DEPARTMENT OF THE ENVIRONMENT
SCOTTISH DEVELOPMENT DEPARTMENT
WELSH OFFICE

Inquiry into the Basis of Design and Method of Erection of Steel Box Girder Bridges

INTERIM REPORT

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DEPARTMENT OF THE ENVIRONMENT

Inquiry into the Basis of Design and Method of Erection of Steel Box Girder Bridges

INTERIM REPORT

This is an abridged version of the Interim Report which is being published in this form with the agreement of the Merrison Committee.

LONDON
HER MAJESTY'S STATIONERY OFFICE
1971
The Interim Report has two Appendices, A and B. Appendix B which deals with Contractual Procedures is presented here. Copies of Appendix A of the Report—(Criteria for the Assessment of Steel Box Girder Bridges with particular reference to the Bridges at Milford Haven and Avonmouth)—may be obtained, by writing to:

The Cashier,
Room 7/09,
St. Christopher House,
Department of the Environment,
Southwark Street,
London SE1.

The price of Appendix A is £2.50 plus £1.00 for surface postage and packing, except for orders from the UK and Commonwealth in which case the price is inclusive of postage and packing. The remittance should be included with the order.
INQUIRY INTO THE DESIGN AND ERECTION OF STEEL BOX GIRDER BRIDGES

COMMITTEE MEMBERS

Chairman: Dr. A. W. Merrison, Ph.D., F.Inst.P., F.R.S.
Vice Chancellor, University of Bristol.

Members: Dr. A. R. Flint, B.Sc. (Eng.), Ph.D., A.C.G.I., F.I.C.E., F.I.Struct.E.
Partner, Flint and Neill, Consulting Engineers; Reader in Structural
Steelwork at the Imperial College of Science and Technology,
University of London.

W. J. Harper Esq., B.C.E.
Director, Building and Contracting Group, Construction Engineer-
ing Division, British Steel Corporation.

Professor of Civil Engineering, University of Manchester.

Senior Partner, Sir Frederick Snow and Partners, Consulting
Engineers.
INTERIM REPORT OF COMMITTEE ON STEEL BOX GIRDER BRIDGES

Introduction
1. Our terms of reference are—

(i) To consider whether the collapse of the Milford Haven and Yarra Bridges necessitates reconsideration of the design and method of erection for any major box girder bridges about to be erected in the United Kingdom;

(ii) To examine the design rules and methods of analysis used for steel box girder deck structures for large bridges, and to draw up an interim technical memorandum for the guidance of bridge engineers, prescribing the rules and methods to be adopted in the design and erection of such bridges, the limits within which such designs may be accepted and any special matters affecting contract procedures.

(iii) To recommend what further research and development should be undertaken into this type of construction.

2. We make this interim report, which is concerned largely with the first of our terms of reference, to give designers of bridges of this kind immediate access to our preliminary conclusions, and to avoid the serious consequences that delay would have on bridges about to be erected, in particular those at Avonmouth and Milford Haven. We must emphasise that because of the very great pressure of time we have worked as quickly as we think is consistent with our advice to designers being reliable. It is possible that in time we may be able to revise it so that it is not so restrictive. However, we feel it unlikely that the advice we shall offer in our final report will differ substantially from that in this interim report. We expect only to amplify and amend in detail what we say now. The report is, in addition, a first step to discharging our responsibility under the second term of reference.

3. At the start of our work we decided that to complete our enquiry under the first term of reference it would be necessary to identify to our satisfaction the causes of the collapses of the Milford Haven and Yarra Bridges and to see what consequences these had for major box girder bridges in the United Kingdom.

4. There are two difficulties with this programme. The first is that the Royal Commission inquiring into the collapse of the Yarra Bridge has not yet completed its task and it would be quite improper for us to comment on what its conclusions might be at this stage. Nevertheless, we have examined the evidence so far submitted to the Royal Commission and we feel sure that there will be lessons to be learned from the Yarra Bridge failure and in our final report we shall comment on these.
5. The second is that in Great Britain there is a very large number of steel box girder road bridges under construction or design—49 in various stages of construction and a further 30 in the design stage for which tenders will be invited shortly—and it would be impossible for us to give detailed advice in all these cases.

6. Our advice to those responsible for the construction of steel box girder bridges is contained in two appendices to this report, one on conditions for structural adequacy and another concerned with methods of erection and contractual procedures. The report itself starts with a summary of what is known of the Milford Haven collapse. This is followed by a guide to the two appendices which explains some of the background to them and which gives some idea of the problems encountered in the construction of bridges of this kind.

7. Although the two appendices A and B, are intended to apply principally to the bridges at Milford Haven and Avonmouth it will be clear that the advice in them may be applied generally to thin-walled steel box girders. We are currently examining those bridges, projected and under construction, which have special features which will entail amplification of the advice we give in this present interim report. Our final report will of course cover these features, and we expect in addition to make some general comments on the whole field, including the present state of design and the adequacy of guidance available to designers and constructors.

8. The method of working we adopted was to set up two Sub-Committees: one to examine conditions for structural adequacy, consisting of Dr. Flint and Professor Horne; and the other to examine methods of erection, consisting of Mr. Harper and Mr. Scruby. The advice of Mr. A. D. Holland, Chief Highway Engineer, Department of the Environment, and the help we have received from members of his staff, have been invaluable to us and quite essential to our efficient working. We owe a very great debt also to the responsible and diligent work done by our secretary, Mr. B. J. Hardy of the D.O.E.

The Milford Haven Collapse

9. In identifying the cause of the collapse of the Milford Haven bridge we have studied carefully the technical reports which have been written on the accident, we have visited the site at various times and spoken with those responsible for the erection, and we have talked with Sir Ralph Freeman, Dr. Oleg Kerensky and Dr. C. W. Brown of Freeman, Fox and Partners, consulting engineers on the project. We should like here to acknowledge the debt we owe to various members of this firm, and particularly to Sir Ralph Freeman, for the frank and courteous way they have dealt with all our enquiries. Appendix A of our report owes a great deal to the knowledgeable criticism they have made available to us. We have also had meetings with Col. W. Brundan the Engineer and Surveyor to the County of Pembrokeshire, the representatives of A. E. Farr Ltd. and of John Thompson Horsley Bridge Co. Ltd.; again we must thank them for their co-operation.
FIGURE 1.
GENERAL ARRANGEMENT
MILFORD HAVEN BRIDGE
STAGE OF ERECTION AT ST. MARY END
AT TIME OF COLLAPSE 2nd JUNE 1970

FIG. 2.
10. The four reports available to the Committee analysing the collapse of the bridge under construction at Milford Haven, and the cause of this collapse, were:

(a) A report dated 3 August 1970, together with addenda submitted by Sir Hubert Shirley-Smith at the request of the Coroner in charge of the inquest on those killed in the collapse;

(b) "Milford Haven Bridge—Partial Collapse" by Sir Alfred Pugsley, dated 15 September 1970, written at the request of Freeman, Fox and Partners, consulting engineers on the Milford Haven Bridge, together with an addendum dated 19 September;

(c) "Milford Haven Bridge Collapse" by the Structures Department of B.A.C., dated 2 September, written at the request of Freeman, Fox and Partners, with appendices I-IV;

(d) "Examination of the Damaged Road Bridge over the River Cleddau, Pembrokeshire" by F. H. Jones of the Royal Aircraft Establishment, Farnborough, dated September 1970.

Milford Haven—The Collapse and its Cause

11. The superstructure of the bridge at Milford Haven consists of a constant cross-section trapezoidal steel girder of welded construction (Fig. 1) whose width across the top is 41 ft. (top flange), across the bottom is 22 ft. (bottom flange) and with sides of depth 18 ft. (side webs). Although the girder is stiffened by longitudinal trough sections and welded flats, there is no substantial stiffening of the cross-section as such except where the girder passes over its pier supports. At each of these points the whole cross-section is filled with a stiffened plated diaphragm.

12. The steel superstructure is built up of 48 pre-assembled steel boxes of lengths between 50 and 60 ft., each of which has a weight of about 100 tons. The method of erection is that each box is rolled on bogies along the previously constructed part of the superstructure; it is then swung out on heavy launching arms until it is contiguous with the last box erected, and is then welded to it.

13. The collapse occurred on 2 June 1970, during the course of erection at the South end of the bridge. At the time Boxes 48-41 had been successfully welded into position and Box No. 40 was being rolled along the superstructure prior to being launched (Fig. 2).

14. The sequence of events at the time of the collapse has been described by Sir Hubert Shirley-Smith in his report to the Coroner and the following is abstracted from that report:

"The Collapse of the Cantilever

This occurred on Tuesday, 2 June 1970, at about 2.16 p.m. The day was fine and sunny; there was no breeze and the air temperature was 75° F.
At the time of its collapse the cantilever on the south side, jutting out towards the river from Pier No. 6, consisted of Boxes 41, 42, 43 and half of Box 44, making a total length of 196 ft.

Box No. 40 had been placed on four bogies and was being winched out on the rail tracks to the end of the cantilever. It had gone about 50 ft. clear to the south of Pier 6 when there was a sound variously described as a 'click' or a 'bang' or a loud 'crack', and the cantilever began slowly to collapse.

As can be seen in the photograph, the steelwork buckled over the top of Pier 6, but apart from that the whole cantilever remained virtually intact and fell slowly, making a 'loud rumbling roar' until the end of it struck the ground. The steelwork fell on the centre line of the bridge and did not deviate appreciably to either side.

The end of it that hit the ground was, of course, buckled upwards by the impact, but the steel superstructure remained as a unit, sloping up at an angle of about forty-five degrees to the top of Pier 6. According to a witness the collapse from start to finish took about eight seconds.

The new Box 40 that was being rolled out slipped forward off its bogies as the deck tilted down and slid on down to the ground, where it landed damaged, just beyond the end of the cantilever. The bogies fell down the slope after the Box and one or more of them crashed into it on the ground, where other items of temporary material, including the launching arms, also landed and were badly damaged.

The cantilever, which weighed nearly 500 tons, imposed a downward reaction on the top of Pier 6 and an upward reaction on the South Abutment at the end of the anchor span. As the front end of the cantilever struck the ground with terrific impact, the far end of it was, in my opinion, temporarily lifted off the top of Pier 6, tending to throw the anchor span up and transmitting sufficient force to the end bearing to break one of the 48 bolts and cause some cracking at the edge of the tie back. The west side of the diaphragm at the end of Box 48 over the Abutment was displaced about \( \frac{1}{2} \) inch to the north.

In my opinion the sequence of events from this stage was as follows:

As the anchor span fell back again, the end of it adjacent to Pier 6 was badly buckled by impact with the top of the pier. The bottom flange of the anchor arm landed at a level 2 ft. or more below where it had previously stood. The part of it above the temporary steel trestle fell right down on top of the trestle, which buckled the bottom flange upwards about 9 ins.

The top of Pier 6 was displaced 14 ins. to the south by the reaction from the collapsed cantilever and probably also by the reaction from the anchor arm when it fell back after being jerked upwards. Four lateral tensile cracks up to \( \frac{1}{2} \) inch in width can be seen on the base of the north side of Pier 6, no doubt as the result of the deflection of the top of the pier to

* Not included in this report.
the south. The steel-work has flattened down considerably over the top of Pier 6, where the level of the deck is now about 10 ft. lower than it was before the collapse.”

The Report for the Coroner by Sir Hubert Shirley-Smith

15. Sir Hubert Shirley-Smith’s investigation was confined to a detailed inspection of the damaged steelwork on the site, a careful reading of the design and erection drawings of the bridge, and interviews with a large number of people who had been responsible for the design and erection of the bridge and those who had witnessed its collapse.

16. He was left in no doubt from this careful investigation that the primary cause of the collapse was the failure of the steel diaphragm over Pier 6. This member was in a highly stressed condition, particularly because of the compressive forces developed along the lower edge of the diaphragm by the inclined side webs. Sir Hubert draws attention to a number of other factors which, though relatively minor in themselves, combined to precipitate failure. These included the difficulty of keeping flat the large steel diaphragm and the impossibility of avoiding the distortions and welding stresses which would have occurred in its fabrication.

Cause of Milford Haven Collapse

17. As a result of all our investigations and discussions we are left in no doubt whatsoever that the primary cause of the collapse of the Milford Haven Bridge was a failure of the diaphragm over Pier 6, and that this failure was certainly not primarily due to manufacture of the bridge or its components. The diaphragm as designed simply was not strong enough to resist the severe compressive forces it was subjected to during erection.

General Design Considerations for Steel Box Girder Bridges

18. Two related questions are thrown up by the Milford Haven collapse: the first question is whether the fundamental knowledge of structural mechanics available to the engineer has reached a stage at which it is reasonable to undertake with confidence the design of large thin-plate box girders, now so commonly used in bridge-building; the second question is whether guidance in the use and detailed application of this fundamental knowledge is accessible to the engineer.

19. Our answer to the first question is that current knowledge of structural mechanics justifies engineers proceeding to the design of large box girder bridges, including the use of designs in which the effects of possible buckling are taken into account. But the simple fact that a structure incapable of sustaining specified loads was not exposed by presently accepted checking procedures leads us to the conclusion that the guidance in the use and application of the available knowledge was and is inadequate. Once we had reached this conclusion, our sub-committee of Dr. Flint and Professor Horne drew up an
interim basis for appraisal of structural adequacy intended to supplement
BS 153* which can be applied in particular to the Milford Haven and Avon­
mouth Bridges. These criteria represent the best advice which it has been
possible for us to assemble within the time constraint to which we have been
obliged to work, and they are endorsed by us all.

20. We have already subjected the design criteria in Appendix A to the
criticism of a number of professional engineers and research workers and we
are grateful for the unstinting help we have received from them.

General Criteria for the Appraisal of Steel Box Girder Bridges

21. As we have said in para. 19 above, we have written criteria for the design
appraisal of steel box girder bridges and these are contained in Appendix A.
In this section of the report we give the background to the writing of these
criteria.

22. It is important to understand that very large areas of thin plate are used
in the construction of box girder bridges, that at Milford Haven being the
deepest trapezoidal box girder yet designed. The only British Standard Speci­
fication for steel girder bridges is inadequate for the design of box girders of
this kind and it would be right to say that in work of this nature design is
pushed to the limit of the engineer's knowledge and, indeed, beyond the limit
of research experience. In such a situation it is of the utmost importance that
not only are adequate safety factors incorporated in the design but that the
effect of imperfections of various kinds is properly appreciated and allowed for
also. It is with these considerations in mind that our criteria for design have
been constructed. We have been able to take account of the most recent work
in the field, and we must emphasise that a considerable amount of it is very
recent. There also remains the urgent need for further experimental evidence
applicable to box girders to verify theoretical approaches which have of
necessity, been used in our work.

23. Although the Milford Haven collapse was due to the failure of a single
structural member, a diaphragm, our investigations have lead us to conclude
that there are wider implications in considering the design of these bridges.
For this reason we have written a basis for appraisal of structural adequacy
covering all aspects of the components of the box girder bridges like those at
Milford Haven and Avonmouth.

24. The general approach used in constructing our basis for appraisal of
structural adequacy is to lay down a series of load factors which should be used
in determining what would be safe stresses in the components of the girder
compared with the stress which would lead to a collapse or to the girder becom­
ing unserviceable. We regard these load factors as adequate for security and
consider that there is no justification at the present time in reducing the load
factors we recommend.

* BS 153, Parts 3B and 4 (1958). Specification for Steel Girder Bridges. This speci­
fication is primarily intended to apply to the superstructure of simply supported
steel bridges up to 300 ft. span of conventional design.
25. We define also the way that various combinations of load should be taken into account and we give guidance as to the way stresses should be calculated. We give rules, too, for calculating the results of various imperfections: residual welding stresses, mechanical deformations, and lack of fit between the box girder and its supports. Methods are given for the assessment of strength of panels, stiffened panels and the stiffeners themselves, and for the analysis of the various major components used in the box girder.

26. To make our design guidance such that there is no loss of the economy in using box girder construction, we consider it essential that short term experimental work be put in hand aimed at producing the data necessary for the Committee. We are prepared to provide advice as to the nature of such investigations.

Methods of Erection and Contract Procedures

27. A major part of our final report will be concerned with the broad area of responsibility of all parties concerned in the design and erection of bridges. We feel that the tragedies at the Milford Haven and Yarra Bridges have brought to light and emphasised weaknesses in procedures which will need to be looked at carefully. In Appendix B we make a number of recommendations which, though admittedly preliminary, we feel of sufficient importance that we would regard their immediate application as mandatory. They are self-explanatory and it does not seem of any value to summarise them here. We should, however, like to draw particular attention to our judgement that we consider it essential that the Consulting Engineer's permanent design should be checked by an independent engineer who will issue a certificate to the effect that the design, modified if necessary, will comply with the general criteria we have laid down in Appendix A. A check should similarly be made that the stresses in the structure during erection also comply with the criteria given in Appendix A.

28. We do not believe that this procedure will lead to any undue delay in the design stage, but as a simple safety precaution we feel that its value could hardly be overestimated. A major box girder bridge is expensive, and the hazards in the construction industry are already such that we feel that this independent checking procedure would be a very small price to pay if it helps in avoiding the sort of disaster we have been concerned with. And we have no doubt at all that this will be the case.

Conclusions and Recommendations

29. The collapses of the Milford Haven and Yarra Bridges will have raised questions and doubts—very understandably—about the safety of the steel box girder as a general element in bridge-building, and we assume that this is one of the reasons, if not the primary reason, for the existence of this Committee. We have now considered this problem in the light of the general expertise in design and erection of large structures which is available within the Committee, and we can say with complete confidence that such general fears are without foundation. At the same time, in spite of the simplicity of the box girder as a bridge element, when large areas of thin steel sheet are used in its construction
there is no doubt that considerable skill and care must be exercised by both designers and those responsible for construction. But again, as we have said in para. 19 above, the methods available to the engineer are adequate to deal with the problems involved although not necessarily as yet in the most efficient manner. With general guidance of the kind in the appendices to this report, there is no reason for doubting the safety and general soundness of such structures. Indeed, we would go further and say that a good deal of the advice we offer in this interim report is no more than what we should regard as sound engineering practice which could well be applied to other engineering structures, certainly to other types of bridge structure, and it would be unfortunate if this general advice were to be restricted in its application.

30. Certain reservations must be made concerning the endorsement of the report; these concern Professor Horne and Dr. Flint. Because of the commitments entered into by Professor Horne before the setting up of the committee, it was agreed that his responsibility for the report of the committee should exclude:

(a) those parts dealing explicitly and specifically with the collapse of the Milford Haven Bridge, namely paras. 9 to 17 inclusive, and

(b) those parts dealing with contract procedure, namely paras. 27 and 28 and Appendix B.

Similarly Dr. Flint had certain commitments regarding the forthcoming erection of the Milford Haven Bridge, he therefore cannot be associated with the report in so far as it concerns the strength during erection of the Milford Haven Bridge. The Committee emphasise that these restrictions have in no way inhibited the Committee in its investigation or in reaching its conclusions, and, apart from the reservations noted, the report and its appendices are fully endorsed by the whole Committee.

31. In this interim report we have been concerned mostly to offer advice and guidance in both design and erection to those responsible for the bridges at Milford Haven and Avonmouth, where the present state of construction requires immediate advice. As we have remarked already a good deal of this guidance is quite general in character and, a fortiori, will be applicable to other box girder bridges with similar design features.

32. In our final report, which we shall present at the end of this year, we shall in the first place be concerned to amplify the advice to designers and constructors given in this interim report. We expect to make it more general so that it covers bridges with features absent from those at Milford Haven and Avonmouth. We expect also to make more general comments about the way that guidance of the kind we give here should be formed and the way in which it can be made available to engineers. We shall in the meantime advise the D.O.E. of any developments or modifications which occur to us as and when they arise. In order that we may concentrate our efforts as fully as possible on the next stage of our work, we would particularly ask that any enquiries which may arise relating to the criteria for appraisal should be channelled to us through the D.O.E.
Inquiry into the Basis of Design and Method of Erection of Steel Box Girder Bridges

Appendix B—Contractual Procedures
APPENDIX B—CONTRACTUAL PROCEDURES

1. The Sub-Committee responsible for the examination of the contractual and erection procedures is reviewing, inter alia, the responsibilities of the Engineer and the Contractor, the procedures whereby these responsibilities are discharged and the areas of uncertainty attendant upon the current contractual arrangements. Although these studies have yet to be finalised certain aspects are considered to be of sufficient importance to be published as necessary recommendations to discharge the first term of reference.

2. The general conclusions and recommendations which the Sub-Committee considers should apply to the structures referred to in the first term of reference and for which contracts have already been, or are shortly to be let are dealt with in paras. 3 to 24. These refer to the Engineer and the Contractor.

THE ENGINEER'S RESPONSIBILITIES

a. Permanent Design

3. From the Sub-Committee's investigation of present practice there is some doubt as to whether the design assumptions and analytical procedures adopted for the design are rigorously checked by an engineer who is sufficiently remote from the design team to remain uninfluenced by the creative process associated with the bridge design in question.

4. In all cases the Committee considers it essential that the Engineer’s permanent design should be checked by an independent engineer both for the design concept and the method of analysis of stresses and a certificate furnished to this effect and for compliance with the criteria set out in Appendix A. The independent engineer should have experience and qualifications commensurate with the magnitude and complexity of the design in question.

5. The Committee considers that the independent engineer may be a member of the same organisation as the Engineer provided:
   
   (a) this situation is acceptable to the Employer;
   
   (b) he was in no way associated with the design concept or analysis.

6. The detailed appraisal required will be additional to that normally undertaken D.O.E. Bridges Engineering Division. It would, if undertaken by the Department itself, necessitate the availability of additional staff resources for considerable periods of time.

b. Erection

7. Under the terms of the Engineer's Agreement with the Employer the Engineer is, inter alia, responsible for the supervision of the works and for exercising care and diligence in such duties; the extent to which he is obliged to check the Contractor’s method of working is not defined. Similarly, Clause 14 of the I.C.E. Conditions of Contract requires the Contractor to provide the Engineer with such particulars of his arrangements for executing the works as the Engineer deems necessary; this of course does not relieve the Contractor of his responsibility.

8. The Sub-Committee in their inquiries noted that the obligation assumed by the Engineer concerning the checking of the strength and stability of the structure during erection often went further than required by the A.C.E. or the D.O.E. Model Agreement between the Engineer and Employer.
9. The Committee recommends that this additional requirement should be made mandatory by the inclusion into the Agreement of a clause of the form recommended by the I.C.E. Committee on Safety in Engineering(*), which will place on the Engineer responsibility for “examining Contractors’ proposals and details and the checking of the adequacy, stability and safety, of the proposed methods of construction and temporary works”. This should not relieve the Contractor of any of his responsibilities under the terms of the Contract.

10. The checking of stresses in the structure during erection should be in accordance with the criteria given in Appendix A.

11. The Committee recommends that the obligations noted in paras. 9 and 10 be incorporated in the agreement between the Employer and the Engineer for structures referred to in para. 2.

12. The importance of correctly calculating deflection of the cantilever in a cantilever erection condition is recognised by Engineers and Contractors alike. Deflections should be accurately measured at regular intervals agreed by the Engineer at a time of day at which the ambient temperature can most easily be correlated with that assumed in the calculations. If the disparity between the measured and calculated deflection exceeds the permitted tolerance defined by the Engineer erection should be discontinued until the Engineer is satisfied as to the reasons which have caused the disparity and that the safety of the bridge during the remainder of the erection and in its permanent condition is in no way impaired.

c. Resident Engineer and Site Staff

13. The Employer should require the Engineer to satisfy him regarding the sufficiency of the qualifications and experience of the site staff and the adequacy of their number.

14. In accordance with Clause 2 of the I.C.E. Conditions the Resident Engineer’s terms of reference and delegated powers should be put in writing to the Contractor.

15. A working brief should be issued in writing to the Resident Engineer by the Engineer (which is not for communication to the Contractor) and a copy made available to the Employer if required.

16. This brief should make clear the extent to which the Resident Engineer is empowered, without reference to the Engineer, to approve changes in the design of the permanent or temporary works and any other changes in fabrication or erection procedures proposed by the Contractor. The Resident Engineer should not be permitted to agree to any other changes without permission from the Engineer.

17. We interpret Clause 15 of the Conditions of Contract as meaning that the Contractor is required to satisfy the Engineer regarding the sufficiency of the qualifications and experience of the Contractor’s site staff and the adequacy of their number. This interpretation should be rigidly enforced.

d. Working Tolerances

18. A complete schedule of all working tolerances and imperfections which may be permitted during fabrication and erection should be promulgated by the Engineer to all concerned in existing contracts and specified for future contracts and should not exceed those given in Appendix A.

THE CONTRACTORS RESPONSIBILITIES

19. In connection with the second term of reference, the Committee will give careful consideration to the suitability of the present contractual relationship, procedures and methods of sub-contract for the building of major bridges, and will consider in greater detail the precise nature of the information which the Contractor should be required to provide.

20. It is important where bridgework is carried out by sub-contract that the general obligation of the Contract should be invoked so that it is brought home to the main Contractor that it is his responsibility to effect strict compliance with requirements such as those contained in Clause 14 of the I.C.E. Conditions of Contract. It is strongly recommended that the position is clarified by the Engineer by inclusion into the Specification of clauses similar to those in para. 24.

21. Where the superstructure of bridgeworks is undertaken by sub-contract the main Contractor should be firmly held to the obligations imposed by Clause 4 of the I.C.E. Conditions of Contract.

22. The Committee does not consider Clause 14 of the I.C.E. Conditions of Contract to be satisfactory in its present form where it affects special structures of the kind which this Committee is concerned. We intend to make recommendations to the Joint Contracts Committee in this connection.

23. The Committee have considered this problem in the context of Milford Haven and considers that the situation is satisfactory, so far as Milford Haven is concerned, provided that the clauses in the existing specification reproduced in para. 24 are strictly enforced.

24. The following clauses are quoted from the Milford Haven Specification:

"Construction Methods and Equipment"

Where certain methods of construction have been assumed in design, these are described in the relevant sections of this Specification, the Bill of Quantities or the Drawings. Where the Contractor wishes to adopt other methods which may or may not entail alterations to the design of the permanent Works, the Contractor shall check the stresses arising during construction and submit his calculations to the Engineer for approval. Material added to facilitate construction of the superstructure and in excess of that shown on the Contract Drawings will be paid for at the appropriate schedule rates if the construction scheme is approved. The Contractor shall make all necessary calculations for camber, stability and stresses during erection of structures, and shall submit them to the Engineer for approval. So that the Engineer may verify that the proposed methods of construction conform to the requirements of this Specification the Contractor shall, before starting the work of construction, inform the Engineer fully as to the method of construction he proposes to follow and the amount and character of the equipment he proposes to use.

The method of construction proposed to be used shall be subject to the scrutiny of the Engineer, but such scrutiny shall not relieve the Contractor of any responsibility for the safety of the proposed method of construction or of the equipment or from carrying out the work in full accordance with the Drawings and this Specification.
The Contractor shall not depart from his proposals for fabricating and erecting structures without the Engineer's written permission.

_Erection Scheme_

The Contractor shall prepare his own erection schemes and at least 2 months before commencement of erection shall submit sufficient calculations of erection loads and stresses to satisfy the Engineer of the soundness of the scheme." (Paras. 9 and 10.)