60th IMESA CONFERENCE EAST LONDON
Siyaphambili | Engineering the Future

OPPORTUNITIES IN THE CITY OF CAPE TOWN TO SUPPORT A SECONDARY MATERIALS ECONOMY IN BUILDERS' RUBBLE THROUGH UPTAKE IN ROAD REHABILITATION AND CONSTRUCTION

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ABSTRACT

Builders' rubble is usually landfilled in South Africa, in spite of its re-use potential. Based on international experience, the biggest opportunities for recycled builders' rubble lie in road building. For example in Japan and the Netherlands with 90-95% diversion rates of construction and demolition waste from landfill, about 80% of the diverted material is used in road construction.

The builders' rubble market in the City of Cape Town (CCT) is showing robust growth. There is scope for market expansion as a result of drivers such as rising virgin material costs, and increasing transport and waste disposal costs. An estimated 518 000 m³ of builders' rubble (based on weighbridge tonnages from CCT landfills) is landfilled annually in the city. At least 25% of this material is suitable for sub-base in roads. Therefore, an extra 130 000 m³ of high quality material with a value of R13-17 million could be available to the market per year in the CCT. The current crushing capacity in the City is in excess of 618 000 m³ per year. Based on market analysis presented in this paper, it is expected that an extra 400 000 m³ per year will be available in the next three years.

Secondary material of sufficient quality for road construction in the private sector is already available. Construction companies cite lack of specifications and reluctance on the part of government to include secondary materials, as the main stumbling blocks for industry.

Further work to develop the builders' rubble economy is focussing on best practice guidelines for the crushing industry for the production of high quality products. In the longer term, the goal is to stimulate the development of material specifications for road building aggregates that include processed builders' rubble, through a partnership of academia and road industry bodies.

INTRODUCTION

Builders' rubble is usually landfilled in South Africa, in spite of its re-use potential. Based on international experience, the biggest opportunities for recycled builders' rubble lie in road rehabilitation and construction. For example in Japan and the Netherlands with 90-95% diversion rates of construction and demolition waste from landfill, about 80% of the diverted material is used in road construction. By recycling builders' rubble in this way, extra value is extracted from construction material resources, thereby increasing the volume of available materials, generating extra revenue and creating jobs in the handling and processing of builders' rubble.

In order to shift the flow of construction materials in the South African economy from the business-as-usual approach (i.e. extract, use, demolish and dispose) to a circular economy approach, the following aspects should be considered:

- the inherent value of builders' rubble
- the business case – balancing the inputs required to re-process the material for re-entry into the economy, and the market value of the product, and
- the job creation potential – a key consideration in the South African context

BUILDERS' RUBBLE AS A VALUABLE RESOURCE

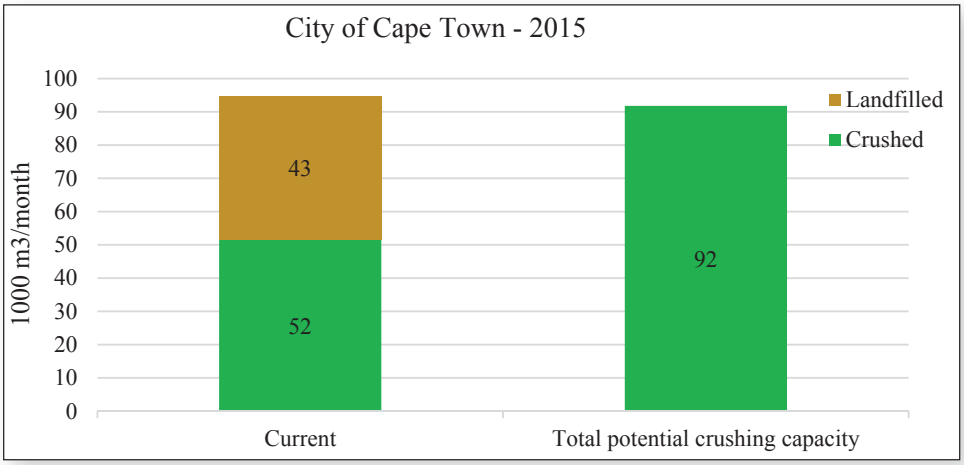
Builders' rubble as a secondary material can be considered to have value due to the resources that have been expended to produce the material – from the energy of extraction and processing of virgin materials, to the energy and handlings costs in distribution networks, to the use of the material in the construction phase, and finally to the deconstruction and demolition to produce builders' rubble.

Furthermore, builders' rubble retains many useful properties of the 'primary material', for example tensile and compressive strength of recovered concrete, a range of particle sizes available for grading specific material required, or simply an inert volume useful in fill applications.

However it must be recognised that secondary materials such as builders' rubble do not come neatly packaged. There is a history of handling, and possibly mis-handling, that affects the quality and usefulness of the composite material. Consistency of supply is another factor to consider in the use of secondary materials. These concerns will be addressed in more depth in section 3.

Although there may be negative effects due to the material being a secondary resource, there may also be properties of the secondary material that improve its performance relative to virgin materials. For example, recovered concrete aggregate exhibits self-cementing properties due to unhydrated cement particles within the matrix, meaning that secondary concretes may have higher strengths than a primary material (Rudman and Jenkins 2015).

FIGURE 1 Available Material and Crushing Capacity in the City of Cape Town



Builders' rubble as a valuable resource in the City of Cape Town?

Builders' rubble is therefore a value resource. What would the potential be for a secondary materials market driven by application of the material in roads?

This question was addressed in the City of Cape Town (CCT) by considering the value chain for builders' rubble, from the generation and supply of builders' rubble from construction and demolition sites, as well as crusher plants, to the demand side in the application of the material. Local and provincial government,

the crushing industry, construction and demolition companies, as well as geotechnical experts and researchers in the performance of builders' rubble in roads, were consulted.

This paper will present this work including the status quo of the builders' rubble market in the CCT, the factors driving the market in builders' rubble, the current and potential job creation, as well as developments supporting the application of builders' rubble in roads.

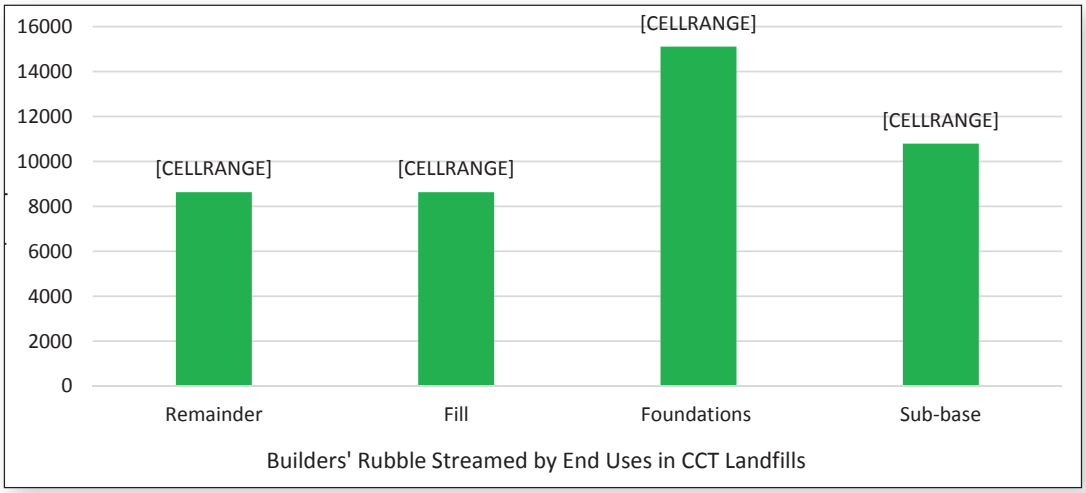


FIGURE 2 Available builders' rubble - volume and value by application based on crusher survey data
**Please note due to the focus on roads, the potential value in terms of production of construction materials has not been investigated.*

THE CCT MARKET IN BUILDERS' RUBBLE– STATUS QUO

Feedstock – current and potential

Current crushing capacity in the CCT is at least 52 000 m³/month, as derived from a survey of six major crushing operations (Figure 1). Over the next two years it is expected that the crushing capacity will be 92 000m³/month as two crushing companies will further invest in expanding their operations and it is expected that a new crusher will come online (Figure 1). Three of the six crushers surveyed accept external materials and are confident that material throughput in their business could double overnight, with builders' rubble easily sourced and products moving well.

Landfills are the biggest repository of available feedstock to the builders' rubble market currently, albeit at a relatively low quality due to the lack of separation at source. The volumes of builders' rubble disposed of at landfill give an indication of the amount of builders' rubble generated in the CCT.

Large volumes (518 000 m³) of builders' rubble are landfilled every year in the city, which is an average of 43 200 m³ per month (Figure 1). An average of 6% of the builders' rubble disposed of at landfill is used for landfill cover, as well as the construction and rehabilitation of landfill access roads.

The current data indicates that in 2-5 years, almost all available feedstock will be processed in the CCT, either at landfills for cover or by the crushing industry. However, the current data on builders' rubble generated does not include mixed loads disposed of at landfill, only loads with less than 10% contamination are captured in the data. Segregation at source is not common practice on construction and demolition sites, therefore it is expected that large volumes of mixed waste is disposed of at landfill and not recorded as builders' rubble. Furthermore, neither the builders' rubble illegally dumped at multiple sites around the City nor any waste from construction material production is captured in the data. Therefore, crushing capacity is unlikely to outstrip supply.

Feedstock quality

A GreenCape survey of end users of processed builders' rubble revealed application in construction materials, fill, as aggregate in foundations, parking lots as well as road construction and rehabilitation, where the roads remain the responsibility of the private sector. Furthermore, consistent suppliers of processed builders' rubble were identified for all applications, suggesting that the available feedstock quality satisfies the end users in the market. Regarding material stockpiled at landfill, both a South African and a Dutch expert in builders' rubble recovery and crushing estimate that 50-60% of the material disposed of at landfill in the CCT is suitable for the higher value applications in foundations of buildings or as sub-base in roads, with 20-30% of the total rubble suitable for sub-base and even base courses in road construction.

Therefore, for sub-base material in road construction, an extra 11 400 m³ of high quality material (25% of total landfilled) with a value of R1.1-1.5 million is available to the market per month in the CCT (Figure 2).

Factors driving the market in builders' rubble

It was initially assumed that there is a limited market in builders' rubble in CCT, indeed anywhere in South Africa, due to the lack of external drivers common in countries where a thriving market in builders' rubble is evident.

Landfill fees are low in general, with very few municipalities even achieving cost recovery for their landfill operations. The CCT has however based their landfill tariffs on cost recovery, which are still 1 or 2 orders of magnitude lower than countries with large recycling economies. In fact, clean builders' rubble, with less than 10% contamination, is disposed of free of charge at all CCT landfills and drop-offs.

Furthermore, although waste legislation requires waste minimisation and diversion at all levels of society, there are no legal incentives or disincentives regarding any non-hazardous construction and demolition waste stream.

However, as documented above, there is currently at least 55% diversion of clean builders' rubble in CCT. It is clear that the business case for the processing and application of builders' rubble exists in the CCT.

- Current drivers of the economy, include
- Rising virgin material prices,
- Regulations for landfill design,
- Cost of transporting the waste, and

Increasing disposal costs – due to limited landfill airspace

High virgin material prices are cited as the primary factor limiting growth in the construction industry (Windapo & Cattell 2013). Because of rising energy costs, low supplies of building sand and gravel, and environmental impact assessment (EIA) requirements for new quarries, mines and borrow pits; consistent increases in virgin material prices are expected, with greater annual increments in gravel and building sand as the resources become depleted. More stringent regulations regarding landfill construction and operation are now in place. This means that landfill gate fees will rise, in some cases, up to 50%. Increasing

transport costs, associated with material supply and wastes for disposal, favour a local source of secondary material and reduction or elimination of waste from site by reusing 'waste' materials.

Due to the scarcity of landfill airspace, incentives to divert wastes and disincentives to dispose of waste may very well be implemented at local municipal level in the next 5 years if current practice of disposing of large volumes continues.

In the analysis of business models for major crushers in CCT, transport distance is the key factor driving the business case. Due to the low value of builders' rubble relative to the high costs of transport, a market in builders' rubble will be at a limited local scale, unless external incentives drive further diversion from landfill. Stand-alone crushing operations capitalise on the lack of landfill infrastructure, being sufficiently distant from landfill to charge a small gate fee to cover the costs of producing high quality material. Construction and demolition companies with crushing operations, benefit from access to material generated on their sites, and are able to either crush on site or utilise reverse logistics in transporting 'waste' from one site to a central processing site.

Current and potential job creation

Job creation is a key national goal highlighted in both the National Development Plan (NDP) and the Department of Trade and Industry's (the dti) Industrial Policy Action Plan (IPAP), where an emphasis is placed on 'green jobs'.

Based on the survey of six major crushers in the CCT, there is an average of 9.7 jobs created per 1000m^3 of builders' rubble processed. Within this data, there is a large range from 1.2-30 jobs per 1000m^3 processed. The discrepancy in job creation is accounted for by the quality of products from the crushing operations. The higher job creation numbers represent the crushers producing the highest quality products, with job numbers in the lower range associated with crushers producing material for fill applications only. Therefore, stimulation of the market towards the higher quality applications, such as in roads and foundations, will create a larger number of income opportunities.

It must be noted that the jobs created are at the lowest skill levels, and to some degree in the handling and processing of builders' rubble, it is possible to substitute labour for energy and highly expensive equipment. Well-functioning markets in builders' rubble in developed countries are serviced by large and very expensive plants, with higher tech sorting, screening and processing equipment than is used in the South African crushing industry (R. Leeftink pers. comm. 2015). The limited external drivers in South Africa currently do not allow profit margins that would accommodate such expensive machinery. Hand sorting once material is of a suitable size, using a system of conveyors is a workable solution, in terms of capital expenditure, with lower energy demands, and the potential to include low skilled labour. Given sufficiently mechanised handling and efficient crushing upfront, the quality of material processed is not affected and is suitable for the low volumes of builders' rubble generated in a developing economy (R. Leeftink pers.comm. 2015).

The demand side – application of builders' rubble

The primary market for crusher operators is composed of smaller construction companies who have been constrained by increasing virgin material prices, with application of the material predominantly in fill, but also in construction materials, foundations and road sub-base.

Some of the larger construction companies with the resources to crush on their own sites, report cost savings due to limited logistics and reduced handling of material such that secondary material has a competitive advantage in a highly competitive market. These companies routinely include secondary material in sub-base layers in roads, where these roads remain under the authority of the private sector, as well as producing secondary concrete aggregate to be included in concrete mixes.

APPLICATION OF BUILDERS' RUBBLE IN ROADS IN THE CCT – OPPORTUNITIES AND CHALLENGES

The use of builders' rubble in roads globally

Builders' rubble is routinely used as road building aggregate in many countries around the world, including Australia, China, Germany, Japan, the Netherlands, and the USA among others (Cameron, Rahman, Azam, Gabr, Andrews & Michell 2013; Paige-Green 2010; CCAA 2008). There are also successful projects documented in developing economies such as Brazil and India (Paige-Green 2016 pers. comm.; Jenkins pers. comm. 2015).

Across these different contexts, there are differing construction methods, a range of parent materials, as well as differing climate and hydrological conditions. In spite of these differences, there is the common factor of successful road projects including builders' rubble. This suggests that the application is relatively robust, with performance envelopes sufficiently large to accommodate these differing conditions, especially if the material is used in road sub-base courses. An important further factor, is that road construction must always adapt to local conditions, including the available material. Secondary materials constitute an alternative 'mine' or 'borrow pit' from which material can be accessed, provided the required volumes and quality are available within a financially viable radius of the project.

The performance of builders' rubble in roads

Research into the performance of builders' rubble in roads has been conducted in many regions around the world, with the Netherlands a front runner due to their lack of accessible natural aggregate; river aggregate can no longer be mined in the Netherlands, consequently all virgin road building aggregate must be imported at high cost (Van de Ven 2015).

Due to the differences in South African road construction techniques, local research is vital to ascertain the performance of builders' rubble in roads under local conditions. The University of Stellenbosch has developed a research focus in this area in association with the Technical University of Delft (TU Delft), the Netherlands.

Work to date has found that the performance indicators such as shear, resilient modulus and permanent deformation characteristics show comparable results to that of G1-G4 road building aggregates. In this research the findings were based on compositions of recovered concrete aggregate mixes, with up to 30% clay masonry for comparison to the lower G classes (Rudman & Jenkins 2015). The governing parameters are:

- effective source separation of rubble streams, with a good source of clean concrete aggregate needed
- accurate screening and secondary crushing of material
- composition (proportions of concrete to clay brick)
- degree of compaction, and
- moisture content.

In terms of durability, self-cementing behaviour was prevalent in all secondary material mixes tested. This is as a result of the latent bonding properties within the material composition. The stiffening of the material could be advantageous to the material fatigue and deformation properties (Rudman & Jenkins 2015). On the other hand, some concerns have been raised that the too stiff layers and over stressing of the material could lead to premature reflective cracking which ultimately leads to accelerated effective stiffness loss of the material.

Research at Stellenbosch University regarding the potential of this material to develop shrinkage cracking has been undertaken and is still ongoing. Preliminary shrinkage test results have demonstrated that secondary aggregate mixes do not have the problem of micro-cracking of cemented materials (Semugaza 2016).

Benefits to CCT Municipality – solid waste management

The diversion of builders' rubble from landfill will save operating costs, and constitutes in effect an extra 'revenue' stream for the CCT as clean

builders' rubble is landfilled for free. If 60% of the current volume of builders' rubble entering landfill sites in the City was diverted, with an estimated cost of R395 per ton of waste handled at landfill, the annual cost savings would be R221 million. This figure is equivalent to 93% of the capex budget for the City's 2016/17 solid waste management budget (CCT 2016).

It is important to note that the clean-up costs per ton of illegally dumped material are five times that of refuse removal for the City of Cape Town, a significant cost to CCT at R350 million per year spent on urban cleansing of litter and illegal dumping (CCT Solid Waste Department 2015). The absorption of this material into the formal economy will be of great benefit to municipalities and residents, with further funds available for other municipal projects.

Data from the City of Cape Town documenting the spatial distribution and volumes of illegally dumped materials indicates that illegal dumping largely mimics the infrastructure gaps in the City, i.e. where there are no landfills or crushing operations (E. Abrahams pers. comm. 2016). Therefore, it is expected that development of processing infrastructure in these areas would capture the majority of the material dumped.

Challenges in applying builders' rubble in roads

The public sector representatives surveyed cited the general lack of quality control in the crushing industry as the main barrier to the use of builders' rubble in roads.

Many public sector entities are only willing to consider secondary materials once the specifications for road building aggregate are inclusive of secondary materials.

A section of the private sector surveyed, major construction companies, listed the refusal of the public sector to accept builders' rubble as the main stumbling block to the development of the market. Another factor cited was the need to have a waste licence to process builders' rubble as plants will trigger the thresholds for waste management activities associated with the Waste Act (National Environmental Management: Waste Act (NEM:WA) No 58 of 2008).

From a private sector perspective, the lack of infrastructure is limiting feedstock supply. As a result, existing crushers and potential new players are looking towards expanding the crushing capacity in the CCT as noted above.

DEVELOPING THE MARKET IN BUILDERS' RUBBLE

Possible interventions to capitalise on opportunities in the builders' rubble market

Both public and private sector involvement is needed in order to take advantage of the opportunities in the secondary materials market in builders' rubble (Figure 3).

In order to stimulate the supply of builders' rubble, separation at source for good quality feedstock is required from the private sector, while the public sector could support the market by requiring diversion targets and reporting on builders' rubble diversion from landfill using by-laws, as well as municipal procurement policies allowing for and favouring the use of secondary materials.

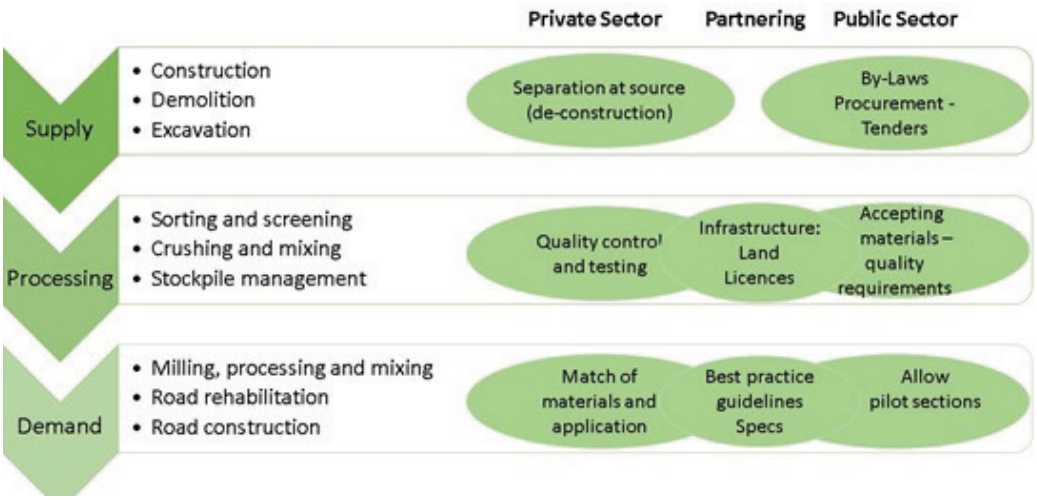


FIGURE 3 Primary points of intervention along the builders' rubble value chain for the public and private sectors

There is an urgent need for quality control and governance of crushing operations to produce materials of verified quality to satisfy end users for the high value applications (such as foundations and subbase in roads). A market-led approach is preferable as the quality control guidelines are more likely to be specifically suited to the industry and to gain industry buy-in, than regulatory intervention in industrial operations. The public sector role would be to confirm acceptable quality criteria, and accept those materials meeting the criteria. There is great potential for partnering between public and private sectors in the setup of crushing operations, particularly in the supply of appropriately zoned and licensed land for crushing plants, such as landfill sites.

On the demand side, it is the responsibility of the private sector to correctly match material quality with application, adapting the road construction and rehabilitation approach according to the available materials. Public sector involvement in the development of best practice guidelines for the application of processed builders' rubble, as well as in authorising the laying of pilot sections, is vital.

Current work supporting market development – public sector

Within the public sector, the Department of Environmental Affairs and Development Planning, Western Cape (DEA&DP) has developed a model solid waste management by-law for application province-wide at the discretion of municipalities. The model by-law includes a requirement for Integrated Waste Management Plans (IWMPs) and requires waste minimisation for all construction and demolition activities.

CCT plans to strengthen the requirements for waste diversion from landfill through the application requirements for construction and demolition activities. All applications currently require an IWMP, with details of all streams to be generated with estimated volumes, as well as planned re-use, recycling or disposal of those streams. The City plans to supply a database of contacts for alternatives to landfill disposal. Reporting on IWMPs attached to each application is to be addressed, such that site sign off will be dependent on compliance to IWMP goals, as well as reporting on all waste streams.

Current work supporting market development – research, public and private sectors

Work in this space is focussing on fundamental leverage points to stimulate uptake of secondary materials:

- 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?'

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DEBRIS WALLS – LEARNINGS AND SUCCESSES OF ETHEKWINI MUNICIPALITY

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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.