BRIDGE ENCLOSURE

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ABSTRACT

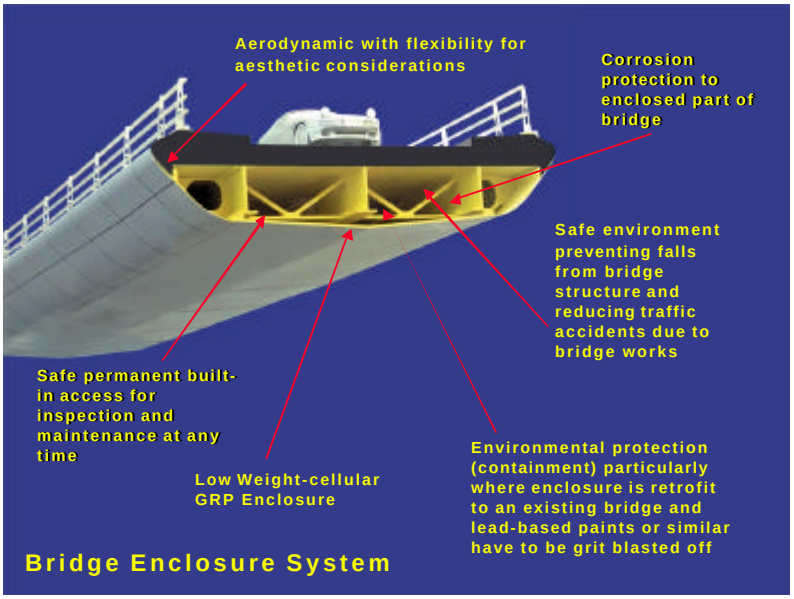
Bridge enclosure facilitates bridge construction, inspection, maintenance, upgrading and operation with minimum traffic disruption. It also provides protection against corrosion, environmental protection, improved safety and convenient clear boundaries between responsible authorities.

Bridge enclosure is a structural floor suspended from the soffit of steel composite, plate girder or concrete bridges. The floor and integral side membranes can be formed in advanced composite materials which encapsulate the structure and provide permanent access to the deck structure, bearings, drainage, pipes, gullies and services. The enclosure forms a working platform giving permanent protected access for inspection and maintenance under safe conditions without the need for scaffolding or mobile access platforms and without need for road closures or railway possessions. Consequently, the authority responsible for an enclosed structure does not need to interface with the other authorities who would otherwise be affected by work on an unenclosed structure.

Bridge enclosures have been applied to a wide variety of structures in the UK, old and new. Extensive deck replacement, steelwork strengthening and steelwork refurbishment, including removal of lead paints, has been carried out within enclosures and contained by enclosures without disruption to the roads/rail lines and environment below.

For new bridges disruption time has been minimised where enclosure is attached to the structural steelwork before both being lifted into position together such that the deck can be constructed from within the enclosure without further disruption.

Bridge enclosure has been designed, tested and used to Government Standards in UK for more than 12 years.



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INTRODUCTION

Whether an old bridge is being refurbished or a new bridge constructed, there are always problems of safe access, environmental protection, corrosive protection and others to be addressed. Many of these problems can be solved by using bridge enclosure, a system developed, tested and used in the UK for more than 12 years.

THE PROBLEM OF TRAFFIC GROWTH

The societies of the developed world, and the same is true of many developing countries, have become dependent on ever increasing degrees of mobility. Whether it is goods being shipped across world markets, businessmen travelling from meeting to meeting, commuters travelling further from home to work, housewives travelling to out of town shopping facilities, the elderly being taken to centralised hospitals, children travelling to distance schools or simply the individual's desire to travel far and wide for leisure. For a long time governments have encouraged this increased mobility and provided for it by extensive road building and in some cases subsidy of upgraded and expanded rail networks. There is now beginning to be a realisation that this never ending increase in both the need to travel and the provision of new and enlarged transport corridors cannot be allowed to continue indefinitely, for environmental reasons if for none other. Consequently investment in new transport corridors has been severely curtailed. Such a change of direction cannot be implemented over night and will require long term policies. In the meantime we have existing transport systems which are grinding to a halt under the pressure of use, and in many cases deteriorating and in desperate need of refurbishment – see Figure 1. We are therefore faced with the imperative of getting better service from our existing transport corridors and halting and rectifying deterioration.

Figure 1 : Typical Traffic Construction at Bridgeworks

THE DIFFICULTY OF MAINTENANCE ACCESS

Under the strain of over use it is increasingly difficult to gain access to inspect, maintain or upgrade the infrastructure on which we depend, without causing massive disruption to users. Increasing awareness of matters of safety and the need to contain environmental pollution caused by maintenance works further complicate the problem. Legislation on safety and environmental protection demand attention to these issues by client bodies, who are also faced with the political pressures to ease and not aggravate traffic congestion and reduce public expenditure at the same time.

THE EFFECT OF PRIVATE FINANCE

One approach to solving some of these issues is to mobilise the private sector, both to bring additional funds and to apply market forces to act as an incentive to achieve greater efficiency. This requires the drawing up of very clear lines of responsibility between the different operators, and is already resulting in clearer recognition of the disruptive effects that one system can have on another. Conflicting priorities at these interfaces between rail service operators and those with responsibility for maintaining the rail infrastructure, between private operators of sections of motorway and public authorities who continue to have responsibility for all the local roads which cross it, at the interfaces between road and rail, rail and light rail, light rail and road, are all absorbing huge amounts of management time. Considerable efforts are being made to identify the true costs of the effects of one system on another.

THE COST OF DISRUPTION

Study of the effects of maintenance works on traffic flows has shown that the simple idea of organising the works to maintain the same number of traffic lanes as originally present does not result in the avoidance of disruption. For example, motorways are provided with hard-shoulders so that vehicles suffering from mechanical breakdown can be pulled off the main carriageway, as can vehicles involved in road traffic accidents, and emergency services can use the hard-shoulders to gain rapid access to deal with incidents. If the hard-shoulder is taken out of use, or used as a running lane in order to allow another lane to be taken out of use, then these facilities are no longer available. Consequently every breakdown results in blockage of a running lane. Emergency service response time is slowed and their ability to clear the carriageway is greatly hampered. Add to this the introduction of any temporary traffic management scheme which is known to greatly increase the number of road traffic accidents, particularly if construction works are in view resulting in distraction to drivers, the effect on capacity can be devastating.

Economic disruption costs can be turned into lane rental charges giving a strong incentive to the disrupter to minimise the disruption that he causes. Similarly reduction in revenue to rail track operators from service providers when the tracks are unavailable or speed restrictions imposed has resulted in huge increases in track possession charges to the disrupter, and a reduction in the number and duration of available possessions.

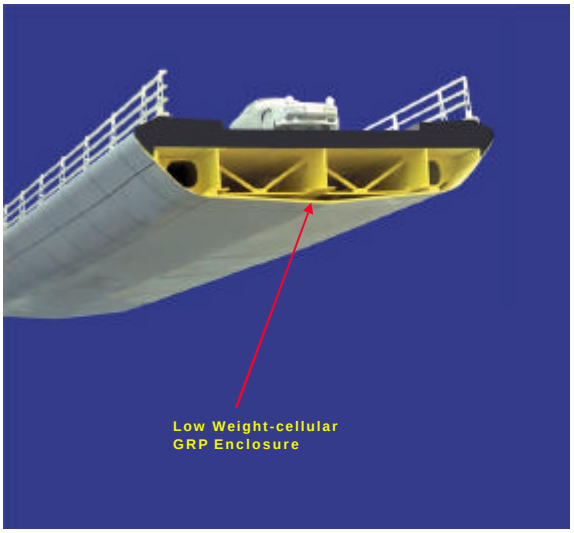
POSSESSION INSTALLATION AND MANAGEMENT COSTS

There are costs to setting-up road and rail possessions. For road possessions (lane restrictions or closures) there is traffic management which requires the planning of lane layouts, setting-out, cones, establishing cross-overs between carriageways, maintenance of layout during works and provision for emergency recovery vehicles. Similarly, with rail possessions there is the planning which requires the booking of the possession, the provision of the necessary safety staff, turning the power off and on, track awareness training and the work programme to suit the limited possession times made available.

BRIDGES, THE POINTS ON CONFLICT

The most common point of interface between two transport corridors is at a bridge where one crosses the other. In addition bridges are some of the elements of the infrastructure that have suffered most from deterioration and overloading by heavier traffic. In the case of repainting operations these can only be carried out in favourable weather conditions. Attempts to carry out painting at night have proved less than successful with dampness resulting in poor paint adhesion. Consequently the capacity and efficiency of existing transport corridors could be greatly enhanced if ways can be found of reducing both the frequency of bridge maintenance and the disruption caused during inspection and maintenance. Inspection has to be added to the equation here because frequent inspection to identify problems early is known to reduce the extent of maintenance works required yet gaining safe access for the inspections themselves can be very disruptive to traffic. It was these issues which stimulated the concept of bridge enclosure.

WHAT IS BRIDGE ENCLOSURE?



It is a structural floor suspended from the soffit of steel composite, plate girder [or concrete] bridges – see Figure 2. The floor and side membranes are formed in lightweight advanced composite material which encapsulate the structure.

Figure 2 : Bridge Enclosure System

BRIDGE ENCLOSURE FOR CORROSION PROTECTION

Initially the main focus of bridge enclosure was on extending maintenance intervals for painted steelwork. To achieve this the approach to the protection of structural steelwork on composite bridges was proposed in 1980 by the UK Transport Research Laboratory (TRL). It relies upon the finding that clean steel does not corrode significantly at relative humidities up to 99%, *provided that environmental contaminants are absent* - see Figure 3. The concept, therefore, was to enclose steel bridge beams, already sheltered by a concrete deck, with lightweight and durable materials, thereby reducing the corrosive effects of the environment to which the bridge is exposed.

Tests were undertaken by TRL for the Highways Agency on a variety of enclosed bridges (approximately 10) over a number of years. Measurements were made of humidity, temperature, time of wetness, atmospheric chlorides and sulphur dioxide. Corrosion rates were measured on bare steel panels. The results of such tests, carried out both inside

and outside the enclosures, confirmed that the method produces an environment of low corrosivity for bare steel with corrosion rates only 2% to 11% of those measured outside enclosures. This suggests that painted steel within enclosure will remain maintenance free for decades. The enclosure method is also applicable to unpainted steel and would also extend the life of weathering steel bridges which have been constructed in unfavourable environments.

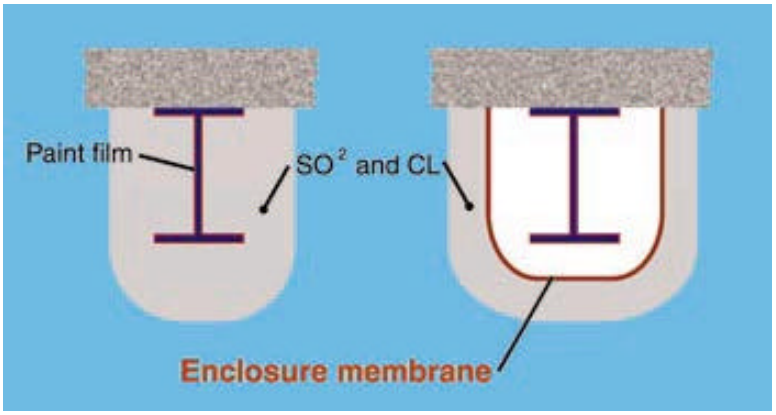


Figure 3 : The Protection of Steelwork by Enclosure

In addition, tests have also shown that enclosure creates an environment of greatly reduced corrosivity for steel which is already corroding, thus supporting the case for retrofitting enclosure to existing bridges.

BRIDGE ENCLOSURE FOR ACCESS

In the early eighties, faced with the need to extensively refurbish the A19 Tees Viaduct, in North East England (Figure 4) high over the River Tees, a major trunk road and a major railway marshalling yard, FaberMaunsell proposed an enclosure which not only protected the steelwork but which provided a permanent work platform from which the refurbishment and future inspection and maintenance of the deck structure, bearings, movement joints, drainage and services could be carried out[3]. This was shown to be cost effective when compared to alternative access systems and proved very successful in terms of the practical issues of erection, use during the refurbishment and ongoing provision of safe and convenient access, as well as corrosion protection.

Figure 4 : Concept of Bridge Enclosure for access, via A19 Tees Viaduct, NE England

BRIDGE ENCLOSURE FOR SAFETY

From a practical point of view, the use of enclosure as an access platform has much to recommend it, but concern has been expressed at the safety issues of creating confined spaces within which work would have to be carried out. Discussion with the UK Health

and Safety Executive soon alleviated these concerns. The conclusion was that enclosure eliminated two of the most common causes of accidents, falls and road traffic accidents at roadworks, both of which are notoriously difficult to prevent due to the temporary nature of the works set up.

The provision of a permanent enclosure presents an opportunity to carefully think through the issues of confined spaces and provide adequate escape routes, fire resistance, smoke baffles and the means to introduce adequate ventilation when work is in progress, integrated into the design of the permanent works.

BRIDGE ENCLOSURE FOR ENVIRONMENTAL PROTECTION

Enclosure provides the means to control the paint dust particles resulting from preparation by abrading and grit blasting and also wind blown dispersion during painting, both now recognised to be important environmental protection measures. Many older bridges have lead based paint systems, the ingestion of which is dangerous enough, but many modern bridges have zinc chromate in the primer, now known to be a carcinogen. Consequently wherever permanent enclosures are not provided the erection of temporary enclosures to facilitate complete stripping and repainting has become common.

BRIDGE ENCLOSURE TO AVOID TRAFFIC DISRUPTION

The practical, safety and environmental benefits of permanent bridge enclosure are very valuable in themselves, but alternatives are available. The pre-eminent benefit of bridge enclosure is its ability to remove traffic disruption from bridge maintenance works, and thereby significantly improve the level of service provided by the transport corridors for which the bridge was built. Once a bridge is enclosed it can be readily inspected and maintenance works carried out without any disruption to the transport corridors above or below. Even when the bridge is in need of major refurbishment this can be carried out from within the enclosure without any effect on the corridor below.

BRIDGE ENCLOSURE FOR CLEAR LINES OF RESPONSIBILITY

The separation of bridge inspection and maintenance functions from the corridor below provides the opportunity for clear lines of responsibility between those responsible for the corridors above and below the bridge, removing the potential for conflicting priorities and the resulting lane rental and track possession counter charging. This greatly simplifies the management task and contractual arrangements between the two bodies.

BRIDGE ENCLOSURE FOR EASE OF CONSTRUCTION

A more recent development in the use of bridge enclosure to avoid traffic disruption is in the construction of new bridges over existing busy transport corridors. Steel composite construction is often favoured in these situations for its speed of construction. Yet it still requires the making good of paintwork at splices, the full final site coat of paint, the removal of deck formwork and falsework and the erection of parapets, all of which required further possession of the corridor below after the steelwork has been lifted into

place. Once the bridge is complete it still presents all of the long term inspection and maintenance access problems associated with steel bridges.
The concept of lifting the steelwork into place with a permanent bridge enclosure already attached, such that all of the above operations can be carried out from within the enclosure, was first proposed in the publication "Steel Bridges for Motorway Widening". It had its first use constructing a new major motorway bridge over the South Wales mainline railway, part of the Second Severn Crossing Approach Roads, with just three overnight possessions – see Figure 5.

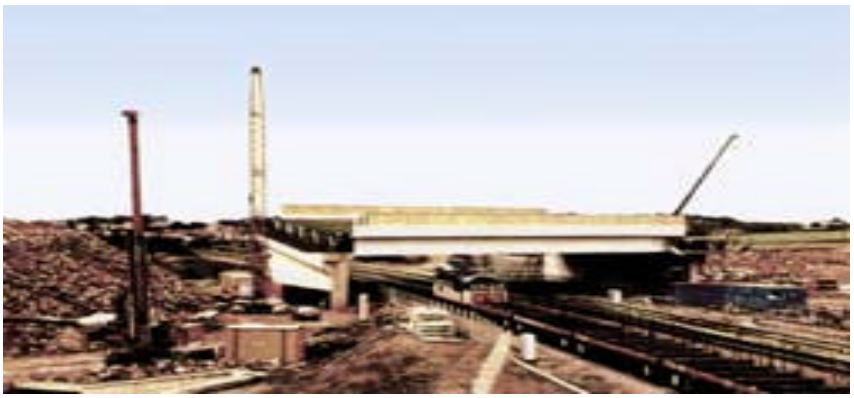


Figure 5 : Construction Work Continues above Live Railway Tracks

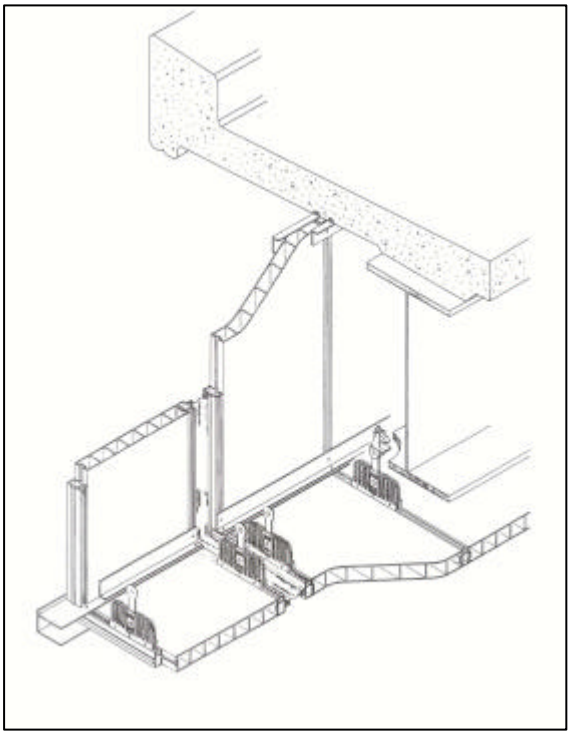
BRIDGE ENCLOSURE FOR SOCIALABLE HOURS

Bridge enclosure provides ready access for inspection and maintenance at any time of the day, and in any weather. Gone are the days, or nights, of working unsociable hours to suit possession times. Gone too is the cold wind and driving rain, but more importantly the lost shifts when conditions are not suitable for painting. Within a bridge enclosure the environment can be controlled to give ideal conditions and better still conditions that do not require repainting of steelwork

BRIDGE ENCLOSURE DESIGN CRITERIA

Comprehensive design is vital to the success of bridge enclosure. The first step must be to select a lightweight and durable material which will not require self defeating regular maintenance and which will not add significantly to the superimposed dead load on the bridge. This means selecting materials with which civil engineers may be less familiar, such as aluminium or advanced composites.

The success of the system is dependent on a proper and full understanding of both the materials and the way an enclosure behaves. The control of air changes and elimination of draughts is vital. The relative movement of the enclosure and the bridge, each under their separate live loading and both subject to thermal effects, must be catered for without compromising the control of draughts. The safety of both maintenance teams and traffic below depend on good structural design including the effects of traffic induced pressure waves, good fire design and appropriate access and escape provision. The UK Highways Agency have led the way with a design standard for Bridge Enclosures – BD67/96 – Enclosure of Bridges, published in 1996 [6]. All of these complex and interactive requirements make it inappropriate to design individual enclosures for every bridge.



Rather, high quality systems must be developed which have been refined to match the task and yet are flexible enough to be applied to any bridge geometry and to allow scope for individual aesthetic expression in their application. The first such system to be readily available in the market place is "Caretaker" an enclosure system developed by FaberMaunsell using Advanced Composite Construction System and available in Europe from Strongwell - see Figure 6.

Figure 6 :Caretaker Bridge Enclosure System

CASE STUDIES FROM THE UK

The variety of cost effective applications of Bridge Enclosures, and in particular the "Caretaker" Bridge Enclosure System which meets in full the requirements of BD67/96, is illustrated by the following case studies. In all these case studies future cost savings are discounted back to the year of installation of the enclosure to allow direct comparison with its cost. The current UK Treasury discount rate for highway infrastructure of 8% is used which is high compared to the "bank base rates minus inflation " of 4% used by other countries and for UK expenditure in other sectors. Even with the high discount rate of 8%, which counts against solutions with good whole life benefits, enclosure is shown to be justifiable.

The assessments for BR Rogiet and Nevilles Cross did not make allowance for future increases in possession costs which it has since become apparent are considerable with the introduction of track leasing to service operators.

Nevilles Cross Bridge Enclosure

Durham County Council, on behalf of the Highways Agency, having taken on responsibility for the maintenance of a bridge carrying a trunk road over the East Coast mainline railway from British Rail, found that the structure was in need of major refurbishment and available track possession times were about to be halved due to the imminent electrification of the line. Being over a deep cutting requiring extensive and costly scaffolding to gain access to the bridge, it was decided to use the last few long possessions to erect permanent enclosure from which the bridge would be refurbished. With the enclosure installed the bridge deck was completely replaced and the steelwork refurbished including extensive

grit blasting of lead paints where the debris was contained within the enclosure, without any further disruption to the railway below. The table below shows how the cost of the enclosure was justified by the savings.

Cost with enclosure	£	Cost without enclosure	£
Materials	100,000	Scaffolding for refurbishment	27,000
Erection including scaffolding	100,000	Possessions during refurbishment	12,000
Possessions for erection	7,500	Scaffolding for future inspection and maintenance	73,000
Management costs	1,100	Possessions for future inspection and maintenance	100,000
Future inspection costs	1,400	Painting costs	7,400
		Management costs	7,700
		Future inspection costs	4,125
Total	210,000	Total	231,225

BR Rogiet Bridge Enclosure

This new bridge carrying a motorway over the South Wales mainline railway was built utilising the enclosure as a working platform for construction. The whole life cost benefit assessment used in the design study is summarised below.

Cost for enclosure and future inspection and maintenance	£	Cost for unenclosed bridge for construction access and future inspection and maintenance	£
Materials	230,000	Rail possessions	54,300
Rail possessions	4,500	Scaffolding	138,800
Savings in paint and silane	(43,500)	Underbridge unit hire	23,300
Future inspection costs	1,400	Motorway traffic disruption costs	28,000
		Management costs	4,000
		Future inspection costs	4,200
Total	192,400	Total	252,600

Replacement Steel Bridges for Motorway Widening

This study was carried out for the Steel Construction Institute's publication [5] of the above title. To illustrate its cost effectiveness it has been compared to the unenclosed steel bridges built as part of the M5 widening.

Cost of enclosure £100,000	
Additional cost for construction, inspection and maintenance of unenclosed bridge:	
	£
Paint and silane	16,900
Traffic management	70,200
Traffic disruption costs	466,200
Access plant	1,000
Extra inspection costs	3,000
Total	557,300

CONCLUSION

Bridge enclosure has much to offer in terms of getting better service from existing transport corridors, by providing safe access and avoiding causing traffic disruption, by providing environmental protection with containment of hazardous and non-hazardous debris from maintenance works and extending the life of the enclosed structure. As access to decaying structures becomes increasingly expensive and difficult, bridge enclosure also offer savings in maintenance costs. There are also established standards for bridge enclosure at National Government levels which could make its application in Europe a real possibility in the short term.

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