THE HIGHWAYS AGENCY

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THE SCOTTISH OFFICE DEVELOPMENT DEPARTMENT

THE WELSH OFFICE
Y SWYDDFA GYMREIG

THE DEPARTMENT OF
THE ENVIRONMENT FOR NORTHERN IRELAND

The Use of BS 5400: Part 10: 1980 - Code of Practice for Fatigue

Summary: This Departmental Advice Note give guidance on the use of BS 5400: Part 10 for the fatigue assessment of highway bridges.

VOLUME 1 HIGHWAY STRUCTURES: APPROVAL PROCEDURES AND GENERAL DESIGN

SECTION 3 GENERAL DESIGN

BA 9/81

THE USE OF BS 5400: PART 10: 1980 - CODE OF PRACTICE FOR FATIGUE

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1. SCOPE

1.1 This Advice Note gives advice on the fatigue assessment of certain structural details which are at present outside the scope of BS 5400: Part 10.

1.2 It also contains condensed load spectra for highway loading which will reduce the amount of computation in those cases where an explicit calculation of Miner's summation (8.4)* is necessary.

1.3 The Note also gives some general advice regarding fatigue sensitive areas in steel/concrete composite structures and a warning concerning the fatigue strength of details constructed from thick plates.

* The numbers in brackets are the relevant clause numbers in BS 5400: Part 10.

2. DETAILS OUTSIDE THE CODE

2.1 Orthotropic Steel Decks (1.5.1 and 5.4)

Designers of orthotropic steel decks subjected to fatigue loading should consult the Bridges Engineering Design Standards Division for advice concerning their stress analysis and detail classification. The criteria to be adopted in the design should however be dealt with in accordance with the procedure given in the Departmental Standard BD 2/79.

2.2 Reinforcement (1.5.2)

R&D Work on the fatigue performance of unwelded reinforcing bars is not complete, but when it is finished it is intended to establish a new classification, class R, which will cover such bars and which will be similar in format and application to the various design curves of structural details already incorporated in Part 10. Other work on the application of such a classification to the fatigue assessment of reinforced concrete structures under highway loading indicate that it should be possible to exempt certain aspects of reinforced concrete designs from fatigue checks. The use of the R classification will be backed up by a quality assurance scheme for reinforcing bars which will include performance criteria under fatigue loading. In the meantime the exemsption given in BS 5400: Part 4 for unwelded reinforcement will continue to apply.

2.3 Socketed Steel-wire Cables

It should be noted that steel-iore cables, such as those used as hangers in suspension bridges, and whose ends terminate in conventional sockets, are liable to fatigue damage at the cable/socket interface. The damage can occur both in cables subjected to fluctuating tension and in cables under constant tension but subjected to lateral oscillations. In the latter case the fatigue lives appear to be sensitive to the degree of restraint against rotation which occurs at the end connection. Sufficient data are not available at present to allow general design rules to be formulated and it is suggested that appropriate test results should be used to examine cases where fatigue is likely to be a problem. The criteria to be adopted in design should however be dealt with in accordance with the procedure given in the Departmental Standard BD 2/79.

3. LOADING

3.1 Condensed Spectra

In cases where an explicit determination of Miner's summation is to be carried out in accordance with BS 5400: Part 10 (8.4) using the standard load spectra of Table 11 of Part 10, the condensed spectra for vehicle and axle weights given in Tables A and B in Appendix I of this Advice Note may be used instead of the full gross weight and axle weight spectra given in Tables 13 and 14 respectively in Part 10. These condensed tables may be used with any of the detail classification given in Part 10 and with the proposed class R.

3.2 Standard Wheel Contact Area

When the standard axle or standard wheel (7.2.2.2) is used in conjunction with the commercial vehicle axle weight spectrum in Table 14 of Part 10 or in Table B in Appendix I, for instance doing and explicit Miner's summation, the wheel contact area may be varied on the basis of a constant pressure of 0.5 N/mm^2 for each particular axle or wheel weight.

4. GENERAL GUIDANCE

4.1 Composite steel/concrete structures

Some studies have recently been undertaken on the fatigue assessment of steel/concrete deck composite structures. Whilst the studies were related to a particular series of designs, some of the findings have a more general application.

a. For the standard type of stud shear connector which meet the requirements of Part 5, use may be made of Tables C or D in Appendix I of this Advice Note to assess whether or not the connectors need to be checked for fatigue when they are used in simply supported longitudinal girders. Both tables are based on the assumption that the connectors meet the minimum static strength design requirements of Part 5. Table C covers the design of normal highway bridges which are subjected to both HA and HB types of loading as specified in Part 2 of BS 5400. Table D is for accommodation bridges which have limited usage and which are designed for HA loading only. Table C illustrates a general conclusion from the studies in that the design of stud connectors is likely to be governed by static considerations at the ends of a span but is likely to be governed by fatigue considerations at mid-span. It should be noted that some conservative assumptions have been made in deriving these tables; thus even though a table may indicate that the fatigue strength or life is inadequate the connector may be found to be satisfactory when detailed calculations are carried out.

b. Where a transverse diaphragm is connected to the bearing stiffeners of the main beams fairly considerable moments will need to be resisted by the stiffener/web weld due to the deflection of the diaphragm and associated deck. The resultant stresses may cause a fatigue problem and the web/stiffener weld may need to be upgraded, for instance by specifying a full penetration butt weld, in order to provide sufficient fatigue strength.

4.2 Thickness effects

The classification of details in Table 17 in Part 10 and the corresponding design curves in Fig 14 are derived from tests on relatively thin specimens (typically 12mm thick). Recent experimental work using thicker specimens has shown that fatigue strength can decrease substantially with increase in thickness. Whilst the experimental data available is not yet sufficient to enable new design rules to be formulated, it is nevertheless recommended that for critical details the following precautions should be taken:-

a. For plates less than 40 mm and greater than 12 mm, the effective design life should be taken as:

[calculated design life] x [1 - 0.02 (t - 12)]

where t = plate thickness (mm)

b. For plates less than 100 mm and greater than or equal to 40 mm, the effective design life should be taken as:

[calculated design life] x [0.44 - 0.004 (t - 40)]

4.3 Design of Details

For some structures, such as footbridges, the appropriate fatigue loading criteria are not specified and it is therefore difficult to assess the fatigue lives of particular welded joints. In other cases some welded joints may be assumed in design to be non-load carrying although in fact they will carry an uncertain amount of load due to displacements within the structure. In both such cases care should be taken over the design of the details in question and if possible the use of fillet welded connection with a classification inferior to class F should be avoided.

5. ENQUIRIES

Technical enquiries arising from the application of this Advice Note to a particular project should be addressed to the appropriate Technical Approval Authority.

All other technical enquiries or comments should be addressed to:-

Assistant Chief Engineer Bridges Engineering Standards Division Department of Transport St Christopher House Southwark Street LONDON SE1 0TE

All enquiries concerning the distribution of this Advice Note should be addressed to:-

Administration of Road Construction 1 Department of Transport Room S7/23 2 Marsham Street LONDON SW1P 3EB Telephone No: 01 212 4944

TABLE A, B, C, AND D

Table A - Condensed commercial gross weight spectrum

Proportion of standard fatigue vehicle gross weight	Proportion of total vehicles
6.75	0.00001
5.03	0.00002
4.09	0.00003
2.14	0.00044
1.06	0.10450
0.82	0.105
0.72	0.090
0.43	0.320
0.20	0.380
Total	1.0

Note: This table is based on Table 13 in Part 10.

Table B - Condensed commercial vehicle axle weight spectrum

Total axle weight (K/N)	Total Number of axles for 10^6 vehicles
256	360
169	700
144	940
99	649000
77	300000
59	517000
47	268000
36	700000
18	420000
Total	2,856,000

Note: This table is based on Table 14 in Part 10.

Table C - Fatigue check table for standard stud sheer connectors

Types of Carriageway:	Dual 3 Lane Motorway Dual 2 Lane Motorway Dual 3 Lane All Purpose Dual 2 Lane All Purpose 3 Lane All Purpose 2 Lane All Purpose (7.3 m & 10 m wide) 2 Lane Slip Road Single Lane Slip Road	
HB Design Criteria	25 - 45 Units HB	
Location of Stud Shear Connectors:	Support ends of a simple span	
Type of girder:	Up to 100 m, simple supported Longitudinal girders	
Type of construction:	Propped	Unpropped
Main girder spacing:	1.5 m - 4 m	2 m - 4 m

If <u>all</u> the conditions noted above are satisfied then no fatigue checks at the ends of the span are necessary.

Note: (1) The stud connectors are assumed to be designed to the minimum static strength requirements of Part 5.

(2) The stud connectors are assumed to have a design life of 120 years and be subjected to the standard load spectra and traffic flows given in Part 10.

(3) Stud connectors at mid-span regions need to be checked for fatigue.

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Table D - Fatigue assessment table for standard stud shear connectors in accommodation bridges

Vehicle Type (See Table 11, Part 10)	Total Weight (kN)	Maximum Allowable Annual Flow/Lane (N) if traffic consisted of only one vehicle type	
		Span ≤ 20 m	20 < span ≤ 100 m
5A-L	250	20	90
4A-H	335	2	10
4A-M	260	15	70
4A-L	145	1,700	7,100
4R-H	280	10	30
4R-M	240	30	120
4R-L	120	6,700	27,600
3A-H	215	70	300
3A-M	140	2,000	8,500
3A-L	90	90,000	443,000
3R-H	240	30	120
3R-M	195	150	630
3R-L	120	6,700	27,600
2R-H	135	3,000	12,400
2R-M	65	Unlimited	Unlimited
2R-L	30	Unlimited	Unlimited

For adequate fatigue strength Σ n/N ≤ 1

where n = actual annual flow of particular vehicle type/lane

N = maximum allowable annual flow of particular vehicle type/lane if traffic consisted of only this vehicle type

Note: (1) The stud shear connectors can be anywhere in the span and are assumed to be designed to the minimum static strength requirements of Part 5.

(2) The shear connectors are assumed to have a design life of 120 years and be subjected to HA loading only.

(3) The bridges are assumed to be simply supported, single carriageway with one or two lanes.