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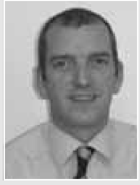

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Development of Eirspan: Ireland's bridge management system

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The road network in Ireland comprises national primary and national secondary roads, and non-national regional roads and local roads. Since 1994 the responsibility for the management and maintenance of the national roads has rested with the National Roads Authority (NRA). In 2001 the Eirspan bridge management system was introduced to coordinate and integrate activities such as inspections, repairs and rehabilitation work to ensure optimal management of the national road structure stock. This paper summarises the reasons for the introduction of the system and gives a review of the distinct activities included in Eirspan. It describes how bridge components are condition rated within principal inspections and outlines how, after the completion of the inventory gathering and first principal inspections, repair works are priority ranked. Future developments within Eirspan are also discussed. Eirspan helps engineers within the NRA to prioritise maintenance needs and maximise the use of available funding. It has proved to be an invaluable tool in helping to maintain the function and safety of bridges throughout the national road network in Ireland.

1. INTRODUCTION

The road network in the Republic of Ireland comprises national primary and national secondary roads, and non-national regional roads and local roads. There are 34 local authorities acting as road authorities who are the owners of the roads. Since 1994 the responsibility for the management and maintenance of the national roads has rested with the National Roads Authority (NRA). Under the Roads Act of 1993 the NRA has 'overall responsibility for the planning and supervision of works for the construction and maintenance of national roads'. The responsibility for the maintenance of the non-national road network lies with the Department of the Environment.

In 1998 a National Road Needs Study Report was produced by the NRA. One of the objectives of the study included collecting limited inventory information for bridges on national roads having a total span equal to or greater than 2·0 m; 1815 bridges in total were identified at that time.[1] A major upgrading of the national road network is in progress as part of the National Development Plan and new structures are being added to the bridge stock.

In 1999 a decision was taken by the NRA to implement a bridge management system (BMS) to coordinate and integrate activities such as inspections and repairs to ensure optimal management of the national road structure stock. Several existing systems were examined including PONTIS (USA), Bridget (USA), DANBRO[2] (Denmark), PONTIS H (Hungary) and BRIDGEMAN (Transport Research Laboratory, UK). Consideration was also given to systems developed by individual firms of consultants, and to developing a system from scratch. It was concluded that a customised version of DANBRO would best meet the NRA's requirements. This new BMS is called Eirspan.

2. HISTORICAL PERSPECTIVE ON BRIDGE MANAGEMENT

As far back as the twelfth century King John subjected the Norman inhabitants of Ireland to contribute to the funding of the maintenance and repair of bridges and highways.[3] In more recent times individual local authorities have conducted their own surveys and in 1988 and 1990 the Department of the Environment, who were responsible for funding the maintenance of national roads before the NRA was formed, produced reports giving guidelines for the inspection, assessment and rehabilitation of masonry and concrete bridges.[4,5] The reports were produced to provide advice to local authorities on strengthening masonry and concrete bridges to the levels required by European Directives, including a gross vehicle weight limit of 40 t.

Before the implementation of Eirspan no centralised system of bridge management had existed in Ireland on either national or non-national roads. Responsibility for bridge management rested with the individual local authorities and, inevitably, practice in relation to bridge management differed considerably from one local authority to another.

Individual senior engineering managers within local authorities were responsible for inspection and evaluation of maintenance and rehabilitation needs. An obvious difficulty with this approach is the absence of a centralised coordination and prioritisation of inspections, and disbursement of maintenance and rehabilitation monies. In the long term the absence of a centralised management system inevitably results in poor value for money and fails to identify the structures most at risk of serious deterioration or collapse.

Structure type	Connaught/Ulster	Leinster	Munster	Total
Masonry	328	214	335	877
Reinforced and prestressed concrete	195	408	284	887
Steel*	17	26	29	72
Corrugated steel	48	45	30	123
Pipe culvert	24	30	35	89
Not registered	30	62	44	136
Total	642	785	757	2184

* Includes composite concrete and steel structures.

Table 1. National route bridge types

3. COMPOSITION OF BRIDGE STOCK

Table 1 illustrates the composition of bridges on Ireland's national routes. The statistics were taken from the Eirspan database in October 2003.

In cases where original structures have been widened the structure type has been categorised as the original structure type. Masonry structures include stone masonry arches and stone slab structures; brick arches are also included as masonry structures although there are only three in total. 'Not registered' structures include those for which the inventory is incomplete, for example railway bridges, or other structures where the deck type could not be determined.

4. WHY IS A BMS REQUIRED?

The deterioration of a bridge commences on completion of its construction. The implementation of a BMS leads to the co-ordination of various types of cyclical and non-cyclical inspections and helps to initiate timely interventions to ensure that the integrity of the bridges is preserved and value for money is achieved.

Eirspan encompasses the essential components of a BMS. It considers the interrelated activities such as inventory gathering, principal inspections, routine maintenance and rehabilitation works required for managing bridges. A set of manuals has been produced to assist users in undertaking the activities. The Eirspan database stores data resulting from the activities and contains a set of computer programs for processing the data.[6]

5. CUSTOMISING DANBRO

During the period of software development an engineer from the Danish Roads Directorate was based in Ireland to coordinate the customising of the system to suit Irish practice. In customising DANBRO for use in Ireland a number of changes were made to the database. For example it was necessary to add a section for masonry structures to the inventory module to facilitate the storing of important geometric and material composition data particular to masonry arch bridges. It can be deduced from Table 1 that 40·1% of Ireland's national route bridgestock comprises stone bridges, whereas Denmark has 2·4% and has little need for a specific inventory section relating to arch bridges.[7] In addition, the system was expanded to encompass the NRA's Technical Approvals process.

6. THE EIRSPAN SYSTEM

The system includes the management of bridges equal to or greater than 2·0 m total skew span on the national primary and secondary road networks. It was initially intended to include retaining walls in the database from day 1; however, it became apparent that there were likely to be more retaining walls than bridges and the NRA decided at an early stage to populate the database with bridges and undertake a further retaining wall survey in the future.

6.1. Organisation

Figure 1 illustrates the bridge management organisation. The NRA Senior Project Manager (Structures) and Project Manager (Structures) establish the procedures to be used and publish such procedures and updates when required. They also arrange funding for BMS activities. A database administrator maintains a central database of structure information and liaises with the NRA project managers, the regional bridge managers and Danish Roads Directorate regarding system upgrades. These three positions are based at the NRA offices in Dublin.

There are three regional bridge managers, one to cover each region of Munster, Leinster and Connaught/Ulster. They are responsible for collecting and registering structural information, managing the inspection and routine maintenance programmes and managing the repair and rehabilitation of bridges in their area. These positions are occupied by Senior Executive Engineers based at County Council Offices in Cork, Kildare and Donegal, as shown in Fig. 2.

Eight firms of consultants were appointed in 2001 under a three-year multiple framework contract to assist the bridge managers in data collection, bridge inspection, structural assessments and compiling tender documents for rehabilitation schemes and supervising construction of such schemes.

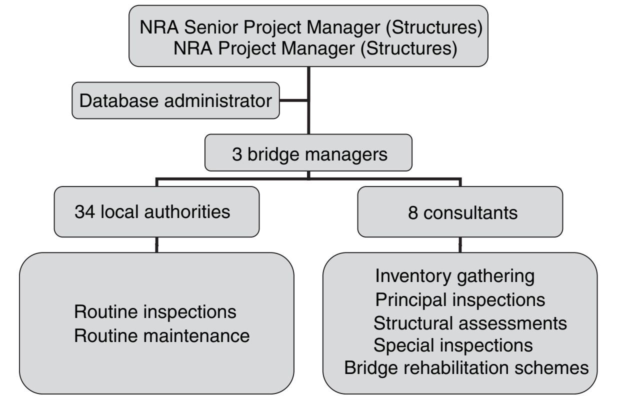

Fig. 1. Eirspan organisation chart

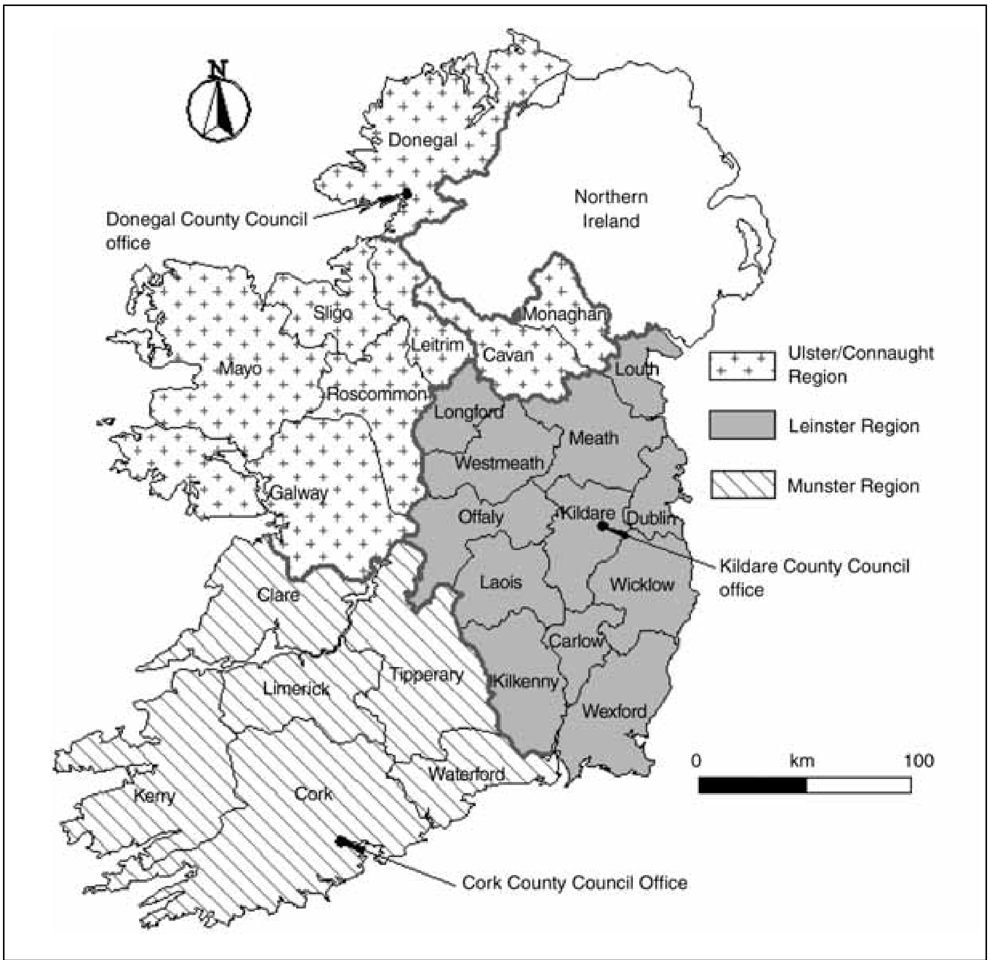

Fig. 2. Ireland's bridge management regions

Each of the 34 local authorities is responsible for undertaking the routine inspections and ensuring routine maintenance is undertaken in their authority each year. The NRA allocates annual ring-fenced funding to each local authority for routine bridge maintenance.

The Eirspan BMS includes a number of activities: the core activities including inventory gathering, inspections and ranking of repair works have already been implemented whereas activities including maintaining the price book register and the budget control register will be implemented in the near future.

In 2001 the consultants commenced the most comprehensive programme of bridge inspection and inventory gathering ever undertaken for the NRA. After a period of approximately one year the database was populated with inventory and condition survey information for all bridges on the national road network.

6.2. Inventory gathering

The aim of the inventory is to give the system users an overview of an individual structure as well as the entire structure stock. The selected data include the name, identification number and location of the structure, the type of obstacle crossed (road, river, railway, etc.), the date of construction and any reconstruction, the types of superstructure and substructure including construction materials, the geometric data (lengths, widths, skew, vertical clearances) and the structure component details (type of bearing, joints, parapet, etc.).

The database can be used to print out reports of inventory data such as a list of vertical clearances on a particular road, or the number and area of bridges in a particular region of the country.

6.3. Principal inspection

The principal inspection is a systematic visual inspection of all accessible parts of the structure. There is no testing carried out during a principal inspection. Its purpose is to evaluate the need for repairs, monitor the performance of routine maintenance and monitor changes in the condition of the structure stock. A condition rating is applied to each of 13 standard bridge components and an overall rating is given for a fourteenth component, 'structure in general'. The bridge component names and condition ratings (CR) are listed on the components overview screen illustrated in Fig. 3. The rating varies from 0 (no or insignificant damage) to 5 (the component has failed or is in danger of total failure with possible implications for traffic safety).

The type and extent of any significant damage is registered along with the need for a special inspection. Damage description is selected from a standard list of defects and two repair methods can be proposed from a standard list of component repairs. A quantity of repair, a cost estimate and the year of execution of the proposed repair are also registered. A list of standard repair rates is used to assist in obtaining repair cost estimates. Digital photographs, which complement the damage descriptions, are stored on the database. An illustration of the database principal inspection photograph screen can be seen in Fig. 4.

The inspector registers whether routine maintenance is being correctly carried out. He also determines the year of the next principal inspection. The inspection interval can vary from one to six years depending on the condition and age of the structure, the traffic intensity carried by the structure and the expected rate of deterioration.

A special inspection can be requested if the inspector is unsure as to the cause of damage, the extent of damage or the most appropriate repair method.

Principal inspection reports can be printed from the database.

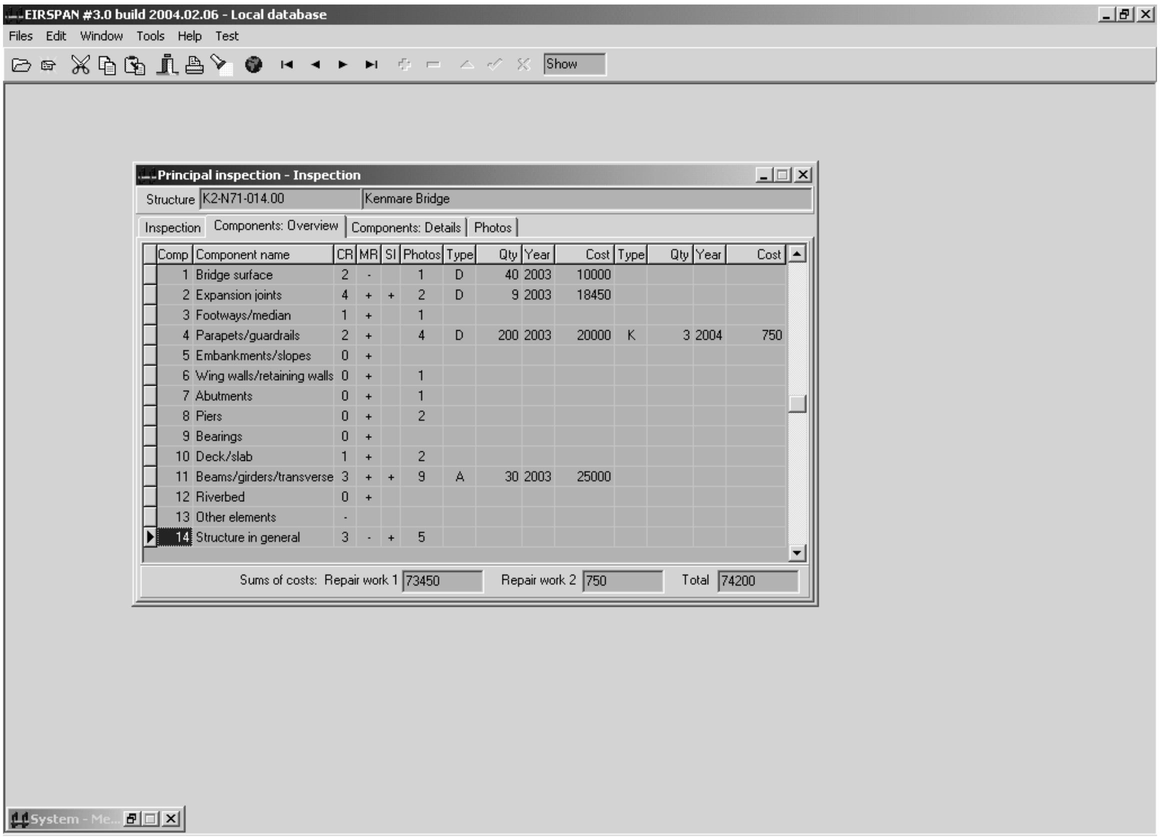

Fig. 3. Principal inspection components overview screen

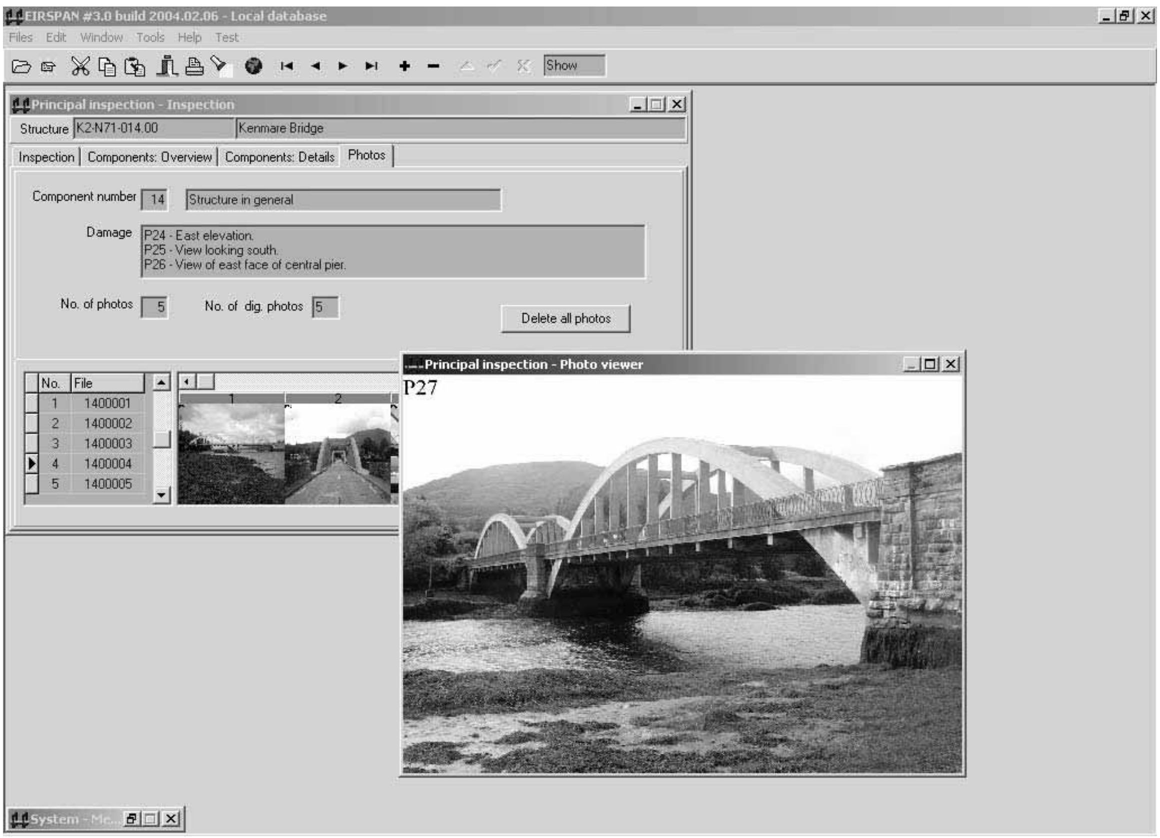

Fig. 4. Principal inspection photograph screen

Other printed reports are also available, such as a total cost estimate of all repair works on a stretch of road for a particular year, a list of special inspection requests for a particular region or a list of principal inspections required in a given year.

Fig. 5. Castlefield Bridge, County Kerry

Castlefield Bridge is one of only two structures which were given a condition rating 5 for component 14 following the first round of principal inspections. Fig. 5 shows the elevation of Castlefield Bridge, a 5·50 m, single-span flat masonry arch in which the rise to the centre of the arch was found to be 1·08 m, and the rise to one quarter point 1·10 m. Fig. 6 illustrates the mortar washout that had occurred between the arch barrel stones. This bridge was subjected to load restrictions immediately following the principal inspection and was strengthened shortly afterwards.

The Castlefield Bridge strengthening design consisted of casting a new reinforced abutment in front of and dowelled to the existing abutment. A reinforced sprayed concrete arch, dowelled to the existing arch barrel, was formed to a more pronounced arch profile than the existing one. The sprayed concrete solution was considered the most appropriate given the speed of construction and minimal road user disruption. Bridge aesthetics was considered to be a low priority as the bridge is hidden from view.

6.4. Special inspection

A special inspection is undertaken, usually by a private consultant, in order to determine in detail the nature, extent and cause of damage to a structure. The inspection therefore forms the necessary basis for a detailed assessment of the damage and the preparation of the most suitable rehabilitation scheme.

Destructive and non-destructive testing, for example to determine the extent of carbonation or corrosion of steel reinforcement in a concrete slab, would be undertaken during a special inspection. Test results are assessed and several relevant repair strategies are proposed. The consultant will then carry out an economic analysis on each of the strategies, including investigating the direct and indirect costs of postponing the strategy, and put forward the optimum solution based on 'net present value'. The indirect costs include the cost of inconvenience to road users. These can be calculated for three road-works situations (speed reduction, diversion and traffic signal regulation) that may give

Fig. 6. Castlefield Bridge, County Kerry

rise to time costs in terms of traffic delays, and driving costs relating to diversion routes.

The economic analysis relies on considerable engineering judgement to estimate values for particular parameters that are sensitive in relation to the overall choice of strategy. The special inspection report includes commentary regarding the level of confidence the engineer has in the value of particular parameters and the level of sensitivity attached to the parameters and in particular how changes to such parameters may affect the choice of strategy.

The regional bridge managers arrange for consultants to undertake special inspections based on special inspection requests highlighted in the principal inspection reports. Typical special inspections have included investigation of post-tensioned structures, concrete condition surveys including structural assessment, and underwater surveys.

6.5. Optimisation

The priority ranking database module, described later, is a tool for obtaining an overview of the order in which interventions to structures should be made. It uses the condition of the structures and the importance of the routes they carry as the significant criteria. The ranking module does not perform economical analyses of the proposed major interventions for the structure stock. The optimisation database module is used for this purpose.

The module uses the economic analyses from the special inspections and considers the economic consequences to society of postponing the works. These consequences will be the direct cost of extra repair work as a result of further deterioration and the indirect cost of road user delays due to, for example, bridge closure or weight restrictions. The parameters required for the programme are the budget for each of the first five years, the price indices and the prices of the repair strategies from each special inspection.

The programme uses an iterative procedure to evaluate an appropriate strategy for each bridge such that the total cost estimate lies within the budget, and the economic consequences of delaying the works are minimised. The result of the optimisation procedure can be altered manually in order, for example, to undertake work on two structures on the same section of road.

Approximately 20 special inspections have been commissioned to date and there is currently insufficient data generated from the inspections to render this module effective. The NRA intends to use this module when more data become available.

6.6. Ranking of repair works

The level of funding available and the resources in terms of labour and plant are unlikely to be sufficient to enable all of the repair and rehabilitation work to be completed at a given time. For this reason a prioritisation strategy is necessary to ensure that those structures most at risk on the most important routes are dealt with first.

Ranking of repair works involves generating an overall priority listing of those structures that need repair or rehabilitation. The structures that require repairs are identified during the principal inspections. In Ireland the ranking is undertaken regionally by the bridge managers, who meet annually with the NRA Structures Section to choose high-priority schemes for the forthcoming year.

The ranking is divided into two parts: preliminary ranking and final ranking. The preliminary ranking is based on, first, the condition rating of the 'bridge in general' and, second, the traffic intensity. The database contains a program to rank the bridges and reports can be produced on a regional basis by the bridge manager or a national basis by the NRA project managers.

The final ranking consists of a manual shift of the ranking of one or more bridges due to factors other than those considered in the preliminary ranking. For example, the consequence of a collapse in terms of available alternative routes, or future plans for the bridge to be by-passed may influence the final ranking of a structure. The final ranking may also be used as a basis for selection of structures for special inspection.

6.7. Routine inspection, maintenance and cleaning

Routine maintenance works are carried out at regular intervals and include work such as sweeping the carriageway over the bridge, removal of vegetation, cleaning the drainage system and repointing stonework.

The responsibility for carrying out the routine inspections and routine maintenance lies with the local authority Area Engineer. The Area Engineer inspection is carried out once a year and also following significant events such as vehicle impact or flooding. During this inspection, the engineer will check all visible structural components and register the need for a principal inspection and routine maintenance. The engineer records from a pre-printed list any routine maintenance works that may be necessary for each component and can print a works order to be handed to the maintenance crew. The works undertaken are then entered into the database and the data sent annually to the regional bridge manager who can check the work and recommend drawdown of the funding allocation.

In the first half of 2003 approximately 200 area engineers nationwide received training from the bridge managers in undertaking routine bridge inspections, implementing maintenance work and using the Eirspan database to report to the bridge manager regarding work done. Routine maintenance training refresher courses will be held annually in each local authority, if required, to facilitate consistency in inspecting and reporting. This is a vital module within the BMS and the local authorities' cooperation in operating the routine maintenance module is crucial.

The NRA is moving to assist local authorities by making the routine maintenance module available via a web link during 2004 to improve access to the database.

6.8. Price book

This module gives an opportunity to provide updated overviews of prices of structural repair work. The prices can be used in compiling cost estimates for repair works emanating from principal inspections and for pricing special inspection repair strategies.

The data for the price book module are taken from the individual tendered rates included in bills of quantities which are submitted as part of tenders for repair works throughout the country. Rates from the two lowest bids are subjected to a price index adjustment and can be entered into the Eirspan database. The quantity of work will influence the unit price entered by a contractor; the price book allows rates to be entered for 'small', 'medium' and 'large' quantities.

The Eirspan structure repair and rehabilitation programme began in 2003 and while rates from tenders are available the module requires considerable time input to enter the items and the rates.

6.9. Budget and cost control

This module gives an overview of costs and work progress for all of the bridge rehabilitation projects at any time. It allows the user to enter design, construction and construction supervision costs for individual schemes. It can also be used to prepare a review of total allocated costs by county and for the country, thereby facilitating budget control throughout the year.

6.10. Archive

During the lifetime of a structure, from the early planning phase to demolition, the various activities will produce documentation to be filed regionally in the bridge manager's archives. Drawings, geotechnical reports, construction specifications, test reports and other documents for each structure are archived. The documents are used in the preparation of tender documents for repair works and to monitor the history of the structure.

The archive module registers all of the relevant documentation and states where original paper copies are stored. A report giving a chronological overview of all of the events and activities in the lifetime of a structure, for example design, construction, inspections and repair works, can be printed.

6.11. Technical approval

Technical approval data relating to the design of new structures, and structural alterations made to existing bridges, were transferred from an independent database, which was written prior to developing Eirspan, to a new module within Eirspan. This module is used only by the NRA project managers in Dublin who are responsible for technical approval.

7. MASONRY ARCH REPAIR TRIALS

Many masonry arch bridges on national routes have suffered from a low level of maintenance in the past and are exhibiting signs of deterioration. Bridges, particularly on national secondary routes, are typically not paved for the full width between the parapets and contain soft verges adjacent to the parapets which allow water to percolate through the fill, removing the fines from the backfill and washing out the mortar between the voussoir stones forming the arch barrel. Fig. 6 shows mortar washout at Castlefield Bridge.

The results of some structural assessments undertaken to date show that there are masonry arches which fail their assessment for 40 t assessment live loading, applied in accordance with BD21/01,[8] due to a reduced effective barrel thickness resulting from a loss of mortar in the arch barrel. In some cases a sensitivity analysis reveals that the bridge would pass its assessment if a full barrel depth were assumed; in such cases repointing of the arch barrel is recommended.

Given the scale of repairs required to arch bridges, the NRA is undertaking trials of various lime mortar mixes and application methods to establish a working specification for undertaking horizontal, vertical and overhead repointing in areas where the loss of mortar is as deep as 200 mm, and as wide as 80 mm between stones at the intrados. It is intended that the specification will be incorporated into the NRA Manual of Contract Documents. The arch repair works will be preceded by the installation of kerbed hardstandings to replace the soft verges, where appropriate, to provide positive drainage on the bridge.

8. FUTURE DEVELOPMENTS AND CHALLENGES FOR IMPROVING BRIDGE MANAGEMENT IN IRELAND

Although the introduction of Eirspan has raised the profile of bridge management in Ireland and greatly improved the inspection regime for structures on national routes there are challenges that lie ahead.

The assessment programme is not yet finished and any rehabilitation works must be well considered. For example, concrete slabs exhibiting concrete spalling, such as at New Line Bridge shown in Fig. 7, should be assessed for structural

Fig. 7. New Line Bridge, County Cork

capacity before any expensive repair works are undertaken. The assessment programme requires completing to establish the number of bridges that are understrength and enable the NRA to prioritise bridge strengthening work.

A number of public–private partnership schemes will be let over the coming years, during which concessionaires will maintain the bridges for a period of 30 years. It is important that the structures within those schemes are managed using the Eirspan system or a system of similar quality to ensure they are handed over in good condition.

Notwithstanding the two-week Eirspan principal inspection training undertaken by the consultants prior to the commencement of the inspections, inconsistencies in the reporting of consultants was encountered. Currently the principal inspection manual gives guidance regarding condition ratings in text only. In the future it is hoped that consistency can be improved by adding a section to the principal inspection manual which provides photographic illustrations for each condition rating and every component.

Consistency between inspections and value for money may be improved by using a lower number of external consultancy firms. Alternatively the possibility of having additional bridge management staff to undertake the core inspections in-house could be considered; additional staff would also improve the effectiveness of Eirspan by facilitating the implementation of the underutilised database modules.

9. CONCLUSIONS

A bridge management system incorporating a systematic inspection and repair programme and efficient use of funding will prolong the useful life of the infrastructure carrying Ireland's national road network and contribute to the well-being of the national economy.

The NRA is faced with the difficult task of allocating limited resources to structure repair schemes. It is essential that those structures that are most at risk and located on important routes are looked at first and that value for money is obtained when choosing a repair strategy.

Eirspan is a bridge management system that aims to prioritise maintenance needs and maximise the use of available funding. It has proved to be an invaluable tool in helping to maintain the function and safety of bridges throughout the national road network in Ireland.

10. ACKNOWLEDGEMENTS

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