LESSONS FROM FAILURES – WEST GATE BRIDGE

Dr Donald E Charrett, Barrister,Victorian Bar

WEST GATE BRIDGE, MELBOURNE (1970)
Introduction

Collapses of buildings or structures almost inevitably generate disputes between the project participants. In addition, there is usually a substantial public interest dimension in such failures, particularly if death or injury results. Government response to significant failures is sometimes swift, and often takes the form of a public inquiry, sometimes a Royal Commission. The terms of reference of such public inquiries typically include determining the causes of the failure, and recommendations to avoid similar failures in the future. The reports of these inquiries are therefore much wider in scope than any report of the litigation between disputing parties involved in the failure, and form a valuable repository of lessons to be learned and guidance for improved practice in the future.

This paper reviews the reports of several public inquiries into high-profile failures of steel box girder bridges in the 1970s. It is suggested that although these relate to failures that occurred some ago, in addition to their historical interest, the reports contain timeless information that is still relevant today. If these lessons from the past are not heeded and learned, then perhaps today's generation of building practitioners will unwittingly repeat them. Although the failures discussed here had a predominantly "technical" cause in respect of inadequacies in the quality of design and/or construction, the focus of the paper is on the contractual and procedural aspects of project execution (particularly time, cost and scope of work), and the extent to which they were contributing factors to the collapse. The deaths resulting from these failures are a salutary reminder that failure to implement the appropriate contractual procedures and execute the works in compliance with the requirements of the contract can have much more serious consequences than a dispute over which party is liable to pay damages.

WEST GATE BRIDGE
Overview

West Gate Bridge was procured under a forerunner of a modern PPP Partnership. In the late 1950s the Government had inadequate funds to finance a new bridge, and accordingly a private enterprise group initiated the project, with the cooperation of the Government. The Lower Yarra Crossing Authority (**the Authority**), a private company limited by guarantee, was vested with various powers by the *Lower Yarra Crossing Authority Act 1965* (Vic). Those powers enabled it to make regulations, borrow money to finance the river crossing, acquire land and raise tolls so that the bridge would be paid for by its users. It was intended that the bridge would become the property of the crown when all loans had been repaid[1]. The bridge comprises 12 concrete spans on the east side and nine concrete spans on the west side, with five steel box girder spans crossing the Yarra, the central three spans being cabled stayed.

Following the unfortunate experience of the failure in service of Kings Bridge, and the Royal Commission's criticism of its procurement via a design and construct contract[2], the procurement of West Gate Bridge by the Authority was conventional: eminent consulting engineers were engaged directly by the Authority to prepare the designs and supervise construction, and contracts were let for the construction in accordance with the engineers' designs.

On 15 October 1970, the 112 m span on the western side of the Yarra known as span 10-11 collapsed suddenly during construction, resulting in the death of 35 people. The Coroner immediately constituted a five-man expert technical committee to observe and record facts on site. The evidence collected by that committee was invaluable to the Coroner and the Royal Commission, which was announced the day after the collapse. Letters Patent dated 21 October 1970 appointed Justice Barber of the Supreme Court, an Australian Professor of civil engineering and a distinguished English bridge engineer as Commissioners. A preliminary hearing was held on 20 October 1970, followed by 80 sitting days between 5 November 1970 and 15 June 1971. It heard evidence from 52 witnesses and considered 319 exhibits. The Royal Commission was charged with enquiring into and reporting on the circumstances surrounding and the cause or causes direct and indirect of the failure of steel span 10-11, and whether any aspect of the design of the steel span was inadequate or undesirable[3]. The Report dated 14 July 1971 is the source of the following observations.

Construction contracts for West Gate Bridge

The original contract for fabrication and erection of the steel box girder spans of the bridge (**Contract S**) was based on a considerably amended Australian Standard General Conditions of Contract for Civil Engineering Works, with a number of other documents incorporated. The Commission criticised the drafting of the contract, particularly the vice of incorporating documents that purported to impose liability on persons not parties to the contract. It quoted as an example of such an inappropriately incorporated document in the construction contract, the minutes of a meeting between representatives of the consulting engineers and the contractor:

"Contract S included a provision for an exchange of design information as follows:-'To ensure that erection calculations will be in accordance with the engineer's design criteria – notably the end conditions under full load FF&P [the consulting engineer for the steel spans] will supply to Werkspoor [the parent of Contract S contractor] a set of bridge design calculations'.

Despite repeated requests from WFC [**Contract S contractor**], FF&P resolutely refused to hand over any calculations."[4] The Royal Commission noted:

"As this matter was of major importance to WSC, its inclusion, merely by way of an incorporated document, can only be regarded as slipshod drafting. We make no comment on other similar instances, save to observe that contracts for works of the magnitude of this project, merit rather more careful consideration."[5]

In view of the significance of the calculations (or the lack of them) in the collapse, this was a major contractual deficiency.

Construction under Contract S commenced in April 1968, with a projected completion date of December 1970. However, the contractor fell seriously behind its program such that by February 1970 the Authority issued a "show cause" notice under the Contract. The contractor issued a counter notice, and a settlement was reached in which WSC retained the work of fabrication and subassemblies of the steel boxes, with all the other work of completion and erection to be carried out by John Holland (Constructions) Pty Ltd (**JHC**) under a new contract (**Contract E**). JHC also constructed the foundations and concrete spans under separate contracts.

Contract E was a "cost plus" labour management contract in which JHC was responsible for the physical task of erecting the steel work, but had no responsibility for engineering decisions relating to final or erection stresses in the bridge. This contract had an exclusion clause which held JHC harmless in contract or tort for any failure to construct and complete the works or any defects, unless caused by gross negligence.

...the basic cause of the tragedy at West Gate was the design inadequacies which led to the safety margins being much too low, and certainly lower than the specified values

The Royal Commission considered the implications of the provisions of Contract E, and whether it had any bearing on the collapse. It noted that the unusual contractual arrangements with JHC, and its relative inexperience in large steel bridge work, put more responsibility on the consulting engineer (FF&P) and made its task more onerous, without changing its legal liability (which remained the skill, care and diligence contemplated by the common law and expressed in the provisions of the consultants agreement)[6].

The Commission considered that this contractual arrangement was a contributing factor in the collapse: *"There can be no doubt that the problem created by the limitation on the responsibility and liability of JHC and the increased responsibility of FF&P became a major cause of serious trouble and difficulty. The failure clearly to define the roles of the FF&P staff and JHC engineers led to a confusion that was disastrous."* [7]

Furthermore, the Commission noted that this situation could easily have been avoided by contractual means:

"All this confusion and difficulty *could and should have been quite easily avoided, had the increased responsibility of FF&P been clearly defined in the first place. It is the greatest pity that nobody seems to have thought of the desirability of amending the contract between the joint consultants and the Authority, contemporaneously with the execution of Contract E, in such a way as to define the consultant's responsibility."* [8]

Cost & time issues

It is notable that cost factors were not identified as having any bearing on the collapse, as the Authority placed no particular financial limits on the cost:

"There was certainly no pressure by the Authority to achieve cheese-paring economies, particularly if by so doing any risk to the safety of the structure was involved."[9]

However, the same cannot be said of time pressures, and the Commission criticised the Authority in the following terms:

"Fundamental to the whole sorry situation was a constant sense of urgency and pressure to complete the construction within specified times. No one can blame the Authority for a desire to keep its contractors up to schedule. The financial consequences of any delay was serious to an organisation working on borrowed capital - and a degree of pressure to reach completion on time is understandable and even praiseworthy. Nevertheless, the determination to keep the work moving at all costs was so extreme as to engender an atmosphere in which speed was the all-important consideration. In a number of instances the burning desire for speed resulted in quick, ill considered decisions which brought about trouble, difficulty and delay, whereas time spent in careful thought, and the adoption of what appeared to be the slower method of procedure would have, in the long run, meant an earlier, and happier result. We are satisfied that this climate of urgency and pressure tended to lower morale, and in fact directly caused some of the more serious errors of judgment upon which we have had occasion to comment."[10]

Erection

The method of erection proposed in the tender by the original steelwork contractor, using two half spans, jacked into position and joined along the longitudinal centreline had not been used anywhere else in the world under similar conditions to West Gate Bridge[11]. The consulting engineer not only neglected or refused to hand over calculations which were vital for the contractor in assessing its erection method[12], but it rarely replied to correspondence requesting technical information, or if it responded it often did not provide the information requested.[13]

The unusual method of erection created a number of difficulties that the Commission found were significant contributing factors to the collapse. In particular, the two half spans, when erected, had a significant difference in camber (of the order of 100 mm) which had to be eliminated before they could be spliced together. JHC used kentledge (seven 8-ton blocks of concrete) on the upper flange of the span as a means of correcting the difference in camber. This kentledge caused a buckle in the upper flange in the vicinity of the 4-5 splice at mid-span. In an attempt to eliminate this buckle, about 30 bolts were removed from a transverse splice in the upper flange of span 10-11 at the 4-5 splice. The Commission found that the removal of these bolts was the immediate precipitating cause of the collapse. Notwithstanding this immediate cause, the Commission was very critical of the quality of the design carried out by FF&P, and considered that it was a significant factor in the collapse:

"Finally, as an overriding circumstance within which the above sequence [of immediate events leading to the collapse] was carried out, the factor of safety for many of the approved erection conditions was already too low, so that the abnormal actions of adding kentledge and undoing bolts reduced the narrow margin even further, and in the latter case left no margin at all."[14]

Design

The technical issues associated with the quality of the design and their contribution to the collapse were canvassed in detail in the Report of the Royal Commission, and these are generally outside the scope of this paper. However, there were several general engineering issues related to the contractual arrangements that may be relevant to other large engineering and building projects. The most significant of these was the consulting engineer's responsibility for checking the erection calculations made by the contractor. FF&P adopted the practice of British consulting engineers designing major bridges and left the analysis of erection stresses to the successful tenderer. The Commission noted that this practice meant that the consulting engineer is primarily concerned with the safety and efficiency of the bridge in service, however *"he must have some regard to the limits imposed by erection problems"*, and *"there must be at least one practical method by which the bridge can be erected."*[15] Whilst in theory the contractor can ascertain what extra strengthening may be required to meet the stresses imposed by its erection scheme, to do so they would have to understand just how the structure was designed. As discussed above, although Contract S stated that FF&P would provide WSC with the design calculations, this provision was not enforceable by WSC against FF&P (which was not a party to Contract S).

In early 1970, concerns had been expressed as to the sufficiency of the design, and the Authority requested FF&P to check their design calculations. However little progress had been made on this check by 2 June 1970, when the Milford Haven bridge in Wales collapsed during cantilever construction of a span. In view of its similar design to West Gate, and the fact that FF&P were the designers of both bridges, the Authority requested an independent check of the design of West Gate. This *"independent"* design check was commissioned by the joint consulting engineers (FF&P and Maunsell), who appointed the associated firm of G Maunsell and Partners in London to carry out the work.

Although the final report of the *"independent"* check was not received until after the collapse, an interim report in September 1970 drew attention to the overstressing which was likely to occur in some of the member splices, and other areas where some overstressing was probable. After the Milford Haven collapse, FF&P themselves found that high stresses in the West Gate bridge were likely at a number of places, which led to their recommendation for a substantial programme of strengthening, requiring an additional 160 tons of steel.[16] The Commission agreed that this stiffening was vitally necessary, but did not accept that it was sufficient to make the structure safe:

"We assert that the basic cause of the tragedy at West Gate was the design inadequacies which led to the safety margins being much too low, and certainly lower than the specified values."[17]

In respect of the execution of the design, the Commission stated:

"We find that FF&P approached the design of West Gate Bridge in a disorganised and unsystematic manner and without any real guidance been given to the engineers doing the work by senior men such as Roberts or Brown. The calculations contain a great many errors of arithmetic and engineering principle and these have gone unchallenged until this Commission. It is doubtful if FF&P had any effective internal checking

system. They certainly failed to give any adequate check to WSC's calculations although apparently prepared to approve them. ... It is for all these reasons that we have formed the conclusion set out in Section 1.1.1. that the primary cause of the collapse of the West Gate Bridge was that 'FF&P failed altogether to give a proper and careful regard to the process of structural design'."[18]

It is to be hoped that this clear message conveyed by the Commission in respect of the quality of the design process has been absorbed, and that similar comments could not now be made in respect of a design office with certified quality procedures to ISO 9000. However, one must question whether the fundamental lessons arising from the quality of the design of West Gate have been learnt in England, when a recent paper by Dr Flint published on the Institution of Structural Engineers website substantially ignores any deficiency in the design and states in relation to the collapse of the West Gate Bridge:

"The causes of this were much more complex [than the cause of the collapse of the Milford Haven Bridge] and were primarily those of adoption of a previously untried and inadequately checked method of erection and failures of site organization and communications between principal parties. These led to release of bolts in the top flange to permit alignment, to an extent that the flanges buckled."[19]

Considering the Royal Commission's unequivocal statement that the basic cause of the collapse was *"the design inadequacies which led to the safety margins being much too low"*, Dr Flint's assertion that the cause was primarily related to the erection method is somewhat surprising. It is even more so when written by a member of the Merrison Committee which accepted the Royal Commission's findings (see below).

The postscript to the West Gate collapse is that the subsequent redesign resulted in a significantly different structural form to the original design. The engineering team assembled by the Authority redesigned the steel spans by eliminating the weight of the concrete deck, and transformed the top flange of the boxes into an "orthotropic deck", in which the road wearing surface is laid directly on the steel. The reconstructed bridge was opened in 1978.

MILFORD HAVEN BRIDGE, WALES (1970)

Committee of Inquiry

In June 1970, a span of the Milford Haven (now known as the Cleddau bridge) steel box girder bridge under construction, collapsed during the erection of a pre-assembled deck section. In December 1970, a technical Committee of Inquiry was appointed by the UK Government to investigate the collapse of the Milford Haven and West Gate bridges. The Committee's terms of reference were to consider whether it was necessary to reconsider the design and method of erection of box girder bridges about to be erected in the UK, to draw up technical guidelines for bridge engineers, to advise on any special matters affecting contract procedures and to recommend further research and development. This five-man committee, chaired by Dr Merrison, the Vice Chancellor of the University of Bristol, included two consulting engineers, the Professor of Civil Engineering of the University of Manchester and a director of a major steel fabricator/contractor.

The Committee concluded that the collapse of the Milford Haven bridge was caused by the inadequacy of the design of a vertical pier support diaphragm, which failed in compression over the column. The lessons from Milford Haven primarily concerned the inadequacy of the design methods used for the permanent design and checking the safety during erection. The Interim Report of the Committee[20] included comprehensive design and workmanship rules for the stress analysis and design of steel box girder bridges which were later confirmed in the Final Report after further research had been implemented.[21] The interim recommendations on checking the design of steel box girder bridges were applied to 51 highway bridges in service in England in June 1971 and 37 bridges not yet in service. Thirty two of the in service bridges and 28 of the unopened bridges were found to need strengthening,. The amount of strengthening steel added to these bridges ranged from negligible amounts up to 12.5%, apart from two "exceptional cases" (undefined, but presumably requiring more than 12.5% additional strengthening steel).[22] The "Merrison Rules" are still used today in the design and checking of steel box girder bridges.

The Interim Report was published before the Royal Commission into the West Gate Bridge published its report, and accordingly its recommendations were made in the absence of the detailed technical and contractual commentary contained in the Royal Commission Report. In its Final Report, the Committee not only accepted the Royal Commission's assessment of events which led up to the collapse, but drew considerable support from it in their recommendations on contractual and procedural aspects:

"While there were also fundamental defects in the erection procedure and permanent design of the West Gate Bridge, we regard the failures of site organisation and of communication between the principal parties - Client, Engineers and Contractors - as of more general significance in this case. There are lessons to be learned from practically every page of the Royal Commission's Report and we recommend all those connected in any way with bridge construction to study it in detail, as we have done. Those who read the Report will see that the recommendations on contractual procedures made in the next chapter are much influenced by the events at the River Yarra and by the Royal Commission's comments on them. In Chapter 3 we aim to suggest procedural principles which we think should prevent situations like that on the West Gate Bridge project from arising at all."[23]

Contractual recommendations

The conclusions of the Committee's Interim and Final Reports included wide-ranging proposals for contractual procedures. These included clarification of the allocation of responsibility between the Engineer and the Contractor, the independent checking of designs and erection methods, vetting of the Engineer's resources and of the Engineer's and the Contractor's site personnel, and appropriate handling of competitive tendering. Appendix B to the Interim Report made specific recommendations on contractual procedures, and the majority of these were confirmed in the Final Report. Whilst these recommendations were made over 30 years ago and were specific to design and construction of major steel box girder bridges under the conventional procurement route of a consulting engineer engaged directly by the Client, it is suggested that they are still applicable today to any major building or construction

works. The Committee's final recommendations on contractual procedures were as follows (citations omitted):

"(i) Four essential elements in procedures for constructing major steel box-girder bridges are:-

(a) an independent check of the Engineer's permanent design;

(b) an independent check of the method of erection and design of temporary works adopted by the Contractor;

(c) the clear allocation of responsibility between the Engineer and the Contractor; and

(d) provision by the Engineer and the Contractor of adequatelyqualified supervisory staff on site with their tasks and functions clearly defined.

(ii) The Client must assure himself that the Engineer will have resources appropriate to the project.

(iii) A certified independent check should be carried out to establish that the permanent design complies with the relevant parts of the Design Rules and is in all respects an adequate one. A differential approach to checking according to the size and complexity of structures would be appropriate.

(iv) Adherence to tolerances and fabrication procedures assumed in the design and systematic checking of fabrication accuracy and distortions during construction are essential; suppliers should take care to mark materials correctly; fabricators should maintain this identification until after assembly.

(v) Competitive tendering, handled appropriately, should lead to good construction.

(vi) Provided Clause 4 of the I. C. E. Conditions of Contract is properly enforced, there is no objection to sub-contracting major parts of steel box-girder bridge works.

(vii) A clear division of responsibilities between Engineer and Contractor is vitally important; contracts between the parties in a major bridge undertaking should reflect their practical engineering relationship.

(viii) A certified independent check of the erection method should be performed by engineers other than the design Engineer, who should nevertheless be given full details of the erection method and have a right of veto over it.

(ix) The Contractor should submit to the Engineer for his approval a construction programme specifying time scale.

(x) The independent checks of the permanent design and of the erection method should be complete by the time work starts and the erection of the relevant part of the superstructure starts respectively; the Client and the Engineer should allow the Contractor sufficient time to prepare himself for the start of work and should be prepared to consider a revision of his programme in the event of slippage.

(xi) The Engineer should carefully watch the progress of construction to ensure compliance with the agreed erection method; he should scrutinise the Contractor's site staff and where necessary exercise his powers under the contract.

(xii) The Client should satisfy himself as to the adequacy of the Engineer's site representatives; the functions and tasks of the Engineer's site representatives should be defined in writing.

(xiii) Those devising the erection scheme should pay careful attention to the safety implications of proposed sequences of operations; discussions with the Factory Inspectorate about safety precautions at an early stage of planning are to be encouraged."

In the period between publication of the Interim and the Final Report, the Department of the Environment issued a circular giving effect to seven of the recommendations made by the Merrison Committee. Three of the Committee's final recommendations were not implemented by the Department [(vi), (xi) and (xii) above]. It is noted that each of these three recommendations (in relation to subcontracting, monitoring of construction by the Engineer and adequate site Engineer representatives) can readily be implemented under most forms of contract provided there is the will to do so, and the scope of work has been defined appropriately.

Amendments to ICE Conditions of Contract

One of the standard form contracts in use for procurement of bridges in the UK in the early 1970s was the fourth edition of the ICE Conditions of Contract (1953). The form made provision in clause 14 for the Contractor to supply to the Engineer information on the erection methods "if required", but with no provision in respect of the time for compliance.

... it is particularly important in the interests both of safety and economy that the Client and the Engineer allow the Contractor sufficient time after the contract has been let to prepare for the start of work, and that they should not unduly pressurise him during the construction period itself.

The Committee recommended to the Joint Contracts Committee responsible for the ICE Conditions of Contract that clause 14 be amended to make it mandatory for the Contractor to submit a programme to the Engineer, and details and calculations of any alterations or modifications to the permanent works involved in construction or erection so that the engineer can assure itself that the completed permanent structure will not be impaired in any way. The fifth edition of the ICE Conditions of Contract issued in 1973 contained provisions along these lines, although the Engineer must request information pertaining to the methods of construction. The seventh edition (1999) formalises the requirements for exchange and approval of information even further, and defines the role of the Engineer, including a requirement for the Engineer to provide *"such design criteria relevant to the Permanent Works or any Temporary Works design supplied by the Engineer as may be necessary to enable the Contractor to comply with sub-clauses (6) [methods of construction] and (7) [Engineer's consent] of this Clause."* It appears that these provisions are consistent with the Committee's recommendation that *"contracts between the parties in a major bridge undertaking should reflect their practical engineering relationship" (vii above).*

Engineer's & Contractor's responsibilities

The Interim Report recommended that the Engineer should have responsibility for *"examining Contractor's proposals and details and the checking of the adequacy, stability and safety, of the proposed methods of construction and temporary works"*, without relieving the Contractor of any of its responsibilities under the contract.[24] However, in the Final Report the Committee revised its view on this issue and considered that the best procedure was to require the Contractor to obtain a certificate from completely independent engineers to the effect that the erection proposals had been checked and found adequate. This change of view was consistent with the Committee's strongly expressed opinion on the appropriate division of responsibility between Engineer and Contractor:

"IT IS VITALLY IMPORTANT THAT THE ENGINEER AND THE CONTRACTOR, ONCE EMBARKED ON THE CONSTRUCTION OF A BRIDGE, SHOULD UNDERSTAND EXACTLY THE NATURE OF THEIR SEPARATE RESPONSIBILITIES. The basic division of responsibility will be the same in the case of large steel box girder bridges as it is in civil engineering works generally. The Engineer's primary responsibility is for the permanent design of the structure, while the Contractor's is for the construction and completion of the works in such a way that the permanent design is properly realised. The Engineer, as originator of the permanent design and the chief authority on it, has a duty to the Client to assure himself that the Contractor's erection proposals and the implementation of those proposals will not result in any impairment of the permanent works. The responsibility for the execution of the works, including all temporary works, remains with the Contractor. We feel it is worth pointing out at this stage that in this report we are concerned, not with the legal responsibilities and liabilities, but with procedures to ensure that steel box girder bridges are safe while under construction and in service. Nevertheless, in any major bridge undertaking, it will be a pre-requisite of success that the legal forms of the contracts between the Client and the other parties should reflect precisely the practical engineering responsibilities and how they are divided between the parties."[25]

In the 35 years since the Committee succinctly summarised the separate roles of the Engineer and the Contractor in this way, there have been many changes in contractual terms relating to the traditional form of construct only contracts, including a significant reduction in the power of the Engineer. However, it is suggested that in relation to the Engineer's technical responsibility for delivery of a project to satisfy the Client's requirements, the Committee's statement is still applicable today, and is ignored at the peril of all project participants.

Time

In respect of the programming of the works, the Committee of Inquiry commented on the adverse impact that undue haste in commencing and carrying out the work can have, and made the following recommendation: *"We consider that, in the case of major civil engineering undertakings, such as large steel box-girder bridges, it is particularly important in the interests both of safety and economy that the Client and the Engineer allow the Contractor sufficient time after the contract has been let to prepare for the start of work, and that they should not unduly pressurise him during the construction period itself. The Client should be prepared to accept that there may be sound reasons for modifying the Contractor's original program and the Engineer for his part should not hesitate to advise the revision of the programme if he judges that the Contractor can no longer keep to it without risk of mistakes occurring."*[26]

> *...there are lessons to be learned from practically every page of the Royal Commision's Report and we recommend all those connected in any way with bridge construction to study it in detail.*

It is suggested that this recommendation may not find favour in today's contracting environment, in which the driving principle is often to start work at the earliest available opportunity (frequently before the design is completed under fast track arrangements), and to execute the work under very tight time constraints under threat of substantial liquidated damages. However, the Committee's clear warning of the importance of allowing sufficient time for preparation and execution of the works should not be ignored, irrespective of the prevailing contractual climate.

Lessons from West Gate Bridge

Based on the issues highlighted above, the following are some of the contractual and project execution lessons relevant to major engineering projects to be learned from the Report of the Royal Commission and the Merrison Committee Reports:

- The contract terms should clearly define the responsibilities of the Engineer and the Contractor in a way that is contractually achievable.
- A labour management contract with limited liability imposes a heavier responsibility than normal on other project participants.
- Inappropriate time pressures from a desire to keep the work progressing may provide insufficient time for properly considered decisions that can lead to errors of judgement.
- The execution of the design should be organised and systematically and adequately checked.
- Both the permanent design and the design of the temporary works and erection methods should be checked by an engineer independent of the designer.
- The Client/Owner should vet the Engineer's available resources and ensure they are appropriate to the design task.

- The Client/Owner should vet the Engineer's and Contractor's site personnel and ensure they are appropriate to the demands of the erection.

Conclusion

Although the West Gate Bridge collapse occurred over 35 years ago, the lessons identified in the Royal Commission and Merrison Reports are still relevant in today's contracting environment, but may have been forgotten in the intervening generation. An eminent well qualified and experienced consulting engineer was appointed in the traditional way to design and supervise construction, and yet the confidence placed in it turned out to have been misplaced, and to have inhibited critical assessment of its decisions. The scope of the engagement of the engineer was not appropriate to the demands placed on it. Time pressures resulted in insufficient time to properly consider various issues, leading to errors of judgement that contributed to the collapse that occurred.

Many of these issues had surfaced in 1908 in the Royal Commission Report into the collapse of the Quebec Bridge during construction.[27] Notwithstanding that this Royal Commission Report has been regarded by generations of engineers as a classic because of its high standards of honesty, clarity and professional competence,[28] it is apparent that many of the lessons learned had been forgotten by the time of procurement of West Gate, particularly the importance of engineering of the erection, and the need for independent review of designs.

[1]Victoria, West Gate Bridge Royal Commission, Report of Royal Commission into the failure of Westgate Bridge (1971) 11

[2]Donald Charrett, ' A Tale of Two Bridges: Issues Arising from Design and Construct Contracts' (2004) 17 BDPS News 28, 36

[3]Victoria, West Gate Bridge Royal Commission, Report of Royal Commission into the failure of Westgate Bridge (1971) 3

[4]Ibid, 41

[5]Ibid, 15

[6]Ibid, 80-83

[7]Ibid, 82

[8]Ibid, 82

[9]Ibid, 84

[10]Ibid, 85

[11]Ibid, 16

[12]Ibid, 41

[13]Ibid, 50

[14]Ibid, 105

[15]Ibid, 40

[16]Ibid, 26, 27

[17]Ibid, 66

[18]Ibid, 67

[19]A R Flint, "Steel Box Girder Bridges" (2001) http://www.istructe.org/technical/db/index.asp?page=281&bhcp=1

[20]Great Britain, Department of the Environment, Committee on Steel Box Girder Bridges, Inquiry into the Basis of Design and Method of Erection of Steel-Box Girder Bridges : Interim Report (1971)

[21]Great Britain, Department of the Environment, Committee on Steel Box Girder Bridges, Inquiry into the Basis of Design and Method of Erection of Steel-Box Girder Bridges : Report of the Committee (1973)

[22]Ibid, 5

[23]Ibid, 4-5

[24]Great Britain, Department of the Environment, Committee on Steel Box Girder Bridges, Inquiry into the Basis of Design and Method of Erection of Steel-Box Girder Bridges : Interim Report (1971) 20

[25]Great Britain, Department of the Environment, Committee on Steel Box Girder Bridges, Inquiry into the Basis of Design and Method of Erection of Steel-Box Girder Bridges : Report of the Committee (1973) 10-11

[26]Ibid, 14

[27]Canada, Royal Commission Quebec Bridge Inquiry, Report (1908)

[28]A Pugsley, The Safety of Structures (1963) 140