DEVELOPMENT OF A COMPUTERISED BRIDGE INVENTORY FOR A STATE ROAD AUTHORITY

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The Highways Department of South Australia is currently developing a computerised bridge inventory system which will be used by the Bridge Inspection Section to rationalise the approach to the inspection of bridges. It will also be used by the Planning Branch to provide a basis for economic comparison of alternatives in the replacement and strengthening of bridges, by the Construction Branch for the rational allocation of maintenance funds and to provide information to the National Association of Australian State Road Authorities (NAASRA) proposed data bank. One of the most important functions of a bridge inventory is to provide a complete and accurate record of each bridge on a highway system. Maintenance of bridges requires complete records in usable form including history of the structure, all repairs, widening, strengthening or reconstruction, or other actions which have been taken, subsequent to inspections. Information should be easily accessible and readily updated; factors which today are made possible by computerisation. However, conflicting requirements must be dealt with. On the one hand data handling facilities should be large enough to provide sufficient information for managing inspection, maintenance but flexible enough to be used for planning functions both at the regional and national level; yet the system developed should not become cumbersome and difficult to use.

The purpose of this paper is to explain the experience that the Highways Department of South Australia has had in relation to the design, implementation and operation of a bridge inventory system.

With the exception of a relatively low mountain range, 500 kilometres long by 80 kilometres wide, extending through the centre of South Australia, most of the settled areas of the State consist of flat alluvial plains crossed by wide shallow creeks and rivers. South Australia has a low average rainfall and is the driest State in one of the driest continents in the world, making it devoid of extensive natural forests thus forcing early bridge builders to use durable but relatively expensive concrete, steel and masonry as raw materials. There is an almost total absence of timber structures; most of those built have long since succumbed to the ravages of fire, termites or dry rot. These environmental conditions suited bridges of beam and slab design of moderate span lengths - usually less than 30 metres

South Australia was founded in 1836 and, consequently, there are few bridges of historic interest. Some of the more interesting structures are wrought iron bridges fully imported from the United Kingdom and erected on site. This practice lasted until the early 1900's when local technical expertise reached a sufficiently high level for these types of bridges to be built using local resources.

Design Loads for Bridges

Although State Road Authorities were formed in each of the Australian States during the late 1920's no comprehensive bridge design standard or codes were used in Australia until 1947. (1) Until that time design loads varied considerably between the States and were generally comparable to the HS10 to about HS15. However, since 1947 all Australian States adopted the HS20 loading or heavier, the latter being restricted to particular routes. Increased pressure from the Transport Industry to raise both legal weight limits and those allowed under permit led to a more substantial design loading being adopted in 1977. (2) This loading retains the concept of the AASHTO type vehicle but is approximately 33 percent heavier. Therefore, a situation exists where the design loading for bridges generally decreases with increasing age. In South Australia approximately 60% of bridges have design loadings less than HS20 standard.

Requirements of a Bridge Inventory System

Bridges represent a sizeable capital outlay requiring regular and rational inspections to preserve the initial investment. The main purpose of a bridge inventory is to catalogue all the information gathered from inspections and other sources so that it may be used for:-

. Setting priorities for the maintenance of bridges.

. Setting priorities for the strengthening or replacement of bridges.

. Planning for a rational bridge inspection programme.

. Route selection for vehicles carrying abnormal loads.

. National data banks for planning purposes on a national scale.

Records must be in usable form and should include information on the history of the structure, all repairs, widening, strengthening or other actions which have been taken subsequent to inspections. Information should be readily accessible and capable of easy updating.

However, the problem of conflicting requirements must be solved. On the one hand the data stored must be comprehensive enough to provide information for the decision making process on engineering, economic and planning aspects, but flexible enough to meet changing conditions and requirements, yet the system used should not be cumbersome and difficult to use.

Several systems have been used for the collection, storage and retrieval of bridge inventory data ranging from relatively simple card systems used in earlier times to extensive computerised data banks made possible by modern technology. A perusal of systems used by numerous authorities reveal that in many cases a considerable effort is expended to collect very detailed information about each bridge in a region, presumably because electronic data processing facilities have made it possible to store and process such information. (3, 4) This leads to a large data bank which contains much irrelevant information, is difficult to manipulate and it is hard to see how such information can be used. An analogous situation is the spare room or attic where items that "may come in handy one day" are kept. The philosophy adopted was to begin with a simple system and aim for an inventory file which would be sufficiently flexible to allow for the later integration of additional information to meet new needs which may arise.

Development of the Bridge Inventory System

Bridges in this State were inspected only spasmodically, usually resulting from reports of signs of distress, until 1972 when Departmental policy was formulated requiring the regular inspection of all bridges within its jurisdiction. A small team of professional engineers and technicians was formed to undertake this task.

The road network in the State is maintained on a two tier system. The main arterial network is administered by the Highways Department through District Offices. All other roads are maintained by local government authorities (County Councils) and financed partly from local taxes and subsidised from Government grants through the Highways Department. The first priority was to register all bridges maintained by the Department.

Initially, a manual reporting system was used but the files generated were soon found to occupy a large amount of space, were awkward to access and difficult to retrieve information from, particularly in regard to the planning functions and re-inspection schedules. During this period computer facilities were expanded, more sophisticated software became available and the advantages of computerising inspection records became more apparent. A Cyber 73 computer with online facilities including visual display units had become available to the Department in 1973 and a decision was made to use these facilities for compilation of the bridge inventory system.

Development of a computerised Bridge Inventory began late in 1976 and was initially aimed at converting and updating about 1200 records of maintained bridges filed in the manual recording system. A relatively simple computerised catalogue system, based on files of punched cards, with three 80 column cards storing the data was used. Using software packages only the system was used to manipulate basic data (mainly concerning bridge identification, location, dimensions, load rating and other administrative data). Development of the system was gradual and generally proceeded from this simple system to a stage where, from the knowledge and experience gained, objectives became more clearly defined and a consolidation of previous work became necessary. During this phase a great deal of consideration was given to deciding on the amount and type of information which should be retained in the inventory, keeping in mind its source, form and the use to which it was likely to be put, together with the most suitable system to maintain it within the constraints of the available computer facilities.

Description of the System

A Control Data Corporation (CDC) data base management system (DMS-170) was available and judged to be appropriate for the implementation of a Bridge Inventory. This system maintains the inventory on mass storage devices which may be accessed either by DMS-170 software or by application programs prepared by or for the user, or a Data Base Administrator who is responsible for preparing and managing the data base. Briefly, the system is a software package based on the concept of a centrally controlled data base, independent of the applications accessing it. Inherent to the system are the means to:-

. Create a common-user data base in which files can be used jointly or joined in relationships.

. Provide and maintain a variety of data on structures for specific users.

. Control, monitor and interpret requests from application programs to access one file or several related files at a time.

The system is being used to form an interelated data bank for the whole Department of which the Bridge Inventory forms one segment.

Records relating to bridge structures and retained on computer files consist of:-

. Bridge Inventory File detailing the location, principal dimensions, material and rating of each structure.

. Inspection Ratings File storing the rating of each structural element. This file also includes in code form necessary repairs or other required action, posting of load limits and target dates for remedial action and reinspection.

. Comments File storing comments qualifying the ratings, other general comments and recommendations.

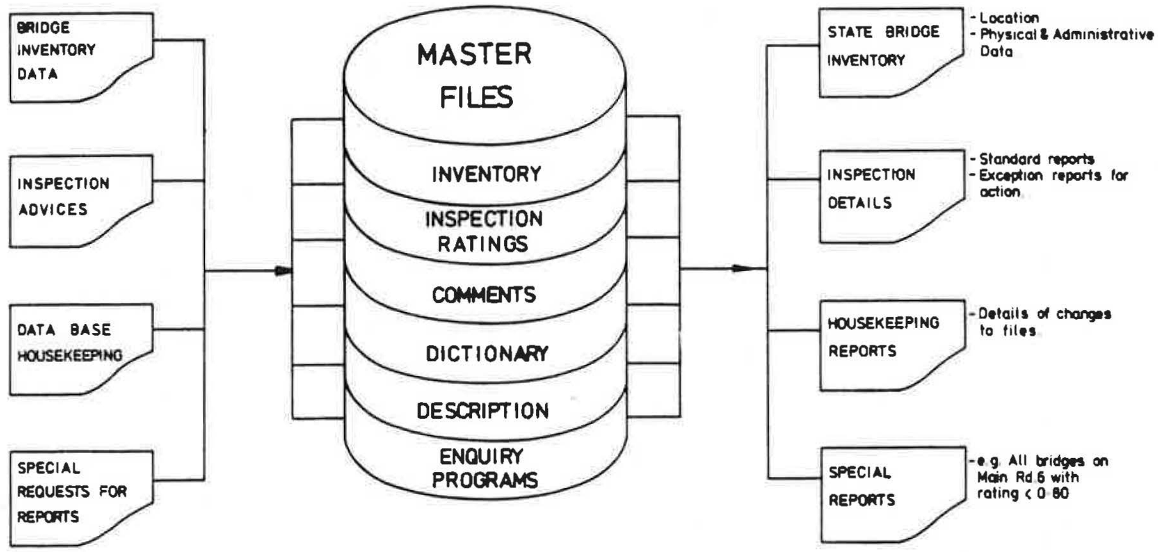
The Inspection Rating and Comments Files contain data from all inspections of each bridge thus providing a complete historical inspection record. Other files required for operating the system are:-

. Dictionary File containing information common to other files e.g. titles of main roads, map names, district areas, report headings, etc.

. Description File containing information peculiar to particular bridges, e.g. river names, local bridge titles.

. Enquiry Program File storing each application program for future use.

Figure 1. Schematic diagram of the Bridge Inventory System



The system has inbuilt protection to prevent inadvertant corruption of existing files but for correction of data the Data Base Housekeeping routine, with its own validation procedures is used. Although the Bridge Inventory system will ultimately be a complete Data Base it is being developed on traditional lines using batch processing to facilitate the transition, from the user's view-point, from the existing system to the new. The interaction between the various files and relationship between the input of data and generation of reports is schematically shown in Figure 1.

Information concerning existing bridges can be broadly divided into two areas:-

1. Information obtained from original plans, design calculations and other records.
2. Information gained from detailed inspections of structures.

Standard coding sheets have been designed and consist of two types viz., a Bridge Inventory sheet and Field Inspection sheets, which are shown in Figures 2 to 4. The Bridge Inventory file includes information describing the structure in terms of location, reference number, principal dimensions and other administrative data. The Field Inspection sheets have been specifically designed for use by experienced engineers familiar with bridge design and likely problem areas. All sheets have been designed so that each inspection is carried out thoroughly and is supported by careful observation and appropriate comments without resorting to copious field notes. These comments are linked with the rating of each element of the bridge and recorded for every inspection carried out. The rating is the subjective evaluation by the engineer of the condition of the particular structural element and is given a value between 1 and 5 (chosen as being a practical range without attempting to be too definitive). The Field Inspection report is finalised by completion of the Recommendation Sheet where each recommendation will be coded for follow-up and costed in man-days work at the site and an estimated cost where warranted.

On completion of a bridge inspection a standardised computer output report is forwarded to the relevant District Engineer who is responsible for the construction and maintenance of Departmentally maintained roads and bridges in that District. Format of the computer print-out is:-

Fixed Data:
Location of structure; type, dimensions, material.

Inspection Report:
Ratings and comments from inspection, Live Load capacity rating.

Recommendations:
Load Limit; Monitoring required by District Staff; Repairs required - Desirable (within 3 years), Necessary (within 1 year), Urgent (within 3 months).

It is envisaged that the standard report will be sufficient for the majority of bridges inspected. However, in special circumstances, the report would be supported by plans for remedial work or a more detailed report.

In the near future it is intended to extend the reporting of the field inspection reports to include a "Repairs Action Report" which will be compiled by the District Staff, returned to the Bridge Inspection Group, coded and included in the computer file for future reference and easy retrieval. The inspection report outlined above is intended to maximise the efforts of all concerned in the process, in so far as record keeping and information processing is concerned.

Data: Too Much or Not Enough?

Careful consideration was given to deciding on the level of information to be retained. The prime objective being to store only that data which was likely to be used. For instance, the volume of traffic using particular structures may be useful in certain circumstances, but in this State where traffic volumes are relatively low it is not an

Figure 2. Bridge Inventory Coding Sheet

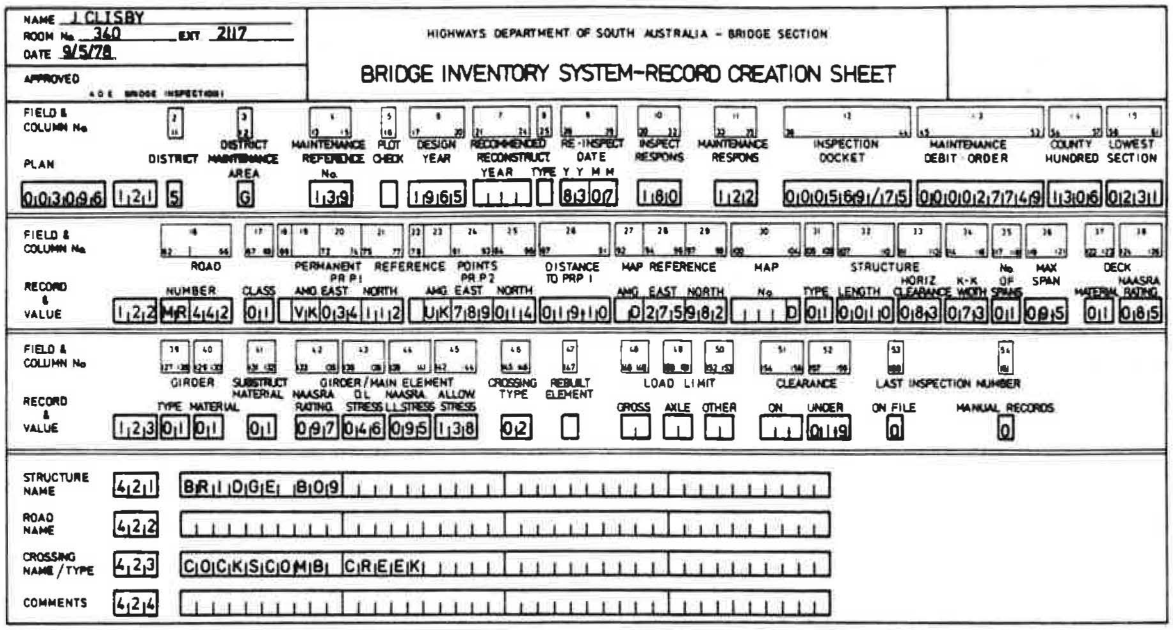


Figure 3. Field Inspection Coding Sheets

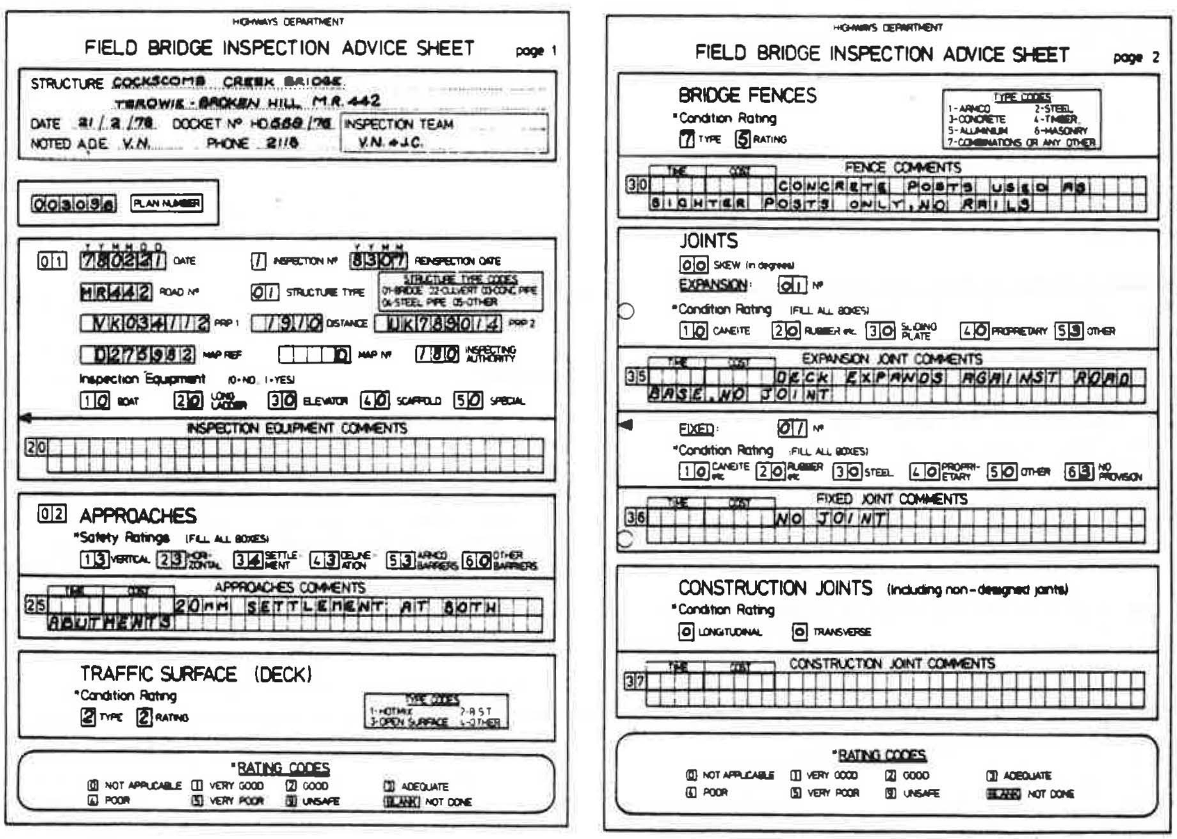


Figure 4. Field Inspection Coding Sheets

HIGHWAYS DEPARTMENT

FIELD BRIDGE INSPECTION ADVICE SHEET page 3

BEARINGS

EXPANSION: 04 Nº

*Condition Rating (FILL ALL BOXES)

13 SHEET LEAD | 20 STEEL PLATE | 30 STEEL ROLLER | 40 ELASTOMERIC | 50 OTHER (inc proprietary)

TIME | COST | EXPANSION BEARINGS COMMENTS

40 SHEET LEAD HAS WORKED OUT
OF BEARING. DECK BINDS ON BACKWALL

FIXED: 04 Nº

*Condition Rating (FILL ALL BOXES)

10 SHEET LEAD | 23 STEEL PLATE | 30 STEEL ROCKER | 40 ELASTOMERIC | 50 OTHER (inc proprietary)

TIME | COST | FIXED BEARINGS COMMENTS

41 MORTAR PADS SHOW SOME CRUS
HING - NOT DESIGNED FOR ROTATION

03 WATERWAY

*Condition Rating (FILL ALL BOXES)

12 SCOUR | 22 SOIL AND GRAVEL DEP | 32 GROWTH | 44 OTHER DEBRIS | 50 CHANNEL PROTECTION

TIME | COST | WATERWAY COMMENTS

42 OLD BRIDGE 5M DOWNSTREAM
RESTRICTS WATERWAY

DECK

*Condition Rating

1 TYPE | 2 RATING

TYPE CODES: 1 CONCRETE, 2 TIMBER, 3 STEEL, 4 MASONRY, 5 OTHER

TIME | COST | DECK COMMENTS

45 GENERALLY GOOD BUT HAS
AREA OF POOR COMPACTION (WATER LEAKS
46 AND RUST STAINS AT TOP OF WEST BEAM
- LEAVE UNTIL NEXT INSPECTION)

*RATING CODES

0 NOT APPLICABLE | 1 VERY GOOD | 2 GOOD | 3 ADEQUATE
4 POOR | 5 VERY POOR | 9 UNSAFE | BLANK NOT DONE

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FIELD BRIDGE INSPECTION ADVICE SHEET page 4

GIRDERS

*Condition Rating (FILL ALL BOXES)

10 PRESTRESSED CONCRETE | 20 REINFORCED CONCRETE | 32 STEEL | 40 TIMBER | 50 MASONRY
60 IRON | 70 OTHER

TIME | COST | GIRDER COMMENTS

50 PAINTING OF GIRDERS FAULTY
IN PATCHES. SOME RUST CAN BE LEFT
51 UNTIL NEXT INSPECTION

PROPPING

*Condition Rating 0

TIME | COST | PROPPING COMMENTS

55

ABUTMENTS

*Condition Rating (FILL ALL BOXES)

13 CONCRETE | 20 MASONRY | 30 TIMBER | 40 STEEL | 50 OTHER

TIME | COST | ABUTMENTS COMMENTS

60 2MM VERTICAL CRACKS AT MID
-POINT EACH ABUTMENT (SHRINKAGE)

PIERS

*Condition Rating (FILL ALL BOXES)

10 CONCRETE | 20 MASONRY | 30 TIMBER | 40 STEEL | 50 OTHER

TIME | COST | PIERS COMMENTS

65 SINGLE SPAN - NO PIERS
66

*RATING CODES

0 NOT APPLICABLE | 1 VERY GOOD | 2 GOOD | 3 ADEQUATE
4 POOR | 5 VERY POOR | 9 UNSAFE | BLANK NOT DONE

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FIELD BRIDGE INSPECTION ADVICE SHEET page 5

WINGWALLS

*Condition Rating (FILL ALL BOXES)

12 CONCRETE | 20 MASONRY | 30 TIMBER | 40 STEEL | 50 OTHER

TIME | COST | WINGWALL COMMENTS

70 MINOR SHRINKAGE CRACKS
71

*RATING CODES

0 NOT APPLICABLE | 1 VERY GOOD | 2 GOOD | 3 ADEQUATE
4 POOR | 5 VERY POOR | 9 UNSAFE | BLANK NOT DONE

MONITORING REQUIRED

INSTRUMENTATION 00 ▷

INSTRUMENTATION CODES: 01 SURVEY, 02 DEMEC POINTS, 03 STRAIN GAUGE, 04 COMBINED

FIELD MONITORING 00 ▷

FIELD MONITORING CODES: 01 By BRIDGE SECTION, 02 By DISTRICT ENGINEER, 03 By BOTH

SUGGESTED RECONSTRUCTION YEAR (Y Y Y Y) 2030

SUGGESTED WORK TYPE 0 ▷

WORK TYPE CODES: 1 RECONSTRUCTION, 2 WIDEN, 3 STRENGTHEN

PRELIMINARY COST ADVICE (in $1000's) 000

HIGHWAYS DEPARTMENT

FIELD BRIDGE INSPECTION ADVICE SHEET page 6

SUMMARY AND RECOMMENDATIONS

PLAN Nº -

04 ☐ HIGHEST PRIORITY OF RECOMMENDED ACTION ▷

0 NO ACTION, 1 DESIRABLE, 2 NECESSARY, 3 URGENT

LOAD LIMIT IN TONNES (00 if NOT APPLICABLE)

00 GROSS LIMIT | 00 AXLE LIMIT | 00 OTHER

NB FURTHER DETAILS VIDE GENERAL COMMENTS

Y Y M M D D [ ] IF DETAILED STATE MINUTE DATE - otherwise all ZEROS

DESIRABLE ACTION by (Y Y M M) 8102

TIME | COST

75 REMEDY SETTLEMENT AT APPRO
ACHES, INSTALL MISSING BOLTS IN APPR
76 OACH GUARD RAILS
77
78

NECESSARY ACTION by (Y Y M M) 7902

TIME | COST

80 GUARD RAILS SHOULD BE CARR
IED OVER BRIDGE TO PROVIDE BRIDGE
81 FENCE. POST TO DECK CONNECTION TO BE
DESIGNED ON REQUEST.
82
83

URGENT ACTION by (Y Y M M) 0000

TIME | COST

85
86

GENERAL SUMMARY/COMMENT

TIME | COST

90 BRIDGE GENERALLY IN GOOD
CONDITION, EXCEPT FOR EXTRUDED SHEET
91 LEAD BEARINGS AND SOME CRUSHING OF
FIXED END MORTAR PADS. PAINT ON GIR
92 DERS POOR IN PATCHES. BRIDGE NEEDS
NEW FENCES.
93

important factor and, therefore, not included in the Bridge Inventory. Omitted for similar reasons are reports or ratings of the minor non-structural elements of a bridge, e.g. kerbs, median strips, lighting standards, etc. which tend to clutter inventory records. If, on inspection, these elements are found to be requiring attention they are referred to in the general Comments File. More important are the major structural elements viz. Deck, beams, bearings, expansion joints, abutments and piers including foundations where accessible.

One of the most important pieces of information, if not the most important retained in a bridge inventory is the load rating of a structure assessed after a thorough inspection. The load rating is usually expressed as the ratio of the live load capacity of the bridge to a standard loading, usually the design loading currently used. In this way the load rating of a structure is a convenient measure of the overall condition of a structure and forms the basis of setting priorities for a bridge replacement or strengthening program.

One serious drawback to bridges rated in this manner is that it does not accurately express the over-load capacity of structures. Most of the existing bridges have been designed on the allowable stress philosophy which result in varying actual factors of safety (i.e. safety factors related to live load only) for different bridge elements. (5) This actual factor of safety for the various bridge elements usually becomes larger as the ratio of dead load to live load increases. Therefore, bridge elements designed on the basis of allowable stresses with high dead load percentages have greater reserve capacities for carrying abnormal heavy vehicles than those where the dead load percentage is small. In the system under development the stresses induced by the dead and live loads are recorded so that the real capacity of each bridge to carry heavy vehicles travelling under permit, can be assessed. Since the majority of structures in South Australia have substantial sub-structures with high dead load to live load ratios, the load rating is confined to the deck slab and/or beams. Massive deterioration of the sub-structure would be required to significantly affect the capacity of the structure or overall load rating.

Almost as significant as the rating, for setting priorities for bridge replacement, are the width of structures and the adequacy of the approach roads for alignment, delineation and sight distance. With increased traffic speeds the width between kerbs for bridges has progressively widened so that some of the bridges built comparatively recently are now virtually sub-standard and considered to be relatively hazardous to traffic. Policy decisions have been made for a long term replacement program for bridges below certain acceptable widths depending on the road classification. Road approaches are an integral part of a bridge and its condition from a road safety aspect is subjectively assessed and recorded and used for determining priorities in a similar way as for width of structures.

Current and Future Developments

Using a computerised data bank of the type described, information can easily be re-grouped logically and globally as a function of the needs of the Department which range from data required for statistical purposes, as for example in the grouping of common problems, cost of common repairs, inspection costs to those providing information required to make decisions on relative priorities for bridge strengthening, widening or replacement.

The Bridge Inventory is used by the Bridge Inspection Team for planning a rational inspection program. South Australia covers an area of 980 000 square kilometres and although over half of this area if of little economic or topographical significance, a large area remains to be covered by a centrally located inspection team. A large proportion of the team's time is occupied in travelling and, therefore, a properly planned itinerary for inspecting bridges grouped according to their location and priority is of paramount importance.

The Bridge Inventory system adopted and described in this paper has been developed with flexibility in mind. It permits extension to and changes to be made to the type of information stored without affecting the usefulness of previously created files. It can also be used by other sections of the Department for their own particular needs by simple extension of recorded information.

Future development of the system will be in the areas of devising methods of optimising heavy load routes, and in combining programs with the digital mapping services for the automatic plotting of bridge locations and selected strategic routes.

Acknowledgements

The author would like to thank Mr A.K. Johinke, Commissioner of Highways, for permission to present this paper and my colleague, Mr V. Nechvoglod for his assistance in its preparation. The views in this paper are those of the author and do not necessarily reflect the views of the Highways Department.

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