figures 10 and 11) The idea behind this method was that large debris would be forced up the sloped walls leaving the flow area open for the flood flow. This worked with respect to the large tree trunks washed down the river. However the vegetation and litter washed down the river still wrapped around the front face of the debris wall thereby restricting the flow area of the culvert. The principle of the conservation of momentum results in the water flow direction rotating towards 90 degrees to the front face of the debris wall. This means that the debris is pinned to the debris wall rather than being forced up the slope of the debris wall.

Although the sloping walls increase the opening into the culvert which is affected by the debris, the blockage is still at the crossing. This means that when the culvert opening is restricted sufficiently the road will overtop with the associated impacts.

DEBRIS WALLS SEPARATED FROM THE CROSSING

Dipdale Road debris walls

The limited success of the sloping debris walls led to a lot of discussion and the concept of making the blockage occur upstream of the crossing was raised by an experienced Professional Technologist, Mr Harry Wenlock. The thought behind this was that a blockage at the culvert almost always meant the overtopping of the road and flooding of upstream properties. Whereas a blockage caused by debris walls upstream of the crossing meant that there was far less probability of the road overtopping and flooding of the upstream properties. The key was to determine the height of the debris walls in relation to the culvert opening as the upstream flooding of properties needed to be minimised as much as possible while the debris walls were still effective to stop

FIGURE 9 The relationship between the percentage of culvert openings available for flow and water height multiplication factor to maintain the same flow as the flow through a completely clean culvert

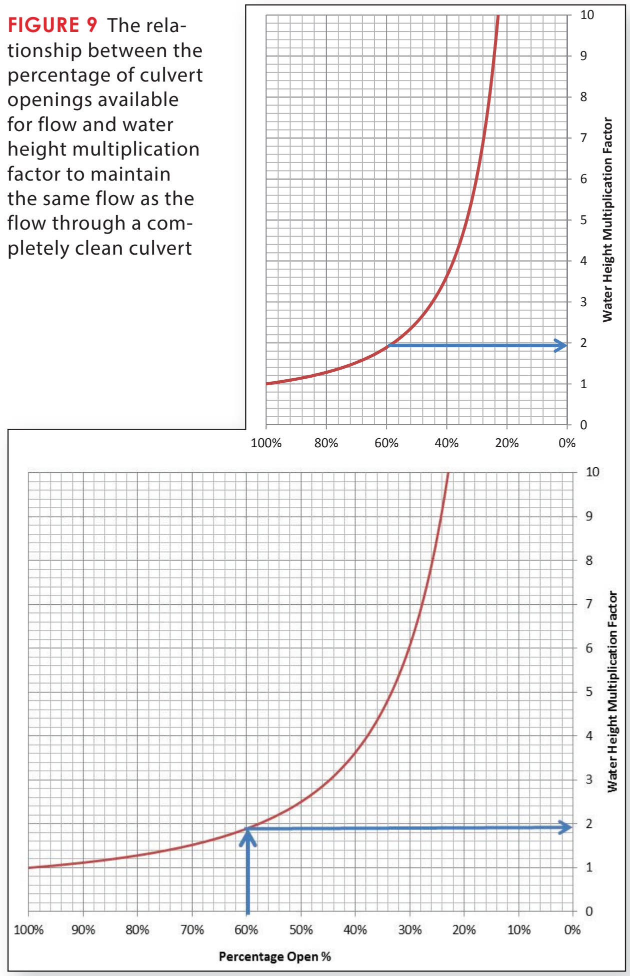


FIGURE 10 Blair Atholl Road culvert

FIGURE 11 Bulbull Drive culvert

FIGURE 12 Dipdale Road culvert with debris walls

FIGURE 13 Close up of debris walls at Dipdale Road culvert

the build-up of debris at the crossing. As with any action taken by a municipality, the risk of any intervention must be assessed. In this case although the debris walls will induce some back flooding if compared with the flow through a clean culvert, the flooding will be less than if the culvert blocked and the road was overtopped.

The first attempt at this methodology was the application at Dipdale Road where small debris walls were installed in the headwall to a single cell culvert as depicted in Figures 12 and 13. The installation was monitored for a number of years and the decision was taken to install some debris walls on larger culverts.

Molife Road Debris Walls

The principle of debris walls on multicellular culverts was then tested on Molife Road culvert. In this instance the debris walls were installed in line with the centre walls of the culvert and approximately one third of the height of the opening. This did not prove successful as seen in the photographs below.

Mugabe Road Debris Walls

The Mugabe Road multicellular culvert crossing carried a major bus route across the Isipingo River. As can be seen from figures 12 to 17, this crossing was prone to blockages and subsequent closure of the road. The impact on the community was large in that the travel time to the workplace was increased by at least 20 minutes and this was associated with an increase in travel costs in what is essentially a

FIGURE 14 Molife Road debris walls and blockage of the culvert

FIGURE 15 Mugabe Road culvert with debris build up

FIGURE 16 Mugabe Road culvert with debris build up

FIGURE 17 Mugabe Road culvert with debris build up – Note the build- up of silt upstream of the culvert


FIGURE 18 Mugabe Road culvert with debris build up


FIGURE 19 The upstream silt in the process of being removed


FIGURE 20 The upstream silt has been removed and the additional cell added


FIGURE 21 Dowel holes for reinforcment into the bedrock


FIGURE 22 Reinforcement for the debris wall dowelled into the inlet slab


FIGURE 23 Casting of the bases for the debris walls


FIGURE 24 Casting of the bases for the debris walls

poor community. As can be seen, the primary cause of the overtopping was the collection of debris on the centre walls of the culvert and hence this site was seen as the ideal place to test this new idea in the use of debris walls separated from the crossing.

The capacity of the crossing was also assessed and found to be marginal in meeting the required minimum level of service specified by the Municipality viz. a 1 in 10 year flood. It was decided to increase the crossing with an additional cell the same size as the existing cells which increased the capacity to a 1 in 20 year flood flow. The project was project managed by a young technician, Mr Nicholas Ndlovu, in the Coastal, Stormwater and Catchment Management Department of the eThekwini Municipality. The first aspect of the project was the installation of the additional cell and the removal of the upstream silt build up as shown in figures 18 and 19.

The next step was to dowel the reinforcement for the debris walls into the bedrock and the existing base of the culvert inlet works


FIGURE 25 Base cast for the debris walls


FIGURE 26 Formwork for the debris walls


FIGURE 27 Debris walls cast


FIGURE 28 Completed debris walls


FIGURE 29 Completed debris walls


FIGURE 30 Approach slab enhancement


FIGURE 31 Debris walls in action after a storm

and to cast the debris walls (figues 20 to 27). These were structurally designed to withstand being fully blocked and damming water to the height of the debris walls.

The apron slab for the culvert crossing was enhanced to focus the low flow through the centre cell of the culvert and to accelerate the water through the culvert during high flows to assist with keeping the culvert free of silt as shown in figures 28 and 29. The acceleration of the water between the debris walls means that any debris that passes the debris walls is pushed to the centre of the downstream culvert opening and passes through the culvert. Furthermore branches or poles which do not span between debris walls but only hit one of the debris walls are turned to align with the culverts and pass harmlessly through the culvert (figures 30 to 33).

The debris walls although effective in stopping the debris from clogging the culvert opening, still needed to be cleaned by the maintenance teams. In this instance, the maintenance team was not briefed on the functioning or cleaning of these debris walls and when using an excavator to clear the debris one of the debris walls

FIGURE 32 Debris walls holding debris - note the acceleration of water towards the centre of the downstream cell

FIGURE 33 Debris including a large tree trunk collected by the debris walls - note that there is no debris on the culvert centre walls

FIGURE 34 Side view of the debris wrapped around the debris walls

FIGURE 35 Debris wall broken by excavator during the clearing of the debris

FIGURE 36 Debris build up while the one debris walls was missing

FIGURE 37 Debris build up while the one debris walls was missing

was broken by the excavator (figure 34). This incident highlighted the need for cleaning teams to understand how the debris walls were designed to function and the care needed in clearing them. While the debris wall was missing another storm event occurred and it was interesting to see the debris immediately built up on not only the centre wall downstream of the broken debris wall but also the two adjacent centre walls (figures 35 and 36). This highlighted the impact the debris walls had on the streamlines through the culvert and the effectiveness of the debris walls.

The dimensions used for the installation of the debris walls are as depicted in Figure 38.

The debris walls are placed the same distance from the entrance of the culvert as the height of the culvert, are two thirds the height of the culvert opening, are braced against the base of the culvert headwall and are placed in line with the centre walls of the culvert (Figure 37).

Due to the height of the debris walls being two thirds the height the culvert opening, should the debris walls have a complete

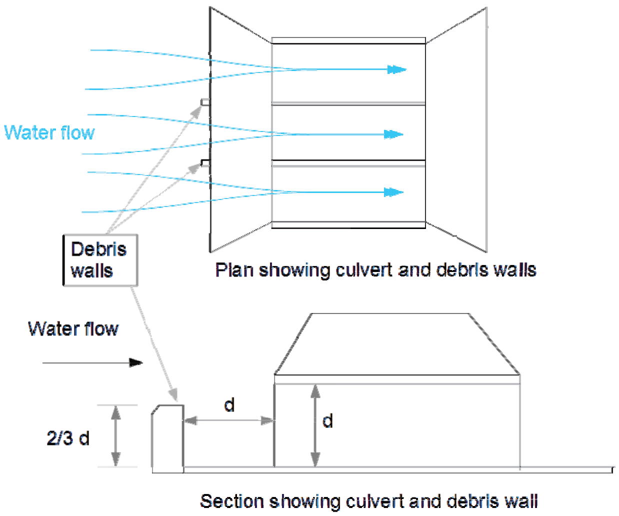


FIGURE 38 This diagram shows the placement and dimensions of debris walls in relation to the culvert

blockage i.e. the debris forms a weir across the entire river at the height of two thirds of the culvert opening, the upstream depth of water will be equivalent to the culvert opening being reduced by 30% by debris.

The chances of the blockage reaching right across the river are significantly reduced. The risk to flooding of upstream properties to the levels previously seen at the culvert without debris walls is greatly reduced.

DISCUSSION AND CONCLUSION

We are still in the learning curve with the use of debris walls in this way. As we have learnt so far, the mathematics can take you so far but the practical application highlights that the variables at each location require some intuition and adaptation. These variables include the type of debris, the flow regime of the stream, the configuration and alignment of the culvert crossing and the upstream channel shape.

The use of this debris wall design is being rolled out to the multicellular culverts throughout the eThekwini Municipality and is proving to be very successful in reducing the occurrences of overtopping and the associated damage. As highlighted in this paper, the training of the maintenance teams is imperative and it is only the combination of good design and installation and good maintenance programs that ensure the success of these debris walls.

The cost of installing the debris walls is considerably less than the cost associated with upsizing or replacing culvert crossing and therefore debris walls in this form, are cost effective ways of municipalities avoiding the damage cost associated with culverts blocked by debris.

REFERENCES

Equation (1) Mechanics of Fluids B.S. Massey

THE COLLECTION OF NETWORK LEVEL ROAD CONDITION DATA USING AN INTEGRATED TRAFFIC SPEED DEFLECTOMETER: A PARADIGM SHIFT IN ROAD ASSET MANAGEMENT PRACTICE

YESHVEER BALARAM[1], SIMON TETLEY[2]
1. General Manager - Asset Management, VNA Consulting (Pty) Ltd
2. Group Manager - Pavement/Materials Engineering Division, VNA Consulting (Pty) Ltd

ABSTRACT

The collection of Network Level pavement condition data in South Africa is traditionally undertaken by means of driven visual assessments. The issue of subjectivity and the time consuming nature of this exercise have long been acknowledged as a "stumbling block" in the data acquisition process. Furthermore, visual inspections only report on the "perceived" road condition and cannot give actual measurement/quantification of structural condition – this usually being undertaken by a Falling Weight Deflectometer (FWD).

In recent years, a few local consulting Firms have acquired semi-automated data collection vehicles which record visual condition data and profile measurements. Whilst this method of data collection is a significant improvement, visual data still needs to be condition rated. The latest generation survey vehicle is a Traffic Speed Deflectometer (TSD) which offers a fully automated solution. The TSD undertakes continuous deflection measurement using Doppler Laser technology, records surface profile measurements, captures continuous digital imaging, and employs an automated crack detector for crack detection/quantification, at a driving speed between 40 km/h and 80 km/h. The benefits in speed, repeatability and safety of data collection are obvious.

The first TSD began data collection on the Danish State Road Network in 2005. Since then, nine TSD's have been commissioned for various State Road Authorities or Research Institutes around the world including Australia/NZ, China, UK, USA, Denmark, Italy, Poland and South Africa. In April 2016, VNA Consulting (Pty) Ltd acquired the 10th TSD worldwide, the second in Africa, and the first such machine to be operated by a private enterprise. This Paper presents the TSD rationale and discusses the capabilities, outputs and benefits of the device.

INTRODUCTION

Road authorities are responsible for the planning, design, construction and maintenance of their road networks. For a road authority to successfully manage its road network, it needs to know its condition (Wix and Whitehead 2015). Given that the condition data is the key component used in Road Asset Management Systems (RAMS), enabling decision makers to generate advanced road maintenance strategies, the accuracy of this data is intrinsically critical in the identification of optimal cost beneficial strategies. RAMS adopts a systematic approach which begins with the planning and undertaking of road condition assessments. In the past decade, South Africa has seen a gradual shift from manual methods, to semi-automated methods of data acquisition. Road authorities have embraced the use of non-destructive survey vehicles which collect, inter alia, functional and structural road condition data.

Amongst these are Road Surface Profilers (Figure 1) which use lasers to collect functional parameters such as riding quality (in terms of the international roughness index, or IRI), wheel path rutting and macrotexture at traffic speeds. Profilers are often integrated with imaging systems which creates a digital record of the road, later used to "post" rate the road visual