BE 1/73

DEPARTMENT OF TRANSPORT

HIGHWAYS AND TRAFFIC

TECHNICAL MEMORANDUM (BRIDGES) BE 1/73 (1st REVISION)

REINFORCED CONCRETE FOR HIGHWAY STRUCTURES

/AND AMENDMENT NO.1/

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Head of Division
Bridges Engineering Division
Department of Transport
St Christopher House
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TECHNICAL MEMORANDUM (BRIDGES) BE 1/73 (1st REVISION)
REINFORCED CONCRETE FOR HIGHWAY STRUCTURES

1. INTRODUCTION

The Department is at present assisting the British Standards Institution in drafting a document for bridge design and construction which, in addition to bringing BS 153 up to date, will deal with reinforced and prestressed concrete bridges. Until this document is published and adopted by the Department, the concrete grades and design criteria for reinforced concrete shall be as under.

CP 110, The Structural Use of Concrete, must not be used with the Department's current loading requirements for highway structures.

This Revision supersedes Technical Memorandum (Bridges) BE 1/73 issued in January 1973 and is intended to be used in conjunction with the 1969 Edition of the Specification for Road and Bridge Works, as amended by Technical Memoranda BE 6/72, 8/72 and 9/72 together with Technical Memorandum H5/71, Metric Addendum to the Specification. It should also be read in conjunction with Technical Memorandum BE 5/73 , Standard Highway Loadings.

It contains the following substantial amendments:

i. For slabs without shear reinforcement the permissible shear stress has been reduced; Clause 2.1.2.

ii. Overstress is permitted for high yield bars but the stress range has been limited; Clause 2.6.

iii. Overstress has been related to load combinations comparable with those for other forms of construction; Clause 2.7.

Some notes on these changes are given in Appendix II. Amendments and additions to Technical Memorandum (Bridges) BE 1/73 have been sidelined.

This Memorandum, including the relevant clauses of CP 114; Part 2 and CP 116: Part 2 as listed in Appendix I, is mandatory for all reinforced concrete highway structures for motorway and trunk road projects. It is recommended for use where appropriate on other roads.

1.1 GENERAL

The quality of materials, standard of workmanship and requirements for testing in reinforced concrete work shall comply with the 1969 Edition of the Specification for Road and Bridge Works, Series 14 'Formwork and Surface Finish for Structures', 15 'Steel Reinforcement for Structures', 16 'Concrete for Structures', 26 'Materials' and 27 'Testing of Materials and Workmanship'.

1.2 DEFINITIONS

Deformed bar, nominal size effective area of bar and other terms shall be as defined in BS 4449 and BS 4461. CP 114 requires that the bond strength of a deformed bar shall exceed that of a plain round bar by at least 40 per cent.

A reinforced wall is a vertical load-bearing concrete member whose greatest lateral dimension is more than four times its least lateral dimension, and in which the reinforcement is taken into account when considering its strength

1.3 STEEL REINFORCEMENT

1.3.1 SPECIFICATIONS

Reinforcement for highway structures shall be:

i. hot rolled mild steel bars complying with BS 4449,

ii. hot rolled high yield steel bars complying with BS 4449,

iii. hard drawn mild steel wire complying with BS 4482 or

iv. cold worked steel bars complying with BS 4461.

Welded steel fabric reinforcement to BS 4483 may only be used where the fatigue risk is negligible, eg substructures.

1.3.2 MAXIMUM NOMINAL SIZE OF BAR

The nominal size of the bar for either tensile or compressive reinforcement shall not exceed 50 mm but, wherever possible, sizes exceeding 40 mm should be avoided because of the slightly inferior mechanical properties with very large bars and disadvantages in maintaining cover and in lapping and bending.

1.3.3 WELDING OF REINFORCEMENT

Welding of reinforcement is prohibited except in members where the fatigue risk is negligible, eg Freyssinet concrete hinges, cast-in-place piles and end blocks to prestressed concrete beams.

1.4 CONCRETE

1.4.1 CLASSES OF CONCRETE

Mixes shall be either 'Designed Mixes' or 'Standard Mixes'. Classes of concrete shall be as described in Clause 1601 of the DOE Specification. In reinforced concrete highway structures, a class of concrete higher than 30 will not generally be required unless special circumstances justify its use, eg.

i. where parts of a prestressed structure, such as transverse cantilevers and diaphragms, are designed as reinforced concrete members;

ii. where justified by an overall economy in cost, eg columns and long span composite construction;

iii. where required for reasons of durability, eg marine structures.

1.4.2 REQUIREMENTS FOR CONCRETE EXPOSED TO SULPHATE ATTACK

According to the SO_3 concentrations in the surrounding soil or ground water, precautions shall be taken as described in Table 1.

TABLE 1

Concentrations of Sulphates Expressed as SO_3		Requirements for Types of Cement to be used in Dense Fully Compacted Concrete		
Soil %	Ground Water %	Type of Cement	Minimum Cement Content kg per cubic metre	Maximum Water: Cement Ratio by Weight
Less than 0.2	Less than 0.03	Ordinary Portland or Portland-blastfurnace)	280	0.55
0.2 - 0.5	0.03 - 0.12	Ordinary Portland or Portland-blastfurnace)	330	0.50
		Sulphate-resisting Portland	280	0.55
		Supersulphated	310	0.50
0.5 - 1.0	0.12 - 0.25	Sulphate-resisting Portland) Supersulphated or High-alumina/)	330	0.50
1.0 - 2.0	0.25 - 0.50	Sulphate-resisting Portland) or Supersulphated.)	370	0.45
		High-alumina/)	340	0.45
Over 2.0	Over 0.50*	Supersulphated or Sulphate-resisting Portland) plus a protective layer complying with Clause 2006 of the Specification.)	370	0.45
		High-alumina/	370	0.40

* or over 0.25 if magnesium sulphate is the predominant salt.

/ If high-alumina cement is to be used, reference should be made to the report published in August 1964 by the Institution of Structural Engineers on The Use of High-alumina Cement in Structural Engineering.

2. DESIGN REQUIREMENTS AND PERMISSIBLE STRESSES

2.1 METHODS

2.1.1 GENERAL

Generally the strength of members should be assessed by the elastic theory with the assumption that steel and concrete are elastic, within the range of the permissible stresses given in Section 2.5 and 2.6, and that the modular ratio m is equal to 15 but see Clause 3 for the design of reinforced concrete parapet walls and bridge supports.

2.1.2 RESISTANCE TO SHEAR

The shear stress shall be calculated in accordance with the recommendations contained in Clause 316 of CP 114 as amended by Appendix I of this Memorandum. Shear reinforcement, if provided in any member, shall be designed to carry:

i. two-thirds of the shear force where the shear stress does not exceed the permissible value given by Table 3 increased in accordance with Clause 2.7; or

ii. the entire shear force where the shear stress exceeds the permissible value given by Table 3 increased in accordance with Clause 2.7 but the shear stress shall not exceed four times the basic value for any loading combination.

For solid slabs without shear reinforcement, the shear stress shall not exceed the permissible value given by Table 4 increased in accordance with Clause 2.7 and with Clauses 2.5.3, 2.5.4 and 2.5.5 as appropriate.

The critical section for calculating shear stresses in solid slabs under concentrated loads should be taken on a perimeter 1.5h from the boundary of the loaded area, as shown in Fig. 1, where h is the overall slab thickness. The shear stress resulting from the concentrated load should be assumed to have constant value throughout the lever arm depth and length of this critical perimeter.

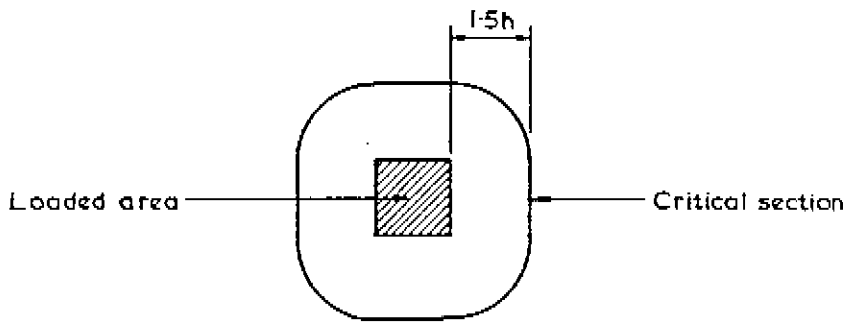

FIGURE 1

2.2 LOADINGS

Where reference is made to BS 153: Part 3A this shall be read in conjunction with Technical Memorandum BE 5/73 , Standard Highway Loadings.

2.3 CONTROL OF CRACKING IN CONCRETE

The calculated width of cracks at the tensile face of the concrete under the action of the worst combination of dead and live loading shall not exceed:

0.25 mm for HA loading (except the two 112 kN wheel loads), or

0.30 mm for HB loading, the two 112 kN wheels or accidental wheel loading.

The width of crack W (see Figure 2) may be taken as:

$3.3C\varepsilon_a$ where the reinforcement perpendicular to the crack consists of deformed bars, and

$3.8C\varepsilon_a$ where the reinforcement perpendicular to the crack consists of plain bars.

C is either the distance from the point at which the crack width is being considered to the surface of the nearest reinforcing bar running perpendicular to the crack or the distance from the point at which the crack width is being considered to the neutral axis whichever is the lesser.

ε_a is the apparent tensile strain in the concrete at the point under consideration in a directipn perpendicular to the crack.

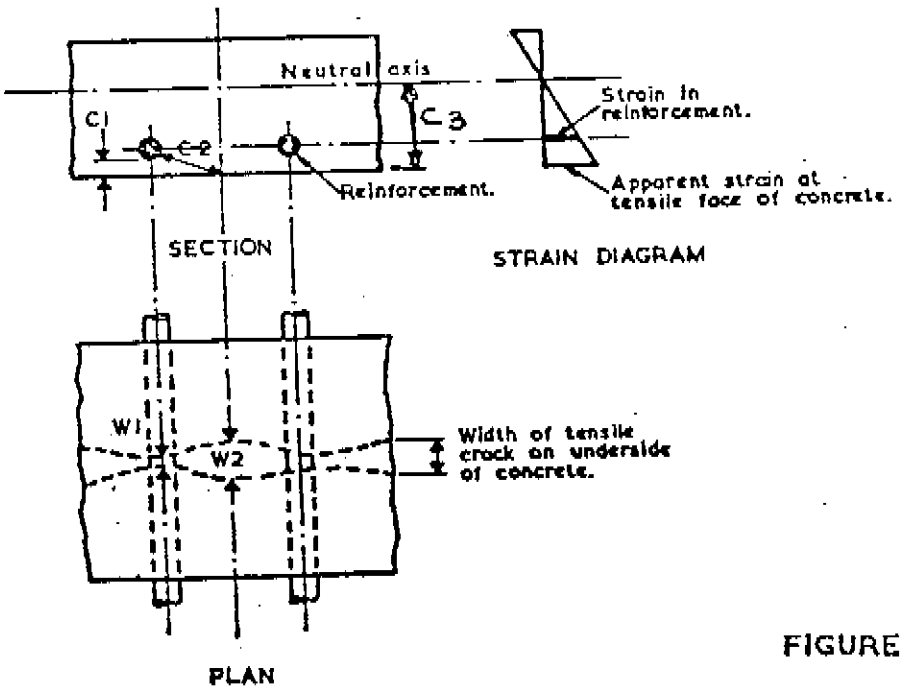

FIGURE 2

Tensile strains in the steel reinforcement and apparent tensile strains in the concrete may be assumed to be proportional to their distance from the neutral axis of the cracked section under consideration and to be equal to each other at equal distances from the neutral axis. The position of the neutral axis and the stresses in the steel reinforcement shall be calculated, ignoring concrete in tension.

The check for crack-control purposes shall be made either at all critical sections or, alternatively, at sections of maximum bending moment only, provided that where bars are stopped or bent up within any span, they are continued beyond the point at which they cease to be required in tension for a distance of at least 50D + $\frac{1}{2}$ la where D is the diameter of the reinforcing bar and la is the lever arm measured to the centroid of the steel.

No check for crack control need be made for:

i. Combination 2 loading. See Clause 2.7 of this Memorandum and Clause 2.5.3.2 of Technical Memorandum (Bridges) BE 5/73;

ii. distribution reinforcement;

iii. stirrups at main reinforcing bars in shear.

2.4 COVER TO REINFORCEMENT

The thickness of concrete cover to the sides and ends of all reinforcement including stirrups and links, shall never be less than that stated in Table 2 or the diameter of the reinforcement whichever is the greater. Where the maintenance of the correct cover may present difficulty, values greater than those given in the Table may be specified by the Engineer.

TABLE 2

Condition of Exposure	Minimum Cover according to Class of Concrete (see also 2.4)		
	22.5 N/mm^2	30 N/mm^2	37½ N/mm^2 and over
	mm	mm	mm
Not exposed to atmosphere, eg internal sides of closed boxes and surfaces protected by a waterproof membrane	40	25	25
Exposed to atmosphere but sheltered eg soffits of slabs between primary members	NA	30	25
Buried below ground level or in contact with backfill	40	30	25
Exposed to wetting and drying and to freezing	NA	40	30
Subject to de-icing salts during winter maintenance, eg roadside structures and piers to overbridges	NA	50	40
Exposed to sea water	NA	NA	60

2.5 PERMISSIBLE STRESSES IN REINFORCED CONCRETE

2.5.1 Basic permissible stresses in reinforced concrete shall be as follows, except for shear in solid slabs without shear reinforcement:

TABLE 3

Class of Concrete denoted by specified 28 day work cube strength	Permissible Stresses in Concrete				
	Compression		Shear	Bond	
	Direct	Bending		Average	Local
N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2
30	7.6	10	0.87	1.00	1.47
22.5	5.7	7.5	0.72	0.85	1.27

Notes on Table 3:

i. The values for bond stress may be increased by 40 per cent when deformed bars are used. This is additional to the overstress permitted by Clause 2.7.

ii. Where Class 37.5 concrete can be justified within the terms of Clause 1.4.1 direct and bending compressive stresses of 9.5 N/mm^2 and 12.5 N/mm^2 respectively will be permitted but the shear and bond stresses given for Class 30 shall not be exceeded.

2.5.2 Basic permissible shear stresses in solid slabs without shear reinforcement shall be as follows:

TABLE 4

Percentage of flexural tensile steel, whether mild or high yield. $100\ Ast/bd_1$	Class of Concrete		
	22.5	30	37.5
	N/mm^2	N/mm^2	N/mm^2
0.25 or less	0.23	0.23	0.23
0.5	0.32	0.38	0.38
1.0	0.44	0.50	0.52
2.0	0.61	0.67	0.70
3.0 or more	0.68	0.73	0.75

NOTES ON TABLE 4:

The term A_{st} is that area of longitudinal tension reinforcement which continues at least an effective depth beyond the section being considered except at a simply supported end of a member where the full area may be used provided each tension bar is anchored by one of the following:

i. An effective anchorage equivalent to 17 times the plain bar size, or 12 times the deformed bar size as appropriate, beyond the centre line of the support; no bend shall begin before the centre of the support.

ii. An effective anchorage equivalent to 17 times the plain bar size, or 12 times the deformed bar size as appropriate, plus $\frac{d_1}{2}$ from the face of the support, where d_1 is the effectivd depth of the member; no bend shall begin before $\frac{d_1}{2}$ from the face of the support.

iii. Provided the local bond stress at the face of a support is less than half the value given in Table 3, a straight length of bar beyond the centre line of the support equal to either one third of the support width or 30 mm whichever is greater.

2.5.3 Where the distance a from the face of a support to the nearest edge of a principal load (See Figure 3a) or the cantilever projection a of the base (including that of abutment, pier and retaining wall bases) beyond the face of a wall or column (see Figure 3b) is less than 2d; the basic stress given in Table 4 may, subject to Clause 2.5.5 and the following provisos, be multiplied by $\frac{2d_1}{a}$;

i. All the main reinforcement shall continue to the support or critical section as appropriate and be provided with an anchorage equivalent to 28 times the plain bar size or 20 times the deformed bar size as appropriate.

ii. A principal load shall be any concentrated load which contributes more than 70 per cent of the total shear force at a support. Loads from abutments, pier walls and columns may be considered as principal loads.

iii. For cantilevers where a is less than $0.6d_1$ special attention shall be given to the need for horizontal links and to the anchorage of main reinforcement.

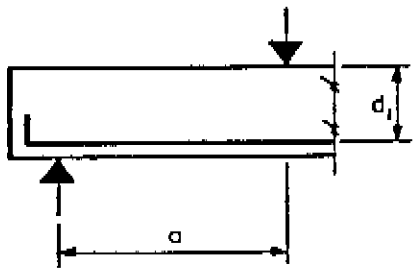

FIGURE 3a

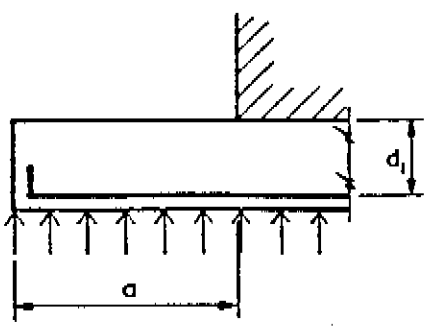

FIGURE 3b

The effect of Clause 2.5.3 is shown below for convenience.

TABLE 5

PERCENTAGE INCREASE IN BASIC PERMISSIBLE SHEAR STRESS GIVEN IN TABLE 4

$\frac{d_1}{a}$	Percentage of flexural tensile steel					Classes of Concrete
	0.25 or less	0.5	1.0	2.0	3.0 or more	
2	300	300	227	137	112	22.5
or more	300	300	248	160	138	30.0
"	300	300	235	149	132	37.5
1.9	279	279	227	137	112	22.5
1.9	279	279	248	160	138	30.0
1.9	279	279	235	149	132	37.5
1.8	261	261	227	137	112	22.5
1.8	261	261	248	160	138	30.0
1.8	261	261	235	149	132	37.5
1.7	239	239	227	136	112	22.5
1.7	239	239	248	160	138	30.0
1.7	239	239	235	149	132	37.5
1.6	220	220	220	136	112	22.5
1.6	220	220	220	160	138	30.0
1.6	220	220	220	149	132	37.5
1.5	200	200	200	136	112	22.5
1.5	200	200	200	160	138	30.0
1.5	200	200	200	149	132	37.5
1.4	178	178	178	136	112	22.5
1.4	178	178	178	160	138	30.0
1.4	178	178	178	149	132	37.5
1.3	160	160	160	136	112	22.5
1.3	160	160	160	160	138	30.0
1.3	160	160	160	149	132	37.5
1.2	139	139	139	139	112	22.5
1.2	139	139	139	139	138	30.0
1.2	139	139	139	139	132	37.5
1.1	120	120	120	120	120	All classes
1.0	100	100	100	100	100	"
0.9	80	80	80	80	80	"
0.8	60	60	60	60	60	"
0.7	40	40	40	40	40	"
0.6	20	20	20	20	20	"
0.5 or less	0	0	0	0	0	"

NOTES ON TABLE 5

The $\frac{2d_1}{a}$ enhancement operates to the left of the stepped line, and twice the Table 3 shear values are critical to the right.

2.5.4 Where the overall depth of a solid slab without shear reinforcement is less than 250 mm, the basic stress given in Table 4 may, subject to Clause 2.5.5, be multiplied by the appropriate factor from the following:

TABLE 6

Overall slab depth	Factor
mm	
250 or more	1.00
225	1.05
200	1.10
175	1.15
150 or less	1.20

2.5.5 The increases in basic stress permitted by Clauses 2.5.3 and 2.5.4 may be used separately or, where both sets of conditions are met, they may be combined but under no circumstances shall the increased basic stress exceed twice the permissible shear stress given in Table 3. The percentage increases permitted by Clause 2.7 are additional.

2.6 PERMISSIBLE STRESSES IN STEEL REINFORCEMENT

Basic permissible stresses in steel reinforcement (including stress range for fatigue purposes) shall be as follows:

TABLE 7

Type of Stress	Permissible Stresses in Steel Reinforcement complying with Clause 1.2.2		
	Mild Steel Bars		All cold worked and hot rolled high yield bars
	Nominal size not exceeding 40 mm	Nominal size exceeding 40 mm	
	N/mm^2	N/mm^2	N/mm^2
Tensile stress other than in shear reinforcement	140	125	230
Tensile stress in shear reinforcement ie stirrups and main bars bent up to resist shear	140	125	175
Compressive stress	125	110	175
Range of stress	265	235	325

2.7 PERMISSIBLE INCREASE IN BASIC WORKING STRESSES

For the two combinations of forces given in Technical Memo. BE 5/73 Standard Highway Loadings, the basic permissible stresses given in Tables 3 and 4 and, except the stress range of 325 N/mm^2 for high yield bars, in Table 7 may be increased by the percentages given below:

TABLE 8

Combination of forces	Increase in basic permissible stresses	
	HA except the two 112 kN wheels per cent	HB loading, or the two 112 kN wheels of HA or accidental wheel loading on footways and verges. per cent
1	0	25
2	15	30

2.8 PERMISSIBLE PRESSURE UNDER BEARINGS

The compressive stress in mass concrete under a bearing shall not exceed $\frac{u_w}{4}$. Where the concrete is suitably reinforced to resist tensile splitting forces, the compressive stress in the concrete shall not exceed $\frac{u_w}{2}$.

u_w is the specified 28 day works cube strength.

3. ULTIMATE MOMENT OF RESISTANCE

When analysing sections of reinforced concrete parapet walls and bridge supports under ultimate loads the following assumptions should be made:

i. The strain distribution in the concrete in compression is derived from the assumption that plane sections remain plane.

ii. The stresses in the concrete in compression are either derived from the short term stress - strain curve given in Figure 4, or, where the compression zone is of rectangular section above the neutral axis at failure, may be taken to be $0.4u_w$ over the whole zone with the resultant acting at a depth of 0.4 times the depth of the neutral axis. In both cases the strain at the outermost compression fibre is taken to be 0.0035.

iii. The tensile strength of the concrete is ignored.

iv. The strains in reinforcement, whether in tension or compression, are derived from the assumption that plane sections remain plane.

v. The tensile stresses in reinforcement are derived from the appropriate stress-strain curves supplied by the manufacturer.

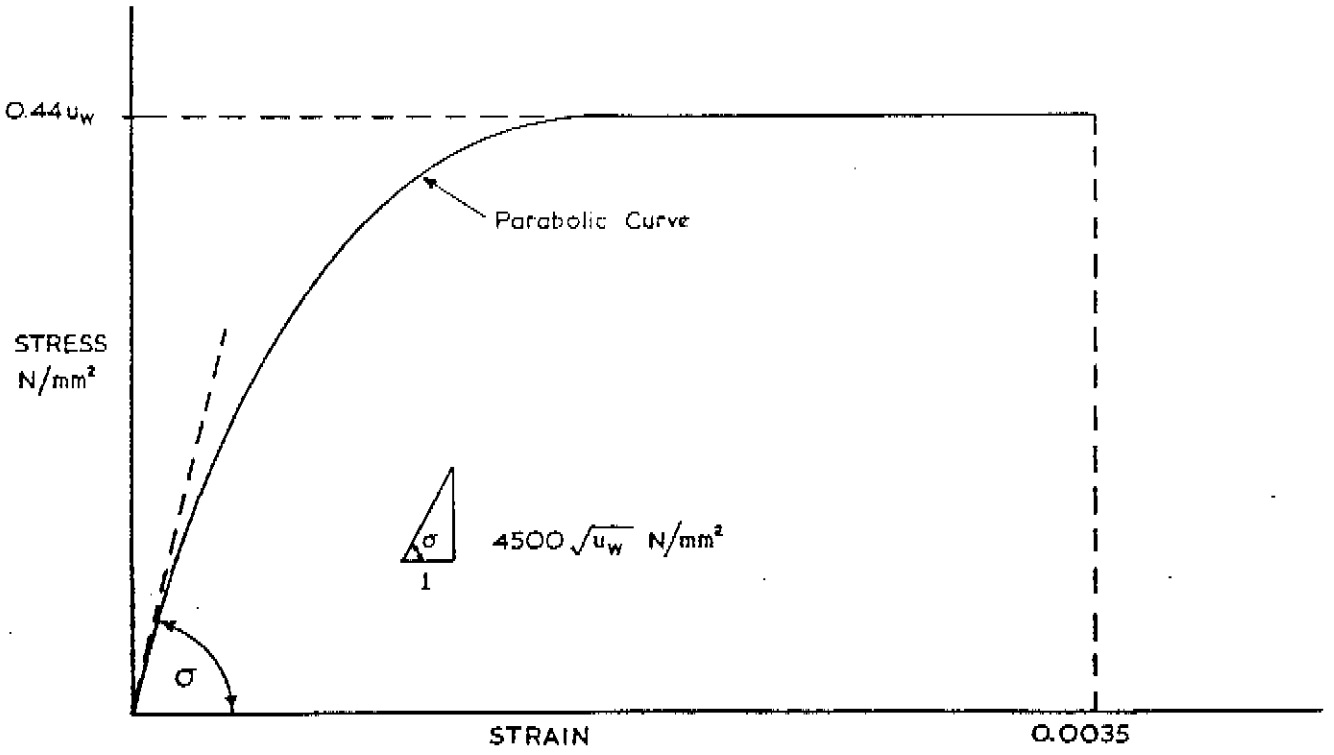

Figure 4. Short term design stress-strain curve for concrete.

K SRISKANDAN
Assistant Chief Engineer
Bridges Engineering Design Standards Division
Department of the Environment
St Christopher House
Southwark Street
London SE1 OTE

9 August 1973

APPENDIX I

CP 114: PART 2 THE STRUCTURAL USE OF REINFORCED CONCRETE IN BUILDINGS

The following clauses are particularly relevant to highway structures.

GENERAL

308 Distance between bars.

309 Stiffness of members.

310 Bond and anchorage; except

1. for d. substitute the following:

   Bending of bars. The bending of bars should be in accordance with BS 4466, bending dimensions and scheduling of bars for the reinforcement of concrete. Where hooks are used, the U-type is preferred.

2. for e. 1 substitute the following:

   the radius of the bend be not less than the minimum specified in BS 4466.

3. for all references to Clause 303 substitute Clause 2.5 of this Memorandum.

4. Hooks should not be used unnecessarily.

BEAMS AND SLABS

311 General; except for the reference to Clause 303 substitute Clause 2.5 of this Memorandum, and omit h, effect of wear:

316 Resistance to shear; except that the permissible shear stress should be taken from Clause 2.5 of this Memorandum, and for 316(iii) substitute Clause 2.1.2 of this Memorandum.

317 Distribution of concentrated loads on slabs; first sentence only.

COLUMNS

321 Reinforcement in columns.

322 Permissible loads on columns.

a. AXIALLY LOADED COLUMNS; except:

1. for Clause 303 substitute Clause 2.5 of this Memorandum
2. for Clause 304 " " 2.6 " " "
3. for Clause 206 " " 1.2 " " "
4. for Clause 208 " " 1.4 " " "
5. for Clause 209 " " 1.4 " " "

c. COLUMNS SUBJECT TO BOTH DIRECT LOAD AND BENDING; except

1. for Clause 303 substitute Clause 2.5 of this Memorandum
2. for Clause 304 substitute Clause 2.6 of this Memorandum
3. Omit the reference to the load factor method described in d.

SUBSECTION 3E: WALLS

399 a. General

SUBSECTION 3F: BASES

340 Bases for reinforced concrete, columns and walls.

CP 116: PART 2 THE STRUCTURAL USE OF PRECAST CONCRETE

The following clauses are particularly relevant to highway structures where the Engineer is satisfied that they are appropriate.

GENERAL

301 General considerations in the design of precast structures; a and b omitting the reference to Clause 4.13.

308 Minimum distance between bars.

309 Maximum distance between bars in slabs.

Reinforced Concrete Beams and Slabs

311 Basis of design; a. Design methods; but omit last 2 paragraphs and for Clause 303 substitute Clause 2.5 of this Memorandum
for Clause 304 substitute Clause 2.6 of this Memorandum.

b. Effective span.

c. Stress reduction coefficient for slender beams.

d. Minimum reinforcement in slabs.

e. Compression reinforcement in beams.

f. T-beams.

g. L-beams.

315 Bond and anchorage; except:

1. for Clause 303 substitute Clause 2.5 of this Memorandum

319 Resistance to shear; except for the omission of

a. (v) hollow floors.

b. 319(iii) substitute Clause 2.1.2 of this Memorandum.

Reinforced Concrete Columns

320 Reinforcement in columns.

321 Permissible loads on axially loaded columns; except:

1. for Clause 303 substitute Clause 2.5 of this Memorandum

2. for Clause 304 substitute Clause 2.6 of this Memorandum

Reinforced Concrete Walls

324 General

Reinforced Concrete Bases

325 Reinforced concrete bases.

Trimming and Bearing for Reinforced and Prestressed Slabs

339 Trimmings for openings.

340 Bearings for precast units, substitute the following:

Precast Units should have a bearing of at least 75 mm.

Composite Precast on in-situ Construction

341 Composite beams; omit paragraphs 3 and 4

342 Beam and slab construction

344 Special design considerations

345 Shear connections;

Substitute Clause 10 of Technical Memorandum BE 2/73, Prestressed Concrete for Highway Structures.

Connections

346 Connections; except

1. Substitute 'structure' for 'building';

2. Substitute the following for all after the first sentence of a (iii);

These details should allow for deviations from correct dimensions and clearances during erection.

APPENDIX C MOVEMENT JOINTS

To be used in conjunction with Technical Memorandum BE 3/72, Expansion Joints for Use in Highway Bridge Decks.

C1 General

C2 Need for movement joints, first paragraph only.

C3 Types of movement joints.

APPENDIX II

NOTES ON THE AMENDMENTS TO PERMISSIBLE STRESSES IN REINFORCED CONCRETE

1. RESISTANCE TO SHEAR; CLAUSE 2.1.2.

It has been shown [1] [2] that the CP 114 permissible shear stresses, below which no shear reinforcement is required in slabs, provide a lower safety margin than is desirable. Table 3 and Clauses 2.1.2 (i) and 2.5.1 of BS 10 were based on these stress levels. In 1967 Amendment No 2 of CP 114 Clause 316a (iv) suggested the need for a conservative approach when calculating the resistance to shear of members without shear reinforcement and this is incorporated in the current edition of CP 114: Part 2: 1969. This is adopted in this Memorandum by the introduction of a table of limiting values for shear stress related to concrete grade and the amount of tensile flexural reinforcement, whether mild or high yield steel. This table, Table 4, is based upon Table 5 of CP 110: Part 1: 1972 in which the ultimate stresses contain a factor $\sqrt{1.5}$ for material strength. The CP 110 stresses have therefore been multiplied by $\sqrt{1.5}$ and divided by 2 so that Table 4 will be directly applicable to unfactored working shear stress. This change will tend to increase the depths of slabs or the amount of tension reinforcement or both but this is generally preferable to the introduction of shear reinforcement The effect of this is virtually to exclude the use of high yield bars for slabs spanningless than 7 metres.

2. PERMISSIBLE STRESSES IN HIGH YIELD BARS; CLAUSE 2.6

BE 10 disallowed overstress for high yield bars. This limitation stemmed from CP 114 Clause 304 although it may be noted that Clause 305 allows stress up to 250 N/mm^2 if due solely to wind. Crack control was not covered in the Code but explicit rules are given in Clause 2.3 so there is no need on this account to limit the stress in reinforcement. The 25% overstress onto 230 gives 287.5 N/mm^2 which is 75% of the lowest rejection level for BS 4499 while the 30% overstress proposed in HB in combination 2 is still only 78% of this rejection level. Trial calculations have shown that the use of these stresses does not introduce a fatigue risk in highway structures though it is considered prudent, for the present, to limit the range of stress to 325 N/mm^2. This limitation will not usually be onerous and avoids the need to calculate fatigue life.

3. LOAD COMBINATION: CLAUSE 2.7

The opportunity has been taken to make the loading requirements for reinforced (and prestressed) concrete comparable with those for steel and composite steel/ concrete construction. This is promulgated in Technical Memorandum BE 5/73, Standard Highway Loadings, to which reference should be made when applying overstress.

4. LOCAL EFFECTS OF WHEEL LOADS

The perimeter, defined in Figure 1, for punching shear together with the increased contact areas permitted for the HA or HB wheel loads mitigate the effect of the reduced shear stresses in solid slabs eg it is not necessary to increase the 160 mm thickness of in-situ slab on M-beams at 1m spacing.

5. AMENDMENTS TO THE MEMORANDUM ISSUED JANUARY 1973

In the Department's current requirements, permissible stresses under working loads are within the elastic range and it is appropriate to calculate shear stress on the basis of lever arm rather than effective depth, i.e. $\frac{Q}{bl_a}$ rather than $\frac{Q}{bd_1}$.

Table 4, which was based on effective depth, has therefore been adjusted by an amount ranging from 9 to 25 per cent to accord with shear stress calculated on the basis of lever arm.

Advantage has also been taken of two further effects, given in CP 110, which are applicable to highway structures. These are:

i. The enhanced shear resistance (increased factor of safety) in short shear spans due to compressive stress; Clause 2.5.3.

ii. The increased shear strength of thin slabs due to scale effect; Clause 2.5.4.

It is appropriate to allow overstress for all types of concrete stress. Rules are given for the calculation of the ultimate moment of resistance of reinforced concrete parapet walls and bridge supports; Clause 3.

These amendments and editorial corrections have been sidelined in this revision of the Memorandum.

References

(1) Permissible shearing stresses in reinforced concrete beams, R. Taylor Concrete and Constructional Engineering, Sept. 1963, Vol. 58, No. 9 pp 359-363.

(2) Behaviour of reinforced and prestressed concrete subjected to shear forces, P E Regan, Proc. I.C.E. 1971, Supplement xvii Paper 7441 S.

DEPARTMENT OF TRANSPORT

ROADS AND LOCAL TRANSPORT GROUP

TECHNICAL MEMORANDUM (BRIDGES) BE 1/73 (1ST REVISION): REINFORCED CONCRETE FOR HIGHWAY STRUCTURES

AMENDMENT LIST NO 1

The following amendments shall be made to the above document to update the Department's requirements pending the general adoption of BS 5400: Part 4: July 1978.

Some amendments require substantial alteration of certain pages; where this occurs, the appropriate pages have been reproduced in full so that they may be included as amended pages.

PAGE	CLAUSE	AMENDMENT
1.	1, para 3, line 2	Delete '1969', insert "1976"
	line 3	Delete 'Technical', insert "Supplement No 1."
	lines 4 and 5	Delete remainder of first sentence
	line 6	Delete 'BE 5/73', insert "BE 1/77"
	1.1, para 1, line 2	Delete '1969', insert "1976"
	1.2, para 1, lines 2 and 3	Delete 2nd sentence, insert the following: "In accordance with these British Standards, deformed bars are now further sub-divided into types 1 and 2."
2.	1.3.1. i, ii and iv	Insert the following at end of each line: "except that no bars shall contain flash welds"
	1.3.3, para 1, line 3	Delete line, insert the following: "piles, end blocks to prestressed concrete beams and buried precast concrete pipes."
	1.4.2, para 1, line 2	Delete '1', insert the following: "NG 16/1 in the Notes for Guidance on the Specification."
3.	Delete page, insert amended page 3 attached	
4.	2.2, para1, line 2	Delete 'BE 5/73', insert "BE 1/77"

PAGE	CLAUSE	AMENDMENT

4. 2.3, para 1, lines 1 and 2
Delete lines, insert the following:

"The calculated widths of cracks at the tensile face of the concrete under the action of combination 1 loading, excluding longitudinal and centrifugal loading, shall not exceed the appropriate value specified in Table 1B for the particular loads given therein. Where crack widths are not specifically calculated, reinforcement should be suitably positioned to limit cracks to acceptable widths having due regard to the particular functions of the structure, its appearance and durability."

TABLE 1B

Live Loading	Permissible Crack Width
	mm
Type HA 112kN wheel loads	0.31
30 units of type HB loading on loaded lengths $\leq$ 6.5 m	0.25
Type HA udl and knl on loaded lengths $\geq$ 6.5 m	0.25
Pedestrian or gantry loading	0.25

6. 2.3, para 5, item i, lines 1 and 2
Delete lines, insert the following:

"i. Combination 2 loading as defined in Clause 2.5.4.2 of BE 1/77;"

item iii
Delete 'at', insert "and"

7. Delete page, insert amended page 7 attached

8. 2.5.1 - Notes on Table 3

item 1, lines 1 and 2
Delete 1st sentence, insert the following:

"The bond stresses may be increased by 25% for type 1 deformed bars and by 40% for type 2 deformed bars."

item ii, line 1
Delete 'class 37.5 concrete', insert the following:

"concrete of class 37.5 or above"

2.5.2, Table 4, row 2, column 4
Beneath '37.5', insert "and above"

PAGE	CLAUSE	AMENDMENT
9.	2.5.3, para 1, lines 1 - 4	Delete lines, insert the following: "2.5.3 For beams and slabs, where a principal line load is within 2d$_1$ of a parallel line support and both are continuous over the full width of the member, the basic stress"
	Item ii, lines 1 - 4	Delete lines, insert the following: "ii. A principal line load shall be any predominantly uniformly distributed line load which contributes more than 70% of the total shear force at a line support. The principal line load shall be applied to the face of the member opposite to the face in contact with the support, as shown in figure 3."
	Figures 3a and 3b	Delete figures, insert amended figure 3 below

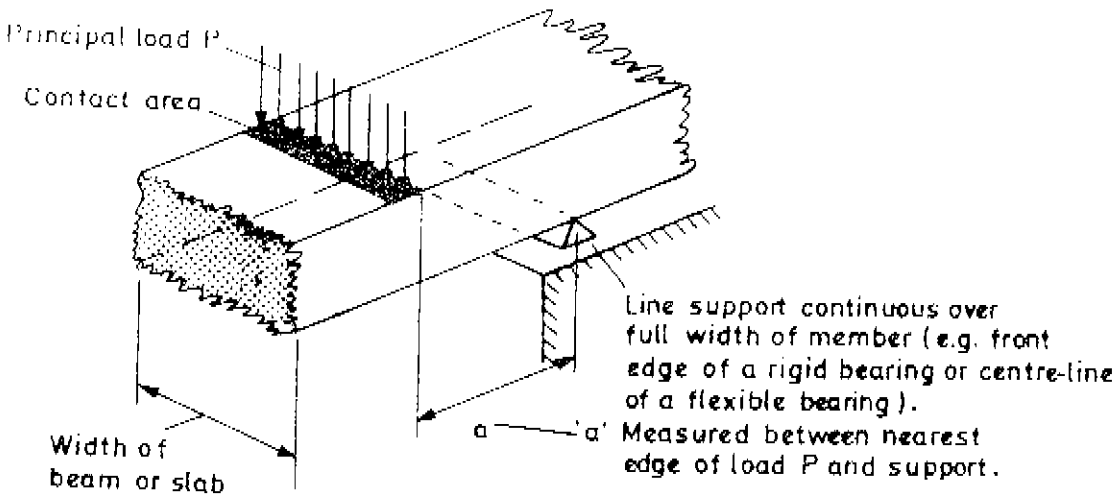

FIGURE 3.

13.	2.7, para 1, line 1	Delete 'BE 5/73', insert "BE 1/77"
	2.8	Delete clause (an amended clause is included on additional page 13A, see below)
13A.	Insert additional page 13A attached	

PAGE	CLAUSE	AMENDMENT
14.	3, para 1, line 2	Delete line, insert the following: "under ultimate loads the assumptions given below should be made. The stresses given in ii. and v. below are characteristic values, ie the design stress to be used in calculating the ultimate moment of resistance is obtained by dividing the characteristic value by the appropriate partial factor for strength. (Unless otherwise stated the loads given in the relevant clauses of BS 5 and BS 1/77 are design loads, ie allowance has been made for the partial factor for loads. Where appropriate, a further factor for method of analysis is also given in those documents.)"
	item ii, line 4	Delete '$0.4u_w$', insert "$0.6u_w$"
	item ii, line 5	Delete '0.4', insert "0.5"
	item ii, line 7	Delete line, insert the following: "fibre is taken to be 0.0035 and in the case of members reinforced only in tension, the depth of concrete in compression is limited to half the effective depth of the member. The partial factor for strength shall be taken as 1.5."
	item v, line 2	Insert additional sentence as follows: "The partial factor for strength shall be taken as 1.15."
	Figure 4	Delete figure, insert amended figure 4 below.

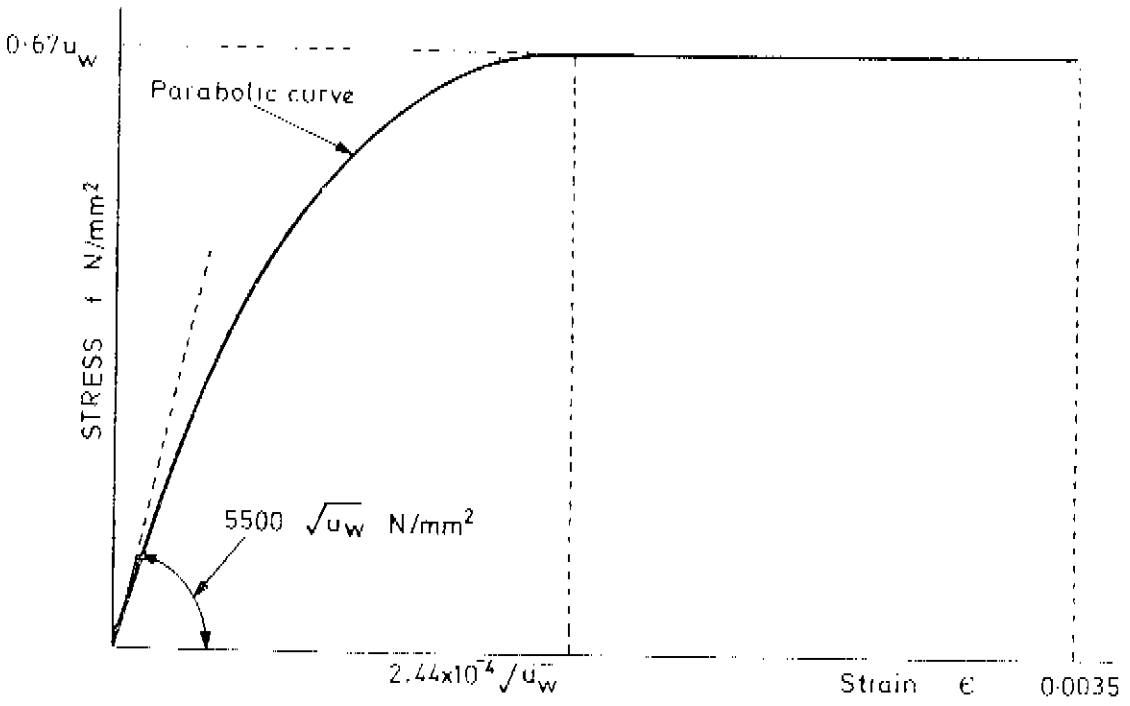

FIGURE 4

NOTE:

The equation for the parabolic curve between $\epsilon=0$ and $\epsilon = 2.44\times10^{-4}\sqrt{u_w}$ is:

$$f = \left[5500\sqrt{u_w}\right]\epsilon - \left[\frac{(5500)^2}{2.68}\right]\epsilon^2$$

PAGE	CLAUSE	AMENDMENT
18.	Appendix II, clause 3, line 3	Delete 'BE 5/73', insert "BE 1/77"

ENQUIRIES

Technical enquiries arising from the application of these amendments to a particular design should be addressed to the TAA for that scheme.

General technical enquiries or comments should be addressed to:

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

Distribution enquiries should be addressed to:

Highways Procedures and Legislation 2 Division
Room P3/030
2 Marsham Street
LONDON
SW1 3EB

Telephone: 01-212-4944

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

31 December 1979

1.4.3 DYNAMIC MODULUS OF ELASTICITY

In calculating the dynamic characteristics of concrete bridges in accordance with Clause 5 of BE 1/77, the dynamic modulus of elasticity of concrete shall be as specified in Table 1 for concrete made with aggregates derived from natural sources and having a density exceeding 2300 kg/mm^3.

TABLE 1

Class of Concrete	Dynamic Modulus	
	Mean Value	Typical Range of Values
N/mm^2	KN/mm^2	KN/mm^2
22.5	35.5	31.5 - 39.5
30.0	38.0	33 - 43
37.5	39.5	34.5 - 44.5
45.0*	41.0	36 - 46
52.5*	42.5	36.5 - 48.5

* for prestressed concrete

1.4.4 COEFFICIENT OF THERMAL EXPANSION

In calculating the effects of temperature as specified in Clause 3.4 of BE 1/77, the coefficient of thermal expansion of concrete shall be taken as 12 x 10^{-6} per ^{o}C.

Once the type of aggregate to be used is known the calculated temperature effects may be checked where necessary using the coefficient of thermal expansion based on the values given in Table 1A for concrete made with aggregates from natural sources. The values in Table 1A contain an allowance for the presence of reinforcement in concretes with a coefficient less than 12 x 10^{-6} per ^{o}C.

TABLE 1A

Aggregate Type	Coefficient of thermal expansion (x 10^{-6} per ^{o}C)
Chert	13.5
Quartzite	12.0
Sandstone, Quartz, Glacial Gravel	11.5
Silicious Limestone	11.0
Granite, Dolerite, Basalt	10.0
Limestone	9.0

(Amendment No 1, July 1979)

TABLE 2

Environment	Examples	Minimum Cover To Reinforcement		
		Class of concrete (N/mm^2)		
		22.5	30	37.5 and above
		mm	mm	mm
(a) All concrete surfaces, except those in (b), (c) and (d) below.	Bridge decks protected by: waterproofing or permanent formwork; internal areas of: pedestrian subways or voided superstructures or cellular abutments; sheltered soffits; parts of substructures permanently under water.	40	30	25
(b) Concrete surfaces exposed to: driving rain or alternate wetting and drying or freezing whilst wet	Walls and structure supports remote from roadside;	Class of concrete not permitted		
	soffits, except as in (a); buried parts of substructures; parts of walls in contact with soil.		40	30
(c) Concrete surfaces exposed to: de-icing salts or sea water spray	Walls and structure supports adjacent to a highway or the sea.	Class of concrete not permitted	50	40
(d) Concrete surfaces exposed to: abrasive action of sea water or water with a pH $\leq$ 4.5	Marine structures; parts of structures in contact with moorland water	Class of concrete not permitted		60

(Amendment No 1, July 1979)

2.8 PERMISSIBLE STRESSES UNDER BEARINGS

The compressive stress in the contact area under a bearing shall not exceed $0.3\ u_w$ except that:

i. Where adequate intermediate packing is provided, the compressive stress in the contact area shall not exceed $0.375\ u_w$. In addition, when the supporting area considered to resist the compressive force is wider on all sides than the contact area, the permissible compressive stress may be increased by multiplying $0.375\ u_w$ by $3/(1+2\ y_c/y_s)$ subject to a maximum value of $0.75\ u_w$.

where y_c is the length of the contact area in the direction considered and y_s is the length of the corresponding side of the supporting area.

For rectangular areas, the direction to be considered should be that having the smaller y_c/y_s ratio.

ii. Where the concrete is reinforced to resist tensile splitting forces, higher compressive stresses may be permitted where such values are justified by tests.

For components with different classes of concrete, the lower class shall be used to determine u_w.

2.9 BURIED PRECAST CONCRETE PIPES

Precast concrete pipes of internal diameter greater than 900 mm, supplied in accordance with the Specification are deemed to comply with the requirements of this memorandum provided that:

i. the concrete cover to reinforcement is not less than that specified in BS 556;

ii. the 28 days works cube strength for the concrete is greater than $50\ N/mm^2$;

iii. pipes not subject to traffic loading are designed in accordance with the data in Building Research Station publication 'Simplified Tables of External Loads on Buried Pipelines'; and

iv. pipes subject to traffic loading are designed in accordance with the method given in the above Simplified Tables, except that the bedding factor F_m shall be taken as 1.9, the bedding shall be as described in the Specification, and the factors of safety shall be taken as:

factor of safety for proof strength F_s (proof) not less than 1.2

factor of safety for ultimate strength F_s (ult) not less than 1.5.

(Amendment No 1, July 1979)