

A BRIDGE MANAGEMENT SYSTEM FOR THE WESTERN CAPE PROVINCIAL GOVERNMENT, SOUTH AFRICA: IMPLEMENTATION AND UTILIZATION

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ABSTRACT

This paper describes the implementation and utilization of the bridge management system (BMS) of the Department of Transport and Public Works of the Western Cape Provincial Government. The implementation of the BMS as well as the visual assessment of all the structures on its road network was completed in 2003. The system consists of inventory, inspection, condition, budget and maintenance modules and is capable of utilizing visual assessment data to prioritize structure maintenance projects. The BMS database is integrated with the Department's Road Network Information System. The system's visual assessment methodology is based on a 4-point DERU (Degree, Extent, Relevancy and Urgency) system for rating observed defects. The Relevancy rating forces the bridge inspector to evaluate the consequences the defect in terms of the structure's serviceability and safety. Each of these parameters is combined in the condition module to determine a priority ranking of structures requiring repair.

During 2006 a bridge and culvert rehabilitation project was identified in the Eden District Municipality, utilizing the BMS for the first time in the validation of assessments and prioritizing of structures in terms of their maintenance needs in that particular region. The project, which included the rehabilitation of 65 structures, was awarded in September 2006 and completed in a period of 15 months. The paper discusses the implementation of the pilot project, lessons learned and proposed enhancements in terms of the BMS, structure visual assessments and the implementation of contracts.

INTRODUCTION

The Western Cape is one of the nine provinces in South Africa and the Roads Infrastructure Branch of the Provincial Government of the Western Cape (PGWC) Department of Transport & Public Works, is currently responsible for the management of 6 000 km of paved and 10 000 km of unpaved roads. These are basically all rural roads in the province that are not national routes, and include approximately 2 300 bridges and major culverts. Prior to 2000, a bridge database with limited inventory information on each bridge, a plan database consisting only of a listing of as-built drawings of each bridge and condition-based bridge inspection forms were used to manage the structures on provincial roads. This “system” did not produce meaningful results and thus there was no real management of bridge maintenance and rehabilitation.

The PGWC identified the need to acquire a management system to motivate for and allocate limited available funds to rehabilitation projects where most needed and to projects where the long-term benefit would be the most cost effective, i.e. to have a BMS in place in order to be able to identify projects in order of importance and also to maintain long-term bridge rehabilitation at an optimum level. It was imperative that the system generate credible information in the eyes of the decision-makers, thereby building confidence in the identification, prioritization and planning processes in order to prevent regress to traditional *ad hoc* and political decision-making processes. As in the case of most road authorities, bridge and road maintenance and rehabilitation are funded from the same budget and have to “compete” for funds.

In order to effectively integrate bridge rehabilitation with road rehabilitation (which normally occurs more frequently), it was important that the BMS be sufficiently reliable and effective for future integration with other management systems, such as the Pavement Management System and Road Maintenance Management System. A further requirement was that the system should be able to cater for other road structures such as culverts and retaining walls. A culvert module was thus developed and incorporated into the system. The BMS was required to make provision for structure *type* for the purpose of visual assessments and structure *classification*, in accordance with the PGWC definitions based on minimum span length and total structure length. Modules to accommodate retaining walls, sign gantries and minor culverts are in the process of being included in the system.

In 2000 the Provincial Government Western Cape adopted the STRUMAN Bridge Management System [1] developed by the Roads and Transport Division of the Council for Industrial and Scientific Research (CSIR Built Environment) together with Stewart Scott International. During the following 3 years, all 2 300 bridges and major culverts on the provincial road network were inspected and the data captured into the Bridge Management System.

During the past few decades, little attention has been given to the overall condition of structures in general, and many of the bridge rehabilitation projects that were commissioned were done on an *ad hoc* basis. Using the BMS, the Design Directorate now proposes a program of rehabilitation of all bridges and major culverts in the province that are in need of remedial work and/or safety-related improvements.

BACKGROUND

Description of the BMS and modules

During the first phase of the project, the inventory and inspection modules were customized to meet the needs of the Department, which included the development of a culvert module and the integration of the BMS database with the Road Network Information System (RNIS). A map module front end was also developed and integrated with the other BMS modules for graphical viewing of the structure data. This was based on shape files exported from the Department’s Geographical Information System (GIS). The system is currently being updated to include access to bridge and culvert drawings in electronic format. The BMS has also been made accessible to regional offices and other authorized users via the internet.

As in the case of most bridge management systems, the STRUMAN BMS consists of an Inventory module, Inspection module, Condition module and Budget module. Its main distinction is perhaps in the Inspection module where the focus is on the observed defects of the various structure elements rather than the overall condition of each element. The PGWC's system therefore basically consists of the following:

Inventory Module

This is the basic module of a BMS and consists of detailed inventory data for bridges and culverts. The original inventory module was customized and expanded to meet the requirements of the PGWC. The main sections are as follows:

- Location details
- Contract details
- Structural features
- Design characteristics
- Hydraulic data
- Dimensions & geometry
- Services details
- Road configurations & traffic volumes
- Archive details – electronic linking of drawings for each rehabilitation project
- Rehabilitation history – information and photo links for each rehabilitation
- Factors influencing field inspection
- Inventory photos – photographic history of structure

Inspection Module

This module contains the detailed inspection data for each structure. The main sections are:

- Inspection heading & summary
- Ratings
- Remedial work activities
- Inspection photos – photos of all observed defects

Condition Module

Bridges and culverts are prioritized according to pre-set parameters. In the Condition Module structures are prioritized in order of the need for repair/rehabilitation. All structure items have adjustable weighting factors built into the prioritization algorithm so that important items such as abutments, piers and decks (in the case of bridges) that have defects with a high degree (D) rating combined with a high relevancy (R) rating have a greater influence on the Priority Index (PI) of a structure than other minor items such as parapets, deck joints and bearings. The Condition Index (CI) is used to rank the structures in terms of overall condition as opposed to the need for receiving maintenance. The Functional Index (FI) is combined with the Priority Index to take into account the strategic importance of the structure and/or route on which it is located. The Overall Priority Index (OPI) is a weighted combination of the PI and FI.

Budget Module

The pre-defined remedial work activities that are utilized during the visual assessments for identifying required repairs to defects have associated unit costs. These costs are used in the budget module to determine estimated repair costs for individual structures. Optimization is done using the relevancy/cost ratio per defect and budget limits per year. Repairs are allocated to the 'Current year', 'Year 2 – 3' or 'Year 5 – 10' or 'Routine' categories based on the urgency rating (U). In the case of

structures that have been identified for repair, either selected or all repair items for these structures are allocated to the 'Current year' and the budget is re-optimized.

Structure Inspection rating methodology

The BMS utilizes a defects-based rating system (DERU) whereby each defect of a structure element is rated according to its degree (D), extent (E), and relevancy (R). An urgency (U) rating is also given to indicate the perceived urgency of the proposed remedial activity. Only the worst defect (highest relevancy or highest degree for the same relevancy) on each item or sub-item is rated, but each defect is assigned a remedial work activity with an urgency rating.

Each of the DER ratings is rated on a scale of 1 to 4 as follows:

- D = Degree of severity of defect (1 = minor to 4 = severe; 0 = no defect)
- E = Extent of defect on bridge element (1 = local to 4 = general)
- R = Relevancy of defect to serviceability of bridge element (1 = minimum to 4 = critical)

The Relevancy rating forces the bridge inspector to evaluate the consequences of the defect in terms of the bridge serviceability and safety. Each of these parameters is combined in the condition module to determine a priority index for each structure. A remedial worksheet is used during structure inspections to summarise the items requiring repair. In the case of an element that does not exist or is missing (e.g. guardrails, invert slab), both D and E are rated as 4. The bridge inspector is therefore not required to rate the condition of each structure item, but only the defects observed on each item. A visual assessment manual was also developed to improve uniformity of the inspector rating standards.

OUTPUT OF THE BMS ASSESSMENTS

Assessments carried out from 2001 to 2003

During a period of approximately two years (2001 to 2003), 15 bridge inspectors (most of them based in the Cape Town area) were used to inspect the 2 300 structures (850 bridges and 1450 major culverts) in the province's five District Municipality regions and the Cape Town Unicity (excluding structures that fall under the jurisdiction of the City of Cape Town). The locations of all these structures are shown in Figure 1. As many as possible of the locally-based bridge engineers were given the opportunity to engage in bridge inspections for the PGWC.

The inspectors were not only required to carry out principal inspections, but also to obtain all the relevant inventory information of each structure – either from as-built design drawings, if available, or from measurements on site if drawings were not available. Inspectors were required to record all visual defects – not because it is the intention that all defects will eventually be repaired, but to have a reference base for all the defects. This information, together with the inventory and inspection photographs, was then captured by the inspector into the BMS – each bridge inspector received a copy of the BMS inventory and inspection modules for this purpose. On completion, the electronic data was submitted to the PGWC for incorporation into the main database.

Although significant emphasis was placed on quality and uniformity during the compulsory BMS training course and the briefing sessions, the recorded inventory information and especially inspection ratings were not always of the required consistency necessary to obtain reasonably accurate prioritization of rehabilitation needs. The reason for this inconsistency could be attributed to the fact that not all the inspectors had similar previous bridge design and rehabilitation experience, and 15 bridge inspectors are perhaps too many to achieve a satisfactory degree of consistency.

This was the first round of inspections with the STRUMAN system and thus electronic comparisons with previous inspections were not possible. However, for a certain number of structures where the conditions of the structures were well known, the results obtained from the BMS were verified. By observing the defects shown on the inspection photos for these structures and through

verification inspections of the structures, the BMS prioritization of these structures (relative to each other) could be assessed. By being able to calibrate various system and weighting factors in the condition module, it was possible to optimize the BMS output to produce results that were considered to be accurate and realistic as far as these structures were concerned. The most important aspect was to verify that the structures at the top of the priority list were in fact those most in need of repair i.e. to verify the calibration of the prioritization algorithm.

At this stage it is envisaged that principal (lower cost) inspections will be undertaken every 5 to 7 years as well as on completion of the repair and rehabilitation of structures. The inspections are only visual, but they are the BMS's primary data source for determining the structure's condition, and diagnostic testing is generally only used for detailed project level inspections after identification of repair projects.

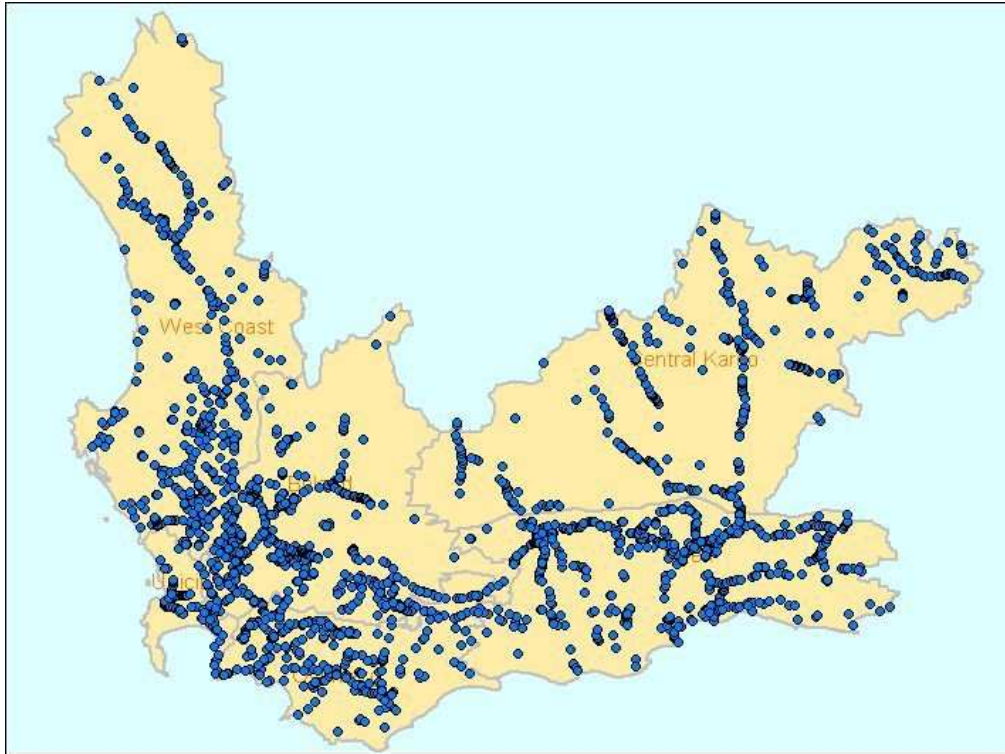


Figure 1 Map showing all structures in the BMS database

Prioritization of structures

Prioritization of all the inspected structures on all the roads (Trunk-, Main- & Divisional Roads) in the province was done. All structures with a Priority Index value below 60 were identified as requiring attention and displayed in the Map module. The number of structures on the Provincial road network that met this criterion is about 175. Areas (with a radius of approximately 50 km) were identified where the highest concentration of structures in the above category were situated. Each of these areas was earmarked as a project and all the structures in these areas were identified to be included in the project.

For sound economic reasons (e.g. cost of site establishment) it is beneficial not only to rehabilitate the high priority (worst condition) structures on the higher road classes – which were evidently scattered over the whole province – but also to include structures situated on lower road classes and with a lower priority (but with high benefit-cost rehabilitation needs) that are in close proximity to the identified project areas. The aim is therefore to group bridge rehabilitation into

projects of suitable size that can be awarded to one construction firm. The final selection of structure maintenance projects also takes into account planned road maintenance projects.

Identified repair work

The results of the inspections highlighted a number of common problems throughout the province. However, as expected, a number of these defects were found to be more pronounced in coastal and high rainfall areas. Rehabilitation needs included the following:

- Routine maintenance repairs
 - Approach embankment and scour protection works
 - Approach and deck re-surfacing
 - Cleaning of waterways and siltation inside culverts
 - Removal of vegetation from sidewalks and deck joints
- Road safety improvements
 - Installation, extension and attachment of guardrails at bridge abutments
 - Warning signage
 - Reconstruction/repair of bridge parapets and handrails
- General serviceability repairs & protection
 - Repair of spalled concrete
 - Replacement of bearings
 - Replacement of deck joints
 - Crack sealing and durability enhancement coatings

PROJECT IMPLEMENTATION IN SOUTH WESTERN REGION

Overview

One of the regions with a high concentration of structures in a poor condition was the Eden District Municipality area (south western region of the province), which had about 50 structures with a priority index less than 60, as well as many other structures requiring lesser rehabilitation and safety improvements.

An area (with a radius of approximately 50 km) within the Eden region were identified where the highest concentration of structures in the above category were situated. The BKS/GOBA Joint Venture was appointed by the Department of Transport and Public Works, Provincial Administration Western Cape: Road Infrastructure Branch in January 2005 to undertake detail design, tender documentation and site supervision of the rehabilitation of 65 bridges and major culverts in the Calitzdorp, Oudtshoorn and De Rust area. The locations of these structures are shown in Figure 2.

The Report Stage of this appointment was completed in May 2004 and the Consultant was instructed to proceed with a Detail Assessment Report based on the recommendations in this report. This process consisted inter-alia of further detail site investigations related to concrete condition and asphalt surfacing.

A final scope of work was decided on based on the findings of these investigations as well as further presentations to the Branch officials. On completion of the Detail Assessment a detail cost estimate of the works was submitted (Construction Cost Option A). This cost estimate was significantly higher than that which was originally anticipated in the Report Stage. The main factors contributing to the additional costs related to the following items, which were identified during the detail site investigations:

- Extent of the asphalt on the bridge decks and approaches that was to be replaced (this was mainly due to provision for asphalt on all bridges located on gravel surfaced roads as well as the length of the approaches that was resurfaced);
- Upgrading of drainage elements to bridge approaches;

- Upgrading of approach guardrails and other road safety features;
- Extent and type of the coatings to concrete surfaces.

Based on this estimate, budgetary provisions and the fact that this contract was mainly intended to address bridge remedial measures only, it was subsequently decided to re-assess the scope of work and omit all the road works items that were not considered to be essential for the safe functional operation of the bridges and which could be done during routine maintenance work or other road works contracts at a later stage. The scope of work was also discussed and evaluated in detail on site and at various meetings with the Chief Engineer Structures as well as a representative of the District Roads Engineer (Construction Cost Option B).

After these additional investigations all the findings were consolidated in a Detail Assessment Report to provide final recommendations and costs, which was completed in January 2006.

Based on these recommendations a contract was advertised during 2006 and construction commenced in September 2006. The construction of the above work was completed in January 2008.



Figure 2 Map showing all structures included in the rehabilitation project

Key conclusions from Detail Assessment Report

The following key conclusions were made in this report:

- The condition of the concrete of the structures was generally good although it was considered advisable in some instances to perform limited repairs and apply protective coatings;
- The structures were generally in a fair to good structural condition except for the specific structural problems, which need to be addressed to ensure the safe functional operation of the structures;
- Although most of the asphalt over the bridge decks appeared old with excessive voids and poor compaction, most surfaces were still serviceable. There were however, reservations

regarding the remaining life expectancy of the asphalt and it was recommended that the asphalt be replaced on all the structures designated for new joints;

- The waterways and approaches were in a reasonable condition requiring attention in some instances mostly to limit further scour damage and blockage of drainage openings. Drainage also required attention;
- The majority of bridge joints was in a fair to poor condition and did not satisfy the functional requirements for which they were intended. Various remedial options were proposed;
- There were a number of minor defects associated with the kerbs and sidewalks;
- Although there was a general problem with missing or vandalized aluminium handrails, the concrete parapets were in a fair condition with a general problem of reinforcement corrosion. New precast reinforced concrete railings were proposed in instances where vandalism had occurred;
- Bearings were generally in a good condition;
- Selected road safety elements were also identified for repair;
- No significant impact on road and rail traffic was expected;
- Environmental issues were to be addressed by means of an Environmental Management Plan;
- Preferential Procurement targeted procurement goals were identified considering the capacity of the local community and also the nature of the construction.

Recommended Rehabilitation Strategies

Two rehabilitation strategies, as noted above, were provided with the following main provisions:

- **Construction Cost Option A:** This strategy recommends that, in addition to the proposed bridge remedial activities, all the desirable road works be carried out in the vicinity of the structures. In this option, it is important to note that where asphaltic plug-type joints were proposed, provision was made to replace the asphalt surfacing to ensure that it would have a service life similar to that of the bridge joints as this would ensure an optimum use of resources. Extensive upgrading of approach guardrails and drainage elements were also proposed in this option. The viewpoint was also taken that for the gravel roads, new asphalt surfacing would be provided over the exposed concrete surfaces of the bridge decks.
- **Construction Cost Option B:** This strategy addresses, in addition to the proposed bridge remedial activities, the items that relate to the bridge and the approaches on the basis that the structures are to be repaired to a safe functional condition; additional interventions that were identified would be done under routine road maintenance contracts at a later stage. In this option asphalt surfacing was only replaced where it was in need of immediate repair and where it could affect the integrity of the structure, or where it was essential for joint replacement activities. Ancillary elements that impacted significantly on road safety were also addressed in this option, but upgrading of road elements was minimized.

The recommendation to proceed with the second option was finally accepted for implementation.

Summary of planned and actual costs

Project cost estimates during the planning stages for the above options are summarized in Table 1 with the final construction costs, which are based on moderated rates as received from the contractors. These amounts include pro-rata allowance for Preliminary & General cost items. The following observations are made with reference to these costs:

- A major part of the cost related to ancillary items such as traffic accommodation and road

works (drainage, asphalt surfacing, signage and guardrails). The repairs to these elements were however considered an essential functional remedial action.

- A comparison of the estimated to the final cost indicated a reasonable correlation and cost increases were generally attributed to the remoteness of the site, spread out nature of the work and oversupply of work in the industry, except for the components as noted below.
- The most significant cost increase (Estimate vs. Final) was primarily attributed to the asphalt resurfacing of the bridge decks. This activity was recommended to ensure that the roadway and joints (after repairs) would have a similar life expectancy. The tendered values were however found to be significantly higher than the estimate as provided in Cost Option B above. The main contributing factor related to the over subscription of construction work in the industry, increased bitumen costs, as well as the premium that has to be paid for working with small quantities on remote sites.
- Another cost increase related to the repairs to the parapets and handrails. In these components it was found that, after cleaning and preparation, the concrete condition was in general worse than anticipated, which resulted in additional costs with respect to repairs and coatings.
- Scour protection works were also more costly due to limited sources of rock in the area.

Table 1 Comparison of planned and actual costs

Ref.	Description	Option 1 Amount (R 1000 's)	Option 2 Amount (R 1000 's)	Final Amount (R 1000 's)	% of total in Final Amount	% var. Final vs. Opt. 2
A1	Traffic Accommodation	R 2 809	R 2 812	R 2 473	7.7 %	- 12.1 %
A2	Road works	R 16 589	R 7 484	R 13 731	42.5 %	+ 83.5 %
	Parapets, handrails	R 6 599	R 5 745	R 5 906	18.3 %	+ 2.8 %
	Joints	R 2 052	R 2 197	R 2 166	6.7 %	- 1.4 %
	Concrete & structural	R 6 226	R 5 996	R 5 433	16.8 %	- 9.4 %
	Scour & miscellaneous	R 2 510	R 2 513	R 2 588	8.0 %	+ 3.0 %
A3	Structures subtotal	R 17 387	R 16 451	R 16 093	49.8 %	+ 12.5 %
	Construction cost subtotal (A1+A2+A3)	R 36 785	R 26 747	R 32 297	100.0 %	+ 20.8 %

Key conclusions from the repair contract

In addition to the above the following conclusions were made as a result of the experience attained during the repair contract:

- Access and traffic accommodation requirements have significant cost implications;
- Spall repair measuring and structuring of payment items require careful consideration as quantities could vary significantly once breakouts proceed on site. The location and number of breakouts also have a significant impact on cost and time on a repair contract.;
- Geographical location and the number of structures in a contract have significant management

and cost implications;

- On completion of a rehabilitation project, the recording and inclusion of details of specific repair and maintenance interventions on structures in the BMS is essential. This should include a comprehensive record of costs, product specifications, installation dates, product guarantees as well as requirements for future maintenance interventions;
- The necessity of combining ancillary repairs to structure approaches and road surfacing must be carefully assessed with structural repair contracts and should preferably form part of road maintenance activities. This could also include bridge joint repairs which are generally performed by specialist subcontractors.

EVALUATION OF THE BMS DATA IN TERMS OF THE PROJECT

Reprioritization

After completion of the repair works, all 65 of the structures were re-inspected using the BMS assessment approach and reprioritized as part of the main database. As far as the Priority Rankings are concerned, more than 80% of these structures are now in the lower 60% of the priority list. The structures that were originally in the Priority Index < 60 category required structural repairs; all of these structures are now in the lower 60% of the priority list. As far as the Condition Rankings are concerned, all of the 65 repaired structures are in the lower 50% of the priority list. Table 2 shows the revised Priority and Condition Indices and rankings of 13 structures based on the visual assessment data after the completion of the repair works. Figure 3 shows examples of structures where structural repairs were performed

Table 2 List of repaired structures where structural repairs were performed

Structure Name	PI	PI Rank	CI	CI Rank	Repairs
Stolsvlakte Road/Rail	100	828	93.4	1805	Provide new RC wingwalls
Cango River	99.5	780	96.7	2050	Provide scour protection works
Le Roux Station Road/Rail	99.1	734	94.5	1901	Repair major spalling and cracking
Meule River	100	829	100	2226	Provide scour protection works
Olifants River (Oudtshoorn)	100	856	99.3	2209	Replace bridge handrails and repair major spalling
Grobbelaars River	100	833	100	2227	Underpin pier foundation and provide scour protection
Vlakteplaas Road/Rail	100	845	100	2230	Provide gabion wall to support approach embankment
Olifants River (Volmoed)	99.6	784	96.7	2051	Reconstruct new RC elements to provide structural capacity
Vlei River	100	820	98.8	2183	Repair major spalling on beams and apply surface protection
Touws River	99.9	809	99.3	2207	Provide gabion and rip rap scour protection
Culvert on TR 31/5	100	1815	92.24	1711	Seal inject cracks and construct new pier to strengthen element
Culvert on TR 31/6	100	1861	93.6	1822	Provide epoxy bonded plates to strengthen element
Culvert on TR 33/2	100	1956	100	2304	Provide culvert invert slab as scour protection



a) Structural repairs to culvert



b) Replaced bridge handrails



c) Repairs to bridge abutment



d) Repairs to culvert deck soffit

Figure 3 Examples of structural repairs a) repairs to culvert wing walls, abutment walls as well as deck slab, b) replacement of existing steel bridge handrails with precast concrete rails, c) repairs to bridge abutment by means of externally reinforced concrete elements, d) repairs to culvert deck soffit by means of externally bonded steel plates

BMS results compared with project outcomes: evaluation and recommendations

The use of the 2003 BMS assessment results for defining the scope of the pilot bridge and culvert rehabilitation project in the Eden region, experiences during the contract period and the reassessment of the structures after the completion of the repair project give rise to the following observations (*Specific recommendations are noted in italics*):

- In a number of instances significant additional repairs were carried out that were not evident from the original inspection data. These included major structural repairs, coatings to concrete elements and joint installation items. This can primarily be attributed to the fact that certain defects were not readily visible by visual inspections and could only be identified by means of a detailed structural assessment, diagnostic investigations (e.g. testing of core samples) or exposure of concrete surfaces by removal of paint or asphalt surfacing during construction. Joint repairs were also considered important to ensure long term serviceability of the roadway and were included as part of the works but were not always considered a defect by the

inspectors. *The recording of these activities cannot be readily tracked from the BMS as some repair items were identified in the Detail Assessment Report stage. Consideration should be given to include a pre-repair Principle Inspection in the BMS.*

- Major repairs were performed on 20 of the structures. These included severe erosion damage repair by means of concrete underpinning and gabion or rip-rap protection, concrete deterioration repair by means of patching and coatings, structural repairs using steel plates, new reinforced concrete elements and the complete replacement of a structure. *Generic BMS repair activities should be updated to allow for major repair options and inspectors should be advised to take a conservative approach. For example, if cracking is suspected to be of a structural deficiency origin, a major structural repair item should rather be noted. A clear distinction should also be made between normal maintenance type activities (e.g. painting, joint repairs and bush clearing) and once-off repair activities (e.g. major structural repairs and scour repairs) in the BMS. This would enable asset managers to plan and manage their budgets and program maintenance activities efficiently.*
- In some instances, defects that were not repaired under the repair contract were kept on record. These items were either not serious enough to warrant the associated repair costs or the ratings were amended as a result of the findings in the Detail Assessment Stage to a non-critical status. Examples of this included non-structural cracking and bearing replacement items. It was however considered important to retain a record of these defects for future reference purposes. *Consideration should be given to include such items in the inventory module as well.*
- Additional defects were noted in isolated instances mainly for monitoring purposes. For example, observation of scour risk at one of the structures was noted. The monitoring of certain aspects is considered important and suitable mechanisms are required to ensure this. These include waterway scour and debris buildup as well as structural cracking in some instances. Related defects have been retained in the inspection listing with suitable monitoring frequencies to ensure this, even if repairs have been done to these elements. *Monitoring of specific items should also be communicated to the local road authorities and where specific actions are required (e.g. cleaning of vegetation in bridge openings), these should followed up. Ideally this should be done by means of an integrated Bridge Management System which is actively managed on a routine basis.*
- The inventory module has been provided with specific data fields for drawings and photos of repairs and retrofitting which has been updated. In addition standard inventory photos, which show the structure and waterway, are updated to provide a historic record and are particularly useful to assess riverbed changes and to provide a record of upgrading of ancillary elements such as repairs to bridge railings. *Key inventory photos such as views of watercourses and safety features should be taken at regular intervals as these may be useful in analyzing flood behavior or accident cases. This will also assist in the monitoring and control of maintenance activities.*
- Road maintenance activities can impact significantly on the intended repair strategy and close interaction with the responsible parties is important. Integration at critical levels of Pavement and Bridge Management Systems is important. *Joint replacement and bridge surfacing interventions as well as road safety are examples of this.*
- Substandard geometric elements such as bridge widths are recorded in the Inventory but are not flagged clearly. *Geometric upgrading must be flagged to ensure consideration for future upgrades.*
- This contract provides the ideal opportunity to update unit costs provided in the BMS to facilitate more effective usage of the budget module. These should be updated regularly based on the most recent repair contracts. *Budget module costs should be calibrated to allow for area specific properties, adjustments to isolated repair interventions and contingency factors.*

- A detail comparison of asset value, maintenance intervention cost and associated benefits did not form part of this study but would be a useful addition. *Consideration should be given to the development a bridge specific Cost/Benefit module, which should include accident and vehicle operating costs.*

CONCLUSIONS

The development and implementation of the STRUMAN BMS for the Western Cape Provincial Government has led to a significant improvement in the management of structures on the provincial road network. All 2 300 bridges and major culverts were visually assessed during the period 2001 to 2003 using a defects-based system. The 175 worst structures were identified for inclusion in a bridge repair and rehabilitation program. Other structures with a lower priority will also be included in the rehab projects due to their location in relation to the high priority structures. A pilot project in the Eden District Municipality has been implemented after which projects for the repair of the remaining high priority structures will be carried out. The project implementation provided a number of guidelines that should be taken into consideration in the enhancement of the BMS, structure inspection projects and implementation contracts. These relate mainly to recording and tracking of defects as well as costing and grouping of repair activities in contracts. The pilot project has thus highlighted a number of areas for the improvement of the BMS and for more effective management of the maintenance and monitoring of structures.

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