Section 1
INTRODUCTION

Much of the aesthetic appeal of design is achieved through the endeavours of design teams who seek to convert the abstract into the functional, compatible with the laws of science, arts and nature. Whilst our landscape has been shaped and marked by the many iconic 'state-of-the-art' flagship projects, other challenging design solutions pass into the shadow of the infrastructure support that many of us take for granted.

The post-industrial era, particularly, has provided opportunities for the designer to explore the limitations of understanding and provide solutions that stand as evidence of beauty, scale, functionality and purpose. That we can still enjoy the benefits of their appreciation and vision centuries after their completion says much about the position occupied by the designer, whether as architect, engineer or design consultant. Society's debt to designers is well documented and establishments continue to laud and honour their many achievements.

The names of Wren, Telford, Stephenson, Rennie, Tarmac and Brunel still illuminate past horizons, whilst Arup, Foster, Rogers and others light up the path from the present into the future. Whilst the continuum from Wren to Rogers covers the period of modern history, much has changed in the use of design in the modern environment. Materials and processes have altered, fashioned by technological advances. Concepts and philosophies have evolved to encompass client involvement and the legal framework has been developed to impart further responsibility and ownership on individuals and the design team generally.

Regardless of such change, good design has always embraced health and safety issues, but it is the visibility and transparency of this outcome that is now different. The modern challenge to designers is no more limiting than in the past and many would argue that there are now greater opportunities for designers to use their creativity in addressing the health and safety implications associated with their designs.

Design insight and technical advances are unfortunately built on the foundations of design failure, and it is to the credit of our predecessors that the painful lessons learnt have given rise to procedural, technical and managerial improvements, and the delivery of more effective and robust project management regimes. Aligned to this situation is the perspective now demanded that designers comprehensively appreciate the health and safety discharge of duties, which represents the modus operandi of this book.

Whilst an appreciation of design success provides the necessary perspective that leads to progress and also facilitates an understanding of design evolution, an analysis and appraisal of design *failure*, as tabulated in Table 1.1, offers a further vehicle to the necessity of change, allowing us to learn in equal measure and move forward, aware of the need to avoid the mistakes of the past. Such movement must also acknowledge the sanctity of human life, which is enshrined in the Health and Safety at Work, etc. Act 1974 (hereafter HSAW 1974).

The extension of and challenge to technical boundaries has never been incompatible with the demands of a 'safe and suitable' working environment. Prestigious buildings can offer constructability, operability, maintainability and replaceability all within the acceptable framework of health and safety.

Table 1.1

DESIGN FAILURES

Year	Description	Structure	Fatalities	Comments
1879	River Tay, Scotland	Bridge failure	75 (no survivors)	Court of enquiry made significant criticisms of the design engineer
1925	Llyn Eigiau, Dolgarrog, Wales	Dam	16	Led Parliament to pass the Reservoirs (Safety Provisions) Act in 1930
1966	Aberfan, Wales	Colliery spoil tip	144	Tribunal led by Lord Justice Davies
1968	Ronan Point, Canning Town, London	High rise flats – gas explosion	4 (17 injured)	Introduced concept of disproportionate collapse and brought about fundamental changes to the design philosophy of building structures in the UK
1970	Cleddau, Milford Haven, Wales	Box girder bridge collapse	4	Merrison Committee set up and prepared Interim Design and Workmanship Rules (IDWR)
1972	River Loddon	Bridge collapse	3 (10 injured)	*Interim report of the Advisory Committee on Falsework* (HMSO, 1974) (The Bragg Report) and subsequently BS 5975 (1982) *The Code of Practice for Falsework*
1973	Summerland, Isle of Man	Leisure complex fire	50 (50 injured)	Enquiry commission identified many human errors and failures and some very ill-defined and poor communication
1973	Camden School, London	Sports hall roof collapse	None	Conclusions included lack of bearing, lack of reinforcement continuity, rebar corrosion and conversion of high alumina concrete Current codes of practice reviewed
1974	Flixborough, Yorkshire	Chemical plant explosion	28 (36 injured)	Shortcomings identified in the official enquiry led to significant tightening of the UK government's regulations covering hazardous industrial processes
1984	Abbeystead	Pumping station explosion	16 (28 injured)	HSE report made numerous recommendations in respect of design and construction as well as operational management
1985	Valley Parade, Bradford, Yorkshire	Football stadium fire	56 (265 injured)	Popplewell Inquiry (1986) resulted in new legislation governing safety at sports grounds around the UK
1988	Piper Alpha, North Sea	Oil platform fire and explosion	167	Public enquiry chaired by Lord Cullen (Report 1990) Offshore Installations (Safety Case) Regulations 1989
1989	Hillsborough, Sheffield	Football stadium	96	*Final report into the Hillsborough Stadium Disaster* (HMSO, 1990), (The Taylor Report)
1994	Port of Ramsgate	Passenger walkway collapse	6 (7 injured)	Inquiry identified numerous areas where lessons needed to be learnt
1994	Heathrow, London	Tunnel collapse	None	Recovery took 2 years and cost around £150 million
1998	Docklands Light Railway, Lewisham	Tunnel collapse	None	BS 6164 (*Code of practice for safety in tunnelling in the construction industry*) amended
1999	Avonmouth, Bristol	Maintenance platform failure	4	Kvaerner (Clevelend Bridge) Ltd and Costain Ltd fined £500,000 each and costs of £525,000

1.1 Major design failures in British history

Table 1.1 is not an exclusive list but does catalogue a number of high profile historical design failures that have been the subject of forensic analysis and the basis of procedural and statutory change.

A further insight is offered below into a selection of these cases and one other (Nicholls Highway Project) in order to appreciate mechanisms of failure and to provide a rationale towards an understanding of the procedural controls now implicit in achieving compliance with current construction related legislation.

Tay Bridge disaster[1]

The collapse of the Tay Bridge, with the accompanying loss of life, cast a shadow over Victorian engineers.

- Designed for North British Railway by the engineer Sir Thomas Bouch (1822–1880).
- Eighty-five spans, 13 of which were navigation spans. Eleven of these were 245 feet long and two were 227 feet long; the remainder of bridge spanned between 67 feet and 164 feet.
- Contract went to the lowest bidder – Charles de Bergue – and was completed by Messrs Hopkins, Gilks & Co. of Middlesborough due to the personal illness of Charles de Bergue.
- Tender price was £217,099 18 s 6 d.
- Disaster occurred on Sunday 28 December 1879.
- Evening train from Edinburgh to Dundee consisting of one engine and six carriages crossed onto bridge at 07:14 pm in the teeth of a strong westerly gale of 60–0 mph (Beaufort scale of between 10 and 11).
- Driver had no warning as train ploughed off bridge; engine found with throttle fully open.
- No survivors; 75 dead.

Rothery, the wreck commissioner, saw fit to publish his own report in which he wrote:

> *The conclusion then, to which we have come, is that this bridge was badly designed, badly constructed and badly maintained … For these defects both in the design, the construction and the maintenance Sir Thomas Bouch is, in our opinion mainly to blame. For the faults in design he is entirely responsible. For those of construction he is principally to blame in not having exercised that supervision over the work which would have enabled him to detect and apply a remedy to them. And for the fault of maintenance he is also principally, if not entirely to blame in having neglected to maintain such an inspection over the structure as its character imperatively demanded.*

[1] *The Report of the Court of Enquiry*, W. Yoland and W.H. Barlow (1880). *An Addendum to the Enquiry Report*, H.C. Rothery (1880).

Summerland disaster[2]

On the evening of 2 August 1973, a fire started outside a leisure complex on the Isle of Man close to one of the walls and spread to the interior. The building quickly became engulfed in fire and all floors at and above entrance level were completely destroyed. The majority of the 3000 people within escaped, but 50 people perished, with a similar number treated in hospital. At the time, in terms of loss of life, this was the worst peace-time disaster in the British Isles since 1929 (Glen Cinema Disaster, Paisley – 71 deaths). The casualty numbers were attributable to the rapid development of the fire and the delayed evacuation of the building.

Some of the report conclusions were as follows:

- *No efficient design management was applied … It is a design team's responsibility to consider carefully the functions of a building, particularly from the point of view of its efficient usage, comfort, maintenance safety. Elsewhere the Commission has been critical, not so much of the part choice of certain materials, but of the way they were used, with little understanding of their limitations.*
- *No one ever stood back and looked at the project as a whole.*
- *The motive (of Trust House Forte Leisure Ltd) was the earliest opening date, but the procedures verged on the irresponsible.*

Some of the recommendations included the following:

- *In the designing of a building a named person should be in charge from the outset and take and be known to be taking the major design decisions.*
- *Architects and clients should together carefully consider the requirements and performance of a building-in-use at the stage when conceptual designs are proposed.*
- *Architectural training should include a much extended study of fire protection and precautions.*
- *A set of detailed and up-to-date plans of the premises, showing the essential structure and services, should be available in all occupied buildings.*

The Abbeystead explosion[3]

Designed as part of the Lancashire Conjunctive Use Scheme (Lune–Wyre Transfer Scheme) to meet the expected water supply requirements of the area, the Lune–Wyre transfer link comprised the Lune Intake and Screenhouse, the Lune Pumping Station, the Quernmore Pipeline, the Wyresdale Tunnel and the Abbeystead Outfall Station.

- Security, environmental considerations and protection of valves against freezing dictated that the proposed valve-house building at Abbeystead should be largely underground.
- Design enquiries suggested limited geological information based on Ordnance Survey geological maps made in 1870s.

[2] *Report of the Summerland Fire Commission*, Government Office, Isle of Man (1974).
[3] *The Abbeystead Explosion*, Health and Safety Executive, HMSO (1985).

- Obtaining further information via drilled bore holes was considered, but only a few were actually drilled.
- The decision to limit borehole information was supported by an independent specialist.
- Routine conditions prevailed.
- Traces of flammable natural gas were detected during tunnel driving, but contractors and consulting engineers regarded the tunnel to be gas-free by normal tunneling standards.

Important characteristics in relation to the Abbeystead explosion were:

- All the contents of the tunnel, both liquid and gaseous, discharged into a room with limited natural ventilation.
- Water passed through a concrete lined tunnel, i.e. a tunnel not designed to be watertight.
- Ground water from the strata surrounding the tunnel leaked in rather than tunnel water leaking out.

Client:	North West Water Authority
Designer:	Binnie and Partners
Contractor:	Edmund Nuttall Limited
Commencement:	End of 1975
Completion:	Spring 1979
Contractual responsibilities:	Ended 15 December 1980

On the evening of Wednesday 23 May 1984, between 1830 and 1900 hours, a party of 44 people, including 8 employees, was assembled at the Abbeystead Valve House (the visit was to address residents' concerns that water pumped into the Wyre at Abbeystead had aggravated local flooding).

- Prior to the visit no water had been pumped for 17 days; it was intended to pump during the visit as a demonstration.
- A telephone call was made at about 1912 hours for pumping to start at the supply end. After 10 minutes, after no water flowed, a further telephone call was made and the order given to start up second pump.
- An explosion occurred at around 1930 hours.
- Eight people died at the scene, eventually rising to 16 people; no one escaped without injury.
- Substantial damage caused to the valve-house.

The explosion was caused by ignition of a mixture of methane and air, which had accumulated in the wet room of Abbeystead Valve House. No source of ignition for the explosion has been positively identified.

Numerous recommendations in respect of design and construction and operational management were highlighted in the Health and Safety Executive (HSE) Report.

HSE prosecuted. After an appeal Binnie and Partners were found to be 100% responsible.

Port of Ramsgate ferry disaster[4]

Shortly before 0100 on the evening of Wednesday 14 September 1994, part of the passenger walkway at No 3 Berth at the Port of Ramsgate collapsed. One end of the walkway fell 10 metres, embedding itself in the deck of the pontoon that had provided the floating seaward support for the structure. Six members of the public were killed and seven received multiple injuries.

Client:	Port of Ramsgate
Designer:	Fartygsentrepenader AB
Contractor:	Fartygstionstructioner AB
Approval organisation:	Lloyds Register of Shipping

In early 1994 the single-deck Berth 3 linkspan at Port Ramsgate was substantially modified to provide an upper deck with a new upper vehicle bridge, and a separate high-level walkway was installed to lead from a new shore building to the passenger deck of a ferry. On 28 April 1994, the completion certificate for the Berth 3 upper-deck project was signed. The passenger walkway was brought into use on 12 May 1994.

Review of the design revealed that it did not provide the support and articulation necessary to match the overall design concept. The walkway was designed in such a way that it was likely to be torsionally stiff. As such, the design did not allow for the roll of the pontoon and the design calculations of the loadings on the cantilevered support stub axles were inadequate. It appeared that the designers had failed to visualise how the static and dynamic loadings would be carried and therefore failed to consider the effects of fatigue on the support stub axles. No fatigue calculations were made. Additionally, no provision was made for continuing maintenance of the upgraded structure, lubrication facilities were not installed, suitable access for maintenance was not incorporated in the design and no manual or other written instructions were provided.

The report concludes that the collapse was caused by a series of errors in the design, some of which were gross. Underlying the mechanical causes of the collapse were the failures of major parties engaged in the project to carry out their respective functions adequately.

In particular, there was:

- a failure of any of the parties to carry out a risk assessment for the project allowed safety-critical design failures to be made
- the failure to have a project plan that provided for the effective monitoring of the project allowed defects in design and fabrication to remain undetected.

Even when defects became apparent to certain individuals, the lack of adequate systems of liaison and communication prevented effective action being taken to remedy them and, more importantly, prevented any fundamental consideration of a series of defects and problems which might have led to the questioning of the underlying technical causes of these defects.

[4] *Walkway Collapse at Port Ramsgate. A Report on the Investigation into the Walkway Collapse at Port Ramsgate on 14 September 1994.* Health and Safety Executive, HMSO (2000).

Among the lessons learned were the need for:

- promotion of effective project management
- competent design and fabrication
- adequate maintenance information
- proactive risk assessments
- effective communication.

All were convicted of serious offences under HSAW 1974 and record fines and costs (£2.4 million) were imposed.

Heathrow Express tunnelling project[5]

The tunnels collapsed in the early hours of Friday 21 October 1994 and continued to fail over a number of days. Although there was no loss of life or injury the failure brought chaos to the heart of Heathrow Airport.

Client:	British Airports Authority
Main contractor:	Balfour Beatty Civil Engineering
Tunnelling consultant:	Geoconsult

Described by the HSE as 'one of the worst civil engineering disasters in the last quarter of a century'.

As well as criticising 'poor construction' the report also underlined the following:

- '*breaking the link between design of permanent and temporary works created difficulties in taking an integrated design approach to risk reduction*'
- a catalogue of design and management errors, poor workmanship and quality control were at the root of the catastrophic tunnel collapse
- errors were made leading to poor design and planning, a lack of quality control during construction, a lack of engineering control and most importantly a lack of safety management
- '*risk assessment should be a fundamental step in the procedures adopted by all parties: it is inappropriate wholly to leave the control risk to contractors*'
- '*those involved in projects with the potential for major accidents should ensure they have in place the culture, commitment, competence and health and safety management systems to secure the effective control of risk and the safe conclusion of the work*'
- '*collapse could have been prevented but for a cultural mindset which focused attention on the apparent economies and the need for production rather than the particular risks*'.

Outcome:

- Balfour Beatty was fined £1.2 million for two offences under HSAW 1974.
- Geoconsult, the tunnelling consultant, was fined a further £500,000 plus £100,000 costs.

[5] *The Collapse of NATM Tunnels at Heathrow Airport*, HSE Books (2000).

- The total fine of £1.7 million was a record at the time for offences under health and safety legislation.

Nicholls Highway tunnel collapse, Singapore[6]

This catastrophic collapse occurred on 20 April 2004 on a section of cut and cover tunnel built under contract C824 for Singapore Metro's new Circle Line. Excavation of the 15–20 m-wide trench had reached 30 m below ground level when retaining walls gave way, caving in over a 110 m length. As a result four workers died.

Client:	Singapore Land Transport Authority
Joint venture partners:	Nishimatsu and Lum Chang
Sub-contractors:	Numerous
Procurement	Design and build

Findings include:

- lack of continuity between design and construction
- failure to apply the same safety factors to temporary works as to permanent works
- lax safety culture
- engineers failed to address properly the risks of low probability and high magnitude accidents because they had not seen them occur before.

Report recommendations included:

- a balancing of production measures against safety measures
- the provision of a temporary works designer responsible for checking design and the installation of temporary works
- attention to the performance of non-standard designs.

It was observed that contractual complexity with poor definition of responsibilities and inadequate lines of communication combined with lack of interaction between designers and constructors were key factors in both this collapse and the Heathrow Express collapse.

1.2 Additional Reports (The Bragg Report and HSE Research Report 218) into design failure

Many of the criticisms identified by the above cases are further endorsed in both the Bragg Report[7] (see below) on falsework collapses and the HSE Research Report 218[8], which looked at causation effects of site accidents.

[6] *New Civil Engineer*, 23 September 2004.

[7] *Final Report of the Advisory Committee on Falsework*, Health and Safety Executive, HMSO (1976).

[8] *Peer Review of Analysis of Specialist Group Reports on Causes of Construction Accidents*, Research Report 218, Health and Safety Executive, HMSO (2004).

The Bragg Report

The aim of the Bragg Committee was to find out why accidents associated with false-work/formwork collapses occurred and to recommend how they might be avoided, with particular reference to the collapses at Loddon Viaduct (23 October 1972: three men killed and ten others injured), Birling Road overbridge (23 March 1971: one man killed, five men seriously injured and twelve others slightly injured) and similar accidents in Europe, the Middle East, Canada, Australia and America.

Studies showed that there were multiple causes for the failures, but that each failure composed of two elements: the technical cause that led to collapse and the procedural errors that allowed the faults to occur and to go undetected and uncorrected.

The principal recommendations are outlined in Table 1.2.

Table 1.2

PRINCIPAL RECOMMENDATIONS OF THE BRAGG COMMITTEE

	Description	Procedure
5.	In his calculations the designer should allow for possible variations in positioning and alignment, which are inevitable even with good workmanship. The drawings should state the tolerance within which the falsework must be constructed.	Constructability
6.	All falsework must be *designed*, even if on a small job the design is only a sketch. The designer, especially if he is not on site, must have a proper written brief, which must include all the factors that might have to be allowed for.	Systematic and disciplined approach
10.	Suppliers of proprietary materials should be required to specify the conditions of test, the failure loads and the mode of failure of each item of equipment in addition to any recommendations about safe working loads.	Material limitations and supply chain information
11.	Tests should be carried out on new materials to check the validity of claims made for them and on used materials to check the deterioration which occurs in service.	Quality assurance
12.	The designer should assume that previously used material will be incorporated in falsework and must use appropriate stresses. If there are critical areas where he has assumed the use of new material these must be clearly indicated on drawings.	Communication
15.	The falsework design and, if he requests them, the calculations that were made must be submitted to the designer of the permanent works for comment. If the person responsible for the permanent works is an architect without engineering qualifications he must submit them to his consulting engineer unless the building method is traditional in all respects.	Design interface between temporary and permanent
16.	The philosophy of preparing and checking the design, of not modifying it without assessing the resulting effects and of having any doubtful points checked must apply in all cases, major and minor.	Co-ordination
17.	On all sites the contractor or construction organisation must appoint a properly qualified temporary works co-ordinator whose duties are to ensure that all procedures have been followed, that all checks and inspections have been carried out and that any modifications or changes have been properly authorised. Falsework may not be loaded or struck without the written permission of the temporary works co-ordinator.	Co-ordination, competence and ownership
18.	Communication between designers and others on and off site must be improved. Drawings must be clear and loading diagrams must be provided.	Team integration and communication

Research Report 218

Research Report 218 identified that:

- Regulations need to be read in conjunction with the relevant Approved Code of Practice.
- Designers have a vital contribution to health and safety matters on all projects. Obviously theirs is not the only contribution but it is an influential and critical contribution as an integrated part of the health and safety management team.
- The cultural shift places emphasis on designs that are safer and healthier to build; operate; maintain and demolish.
- Many designers remain intransigent and fail to embrace the challenge.
- The challenge is for a radical change from within the design fraternity.
- 'The Report concludes that almost all accidents in construction could have been prevented by designer intervention and that at least 1 in 6 of all accidents are at least partially the responsibility of the lead designer in that opportunities to prevent accidents were not taken.'
- Designing from the health and safety perspective of construction workers continues to be one of the challenges of delivering good design.
- It is at the conceptual design stage that many decisions are taken that irrevocably shape the construction process. In the early stages of design effective health and safety management can influence the entire process and contribute to added value through commercial viability.
- Health and safety is an issue that has to be managed through the design process and on-site. It has to become a management, not a medical, issue if the industry is to prevent ill-health. The construction industry's safety culture is a collective commitment to safety.
- 'The final numbers are not just persuasive but absolutely convincing. Designers can do more.'
- The risk-tolerant culture of the construction industry, including that among clients and designers, must be changed.
- Cost, not safety, cannot remain the culture. Construction is price and not quality driven despite the initiatives since the Latham report.
- Paper-chase bureaucracy is not the fault of regulations but of those who abdicate managerial duties and fail to make decisions about what is relevant and what is not.
- Simply completing a documentary record and reviewing it is inadequate and unhelpful.
- Something like 60% of accidents have their roots upstream of what happens on the construction site.
- The designer, like other construction professionals, has moral, professional, financial and statutory obligations to be fulfilled in the discharge of design duties.
- Further accident prevention could have occurred by design intervention (43%) or by having a temporary works designer (1 in 6).

Thankfully there has been change, but there are still lessons to be learnt and whilst the criticisms contained within the above incidents/reports can over-shadow us all, they should simply serve as a reminder of the seriousness of the business of construction and the need for constant vigilance in ensuring that procedures and processes achieve their intended objective.

Failure is rarely uni-causal and therefore all duty holders have a contribution to make. This is no more apparent than in the role and function discharged by the design team, who are high up in the supply chain and invariably function as the professional adviser to the client (and others).

Every effort must be made to adopt a pro-active integrated team response and avoid the spectre of repeat situations, but it should not be assumed that all the lessons from past occurrences have been embedded into the designer's psyche. Procedures and controls must constantly challenge any suggestion of complacency.

The role of the designer implicitly confers a consummate need in matters of health and safety management to *contribute* arising from sufficient *consideration* of associated hazards, coupled with due *communication* within a *co-operative* and integrated team framework. The attainment of these objectives can be thwarted singularly or collectively by the spectre of the fragmented team, complacency, professional arrogance or the 'radar screen of awareness' being switched off.

As noted in paragraphs 109 and 110 of the Approved Code of Practice (ACoP)[9] to the Construction Design and Management Regulations 2007(CDM Regulations 2007):

> *'Designers are in a unique position to reduce the risks that arise during construction work, and have a key role to play in CDM Regulations 2007. Designs develop from initial concepts through to a detailed specification, often involving different teams and people at various stages. At each stage, designers from all disciplines can make a significant contribution by identifying and eliminating hazards, and reducing likely risks from hazards where elimination is not possible.*
>
> *'Designers' earliest decisions fundamentally affect the health and safety of construction work. These decisions influence later design choices, and considerable work may be required if it is necessary to unravel earlier decisions. It is therefore vital to address health and safety from the start.'*

Design teams are therefore key players as well as essential contributors and communicators in matters of health and safety management, and each team member must acknowledge that ineffectiveness in either is a precursor to failure in both project success and the discharge of statutory duties.

The following table, Table 1.3, summarises further some of the contributory mechanisms that have led to historical failure. They should all forewarn design teams of vigilance towards the avoidance of complacency.

[9] *Managing Health and Safety in Construction,* Approved Code of Practice (L144), HSC, HSE Books (2007).

Table 1.3

CONTRIBUTORY FACTORS TO HISTORICAL FAILURES

Category	Detail	Reference
Procedural	No training manual	Avonmouth Bridge
	Permit type system identified in risk assessment was not implemented	Avonmouth Bridge
	Lack of monitoring in respect of procedural compatibility	Avonmouth Bridge
	Lack of safety in design and construction	Avonmouth Bridge
	Allocation of responsibilities unclear	Cleddau Bridge
	Safety procedures inadequate	Hillsborough Stadium
	Outdated safety certificates	Hillsborough Stadium
	Inadequate 'permit to work' management systems	Piper Alpha
	Ineffective safety management systems	Piper Alpha
	Communication failure	Piper Alpha
	Safety audits-ineffective	Piper Alpha
	Lack of emergency planning	Piper Alpha
	No efficient design management applied	Summerland
	Lack of holistic overview	Summerland
	Ill-defined and poor communications	Summerland
	Failure to carry out a risk assessment	Port of Ramsgate
	Roles poorly understood	Heathrow Tunnel
	Lack of engineering control	Heathrow Tunnel
Technical	Lack of control (physical stops)	Avonmouth Bridge
	Inadequacy of design of a pier support diaphragm. Bridge design and construction code of practice was inadequate for such application.	Cleddau Bridge
	Inadequate fire protection	Piper Alpha
	Design simulation failure	Piper Alpha
	Design failure (mechanical)-lack of appreciation	Flixborough
	Discrepancies in sub-structure information	Tay Bridge
	Design inadequacies	Tay Bridge
	Inferior workmanship	Tay Bridge
	Use of materials – lack of understanding	Summerland
	Inadequate site investigation	Aberfan
	HSE investigation failed to reveal any calculations had been carried out for the overburden pressure along the tunnel	Docklands Light Railway
	Design faults	Ronan Point
	Design faults	Cleddau Bridge
Organisational	Lack of training	Avonmouth Bridge; Piper Alpha
	Health and safety reports not acted upon	Avonmouth Bridge
	Inadequate levels of supervision	Tay Bridge
	Poor communication and failure	Tay Bridge
	Lack of adequate systems of liaison and communication	Port of Ramsgate
	Lack of communication	Aberfan
	No attempt to evacuate the 3000 people present until visible evidence of the flames prompted a panic-stricken rush for the exits, where many people were crushed and trampled.	Summerland
	Failure of site organisation between the parties	Cleddau Bridge
	Poor workmanship and inspection procedures	Ronan Point
	'All the hallmarks of an organisational accident'	Heathrow Tunnel
Managerial systems	No effective management response to previous incidents	Avonmouth Bridge
	Poor design and planning	Heathrow Tunnel
	Minimal qualifications	Piper Alpha
	Poor practices and ineffective audits	Piper Alpha
	Lack of provision of effective monitoring	Port of Ramsgate
	Lack of safety management	Heathrow Express
	A catalogue of design and management errors	Heathrow Express

It is vital that the issues associated with the list of failures remind us all of the link between the legacy of the past and the challenges that lie ahead. For both the design and project team, the outcomes of forensic analysis must ensure that our systems of control provide a route whereby duties are effectively discharged, that health and safety hazards are satisfactorily managed and that adherence to the process is demonstrable without being excessively burdensome. This is the thrust of the Construction (Design and Management) Regulations 2007.

Successful attainment is dependent on the calibre of design managers, the competence of the design team, the efficacy of process control and the commitment to continual improvement in all design matters affecting project outcomes.