7.0

The Cost of Bridges

7.0 Introduction

If a bridge is to be built in place of the level crossing, certain basic assumptions must be made:

- the minimum height above railway should allow for future overhead electrification, if the line concerned is not electrified. This will eliminate the need to rebuild the bridge if the line is subsequently electrified. This therefore requires a minimum clearance height above rail level of 4.780m[157], therefore, rail height assumed at ground level, 0 metres; underside of span at + 4.780 metres; road surface on top of span assumed at + 6.0 metres. It is unlikely many rural railways can present a business case for electrification.
- a minimum width between abutment wall and gauge rail of 3m should be allowed to give a safe cess on both sides of the track[158].
- the carriageway width should not be of greater width than that required at the AHB level crossing, 6.1m, or 5m if the actual daily road vehicle user is less than 4000[159].
- the footpath width should be of no greater width than that required at the AHB level crossing, 1.5m or reduced to 1.0m if the actual daily pedestrian user is Category C[160] (Rural areas, assume minimum pedestrians).
- the span is over a double track railway with two 3 metre cesses giving an 11 metre span; if railway is single track, then in most cases, the design should allow for possible future double tracking.
- the approaches to the bridge should be at a gradient of 1 in 10[161].
- the embankment on the approaches should have a slope of 1:1.5 to the height of the embankment.

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157 Railway Safety Principles and Guidance Part 2, Section A, page 29, Guidance on the Infrastructure, HMRI/HSE, 1996, ISBN 0 7176 0949 9.

158 Railtrack Master Rulebook, Section Bii, Railway Group Standard GO/RT 3000, 1999, Railtrack plc.

159 Railway Safety Principles and Guidance Part 2, Section E, page 39, Guidance on Level Crossings, HMRI/HSE, 1996, ISBN 0 7176 0952 9.

160 Railway Safety Principles and Guidance Part 2, Section E, page 34 & Appendix C, Guidance on Level Crossings, HMRI/HSE, 1996, ISBN 0 7176 0952 9.

161 Personal discussion, author and several civil engineering colleagues; Consensus that gradient would normally be in the range 1 in 8 to 1 in 12.

- the bridge is built alongside the existing crossing; the bridge will be at 90^0 to the railway; if skewed, there is an increase in span and therefore cost. Some bridges, will by necessity, be skewed.
- land take is kept to a minimum; the bridge is on railway land; approaches on purchased land, existing redundant roadway exchanged at similar rate/area; possibility of such is minimal and has not been considered in figures.
- design life of 120 -125 years.
- the site is on level ground.
- bridge and approaches designed to tie in with the existing road with minimal alterations to road at bridge approach extremities.

7.1 The cost of bridges

As with level crossing costs, the actual costs of any bridge are very difficult to establish, for the same basic reasons as those mentioned in the previous chapter for level crossings. These include:

- the road layout and pedestrian approaches
- side roads and access points
- stability of the railway track whilst bridge construction is being undertaken
- ground conditions will affect the type of foundation required
- weather conditions can affect the construction of bridge approaches and, particularly, earthworks
- railway traffic
- competitive tendering

The costs of the civil engineering works involved have been calculated from Spons Civil Engineering and Highway Work Prices Book[162], with an adjustment of 6% made for inflation since publication to bring the data up to 1998 prices. This publication enjoys wide use in the civil engineering field for such pricing. The cost of land take has been taken from the Property Market Report published by the Valuation office[163].

[162] Spons Civil Engineering & Highway Works Price Book, 1998, ISBN 0 419 23050 5.

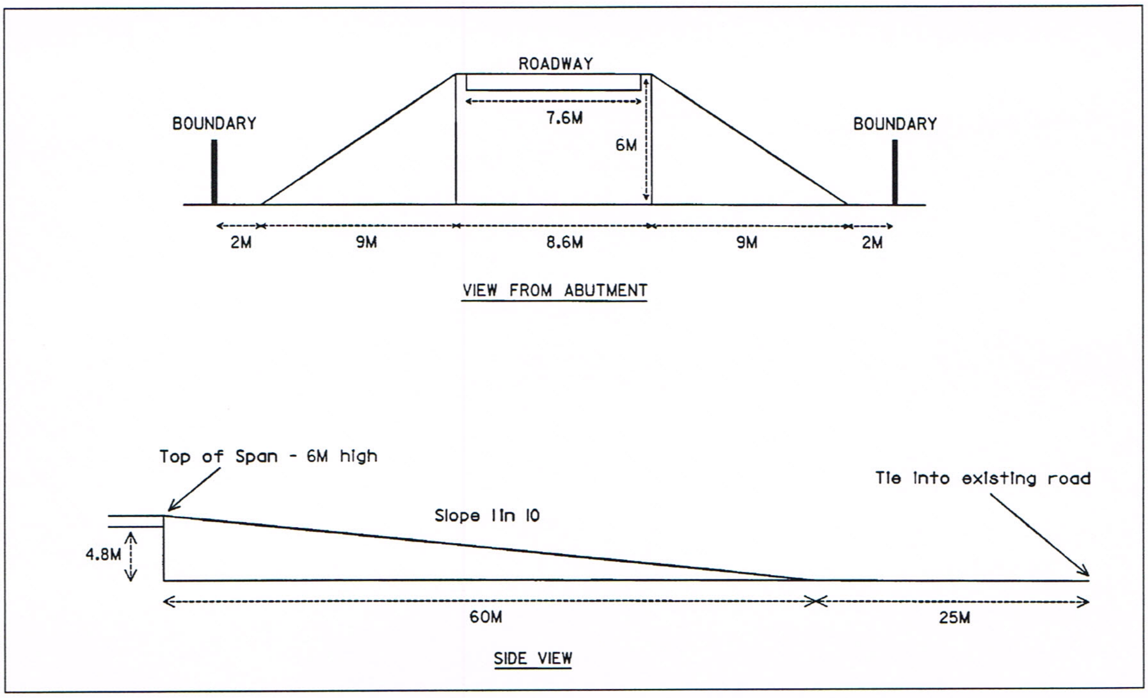

Figure 7.1

Sketch showing the road approach looking from the bridge abutment and maximum width of land take at abutment

CAD sketch: Chris Dawson

7.2 Footprint of Bridge and Land Take

Presupposing our bridge to be wide enough for a 6.1 metre road and 1.5 metre footpath, it will be seen from the aerial view of the sketch (Figure 7.2) that the approach footprint on one side of the bridge will require an area of land of approximately 1615 square metres, and thus both sides will require **3230 m^2** which equates to 3863 yd^2; approximately **0.8 of an acre**. It is therefore assumed that one acre of land would require purchase. The smaller bridge with a 5 metre road and 1 metre footpath will require 445 m^2 less. This is not considered to be significant. Table 7.A shows the average price of agricultural land in the United Kingdom. It will be noted that this ranges from £1670 to £5090 per acre, dependent on the location and type of agricultural use. For this exercise, a figure of **£3700 per acre** will be used.

[163] Valuation Office, Spring 1998, Property Market Report, (Executive Agency of the Inland Revenue) ISBN not known.

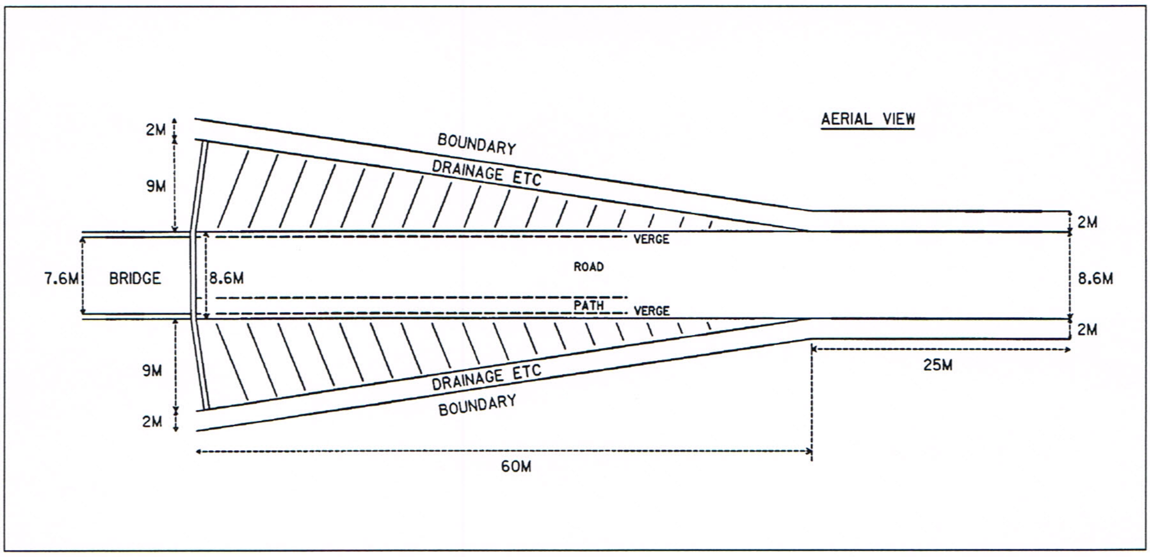

Figure 7.2

Sketch showing the length of proposed land take from abutment to a tie in point on the existing road

CAD sketch: Chris Dawson

Table 7.A

Cost of agricultural land in the UK

Average cost of agricultural land per acre	Arable	Dairy	Mixed
England/Wales	£3384	£3338	£2957
Scotland	£2568	£2417	£1665
Northern Ireland	£3892	£5083	£3225

7.3 Construction Costs

The cost of agricultural land is insignificant when compared with the engineering costs. Four principal components are required:

7.3.1 Construction of the reinforced concrete bridge

Excavation, foundations, abutments, wing walls, reinforcement, formwork, concrete, bearings, expansion joints, precast beams, deck, waterproofing, deck finishing and parapets.

Generally the cost of such a bridge can be estimated by calculating the area under the required span between abutments. Therefore:

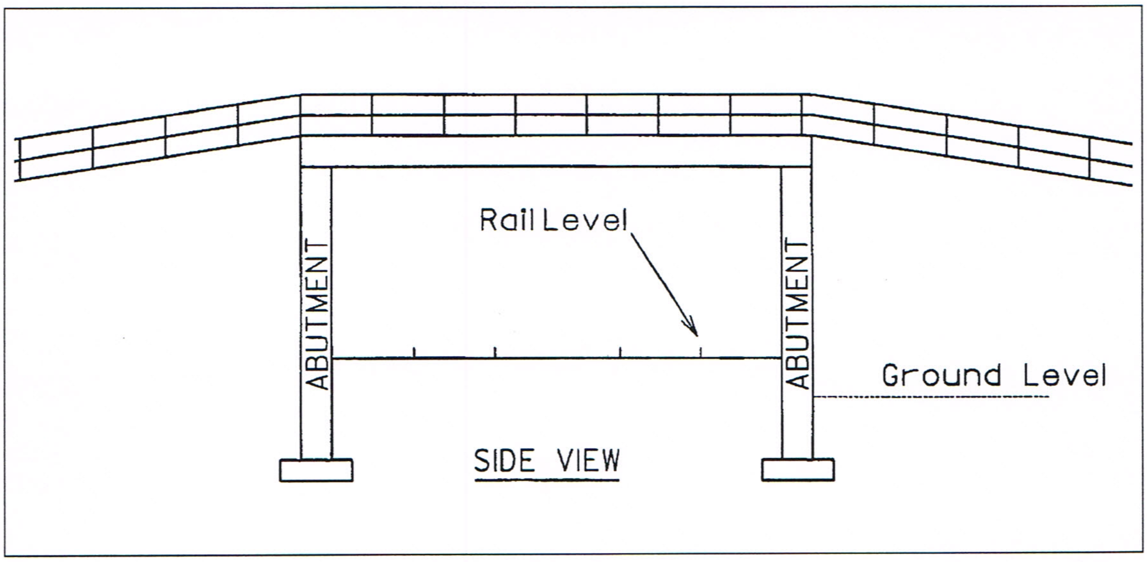

Figure 7.3

Sketch showing the proposed two track bridge;

Width between abutments 11 metres and height above rail level, 4.8 metres.

CAD sketch: Mark Crosby

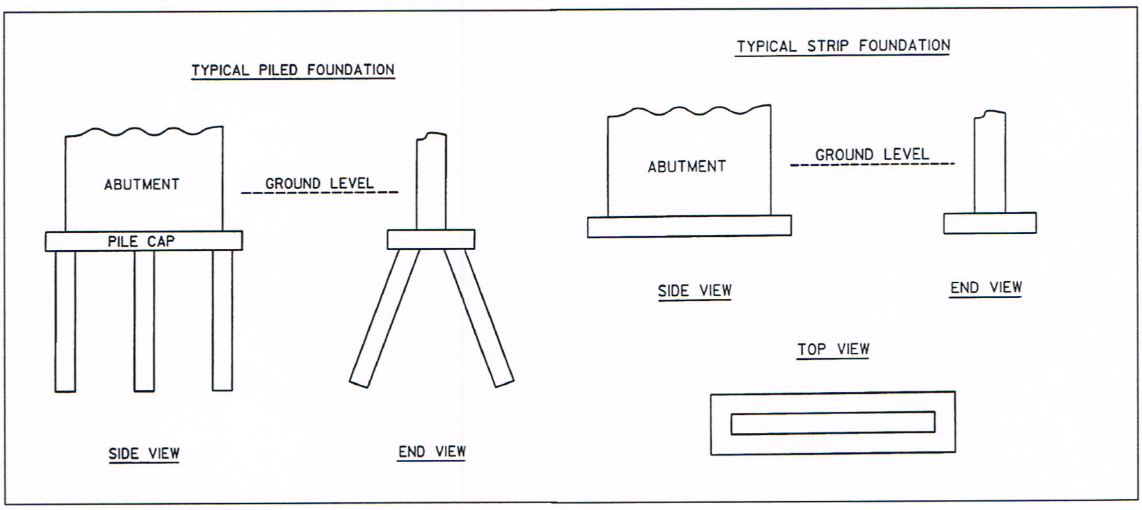

Figure 7.4

Sketch showing the typical bridge foundation design: The piled foundations would be used in poorer ground; the strip foundation would be used in good quality ground and would be cheaper to construct.

CAD sketch: Chris Dawson

Small bridge	**11m x 6m = 66m^2**
Large bridge	**11m x 7.6m = 83.6m^2**

Current costs are in the range £1000 - £1060 per square metre of span, dependent on the type of foundation, with piled foundations probably adding another £250 - £300 per square metre if required. Taking the median, £1030, the cost of the bridge will be **£67980 or £86108** for the small and large bridge respectively.

7.3.2 Earthworks

Land clearance, removal and temporary storage of topsoil over the footprint of approach ramps, filling of any soft spots on ground below removed topsoil, import of suitable well graded fill material, compacting of fill, testing of embankment shear strength during construction, replace topsoil and seed with appropriate grasses. (labour, plant, materials inc.).

With reference to the sketch (Figure 7.1), the main ramp of one the approach embankments has a volume of:

Small bridge **60m x 6m x 7.5m ÷ 2 = 1350m^3**

Large bridge **60m x 6m x 8.6m ÷ 2 = 1548m^3**

Therefore the ramps require **2700m^3 or 3096m^3** fill material respectively. In addition, each embankment side slope requires a further 536.25m^3,

thus; 4 x 536.25 = **2145m^3**

plus the volume of topsoil removed from 'footprint';

thus; (60m x 7.5m x 0.25m) + (60m x 9m x 0.25m) = 247.5m^3 per side

247.5m^3 x 2 = **495m^3** for small bridge.

For the large bridge a further **33m^3** is required.

giving a total fill requirement of

2700 + 2145 + 495 = **5340m^3** for the small bridge

3096 + 2145 + 528 = **5769m^3** for the large bridge

Therefore assume a fill requirement of **5400m^3** with the recovered topsoil being reused on the embankment slopes.

Land clearance, nominal:		**£500**
Excavation of topsoil:	£0.44 x 495m^3	**£218**
Import selected graded fill material:	£11.95 x 5400m^3	**£64530**
Compacting of fill (90%):	£0.26p x 4860m^3	**£1263**
Compacting of fill (10%) around concrete works:	£0.43 x 540m^3	**£232**
Testing of compacting, nominal:	£1500	**£1500**
Replacement of topsoil:	£0.42 x 495m^3	**£208**
Seeding:	£0.48 x 1430m^2	**£687**
Total earthworks cost:		**£69138**

7.3.3 Highway works, Road/footpath

Earthworks, structures, drainage, pavements, footways, signs, lighting, fencing, barriers, including an allowance for accommodation works, statutory undertakings, and landscaping.

The 5 metre wide roadway will cost circa **£699 per metre**; the 6.1 metre wide roadway will cost circa **£845 per metre**.

With a requirement for **182 metres** of roadway on either size bridge, this will cost **£127218** and **£153790** for each width respectively.

7.3.4 Other costs

Include the following which are generally priced as percentages of the construction costs.

Design, Supervision and Planning Supervisor (CDM) 8%,

Site preliminaries, hut, telephone, toilets, small tools, vehicles, 12%

Head office costs, estimating, accounts, marketing, 8%

Profit, risk, 10%

Bad weather contingency, 10%

Finance, cash flow, late payment, 2%

A total of 50% of construction costs must thus be added to arrive at the overall cost.

Table 7.B

Construction cost of bridges and associated highway works

	5.0m Road	6.1m Road
Landtake	£3700	£3700
Bridgeworks	£67980	£86108
Earthworks	£69138	£73918
Roadworks	£127218	£153790
Other costs	£134018	£158758
Total Costs	**£402054**	**£476274**

7.4 Maintenance Costs of Bridges & Highway

Assessing the cost of maintenance for one small bridge, earthworks and 182 metres of rural highway is also difficult to establish. The Department of Transport publish a transport statistics report[164] that shows the annual expenditure by local authorities on all aspects of highway maintenance throughout the country. This expenditure covers highway renewals, structural, bridges, earthworks, re-surfacing, fencing, footpaths, drainage, road sweeping, lighting, winter weather precautions and etc.

Table 7.C shows the total expenditure per kilometre of non-principal roads from 8 local authorities with largely rural areas within the UK. These figures have been taken from the DoT publication mentioned above and adjusted to 1998 prices. This gives an average annual maintenance expenditure of around £2968 per km. From the same publication, separating bridge maintenance specifically accounts for circa 6.03% of the per kilometre figure. It will be noted that the bridge maintenance figure varies widely between counties.

Therefore the annual cost per kilometre of highway maintenance *excluding bridges* is **£2968 - 6.03% = £2789**. With 182 metres of highway to maintain as a result of the bridge construction a typical annual maintenance figure of **£508** would appear to reasonable. Given that the road length if taken over a level crossing is only slighter shorter than that over the proposed bridge, the highway maintenance costs are not likely to increase.

164 Transport Statistics Report: Local Road Maintenance Expenditure in England & Wales 1993/94, Department of Transport, HMSO, ISBN 0 11 551704 9.

Table 7.C

Local Authority Road Maintenance Expenditure

Local Authority	Annual maintenance expenditure per km, non-principal roads	Percentage on bridge maintenance
Lincolnshire	£2576	1.85%
Cambridgeshire	£4381	15.41%
Cornwall	£2702	5.60%
Devon	£3059	3.03%
Somerset	£1955	5.42%
North Yorkshire	£2886	1.88%
Suffolk	£3358	13.41%
Gloucestershire	£2829	1.60%
Average	**£2968**	**6.03%**

The DoT figures do not indicate how many bridges are maintained within these counties and therefore it is not possible to deduce a cost per bridge. Table 7.D shows the views of several authorities and their estimated cost of annual bridge maintenance expressed as a percentage of capital construction cost, including allowance for investment and renewal. The source of this information is Bridge Management[165].

Research in Sweden[166] has suggested that the cost of maintenance is relative to the age of the bridge, climatic and geographical conditions, amount of de-icing salts spread and traffic density. The research concentrated on four city authorities and the national road administration. The average cost of maintenance (adjusted to 1998 figures) was deemed to be **£ 6.75 per m^2** of span.

165 Bridge Management, Inspection, Maintenance, Assessment and Repair, J.E. Harding, G.A.R. Pyke & M. J. Ryall, Elsevier Applied Science, 1990, ISBN 1 85166 456 4.
Surrey County Council: Management of the Bridge stock of a UK County Council for the 1990s, Palmer & Cogswell, p42: Sweden; Bridge Management within the Swedish National Road Administration, Lindbladh, p53: Finland; Development of a Bridge Management System in Finland, Kahkonen, p103: Netherlands; A systematic approach to future maintenance, van der Toorn & Reu, p216/219: Scotland; Highway Bridge Management, Maxwell, p114: Tamar; Engineering management of the Tamar bridge, Halse & Stephens, p184: UK; Management of bridgeworks maintenance in the UK, Smith, p225.

166 Bridge Operation and Maintenance costs, Hans Ingvarsson, Swedish National Road Administration, pages 199 - 204, Bridge Management, Inspection, Maintenance, Assessment and Repair, J.E. Harding, G.A.R. Pyke & M. J. Ryall, Elsevier Applied Science, 1990, ISBN 1 85166 456 4.

Table 7.D

Annual bridge maintenance costs.

Authority	No of Bridges	Annual % cost	Notes
Surrey County Council	1573	0.45%	1.0% renewal allowance
Swedish National Road Auth	11000	3.6%	1.0% renewal allowance
Finland National Road Auth	12000	2.4%	
Scotland Trunk roads	not stated	0.28%	
Scotland Non trunk roads	not stated	0.07%	
Tamar bridge	1	1.15%	inc. 25 yr. major refurb (0.5%)
Netherlands	4000	1.0%	assumed
UK	c.150000	3.0%	OECD recommendation; actual expenditure estimated at 0.3%
Average		**1.49%**	

Assuming the highway authority uses the OECD figure, maintenance of the proposed bridge and highway would range between **£2547** and **£3091** per year.

Table 7.E

Maintenance cost range for proposed small/large bridge

Type of maintenance	Small	Large
Per square metre span	£445	£564
European average 1.49%	£1013	£1283
OECD 3% recommendation	£2039	£2583

Figure 7.5

Modern re-inforced concrete bridge at Lambeg, NIR.

Figure 7.6

Modern re-inforced concrete bridge at Lambeg, NIR. Detail of one abutment. Note the use of rock filled gabions rather than wing walls.

Figure 7.7

Modern re-inforced concrete bridge in Milton Keynes, albeit a road bridge. Note how the wing wall follows the slope of, and supports the face of the earthworks.

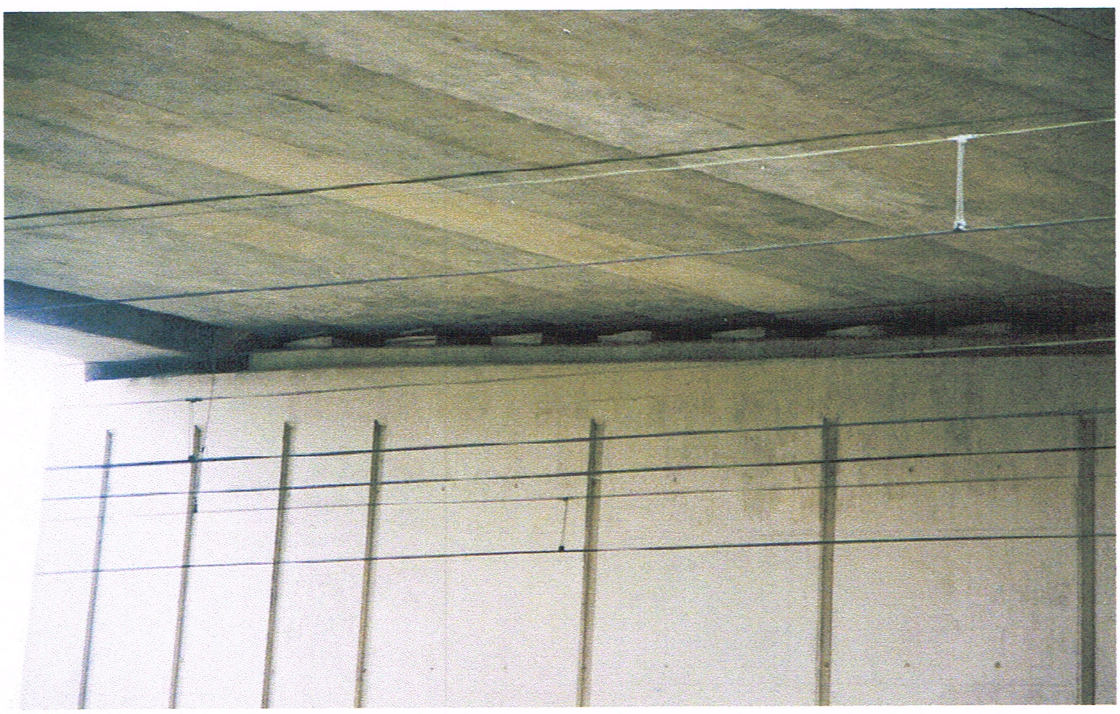

Figure 7.8

Modern re-inforced concrete bridge at Leighton Buzzard, RT. Underside of the bridge; note the precast beams, each sitting on an individual bearing and plenty of clearance for OHLE wires.

7.5 Bridge Whole Life Costs

Table 7.F shows the accumulated costs for both the small and large proposed bridges. One could argue that the accident costs, rail and road delay costs should be deducted from the overall total. This would instantly give a negative cost of building the bridge.

Table 7.F

Bridge whole life costs over 125 years

	Base Cost
Railway Financial Costs	
Small/Large Bridge	**Small/Large Bridge**
Construction of bridge, earthworks and roadworks: Base price £402054/£476274	£402054 £476274
Cumulative bridge maintenance costs @ £2547/£3091 p.a.	£318375 £386375
Cumulative road maintenance costs @ £508 p.a.	£63500 £63500
Cumulative railway delay costs base £2884 p.a.	£0 £0
Total railway costs for 125 years	**£783929** **£926149**
Economic Costs (saved) to Nation	
Cumulative fatality/injury costs, base £26167 p.a.	saving £3.27M
Cumulative rail delay costs; rail passenger and road user, base £3328 p.a.	saving £416k
Cumulative road user delay costs p.a. base £845340 p.a.	saving £106M
Total economic savings to nation	**£109.69M**

7.5.1 NPV

Two Net Present Value Tests at 10% have been carried out on the bridge figures.

- ❑ B1: Pure rail costs - at 10% commercial rate of interest
  - Construction of small/large bridge etc. at £402054/£476274
  - Annual maintenance costs at £3055/3599 p.a.
- ▪ Result: **-£432.6k/-£512k** Railway Financial Cost

- ❑ B2: Pure rail costs - at 10% commercial rate of interest

- Construction of small/large bridge etc. at £402054/£476274
- Annual maintenance costs at £3055/3599 p.a.
- Minus railway savings;
  No LC construction costs at £550k every 25 years
  no LC maintenance costs at £38.5k p.a.
  no track access penalty at £2884 p.a.

- Result: **+£625k/+£545k** Railway Financial Benefit

Similar tests were undertaken on the economic figures at 6% and all are directly inverted from those shown in Section 6.8.1, at +£58.75k (LC2), +£14.9M (LC3) and +£462k (LC4) respectively.

7.5.2 Conclusion

The bridge is very substantially cheaper over whole life cost than the level crossing. The vast reduction in costs can be attributed to an initial capital cost that is around 20% less than the initial level crossing cost. The level crossing has to be modernised another 4 times to meet the bridge lifespan. Secondly, the bridge maintenance charges are only approximately 8% of the level crossing costs over the 125 year period.