Zeitschrift: IABSE surveys = Revue AIPC = IVBH Berichte

Band: 14 (1990)

Heft: S-44: The Eighth UK Report on structural safety (June 1989)

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DOI: https://doi.org/10.5169/seals-932

The Eighth UK Report on Structural Safety (June 1989)

Huitième rapport du Royaume Uni sur la sécurité des structures

Achter britischer Bericht über Tragwerksicherheit

contributed by **The United Kingdom Standing Committee on Structural Safety**
Independent body established by the
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London, UK

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SUMMARY

This paper is a resume of the findings of the Standing Committee on Structural Safety as presented in its Eighth Report to the Presidents of the Institution of Civil Engineers and the Institution of Structural Engineers. It is thought likely that many of the concerns examined by the Standing Committee are also receiving attention elsewhere and this paper will therefore provide additional evidence and perhaps reinforce similar ideas and actions or alternatively stimulate differing viewpoints. For these reasons the main parts of a Standing Committee on Structural Safety report has been made available to IABSE for the first time. The Report on which this is based makes ten principal recommendations in relation to the seventeen topics which it considered over the period July 1987 to June 1989.

RÉSUMÉ

Cet article résume les résultats des recherches effectuées par le Comité permanent britannique sur la sécurité des structures, tel qu'il les présente dans son huitième rapport aux Présidents des deux principales associations britanniques d'ingénieurs civils, ICE et ISE. Bon nombre des affaires examinées par le Comité permanent retiennent aussi l'attention d'autres instances; cet article a pour but de mettre en évidence et de renforcer des idées et des actions similaires ou encore de stimuler des points de vue différents. Pour ces raisons, le Comité permanent a mis cet article sur la sécurité des structures à la disposition de l'AIPC. Le rapport sur lequel se base le présent article fournit dix recommendations principales en liaison avec les dix-sept sujets pris en considération dans la période allant de juillet 1987 à juin 1989.

ZUSAMMENFASSUNG

Dieser Beitrag stellt eine Zusammenfassung des achten Berichtes der britischen Kommission über Tragwerksicherheit an den Präsidenten beider wichtigsten britischen Bauingenieurverbände, ICE und ISE. Verschiedene Sachfragen werden anderswo ebenfalls bearbeitet und dieser Bericht soll ähnliche Ideen unterstützen und zur Diskussion mit gegensätzlichen Ansichten anregen. Aus diesen Gründen werden die Hauptteile der Berichte der Kommission Tragwerksicherheit der IVBH zum ersten Mal zugänglich gemacht. Der Bericht macht zehn Hauptempfehlungen zu den in den Jahren 1987 bis 1989 behandelten Themen.

1. INTRODUCTION

The main terms of reference for the Committee which was established by the Institutions of Civil and Structural Engineers are as follows:

To study trends and innovations in design, construction and maintenance of structures from the safety standpoint.

To consider where further research and development work, or some warning of risk, appears desirable from the safety standpoint.

To report to the two Presidents of the two Institutions and to make recommendations.

The Standing Committee's raison d'etre is to act as a watchdog over trends, innovations and other matters that could have an adverse effect on the safety of structures and, through highlighting these, the help to prevent accidents and mishaps and, incidentally, to safeguard the reputation of the profession. It is an independent body advising the Presidents of the Institutions of Civil and Structural Engineers on potential problems and taking whatever action it can to apprise engineers and others of the consequent risks; thereby helping to maintain the good record of structural engineering in the UK.

The actions taken include pressing Government Department to introduce new measures, proposing to the Institutions that they should establish investigating Committees and hold symposia, calls for additional research and development, and suggesting the need for additional and authoritative guidance documents. Indications of the actions taken are given with each of the recommendations.

Experience is similar to research in that unless the results are disseminated around the industry in a meaningful way, the industry will not benefit form it. The Standing Committee has to examine experience and research and to examine each in the light of the other. It is therefore dependent on receiving information and advice from as many sources as possible. The composition of the Standing Committee represents a wide cross-section of British engineers and the membership changes on a regular basis. The present chairman of the Standing Committee is Professor Anthony Kelly, Vice-Chancellor of the University of Surrey.

2. ACTIONS SOUGHT FROM MEMBERS OF THE IABSE

It has become customary for the Presidents to approve the Report for the widest appropriate publication. This year, for the first time, the main parts of the Report have been made available to IABSE for the interest of civil and structural engineers around the world. It is thought likely that many of the concerns examined by the Standing Committee are also receiving attention elsewhere and so the views of the Committee will provide additional evidence and perhaps reinforce similar ideas and actions being considered there. It may be that differing viewpoints to those given in the Report are held by engineers in other countries (and that there are other matters of equally or greater concern to them). The Standing Committee would be pleased to learn about any of them. Some of these topics could form a basis for discussions of other IABSE national groups so that a consensus of views might be obtained on the actions necessary to improve the achievement of structural safety.

3. DISCUSSIONS ON TOPICS DURING THE PERIOD JULY 1987 - JUNE 1989

3.1 Accidental Damage to Bridges by Impact of Vehicles

Over the past ten years the Committee has continually pressed the Department of Transport, road transport organisations and others to take various actions necessary to reduce the occurrence of accidental damage to bridges by vehicle impact and so to reduce the risk of serious direct and secondary effects of such accidents. One effect could be death or injury to pedestrians on a footbridge struck by a vehicle, and to the occupants of vehicles beneath the bridge. Another effect could be the de-railment of a train due to the demolition of, or severe damage to, a bridge carrying a railway over a road.

Some relevant facts are as follows:

- Nearly 6 000 bridges in the UK carry railways over public roads.
- Many of these bridges were built in the last century and have a headroom between 4.0 and 4.6m.
- A requirement introduced in 1845 was for 5m headroom over a turnpike road, 4.6m above a public carriage road and 4.3m above a private road. Professional re-surfacing has reduced the headroom available today.
- For new bridge construction today the minimum headroom is 5.3m over the width of the highway, with the expectation that this may reduce to 5.0m as a result of resurfacing.
- Bridges below 5.0m should carry a warning sign; but this is not a statutory requirement.
- Except for public service vehicles, there is no restriction on the height of vehicles or their loads in the UK.

International Comparisons

All European countries, except the UK and Ireland, have legal height limits for all vehicles. Similarly with Japan. The UK and Ireland limit only the height of public service vehicles at 4.58m. Other countries limit the height of all vehicles between 4.0m (most European countries) and 3.8m in Japan. In the USA height limits apply to public service vehicles between 3.50m and 4.27m depending on the State.

The number of "low bridges" in each country varies widely, e.g. UK - 3,500, Denmark - 350, France - not known, Germany - 3,575, Japan - 5,560 and USA - 12,839.

Standard headrooms vary from 4.2m - 4.88m in the USA to 5.10m in the UK and Ireland.

Based on information available in 1978, the number of impacts each year on bridges range from 500 in the UK, 84 in Ireland, 50 in Belgium, 2 very severe in Finland, 240 in France, 230 in Germany, 30 in Japan, "negligible" in the USA.

Most countries except Ireland and the USA make use of height gauges to protect bridges - visual, audible, secret or rigid gauges. Rigid gauges are adopted in Finland, France, Germany, Netherlands, Japan and Spain. UK law prohibits their use at present.

For a variety of reasons, including road improvements and some preventative measures taken by the Department of Transport, possibly together with a growing appreciation of the seriousness of the problem by transport drivers and operators, the total annual number of reported incidents of bridge strikes reduced from 400-500 in 1978 to about 300 in 1987. The number of serious strikes on railway under-bridges - defined as those dislodging the track sufficiently as to cause de-railment - has reduced from about 50 to about 10 per annum in the same period. The reduction in total number of accidents applies mainly to "low" bridges but there has been no reduction in the number of accidents to bridges with head rooms above 4.5m. For example, strikes on bridges with headrooms even in excess of 6m have averaged 2 per annum over more than 10 years.

It has been pointed out that the alignment and lines of visibility at many of the 6,000 bridges under railways, that are our main concern, contribute substantially to the risk of serious impact on those bridges. The question of responsibility to improve these sites requires clarification. Neither the Local Authority nor British Rail would readily accept responsibility, but it is essential that the potential risks involved should be brought to their attention.

Many of the bridges carrying railways over public roads are of masonry construction which are unlikely to collapse due to a single impact. However, damage by impact is cumulative and a high proportion of the bridges that are our concern suffer several impacts each year. A careful assessment of these bridges is regarded as being of high priority.

Railway track damage is most likely to occur on these bridges of girder construction which, as in the two cases known in the Republic of Ireland, can result in severe track movement and certain derailment.

Although the main thrust of this report has been the risk of distortion or collapse of railway under-bridges the Committee is also very concerned about the risk of collapse of pedestrian bridges over highways. Some such collapses have occurred, fortunately without loss of life.

The fact remains that a multiple accident involving heavy loss of life due to vehicle impact either on a railway underbridge or on a pedestrian overbridge is highly probable.

A Working Party set up by the Department of Transport reported on the problem in 1988 and proposed a strategy to reduce substantially the number of incidents over the next 5 years. The Report assessed the risk of a strike causing loss of life from a train de-railment as in the order of one in 10 years and identified the following possible measures that were reported in Parliament in July 1988:

(1) improving road signing, including replacement of advisory bridge height signs with mandatory ones and in particular cases, where justified by the risk, installation of infra-red systems which detect overheight vehicles in advance and trigger display of a sign to the driver

(2) structural measures to increase the clearance at certain vulnerable trunk road bridges (in the context of the general bridge strengthening programme already announced)

(3) procedures for notifying local highway authorities and the police of movements of vehicles above certain heights

(4) extensions of requirements for display in drivers' cabs of the height of vehicles and installation of warning devices on certain vehicles to show when lifting gear is raised

(5) consideration by British Rail of the installation of emergency telephones in certain cases

(6) further development of facilities for offering route plans for movements of high vehicles

(7) **advice to licensing authorities to take into account bridge bashing incidents when administering licensing of heavy goods vehicles and their drivers**

(8) **legislation to permit erection to bridges of beams and other devices not forming part of their structure which are designed to arrest an overheight vehicle although the working party considers the practical problems and cost of such devices make them unattractive at least in the short term.**

The Committee has strongly supported the measures proposed and will continue to review progress as and when they are implemented by the Secretary of State. However, in addition to these measures, the Committee has recommended the following:

- there should be a specific requirement that jibs, booms and hydraulic arms be chained down in transit
- local authorities should be encouraged to install height barriers or other warning systems wherever appropriate
- prosecution of haulage companies, as well as of the drivers, should be pursued
- bridge owners should be encouraged to take whatever action may be required to obtain full costs from those responsible for damage in any incident.

A sample survey made by the DTp in 1985 indicated that skip lorries, tipper lorries and vehicles carrying engineering plant together accounted for about one-third of accidents. Further, in some cases, bridge strikes have been due to the jib of hydraulic plant lifting in transit.

The Committee has drawn these facts to the notice of the relevant construction plant and contractors associations.

3.2 The Performance of Structures During the Gale of October 1987

A gale of hurricane force struck the South-East corner of Great Britain over a period of 6 hours during the night of 15-16 October 1987. The area affected can be represented by a triangle roughly from Lyme Regis to Kings Lynn to Dover, with the highest wind speed gusts occurring within the triangle Southampton to Lowestoft to Dover.

Maximum gusts of about 30 m/s on the western fringe of the overall triangle and up to 50 m/s on the east represented forces with return periods ranging from 50 years - the basic wind speed used in structural design for this area - to those with return periods in excess of 200 years. The Committee was therefore interested to examine the damage caused to various types of structure across the area and, hence, to examine whether any changes in the design standards or any other improvements were required to ensure appropriate structural safety.

Immediately after the gale had occurred, the Building Research Establishment at Watford initiated a study, largely based on press reports of damage. The results were published in a Report (BRE 138), The October Gale of 1987; Damage to Buildings and Structures in the South East of England, that identified over 16,700 damage incidents of which 2,901 were classified as major damage - defined as those requiring replacement of one or more elements. It was estimated that 1.3 million dwellings were damaged, costing more than £220 million to repair. In addition, millions of trees were brought down - some causing damage to buildings, occupants of vehicles, pedestrians and to services and transport facilities. The total numbers of deaths and injuries reported were 21 and 290 respectively. Of these, building failures accounted for 10 deaths and 253 injuries.

Damage to roofs of dwellings, shops, offices, schools and factories accounted to 58.4% of the total number of incidents. Of the remainder, 8.4% related to farm buildings, garages and sheds, 13% to "mobile homes", 8% to windows and glasshouses and 4.4% to chimneys of various types.

Fifteen air-supported structures were destroyed - which suggests the need to re-examine the standards applied to the design of these structures. Damage to, or the complete loss of, ten cranes was reported, of which one was on a building site and the remainder are thought to be dockyard cranes. Otherwise, structures designed by professional engineers to relevant codes and standards performed satisfactorily and the Committee supports the conclusion in the BRE Report that:

> **"Structures that had been designed in accordance with British Standards and Codes of Practice generally performed very well. The wind loads experienced on 15-16 October undoubtedly exceeded the unfactored design loads obtained from Code of Practice CP3, but when the safety factors are taken into account, the 200-year return period winds were, in general, resisted. It is concluded that the current package of standards used for design in this country is about right - i.e. there is an a acceptable balance between safety and economy - and that no revisions to the wind loading code are required solely because of this storm".**

In view of the high proportion of damage incidents (>60%) to roofs of domestic and other buildings that are often not subject to engineering design, the Committee recommends that roofs and walls (particularly gable walls and wall-roof connections) should be checked by suitably qualified civil or structural engineers. The Committee also strongly supports a recommendation in the Report for continuing maintenance and repair of older buildings. Corrosion of fixings, connections and, sometimes, of structural members themselves can cause important weakening of a building's resistance.

In its First Report the Committee summarised its discussions on the safety of temporary works, and it was decided to collect and examine all information available on the performance of scaffolding, falsework and formwork in this gale.

From the Press cuttings collected in the BRE survey, it was found that 29 cases of damage to scaffolding were reported, of which 16 resulted in collapse. No cases of damage were reported to formwork or falsework due to the gale. Wind loadings in BS5973 - Code of Practice for Scaffolding - and BS5975 - Code of Practice for Falsework - are based on those of CP3 (Chapter V) - Code of Practice for Wind Loads - all published by the British Standards Institution in Milton Keynes.

Examination of the data led the Committee to the following conclusions:

- for falsework and formwork, the design requirements of BS5975 and the standards of workmanship and supervision required in existing specifications and guides, provide an adequate safety margin against wind forces
- the frequent occurrence of boards lifting from scaffolds (17% of the reported scaffold damage incidents in this gale) points to the need for greater attention to the securing of boards
- although in relation to the severity of the gale, the total number of scaffolds suffering damage is not large (12 major and 8 minor), continuing efforts are necessary to improve the standards of erection of access scaffolds - most of which are traditionally designed and, frequently, inadequately tied.

The Committee recommends that, in addition to a requirement for the scaffolding industry to continue to improve its own standards, there is a need for more energetic enforcement by the Health and Safety Executive of regulations relating to the safety of scaffolding. In particular the attention of local authorities, contractors and sub-contractors should be drawn to the frequent cases in which access scaffolds, fail to meet prescribed standards.

The Committee also recommends that the standards of design, construction and operation of air supported structures should be reviewed.

3.3 Flood Damage to Bridges

Although extensive flood damage of the type experienced in some overseas countries, such as Bangladesh and the Province of Natal (1987), is unlikely to occur in the British Isles, the collapses in 1987 of a railway bridge in central Wales with the loss of 5 lives, and of another one in Berkshire, followed by the collapse of the 127 year-old Ness Viaduct at Inverness in 1989, caused the Committee to question the present state of knowledge on the subject. In particular, the Committee enquired whether bridge owners could have sufficient warning of imminent floods and whether bridge designers, and engineers responsible for maintenance, had sufficient information to establish realistic flood design loads and effective methods of protection against the erosion of foundations.

The prediction of flood peak, volume and return period is dependent on the existence of good hydrological records for a particular area over a sufficient length of time. Since such data are frequently not available, synthetic unit hydrograph techniques have been developed to provide bridge designers with the parameters needed to estimate scour depth for a particular site.

In Great Britain, however, excellent data is available in the Flood Studies Report, held by the Institute of Hydrology at Wallingford, where also a micro-computer programme has been developed which could provide bridge owners and others with information on flood frequency and peak discharge information for specific bridge locations. Level gauges installed by River Authorities give measurements at specific locations that can be monitored directly by telephone.

The protection of bridge piers and abutments against scour damage depends mainly upon the provision of adequate depth of foundation. Trees and other debris brought down on the flood stream present another hazard, particularly to arch bridges that provide an obstruction to flow. It is considered that adequate design methods have been available for bridges built during the past 40 years or so, but engineers may not be aware generally of the more recent developments in hydrological technology and information, particularly in Great Britain.

It should not be assumed that only the older bridges are at risk; the possibility of damaging scour occurring at any bridge must be considered by bridge owners. The importance of including inspection by divers as part of the routine periodic inspection of bridges, is stressed. This practice is applied by British Rail, who are also examining other, more direct, ways of measuring scour, such as by sonar.

Various methods of protecting bridges against scour are available, including rip-rap, blocks or gabions; but the performance of these has not been studied sufficiently under practical conditions or under the wide range of circumstances in which they might be used.

It is not known to what extent co-operation between the Water Authorities, Highway authorities and the Police is effective in issuing and reacting to flood warnings in the various parts of the country. British Rail is establishing better contacts to alert their operations control centres of flood warnings, and it is recommended that other bridge owners should examine whether satisfactory arrangements exist in the areas of their control.

Control over river engineering and land drainage in Great Britain is vested in the Water Authorities but may become part of the National Rivers Authority's responsibility. The attention of this Authority has been drawn to the safety implications of river flows and flooding for bridges and the need for co-operation with highway and railway authorities to provide effective flood warnings.

The construction of cofferdams in rivers can give rise to change in the flow patterns and at times of flood levels such change can produce scour of one or both river banks immediately downstream of the cofferdam. When the cofferdam is removed, the river may not return to its original course but gradually adopt a new regime for some distance downstream. The common practice of allowing cofferdams to be overtopped and flooded during extreme conditions may not always be successful in preventing scour even though it may preserve the integrity of the cofferdam. Thus, it is recommended that the influence of construction works involving cofferdams should be carefully assessed by the river and bridge authorities.

The Committee recommends that wider publicity should be given to the information available from hydrologists and the co-operative arrangements, by direct instrumentation or other means to ensure adequate warning of damaging floods. All bridges with abutments or piers in a river require routine inspection for scour and assessment as regards protection.

3.4 The Use of Resin-bonded Steel Plates to Strengthen Reinforced Concrete

In its 5th Report (1982), the Committee drew attention to some important reservations concerning the application of resins in civil and structural engineering. In particular, the susceptibility of resins to climatic conditions during application and in service, loss of strength with increasing temperature, dependence on surface condition and preparation and the importance of experienced workmanship and supervision were all emphasised.

The Committee also pointed to a lack of information on the long-term performance of resins and, in consequence, advised against their use in critical parts of structures except where it is feasible and economical to effect replacement should it become necessary.

A specific application of resin to strengthen reinforced concrete beams by bonding steel plates to the concrete surface was discussed in the Seventh Report. The method can be attractive to use in certain circumstances but the Committee advised against its wider application until its long term performance had been proved. It further recommended that the plates should have additional mechanical fixings to the concrete to prevent them being a hazard should they become detached.

The Committee has welcomed the research reports of work being undertaken in various Universities on the properties of reinforced concrete beams with bonded steel plates. It must be borne in mind, however, that the properties of resin bonds made under site conditions may not be the same as those made under cover or in a laboratory. The Committee has also welcomed the Transport and Road Research Laboratory's Report, N129, on the results of tests on resin plated specimens after 10 years exposure. The results of these exposure tests and also experience of resin bonded plates in practice, reported at an Informal Discussion at the Institution of Civil Engineers, do not justify any change in the Committee's earlier cautionary advice.

The Committee therefore repeats its earlier advice and recommends that resin-bonded steel plates should only be used after careful structural appraisal of the problem and where frequent monitoring of their performance in use can be ensured and where premature failure of the resin bond can be tolerated and replacement can be effected. Resin-bonded plates should specifically not be used on concrete of unsatisfactory quality or which is deteriorating as a result, for example, of chloride or sulphate penetration or by alkali silica reaction.

If after careful structural appraisal of the problem it is decided to use the method, specialist advice should be obtained on the selection of the plate and resin types and thicknesses, standards of surface preparation and other details. Mechanical fixings must be provided as a construction expedient and to prevent the plates becoming a hazard, should they become detached by failure of the resin bond due to fire, degradation or any other cause. It requires experienced workmanship and supervision and suitable arrangements for subsequently monitoring performance on a continuing basis.

3.5 Bridge Assessment

Two of the principal owners of bridges in Great Britain - British Rail and the Department of Transport - have each issued instructions on the inspection of bridges of various types, and both organisations have established patterns of regular inspection. In both cases, extensive inspections at intervals normally not exceeding six years but, exceptionally, up to 10 years are supplemented by general inspections at not more that two year intervals. A special inspection is made whenever damage has occurred or any other circumstances justifies it. It is believed that most local authorities apply the Department of Transport's systems of inspection to the large number of bridges for which they are responsible.

Attention is drawn to some of the specific requirements for bridge inspection and assessment in Sections 3.3 and 3.6 of this Report; but, overall, the Committee considers that insufficient attention may, in some cases, be paid to the selection, training and briefing of the inspection team.

The inspection and assessment of any but the simplest of structures is a skilled task, requiring an understanding of the designer's intentions as well as a recognition of whether these were realised or not in the actual structure. The inspector must therefore be an engineer with experience and be provided with sufficient background of the design and construction of the structure to fulfil these requirements. The inspector must also be able to recognise when he requires the support of other specialists, such as a materials engineer, to deal with specific problems. Some form of certification might usefully be considered for bridge inspection engineers.

The Committee recommends that training courses, be organised by the Institution of Civil Engineers for engineers and technicians engaged in bridge inspection work.

The Committee also recommends that the design requirements for new bridges and other structures, should include "inspectability".

3.6 The Inspection of Tendons in Post-tensioned Concrete Structures

The collapse of the Ynys-y-Gwas bridge in 1985, reported in the Seventh Report, underlined the need for regular inspection. Although in most types of structure of which the Committee is aware, corrosion of tendons represents a serviceability problem rather than a risk of sudden collapse, the importance of having reliable means of identifying tendon corrosion is clear.

Corrosion may be obvious through the appearance of rust staining on the concrete surface. However, the evidence from inspections of the Ynys-y-Gwas bridge and elsewhere shows that rust staining may not always be evident. The Committee has therefore, strongly supported the efforts of the Transport and Road Research Laboratory and others in this country and overseas to develop an effective non-destructive test method to identify corrosion.

Since 1987, the Committee has reviewed progress in the development of tests for this purpose; but it must be concluded that no suitable NDT is yet available and none is likely to be developed in the near future. However, discussion with research and other individuals, experienced in the field, have established that a sufficient body of experience exists to enable guidelines to be drawn up for structural appraisal, including the use of drilling to investigate tendon condition.

The Committee recommends that the Institutions of Civil and of Structural Engineers should establish a joint Working Party as soon as possible to draft the required guidelines for the inspection and appraisal of post-tensioned concrete structures, including investigation of tendon condition by drilling, outlining all the necessary precautions.

The development of an effective non-destructive method of identifying corrosion in tendons, and also in reinforcement, remains of high priority.

3.7 Cladding Failures

The Committee gave its findings on the problem of cladding failures and made recommendations towards reducing the risk of failure, in its Second Report (1978). It advised that:

> **"The widest possible publicity needed to be given to: providing adequate movement joints, use of corrosion resistant fixings and supports, adequate allowance for dimensional variations (tolerances) and ensuring that the claddings, fixings and supports could be inspected easily and maintained throughout the life of the building".**

With regard to existing buildings, the Committee recommended that inspections be made of those below the standards then (in 1978) known to be necessary, giving priority to buildings having high consequences of cladding failure; for example those fronting busy streets and crowded areas.

Because of the continuing incidence of cladding failures and the substantial number of court cases involving defective cladding, the Committee decided to review the problem. Its earlier discussions were concerned mainly with masonry and pre-cast concrete cladding; but in recent years there has been increasing use of new types such as steel, aluminium, glass fibre and glazed panels.

In making this review, one of the important questions was whether sufficient information is now available to designers and builders to avoid cladding failures in present day work. It was also considered important to examine whether the lessons of the 1950-1970 period (Second Report) had been understood and applied, and whether building owners had accepted the responsibility for inspections in buildings with high consequences of failure.

It was found that, as in the past, engineers had frequently not been involved in the design or construction of claddings which had failed. Some manufacturers appear to have applied the recommendations summarised in the Second Report, but inadequate or insufficiently durable fixings are still common and, too often, insufficient allowance is still made for temperature and other movements.

The advice of the Second Report (1978) reproduced above is therefore reiterated, in particular that fixings and supports should be of adequate corrosion resistance, bearing in mind the life required and the ease with which inspection and repair can be effected.

An undesirable trend in some more frequently adopted other approaches to building is to give the sub-contract supplier design responsibility for cladding. Some overseas suppliers may not be aware of the especially demanding British climatic and other conditions. The aggressive conditions from chloride attack within areas several miles from the coast line, sulphate attack in the industrial areas, rapid wetting and drying as well as the large diurnal temperature changes that can occur in the British Isles, are all problems that need to be taken into account.

The use of new materials and components of unknown performance in service under the conditions prevalent in Great Britain, is another matter for concern. The performance of these materials and also the recent developments in overcladding will require close monitoring for a number of years to come.

Although there are some indications that enlightened building owners are becoming more aware of the need for periodic inspection and maintenance, financial considerations appear to keep these important activities to a much lower general level than the Committee regards as necessary. These remarks apply to building owners in both the public and private sectors.

The Committee believes that sufficient experience and information already exists within the community of professional engineers that, if applied to the design of cladding components, joints and fixings, would substantially reduce the number of cladding failures. An exception is the lack of information on the durability of some new materials under practical conditions. Events over the past ten years or more have illustrated the need for the design and construction of claddings to be in the hands of suitably qualified civil or structural engineers.

In making the recommendation that claddings of all types, whether load bearing or not, should be designed by, and the erection supervised by suitably qualified civil or structural engineers, the Committee recognises that the basis of design requires some improvement. As a first step, the Committee has proposed that an international conference should be organised to bring the engineering aspects of the problem into prominence. It is recommended that the professional Institutions should then arrange the preparation of a Guide for the design and erection of effective cladding.

3.8 Safety in Demolition Work

In its report to the Presidents on Safety on Site reproduced in the Seventh Report, the Committee drew attention to the poor record of accidents in demolition work, accounting for about 15% of all fatalities in building (about 10% of fatalities in construction work as a whole).

Although the Committee is confident that the adoption of its recommendations for improvements in such matters as training, conditions of contract, and publicity, could improve safety substantially, it considered that some special features of demolition work required further examination.

In particular, the scope of demolition work has moved on from the relatively simple masonry or framed building structures to the more complex structures introduced after about 1950. Other important trends are the marked increase in refurbishment activity, work with hazardous materials and on reclaimed industrial sites. The increased potential for accident injury and release of harmful gases needs to be more widely recognised where demolition is taking place on contaminated sites.

The Committee discussed these, and a number of other questions, with a recognised authority in demolition work and also consulted the Health and Safety Executive and others.

Statistics suggest that the risk to members of the public, giving rise to an average of one fatality a year, is associated mainly with inadequacies in access scaffolding on the perimeter of demolition sites and with insufficient support to partially demolished structures.

Few clients appear to recognise the importance of the demolition phase in a development, and their architects may not appreciate some of the structural problems that may arise.

Commercial pressures to expedite work often impose severe limitations on the time available for a demolition contractor to investigate the design and construction features in detail and then to plan the demolition work carefully. Contract documents tend to leave responsibility for investigation to the demolition contractor and to rely on cost penalties to enforce prompt completion. Contractual arrangements framed in this way increase the risks to both the general public and site workers, and limit fair competition.

The demolition industry is itself of variable quality, ranging from companies with experienced staff, including professionally qualified civil and structural engineers, to those that are entirely artisan and may, or may not, have the experience to tackle the more complex structures. Sub-contracting is a common feature throughout the industry and there are many established small groups with experience and a responsible approach to work; inevitably, however, some sub-contractors are not so experienced or so responsible.

The National Federation of Demolition Contractors has done much towards improving the safety record of demolition through its publications and training activities. The Institute of Demolition Engineers provides individual members of the industry with a forum for the exchange of technical information and other services normally expected from a "learned society".

Demolition operations are subject to control by the Health and Safety Executive, and Part 10 of the Construction and General Regulations (1961) in particular. However, demolition contracts of less than six weeks duration do not have to be notified to the H&SE. Although during the past year or so there has been a welcome increase in the activities of the H&SE inspectors on construction as a whole, the number of experienced staff is not large in relation to the size and importance of the construction industry.

The foregoing summary of the Committee's discussion on this subject of safety in demolition presents a number of features that require attention if the present unsatisfactory record is to be improved.

The Committee recommends that the Institutions of Civil and of Structural Engineers and others concerned with the preparation of standard forms of contract should change the present system of control by sanctions to one in which preventative safety systems are built into the tendering and other contractual documents for demolition work. Provisions for thorough investigation of the structure and pre-planning of operations prior to demolition form an essential part of a preventative safety system.

The Committee also recommends that the Health and Safety Executive should apply more effort in the inspection of demolition sites by experienced staff and reconsider its requirement for the notification of only those contracts longer than 6 weeks duration.

Additionally, the demolition industry should pursue the improvement of its own competence more energetically, through training and the employment of more professional staff or structural engineering consultants, including those experienced in scaffolding and temporary works design.

3.9 Safety in Sports Grounds

The incidents such as those at Birmingham, Bradford, Brussels and, more recently, at Sheffield (Hillsborough), are examples of disasters in which lives have been lost partly, at least, because of failures of stands, barriers, fences or walls within sports grounds to provide an acceptable level of safety in the extreme and complex circumstances associated with high crowd densities.

The earlier incidents led to an enquiry by Mr Justice Popplewell and the report in 1986 highlighted the potential deficiencies in many sports grounds and the need for thorough engineering analysis and appraisal of sports grounds.

The "Guide to Safety of Sports Grounds" (1946), published by Her Majesty's Stationary Office in London, gives recommendations that would have reduced the risk of such incidents, but they are not mandatory. The Safety of Sports Grounds Act (1987) has imposed a licensing system on stands having a capacity of more than 500, and these will require proper appraisal in terms of structural condition, crush barriers, crowd-flow characteristics, performance of the structure in fire and associated evacuation times. Many stands will require refurbishment if they are to comply with the guidance document.

A public enquiry led by Lord Justice Taylor has been commissioned to examine the Sheffield (Hillsborough) disaster and urgently report its findings.

The Institution of Structural Engineers' report on "Design and Erection of Demountable Grandstands" led to the establishment by the Institution in 1986 of an Ad-hoc Committee on "The Appraisal of Sports Grounds". The report of this Committee in completed draft form has been submitted to Lord Justice Taylor with an offer by both Presidents for the Institutions to help in any way further with his inquiry into Hillsborough.

The Institution of Structural Engineers' draft report "Appraisal of Sports Grounds" aims to ensure, as far as possible, that an appropriate standard of appraisal is applied throughout the country and tackles the inter-related problems of structural condition, crowd density, flow and management and fire safety. The published version of the report will, no doubt, include guidance related to the Taylor Report and be of international importance.

The risks to public safety that have become evident are not confined to crowded football grounds. They apply to most sports stadia and arenas in which crowds gather and they pose a number of interacting problems of crowd density, movement, control and behaviour related to the provision of access, accommodation and escape. The overall problem is similar to that in traffic engineering and requires a similar broad approach to design, management and control.

The Committee awaits the Taylor report with great interest, and will make whatever recommendations are necessary in due course.

Some specific problems arising during the preparation of the Institution's guides on demountable stands and appraisal of grandstands were considered by the Committee as follows:

Demountable Stands: Special consideration needs to be given to the evidence of lateral instability of such stands due to the "Mexican Wave" effect in a crowded stand, especially on relatively weak foundations. It is understood that the Institution of Structural Engineers' forthcoming report on "Design and Erection of Demountable Grandstands" will cover this matter.

Another matter of concern is that the erection of demountable stands on other than designated sports grounds, is not notifiable to the local authority.

Wind Flutter: The increasing use of long cantilever roofs of lightweight material on stands may create problems due to wind reversals or flutter on such lightweight structures. No report of damage or distress to roofs of this type were received following the October 1987 gale (see Section 3.2); but the longer term effects of corrosion and degradation and, possibly, fatigue, need to be taken into account.

Toxicity of some modern building membranes: There is extensive use of PTFE-coated glass fabric to cover stands, shopping malls and other large open spaces in the USA, Europe and elsewhere. The membrane is translucent, self-cleaning, strong and is claimed to be incombustible. However, there is some evidence that under certain conditions of real fire, the PTFE coating can emit highly toxic fumes.

The Committee makes the following recommendations on these matters:

> **The design of long cantilevered roofs of lightweight material (e.g. in sports ground stands) requires a specialist wind engineering approach and should take into account the long-term effects of corrosion, degradation and fatigue.**

PTFE-coated glass should not be used in buildings or stands until tests have disproved the possibility of its extreme toxicity under certain conditions of real fire.

The Committee also recommends that the Safety of Sports Grounds Act (1987) should be amended to require all temporary (demountable) stands to be notified to the local authority, whether on designated ground or not.

Any further recommendations on the safety of sports grounds must wait until after publication of Lord Justice Taylor's report on Hillsborough.

3.10 Stress Corrosion of Suspension Wires

During the twelve years of the Committee's existence, a number of cases have been drawn to its attention in which metal connections and fixings of various types had failed "unexpectedly". In most cases these failures were due to the incorrect choice of material, often accelerated by aggressive conditions which had not been taken sufficiently into account.

Collapse of a swimming pool ceiling in Switzerland in 1985, with 13 fatalities, due to the corrosion of stainless steel hangers, is a case in point. The collapse of the roof of the Ilford swimming baths in 1975 also demonstrated that the warm, moist, chloride-laden atmosphere at and within swimming pool ceilings was highly aggressive.

In 1988, attention was drawn to failures which had been noticed in some of the stainless steel wires suspending ceilings at some swimming pools in the East Midlands. The cause of failure was identified as stress corrosion after 5 to 10 years exposure in the swimming pool atmosphere.

The Committee advised those concerned to identify and warn the owners of any other such buildings and attention was drawn to the problem in a short article in the Structural Engineer in 1988. However, the problem requires to be brought more firmly and more widely to the attention of the profession and to building owners and their agents.

The Committee strongly recommends that the Department of the Environment should advise owners of swimming pools, in particular, to ensure that ceilings, roof spaces and all fixings are regularly inspected. An immediate visual inspection is recommended and, if any fractured suspension wires or connections or any corrosion staining are found, a full structural appraisal should be initiated.

Owners or occupants of other types of building in which moist, warm conditions occur, such as laundries or wet processing plants, should be similarly advised to ensure regular inspection.

The Committee also recommends that the Institutions of Civil and of Structural Engineers should draw the attention of their members and their clients - who may deal direct with proprietary manufacturers -to the need for independent specialist advice on the choice of materials for use in buildings subject to aggressive conditions.

In view of the number of cases in which the effects of aggressive conditions have been underestimated or the large temperature and humidity changes and gradients have not been fully taken into account, the Committee also recommends that a guidance note should be prepared and issued giving this and other building physical data.

3.11 Structural Safety Implications of Eurocodes and Directives

In 1992 the "Single European Act" comes into force with measures to remove physical, technical and fiscal barriers to trade within the EEC. The preparation of structural Eurocodes has been in progress for a number of years and codes for steel and for concrete structures have been completed. Other codes and standards for construction materials, products and components will follow, as implementation of the Construction Products Directive and other Directives progress.

Fortunately, after a slow start, British engineers in the private and public sectors have taken a prominent part in the preparation of the structural Eurocodes and supporting standards to ensure, as far as is possible, that these new documents are both economical and safe for adoption in Great Britain, and that they are written in a way to assist British engineers to operate throughout Europe and beyond. Nevertheless, in response to requests, the Committee decided that it should examine the safety implications of the considerable changes arising from the Single European Act.

National Codes have evolved against a background of common experience and familiarity with the traditional construction practices in that country. It must be ensured that differences in environmental conditions and differences in the construction practices between countries will not result in adverse effects on the present margins of structural safety.

Some of the terminology used in the structural Eurocodes is new and may be misinterpreted unless the context is carefully examined. It is also possible to envisage errors in communication resulting in misunderstanding and oversight when the designer is from a different traditional background from that of the supervisor, inspector or contractor.

Elsewhere in this Report (Section 3.7), the Committee draws attention to the particularly harsh and often aggressive climatic conditions that pertain in a considerable part of the British Isles. Materials and components that perform satisfactorily in other parts of Europe may not do so in Great Britain and vice-versa. Laboratory tests and accelerated weathering tests cannot adequately reproduce actual exposure conditions and, therefore, some concern must be expressed about requirements to accept materials and components from another country based solely on tests and experience in that country.

The Committee envisages the necessity to monitor and advise the appropriate Standing Committee of the European Commission as to which construction products are likely to influence the safety of structures.

This is because a two-tier system of quality assurance and certification is intended to be implemented under the Construction Products Directive; one where the CE-mark is justified by manufacturers declaration, the other where it is only granted as a result of comprehensive third party certificate.

The Committee proposes to maintain a watching brief on the safety implications of the Single European Act and recommends that the professional Institutions should continue to ensure that the profession is adequately represented in the preparation of all Eurocodes and standards.

The Committee also recommends that the Institutions take steps, through educational and continuing professional development initiatives, to help prepare their members to make use of the Eurocodes as soon as they become available. It is important that the individual members of the professional Institutions should take advantage of all such initiatives to help overcome the technical, human and commercial problems that may arise and to ensure that the general quality and overall safety of construction is not impaired.

3.12 Safety of Chair-lifts and Cable-cars

In its Seventh Report, the Committee drew attention to a potential problem arising from the increasing number of passenger-carrying ropeways in the British Isles, in the form of ski-lifts in Scotland and chair-lifts and cable-cars at leisure parks elsewhere. The problem was highlighted by the collapse of a pylon in the French Pyrenees in 1987, resulting in 5 dead and 100 injured.

In the UK, onus for the safety of chair-lifts and cable cars is on the owner and operator, who are expected to comply with the general requirements of the Health and Safety at Work Act, 1974.

The Committee is examining whether this present system of safety enforcement is adequate and will report its findings to the Presidents of the two Institutions in due course.

3.13 Structural Damage to Buildings by Gas Explosion

For most of the 20 years since the collapse of a high rise building resulting from a gas explosion at Ronan Point, the Building Research Establishment has maintained records of gas explosion incidents and other types of accident in which structural damage has resulted. The Committee has reviewed these statistics at frequent intervals and has reported its advice, and some actions it has taken on the subject, in most of its seven previous reports.

Incidents of damage due to gas explosions of various types have, over a number of years, resulted in an average of about 10 deaths and between 20 and 40 cases of significant structural damage each year. During the past 3 years, the number of gas explosion incidents has remained at about the same level overall and, in fact, there has been little improvement in the gas explosion statistics in 20 years.

Although some suppliers of bottled gas and British Gas have put considerable effort into ensuring safety and, in particular, into educating consumers, the lack of effect of their campaigns and of actions taken by the Department of Environment, suggests the need for a closer examination of the gas safety problem to identify any other actions that might be more effective.

The Committee is aware of the public concern about risks due to methane gas, highlighted by such incidents as Abbeystead and problems with some housing developments on re-claimed land. From the Committee's discussions on this subject, it became apparent that further and more extensive investigation was required to provide designers and others with information and guidance necessary to deal with the several different types of problem that could arise. The Committee therefore welcomed the initiative taken by CIRIA (Construction Industry Research and Information Association) to undertake this further investigation.

The Committee emphasises, once again, its recommendation for designers of all types of structures to ensure that cavities and ducts are adequately ventilated, underground or otherwise, whether or not gas services are provided in the building.

3.14 Site Safety

In 1987, the Committee reported to the two Presidents that, to improve site safety, a concerted effort would be required by all concerned - designer, client, contractor, equipment manufacturer and workforce. It further recommended that there must be a continuing commitment by the professional Institutions to help promote the objective of improved safety.

The Committee's recommendations included training and it was pleased to find that the subject of safety is now a mandatory part of the Institution of Civil Engineers Professional Training, that additional questions on safety are included in its professional examination and also that wider publicity and construction for safety are being given through a Video and by symposia organised by local Associations.

The Committee also welcomed the initiative taken by the Health and Safety Commission to increase the number of inspections and to carry out a "blitz" on construction sites.

During the period 1980-1983, the annual average number killed on construction sites was 148. The figure for the year ending March 1988 was 157 killed.

Clearly much more needs to be done, and the Committee, as "watchdog" on safety, will keep progress by the various bodies concerned, under review.

3.15 Feedback of Information from Litigation

A problem that the Committee has encountered on a number of occasions is that experts' reports, prepared during the process of litigation, have been withheld regardless of whether the experts themselves, or their clients, required such action. These reports are, of course, private and technically privileged, but they frequently contain facts and new ideas which may have the greatest relevance to questions of public safety.

The Committee suggested to the Law Society that guidance should be given to solicitors which might facilitate the disclosure of experts reports to bona fide organisations, such as this Committee, and encourage clients and experts to give their consent for disclosure in the interests of public safety.

The Law Society has accepted the justification of the Committee's request and it seems possible that appropriate advice will be issued to solicitors to assist the Committee's aim.

Discussions have also taken place with the newly formed British Academy of Experts, the individual members of which provide several hundred reports each year relating to court cases. They have formed a Working Party on the subject of feedback of information and fully support this Committee's objectives.

The Committee firmly believes that the feedback of information from such sources could represent a major contribution to the provision of valuable practical information and be of great help to the profession and industry. Discussions are therefore being continued with the Law Society and other bodies so that arrangements can be made to retrieve and feedback information from litigation.

3.16 Rising Groundwater

The Committee's Seventh Report referred to the potential problems that rising groundwater levels could create in a number of cities in Great Britain and elsewhere. Considerable reductions in the amounts of water extracted by pumping, due to changed industrial practices and other factors, have resulted in some substantial rises in groundwater levels in cities such as Paris, New York, Tokyo, London and also in Birmingham and Liverpool.

The extent of the problem is illustrated by findings in London that, although during the past two centuries pumping lowered the groundwater level by as much as 70m, it is now rising in many areas by about 1m/yr. Unless appropriate action is taken to control groundwater levels, some of the effects could be:

- damage or instability due to differential ground movements
- seepage into basements, tunnels and underground structures
- increased chemical attack on buried steel and concrete.

The investigation being undertaken by the Construction Industry Research and Information Association (CIRIA), in conjunction with Thames Water Research Centre for the London area, has already shown the need for and the economic advantage in installing additional pumping systems to extract water from the aquifer. CIRIA's Report entitled " The Engineering Implications of Rising Groundwater Levels in the Deep Aquifer Beneath London" also calls for a national policy for the management of groundwater levels.

The Committee will continue to keep this important problem under review and help in any way necessary to ensure that the present investigations in the London area are extended to Birmingham and Liverpool and also that effective management systems are introduced for the control of groundwater levels.

3.17 Risk Assessment

Most aspects of structural engineering involve some form of risk assessment, whether explicit or implicit. At one extreme are the explicit analyses carried out for nuclear structures and for a range of major civil engineering projects, based on historical data when using either a deterministic or probabilistic approach. For the generality of structural engineering, however, codes and standards embody safety factors and other limits decided on the basis of implicit analysis.

The Committee believes that it would be helpful to provide a "layman's" description of risk assessment to encourage the wider use of analyses in the planning and design phases for buildings. These analyses would be valuable in reducing the effects, for example, of terrorist activities, vandalism and other crimes or of accidental damage by vehicle impact.

The Committee welcomed the recent papers on the subject and the open discussion in 1988 at the Institution of Structural Engineers, as a useful start towards the type of guide required.

A report by CIRIA (No. 63) included a rational method of determining safety and serviceability factors and indicated the following annual probabilities of death per person in 1970-73:

Mountaineering	10^{-2}
Car Travel	2×10^{-4}
Air Travel	10^{-4}
Home Accidents	10^{-4}
Structural Failure	10^{-7}

ACKNOWLEDGEMENT

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