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Standing Committee on Structural Safety

SEVENTH REPORT OF THE COMMITTEE

for the two years ending JULY 1987

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1. CONSPECTUS

The Sixth Report of the Standing Committee, issued in September 1985, summarised the Committee's discussions during the period of 20 months to July 1985. This Seventh Report, which covers the two-year period ending - July 1987, summarises discussions on six new topics, with particular emphasis on the problems of improving site safety and on investigations into the collapse of a prestressed concrete bridge in West Glamorgan, and it reviews the position on seven matters of continuing concern, of which damage to bridges as a result of vehicle impact is a particularly important hazard.

At the request of the Presidents of the Institutions of Civil and of Structural Engineers, the Committee began in July 1985 to consider the problems of safety on construction sites. With an annual average number of fatalities approaching 150 and serious injuries exceeding 3000 in 1986, construction work in the UK is four times more dangerous than manufacturing industry as a whole. In January 1987, the Committee reported to the two Presidents with recommended actions required to improve matters. The Committee's findings and recommendations are given in Section 2.1 of this Report.

The Institutions have already taken some actions in line with the Committee's recommendations and are considering what further actions they should take. However to achieve significant improvement in site safety will require a concerted effort and commitment by all concerned in the construction process, including the clients. The accident statistics show that such an effort and commitment is long overdue.

The Committee welcomes the Government's initiative, recently announced, to sponsor a series of safety 'blitzes' throughout the country, and to increase the number of Inspectors serving the construction industry on the staff of the Health and Safety Executive (HSE). The Committee thinks that, if some means can be found to make more widely available the mass of information and experience assembled by the HSE, this could facilitate the identification of particular situations and types of work in which large improvements in the safety record would be possible.

Structural collapses are fortunately very rare and, as earlier Reports have pointed out, the record of structural safety in the UK is very good. However, in 1985, a prestressed concrete bridge on a minor road in West Glamorgan collapsed without warning and under its own weight. The Committee has held several discussions with the County Council concerned and with the Transport and Road Research Laboratory, who have been investigating the failure, to examine the causes of failure and any wider implications of this particular incident.

The Committee presents its findings in Section 2.2 of this Report, and it welcomes the reported intention of the West Glamorgan County Council and the Transport and Road Research Laboratory to publicise the findings of their own detailed investigations. It is important that all structural collapses and serious failures should be examined by experts at the earliest possible time to ensure that these rare opportunities of obtaining and publicising valuable information on structural performance are not lost. The Report comments further on this point and also draws attention to the need to maintain full records of important structures, including design, construction and maintenance data. The Committee has some evidence, from another area of its investigations, that valuable information and records have not always been transferred effectively from one authority to another when boundaries have been changed or local authorities have been reorganised.

The Committee has also examined reports of structural failures that have occurred overseas during the period under review. In Section 2.4, a brief account is given on the New World Hotel, Singapore, which collapsed with the loss of 33 lives in 1986.

Although it can be concluded that the chain of mistakes and inadequacies leading to this incident could not occur if normal practices had been followed, it is as well to be reminded of the essential need for professional competence and responsibility in the design, construction and maintenance of structures.

Ski-lifts in the UK are few in number and confined to Scotland; but there is a growing number of chair-lifts of similar construction in leisure parks and recreation areas perhaps, together, totalling about 20. The collapse of a pylon in a ski lift in the French Pyrennes in March 1987, resulting in 5 deaths and 100 injured, caused the Committee to examine whether suitable standards of design and construction are applied to this type of structure in the UK. The magnitude of the risk to life of the small number of chair-lifts in the UK is small compared with that in France, for example, where some 3750 lifts carry 500 million people each year; but the Committee felt it to be their duty to ensure that safety precautions in the UK were at least as good as in other European countries. The Committee's enquiries to date are given in Section 2.6.

The Committee has continued to keep under review the implications of fee competition on structural safety, alkali-silica reaction in concrete, the use of resin bonded steel plates to repair reinforced concrete, and methane risk in underground enclosed structures. The present position on these topics is given in Sections 3.2, 3.4, 3.5 and 3.7, respectively.

Another item of continuing concern is the corrosion of tendons in prestressed concrete. The collapse of the prestressed concrete bridge in West Glamorgan prompted the Committee to re-examine the available evidence with regard to the wider question of the safety of prestressed concrete in the longer term. The conclusions from this re-examination are given in Section 3.3. The Committee believes that the conditions giving rise to the collapse of the West Glamorgan bridge were exceptional, and maintains its view that the corrosion of tendons is a serviceability problem, rather than one likely to cause sudden structural collapse. However, the question that remains unanswered is: why signs of corrosion or distress were not revealed by inspections on this bridge?

The importance of regular and effective inspection of all important structures cannot be over-emphasised. Effective inspection of a bridge depends on the engineer responsible having a thorough appreciation of those features of a bridge, including any peculiarities, requiring specific examination. This requires a clear understanding of the design principles and construction methods involved.

The development of improved techniques to aid inspection is of paramount importance and justifies high priority. In particular, the Committee has reviewed progress in the UK and elsewhere on tests to identify corrosion in prestressing tendons. The Committee welcomes the initiatives by the Transport and Road Research Laboratory in this respect and the international co-operation that has been generated.

In the Sixth Report, the Committee pointed out that, although the UK record of structural safety is good, the profession's reputation in terms of loss of life could have been very different if the Camden School, the Edmonton Swimming Baths or the Plymouth Polytechnic cafeteria had been occupied at the time of collapse, or if the footbridge over the A2 had been carrying pedestrians in a period of high traffic intensity. Fortunately, also, the West Glamorgan bridge's sudden collapse resulted in no injuries.

Against this background, however, is the fact that gas explosions cause between 20 and 40 cases of significant structural damage each year, resulting in an average of 12.6 fatalities. The large mileage of ageing mains network, mis-use by consumers and other factors beyond the responsibilities of the structural engineer are the causes of the majority of these accidents but, once again, the Committee draws attention to the need for designers of structures of all types to ensure that cavities and ducts are adequately ventilated, underground or otherwise, and whether or not gas services are provided in the building.

Another matter of continuing concern to the Committee is that of the risk of bridge failure resulting from vehicle impact, commonly referred to as "bridge bashing". Between 400 and 500 impacts are reported each year, of which about 140 are described as serious and 20 so serious that they could have de-railed a train. The Committee first drew the Presidents' attention to the seriousness of the problem in 1978 and, at the same time, made recommendations on the subject to the Secretary of State for Transport, who took a number of actions in line with those recommendations.

The Committee has reviewed the evidence available and considers that there remains a high risk that a pedestrian bridge carrying pedestrians over a highway will be dislodged at a period of high traffic intensity. There is also a high risk that a girder bridge carrying a railway over a road will be displaced sufficiently to cause de-railment or that a masonry arch bridge under a railway will receive cumulative damage to the extent of causing de-railment. The Committee is very much concerned that not enough is being done to reduce these risks, either by vehicle operators, by bridge owners, or by the Department of Transport. A report, with recommendations for action, will be submitted to the two Presidents at the earliest possible time.

The Committee is encouraged by the actions taken by the Institutions, Government Departments and other bodies as a result of its enquiries and recommendations on a variety of topics. Comments on the Committee's statements and suggestions for new topics requiring investigation are always welcomed, and the Committee hopes that this Seventh Report will stimulate further comments and suggestions. For example, Institution of Structural Engineers' Report on Safety Considerations for the Design and Construction of Demountable Grandstands fills an important need (topic 41 page 22) very effectively. Similarly, the action of the Institution of Structural Engineers in establishing an independent committee on the structural aspects of alkali-silica reaction (ASR), as suggested by the Committee, has been noted with approval.

Individual members take an active part in the Committee's work and several have been done so since the Committee was first established by the Presidents in 1976. To allow for retirements and to encourage a healthy turnover of membership, some new members have been appointed by the Presidents with effect from 1988. They will be welcomed and those members who are retiring deserve everyone's gratitude for their part in the significant contribution the Committee has made in the interests of structural safety.

2. NEW TOPICS DISCUSSED DURING THE PERIOD JULY 1985 - JULY 1987

2.1 SAFETY ON SITE

Introduction

At the request of the Presidents of the Institutions of Civil and Structural Engineers, the Standing Committee has been considering the problems of site safety with a view to making recommendations towards improving the unsatisfactory record on construction sites. The Committee has held discussions with several individuals and has considered a number of papers concerning site safety, including those presented to the ICE Symposium in March 1986. (ICE Proceedings Part 1, February 1986, Volume 80).

Accident statistics

The importance of the problem is well illustrated by the following summary of informaton extracted from HSE publications. The definitions of causes and of responsibilities are those used by HSE.

- 1980-83 : Average 148 p.a. killed (75% employees, the remainder self employed or members of the public).

  1981-1983 : Average 1917 p.a. major injuries (employees only).

  1981-84 : The number of reported accidents increased by 41%.

  Approximately 70% of fatalities occurred in building and 30% in civil engineering work (roughly in proportion to the value of work done in each field).

- In building, main causes of fatal accidents were :

falls from one level to another	55%
struck by falling object	13%
falls from ladders	11%

  In building, fatal accidents occurred in :

new construction	47%
maintenance	37%
demolition	15%

- In civil engineering the main causes of accidents were :

non-rail transport	33%
struck by falling objects	21%
falls from one level to another	16%

- Investigations by the Health & Safety Executive (HSE) into 100 fatal accidents indicated that responsibility might be apportioned to :

management	68%
deceased (own fault)	18%
fellow workers	2%
no clear responsibility	12%

With reference to the high proportion of blame apportioned by HSE to management, there is some corroborative evidence in that the frequency of accidents on the sites of some major national contractors is substantially lower than average.

- HSE statistics highlight demolition, steel erection and roofing workers as being at high risk. Although a small proportion of the total work force, these workers account for 22% of all fatal accidents (but only 4% of all reported accidents).

- Attempts to obtain reliable and detailed accident records for analysis have been unsuccessful :

  - HSE accident records are confidential and, in any case, detailed records are only prepared for incidents investigated by HSE themselves.

  - Records held by major contractors are similarly inadequate and too few in number for multi-factorial analysis.

Comparison with other industries

Statistics show that construction is four times more dangerous than manufacturing industry as a whole.

The petrochemical industry is a good example in which the clients' positive attitude, by specifying arrangements for the management of health and safety in the contract documents, has resulted in a marked improvement in the safety of construction work on petrochemical sites.

In coal mining, the accident record was greatly improved by commitment and sustained effort by management. Under Lord Robens' Chairmanship, the NCB halved the number of mining accidents in 15 years.

Comparison with other countries

The Standing Committee was unable to locate accident statistics on construction sites in other countries. A careful study on this subject could be worthwhile, although it is known that poor site safety is also of concern in other countries, including Japan.

Trends likely to affect site safety

The following trends were identified as potential adverse factors affecting safety :

- Losses in trained, experienced workforce and inadequate intake of apprentices.

- Management contracting and growth in the proportion of sub-contract work generally means that responsibility for safety performance of operatives is even more diffuse.

- More complex building forms, making subsequent maintenance and cleaning operations more difficult.

- Refurbishment, giving rise to difficulties in partial demolition and the use of unfamiliar materials.

- Highly competitive tendering by contractors.

- Construction on contaminated land.

One important trend that may encourage more substantial effort to improve site safety in the future is the increase in litigation and damages awarded by courts to victims of accidents.

Some possible actions

The Standing Committee has identified a number of actions that could be taken to improve site safety and has received a variety of additional suggestions. Broadly, they suggest the need for actions in the fields of :

- Training at all levels.

- Standard forms of contract.

- Management contracting : responsibility for site safety.

- Enforcement of Regulations.

- Information and publicity.

Conclusions and recommendations

The Standing committee is in accord with Lord Robens in pointing out apathy as the greatest single contributing factor to accidents at work. A concerted effort would be required by all concerned - designer, client, contractor, equipment manufacturer and workforce - to improve safety on site. Regulations can have only limited effect unless they are effectively enforced. At present there is too much reliance on regulations and too little on personal responsibility and voluntary effort.

To achieve the concerted effort required will take time and a continuing commitment from the professional institutions and other bodies concerned to ensure greater site safety. The Institutions and their members could do much to help promote this objective, particularly by ensuring that :

- Means are available for the adequate training of operatives on site safety. The state of mind of operatives is just as important as that of management in affecting safety on a site.

- Standard conditions of contract specify the requirements and include an appropriate priced item for site safety.

- Qualification for corporate membership includes proven awareness of the importance of site safety and the precautions required in design, construction and maintenance operations.

- Adequate courses exist for in-career training on site safety.

- Safety publications (e.g. by HSE, CIRIA, BEC, CITB, FCEC, ICE, and IStructE) should be given wide publicity and, in many cases, need to be re-presented to have greater impact on site staff.

- The subject of site safety is given a higher profile (e.g. by conferences, publications, lectures, etc).

- Regulations are reviewed and revised, and the legal liabilities for safety are clarified and publicised, especially those between contractor and sub-contractor (self employed with or without 714 Certificates.)

  There appears to be considerable similarity between the achievement of safety on site and that of quality assurance. Both require commitment by designers and contractors, involving a declared company policy, and an effective management structure operating a documented scheme. Neither is likely to develop without insistence by clients on the operation of effective schemes or without evidence of their cost implications.

Further research

The Committee reviewed some of the research relevant to site safety and considered what further could be done towards improving matters. It recommends that:

- Well designed and conducted research on the causes of human error on site could make a useful contribution to the problem.

- Means should be found to improve the system of reporting accidents to facilitate scientific analysis and, hence, to provide more detailed advice on actions required.

- Methods should be found to improve the system of reporting accidents to facilitate scientific analysis and, hence, to provide more detailed advice on actions required.

- Some means should be found to reward contractors with good safety records and penalise others.

On this last point, research by Leopold and Leonard(1), based on 1981 accident and cost data, found that present insurance systems premiums gave little incentive for contractors to change their practices and that indirect costs of accidents were small compared with turnover. However further research reflecting current cost data of litigation, damages and medical treatment could be worthwhile.

Actions following the report

The Committee welcomes the actions taken by the two Institutions and other bodies following its report. In particular, proposals are being prepared for training at undergraduate and Professional Examination levels and for seminars on safety at a number of centres.

The Co-ordinating Committee on Project Information has made provision for specifying and including a priced item on site safety in standard conditions of contract, and the Institution of Civil Engineers is considering amendments to the 5th Edition.

The Committee is also encouraged by the actions recently announced by the HSE (October 1987) to strengthen its enforcement of safety regulations on site.

2.2 COLLAPSE OF THE YNYSYGWAS BRIDGE, WEST GLAMORGAN

Ynysygwas Bridge at Cwmavon, Port Talbot was an 18.3-m clear span bridge of segmental post-tensioned I-beam construction carrying a Class C County road at a gradient of 1 in 6 over the River Afan. The bridge, built in 1952, collapsed in December 1985 without warning and under its own weight. The Standing Committee instituted discussions with the West Glamorgan County Council, the Department of Transport and the Transport and Road Research Laboratory (TRRL) with the object of establishing :

- The mode and cause of failure.
- The risk to any similar bridges that might exist.
- Any wider implications to the safety of prestressed concrete bridges and other structures.

The bridge, one of the earliest prestressed bridges in the UK, was based on a proprietary design with the nine internal beams of the deck consisting of eight I-sections, each 2.41 m long, stressed together using five profiled prestressing cables. Each cable consisted of twelve 5-mm diameter high tensile steel wires. The internal beams were 0.91 m deep and 0.61 m wide. The edge beams were box beams of similar segmental construction and carried the blockwork parapets.

On each edge of the bridge, a service void was provided between the internal and edge beams covered by 1.83-m wide precast reinforced concrete slabs spanning between them. Two top transverse prestressing cables for each segment passed through these slabs to anchorages in the edge beams. A single bottom transverse prestressing cable for each segment passed through the 127-mm wide diaphragms at the ends of each segment to tie the nine internal beams together.

The transverse joints between segments were 25 mm wide, and were filled with in-situ dry mortar caulking prior to post-tensioning. Metal sleeves were intended to provide continuity of the ducts across the joints. Layers of felt on the beams provided the waterproofing. In 1975, the alignment of the road had been adjusted by the addition of a layer of cement bound material 200 mm thick at the eastern end, tapering to nothing at the western end. A bituminous running surface was added.

Following an initial examination by the West Glamorgan County Council, TRRL was asked to investigate the failure and some salvaged sections of the bridge were transported to the laboratory for this purpose.

Examination by the West Glamorgan County Council

The County Council reported that failure occurred when longitudinal tendons in one or more of the I-beams fractured along two transverse sections near mid-span. The edge beams did not fail and the slabs spanning between the main deck and edge beams were left hanging from them. The cause of failure was found to be corrosion of the longitudinal prestressing cables. Severe corrosion was apparent at a high proportion of the joints between beam segments, but the degree of corrosion did not appear to be related to either the effectiveness of the waterproofing or to the condition of the mortar joints between the segments.

In almost all of the joints between segments, cardboard tubes had been used instead of metal tubes to provide continuity of the ducts. However, because, generally, the metal tubes had themselves disintegrated, the use of cardboard tubes was not regarded as a prime cause.

Corrosion of transverse prestressing cables was, similarly, concentrated at the joints between beams.

During the previous six years, the bridge had been inspected annually, particularly with regard to potential river scouring problems and, in 1980/81, the bridge was reported to have been examined closely prior to and during the passages of nine 50-tonne concrete beams on an 11-tonne tractor unit and 3-tonne bogey. The bridge had been identified as one requiring surfacing and waterproofing maintenance work. However none of these annual inspections had reported warning signs of prestressing cable corrosion, such as rust staining, cracking or deflection of beams.

Investigation by the Transport and Road Research Laboratory

A more detailed investigation by TRRL on some salvaged sections of the bridge has proceeded over a period of more than 12 months and has yet to be reported in full. However, the significant findings by TRRL are summarised as follows :

- The structure failed because of corrosion of the tendons at the joints.

- Corrosion in the majority of the ducts was localised to the joints. Corrosion was severe with heavy loss of section of the tendons.

- Chlorides were also present in grout at both transverse and longitudinal joints and in the corrosion products; but not in grout from within the segments.

- No corrosion was found in fully grouted ducts within the segments. Large voids were found in some ducts, but exposed wires were covered with a layer of cement paste. However, severe corrosion was found along the length of partially grouted transverse ducts.

- Corrosion of the tendons at transverse joints appeared to have been caused by the presence of chlorides in the mortar, the inadequate protection given to tendons by the mortar and grout, and the moist environment under the bridge. Corrosion at the longitudinal joints seemed to have been caused by the inadequate protection given to the tendons.

It seemed likely, because of the width of the longitudinal joint, that the mortar had been poured, rather than tamped into place dry. There was some evidence of chloride ingress (from de-icing salts) into the surfaces of the I-beams and, more particularly, into the joint mortar. Chloride concentrations in the mortar were very variable. Most, if not all chlorides in the mortar probably originated from de-icing salts, although the presence of shell suggests that a dune sand had been used in the mortar and this may have been contaminated with chlorides. The quality of the mortar was otherwise generally good.

- In the edge beams and in the cores of the I-beams the chloride contents were low.

A load test is to be undertaken on an edge beam to determine the residual level of prestress.

Other similar bridge structures at risk

Efforts have been made by the Department of Transport and Local Authorities to identify and inspect bridges having similar characteristics to those of the Ynysygwas bridge. Although segmental construction is currently popular, available records indicate that of 82 segmental bridges in England only four had been built between 1964-1968 and the remainder since 1970. A significant difference between these bridges and the Ynysygwas bridge would appear to be the absence of an in-situ concrete slab above the precast slabs in the latter. Furthermore, in the 1960s, the design and construction of joints was improved to facilitate effective filling.

Although the Department of Transport maintains records of all bridges for which it is responsible, this does not apply to all bridges owned by local authorities. There remains, therefore, the possibility of there being some other unidentified bridge similar to Ynysygwas.

The Committee's observations and recommendations

The need to clear the site and provide temporary bridging prevented the close and immediate investigation necessary to establish the precise mode of failure. However, it seems probable that loss of prestress across many of the transverse joints had increased progressively, and that failure occurred at more than one of these joints, at low ambient temperature. The stability of the bridge may have depended on the transverse cables for some time before the deck collapsed.

Based on the records and information available, the Committee is inclined to the view that the Ynysygwas bridge was unique in several respects, especially with regard to lack of protection against de-icing salts at the joints and the absence of a reinforced concrete deck slab. However, because there can be no certainty that this is so, the Committee recommends that this report and, in due course, the findings of the West Glamorgan County Council and of TRRL should be given the widest possible publicity to bridge owners and engineers.

The Committee is concerned that in none of the annual inspections of the Ynysygwas bridge were the warning signs of corrosion, staining, cracking or deflection, reported. The Committee would have expected these signs to have been apparent in such a case, and the fact that they were not noticed is a matter of considerable importance.

In its Sixth Report the Committee concluded, amongst other things, that: "*......corrosion of reinforcement or prestressing tendons created a serviceability problem rather than one likely to cause sudden structural failure. Nevertheless, it was essential to maintain adequate procedures for inspection and repair. High priority should be given to R&D to improve methods of detecting corrosion and to provide effective methods of prevention and repair*".

The Committee considers that there is room for considerable improvement in procedures for inspection with regard to both frequency and effectiveness. The development of an effective method of detecting corrosion remains a very high priority need.

The collapse of a bridge or any other structure is, fortunately, a rare occurrence in the UK. But the Committee regards it as extremely important that any collapse should be investigated closely by experts as soon as possible after the event. In an earlier Report, the Committee recommended that building owners should be encouraged to inform the Building Research Establishment as soon possible after any collapse and to provide the facilities necessary to enable an immediate investigation to be started. A similar warning system should be set up to alert TRRL of bridge collapses. Much valuable information can be lost if there is any delay before expert investigation.

2.3 RISING GROUNDWATER

A decline in the groundwater abstractions in a number of cities in the UK has resulted in a rise in groundwater levels over the past 20 years, amounting, in some areas, to as much as a 20-m rise. CIRIA is undertaking a substantial programme of investigation on the subject, and the Committee will continue to keep the structural safety implications of these rises in water level under review.

Starting with the London basin, geographical areas have been identified in which various types of foundation or basements in existing structures could be affected within 15-25 years, depending on the future rate of groundwater rise. This information also indicates the areas in which the design of foundations and basements for new buildings needs to take into account groundwater pressures that could develop in the future.

The scale of the problem in London is potentially very large. The Water Research Centre is developing a mathematical model for Thames Water to provide detailed predictions of water level in relation to abstraction and recharge regimes.

2.4 NEW WORLD HOTEL SINGAPORE

In March 1986, a six-storey building - the Lian Yak building - collapsed rapidly and totally to the ground and basement levels with the loss of 33 lives. Hotel New World occupied the top three storeys, and the entire building was completed in 1971.

A report of the Inquiry(2) into the collapse presented to the President of the Republic of Singapore in 1987 concluded that the root and main cause of the collapse lay in the grossly inadequate design. Dead weights were underestimated, and a large number of individual structural members were grossly under-designed. Compared with CP110, the factors of safety of some columns were below 1.0, concrete strengths were generally well below normal requirements, and workmanship was of a low order. Signs of structural distress had been ignored. As a result, cracking developed and propagated, deformation in columns progressively transferred overloads to other columns, resulting in their progressive collapse.

The principal recommendations of the Inquiry relate to the need for competence of the designer, the selection of a competent and responsible contractor - not entirely on the basis of lowest cost - supervision of construction by qualified persons and, lastly, maintenance of a building after construction.

It is as well to be reminded of the need to continue to enforce the recommendations resulting from this Inquiry.

2.5 THE EFFECT OF LIGHTNING ON REINFORCED CONCRETE

The collapse of a proprietary reinforced concrete dome in Australia prompted a suggestion that failure had been caused by a strike of lightning, although subsequently it was attributed to other causes. Cracks in a 27-m high concrete silo in Iowa in 1980 had been attributed to lightning conducted down an external filter pipe, through the reinforced concrete into high moisture content corn in the silo. In South Africa, buried reinforced concrete pipes had been severely damaged by lightning. In this case, damage was concentrated at the joints, between the ends of the longitudinal reinforcing bars. Lanser, Wolde-Tinsae and Greimann(3) subsequently reproduced examples of damage to reinforced concrete by electrical discharge in the laboratory. There is no record of damage to reinforced concrete structures by lightning in the UK, but the Committee felt that the attention of designers should be drawn to the advice given on the subject in BS 6651(4).

2.6 SAFETY OF CHAIR-LIFTS

The collapse of a pylon in a ski-lift in the French Pyrenees in March 1987 caused five fatalities and injured 100, and gave rise to questions about the standards and controls applicable to the design and construction of chair-lifts in the UK, which are growing in number.

The accident in the Pyrenees and at least one other recent ski-lift accident has been reported to be because of failure of the reinforced concrete foundation. The foundation is usually constructed by a local contractor prior to erection of the pylons and lift mechanisms by the specialist lift manufacturer. It is understood that the French Ministry of Transport's new regulations, following the accident, will require more rigorous overall control by an independent expert over the construction of the pylon foundations and installation of the lifts. In France, the Ministry of Transport is also responsible for ensuring that the ski-lift operator maintains and operates the lift to stringent safety standards.

There are 3750 lifts in France which carry 500 million people each season. Over the past 10 years, there has been an average of between one and two fatalities each year. Routine checks on each lift are carried out daily and monthly by the operator and each year extensive tests are made by outside experts.

In the UK, responsibility for the safety of a chair-lift is vested in the owner and operator of the lift, who are expected to comply with the general requirements of the Health and Safety at Work Act 1974. The Health and Safety Executive has not produced any requirements for the design and construction of chair lifts and, although BS 8100[5] covers the climatic loading of chair lift pylons, no other specific guidance on chair-lifts is available from British sources.

The Committee is carrying out further enquiries on this subject, and it would welcome information from structural engineers and others with experience on the design construction or operation of chair-lifts.

3. TOPICS OF CONTINUING INTEREST

3.1 GUIDANCE MEMORANDUM FOR EXPERTS

From its discussions on the implications of the collapse of the Carsington Dam and from other reported incidents, the Committee was concerned with an apparent lack of guidance on procedures in the case of professional experts disagreeing on matters affecting structural safety. In its 6th Report (Item 2.7), the Committee recommended that the Presidents should initiate the preparation of such guidance.

The Committee has commented on drafts of a memorandum on this subject, since prepared by the Legal Affairs Committee of the Institution of Civil Engineers, and it is pleased that the Memorandum is now due for publication.

3.2 IMPLICATIONS OF FEE-COMPETITION

In its 6th Report (Item 2.5), the Committee recommended that the influences of fee-competition on structural safety should be monitored. Although fee-competition has been implemented by UK Government Departments in a number of cases, including design work, supervision and specialist services, there is, as yet, no evidence of its influence on structural safety. To monitor its influence is both difficult and long-term, and the Committee proposes to keep the matter under review.

3.3 CORROSION OF TENDONS IN PRESTRESSED CONCRETE

In its 6th Report (Item 2.9), the Committee reported its findings on the information and test results available on the long-term performance of post-tensioned concrete bridges, of which there are about 600 relatively long span in the UK. At that time, the Committee concluded that corrosion of tendons was a serviceability problem rather than likely to cause sudden structural failure. The loss of one tendon from corrosion would have minimal effect on the overall level of safety but provide adequate warning of possible further damage. It was also concluded in the 6th Report that corrosion of tendons could be predicted during the course of a routine inspection by the appearance of staining, cracking or deflection. On the evidence received, the collapse of the Ynysgwas Bridge is in complete contrast to this view, and it raises the question of which tests could be applied to identify this type of corrosion at a sufficiently early stage before reaching the collapse condition.

The problem of corrosion is not confined to the UK, and in view of the experience referred to in Section 2.2, the Committee was interested to learn of progress made in the UK and elsewhere in the development of tests to identify corrosion instead of or in addition to visual inspection.

The presence and/or risks of corrosion could be indicated by measurement of electrode potential, radiography, chloride ion concentration, depth of cover, carbonisation, and permeability of the concrete. More positive (but potentially damaging) techniques could involve drilling into ducts and the use of endoscopes, with limited effective length of exploration. Ultrasonic pulse techniques and other methods are under development to try and identify fractures of wires or strands. Measurement of prestress at prescribed points is possible by such techniques as slot cutting and jacking.

The Committee strongly supports the need to expand the R&D effort by TRRL and others, to develop effective methods of identifying tendon corrosion for application to routine inspections.

3.4 ALKALI-SILICA REACTION IN CONCRETE

The Committee reported and gave its conclusions on the incidence of ASR in structural concrete in the UK as part of its 6th Report (Item 2.2). Although of serious concern with regard to future maintenance costs, the incidence of ASR had been limited to a small number of structures. Recommendations published by the Concrete Society, if properly observed, would reduce very substantially the risk of ASR in new structures.

Although the causes of ASR are well known and have now been widely publicised, considerations that need to be taken into account by engineers assessing the safety and serviceability of affected structures are less well understood. In particular there is a difficulty in measuring the extent to which the reaction has proceeded at any given time and the extent to which the reaction, which is finite, is likely to progress.

The Committee is aware of some of the extensive research that has been carried out on the subject in other countries, notably the USA and Denmark, of the research in this country and of the efforts made to collate relevant information for use in the UK. The study visit to Japan, organised by the Cement and Concrete Association and reported at the Institution of Structural Engineers, has also provided valuable basic information on the performance of concrete affected by ASR.

It is, however, a matter of considerable concern that a well-designed programme for joint action by the Building Research Establishment and a group of Universities has been seriously delayed by failure of the Science and Engineering Research Council to provide the necessary funds to the Universtiies at the time required. It is to be hoped that this lack of essential funds will be overcome as a matter of urgency.

The Institution of Structural Engineers' Ad Hoc Committee on ASR should provide much needed guidelines for engineers assessing ASR-affected structures.

3.5 USE OF RESIN BONDED STEEL PLATES TO REPAIR REINFORCED CONCRETE

In its 5th Report, the Committee recommended against the general use of resin bonded plates as a means of repairing reinforced concrete bridge decks and emphasised the need for continuous monitoring whenever the method was applied. In its 6th Report (Item 3.4), the Committee referred to discussions with a local authority (West Midlands County Council) on their proposals to use the method on floor slabs in a multi-storey (Police) car park for which they were responsible, and on their proposals to monitor the performance of the repaired structure.

Abolition of the Council as a Metropolitan County in 1986 resulted in the transfer of responsibility to another authority that was unaware of the risks involved and of the need to monitor the construction. The Committee has drawn appropriate attention to the authority now responsible.

As part of its discussions on the subject, the Committee reviewed available information on the use of this method of repair and, in particular, research results from TRRL and Universities working on the system. The review strengthened the Committee's earlier recommendation against the general use of resin bonded plates for repair. Careful consideration should be given to the consequences as far as the service load/ultimate load margin is concerned, to durability and to fire resistance.

The Committee fully supported a suggestion by the Structural Engineering Board of the Institution of Civil Engineers that it was timely now to encourage a review and public discussion of the research findings and practical experience on the use of resin bonded plates. An informal discussion was held on the subject at the Institution of Civil Engineers on 7 October 1987, and will be reported by the Institution in due course.

Referring to the earlier part of this item of the Report it is, perhaps, significant that during the process of transferring resposibilities from an abolished local authority to another, essential information affecting structural safety was lost. Although the Committee has no further evidence on this subject, it seems likely that with each transfer of responsibility from one authority to another, such as occurred extensively in 1974 and again in 1986, some losses in valuable records did occur.

3.6 ACCIDENTAL DAMAGE TO BRIDGES BY IMPACT OF VEHICLES

In each of its 6 Reports since 1978, the Committee has drawn attention to the frequent occurrence of accidental damage to bridges by vehicle impact. To date, the few fatalities from this form of accident have been confined to occupants of the vehicles concerned, but the Committee is more concerned about the possible secondary effects of such an accident which could, for example :

- Demolish a pedestrian bridge over a major road, imperilling both pedestrians on the bridge and vehicles travelling on both carriageways of the major road. At least one such accident has been reported but, miraculously, without loss of life.

- Demolish or severely damage a bridge carrying a railway over a road, with a consequent damage to the rail track and de-railment of a crowded train. A high proportion of bridges carrying railways over roads in the UK are masonry arch bridges with clear heights well below current standards. Many are severely damaged each year.

In 1978, the Committee made recommendations to the Secretary of State for Transport on actions necessary to reduce this important risk, some of which have since been instituted. However, the number of reported incidents of damage to bridges remains at between 400 and 500 per year, with 140 described as serious and 20 sufficiently serious that they could have caused de-railment.

Examination of the records and consideration of the consequences leads to the conclusions that a very serious accident as a result of vehicle impact on a bridge is highly probable. The Committee has therefore decided to give the matter its close attention during the coming months.

3.7 METHANE RISK IN UNDERGROUND ENCLOSED STRUCTURES

Arising from the Committee's discussion on the explosion at Abbeystead in 1984 (6th Report, Item 3.5), it was apparent that information was lacking for engineers on the properties, origin, explosive mixture and the natural accumulation of methane. While the presence of methane should be apparent in coal measures or rubbish tips, the presence of buried natural vegetation, peat or a marsh is not always observable.

The Committee has initiated the preparation of a short guide on this subject. However, it wishes to reiterate its earlier advice (6th Report, Item 3.5) concerning the need to ensure adequate venting of confined spaces or underground construction into which methane could permeate, and also to ensure that the venting is maintained clear.

4. TOPICS FOR FUTURE DISCUSSION

The list of nearly 60 topics considered by the Committee during the past 10 years (Appendix 1) includes some on which a relatively simple action or statement was sufficient to provide the necessary warning or reassurance to the profession concerning structural safety. In some other cases, it has been necessary to maintain a watching brief over trends and developments for a period of years before any constructive statements could be made or actions taken. Then there are several problems such as site safety, "bridge bashing", corrosion of reinforcement and tendons, and the need for effective inspection and maintenance of structures generally, that require extensive evaluation and clear guidance by the Committee, followed by well directed actions and publicity to achieve the goal.

Section 2 and 3 of this Report include topics of these various types and, in addition to maintaining a watching brief over such matters as rising groundwater, the safety of ski-lifts and the use of resin bonded plates to repair reinforced concrete, the Committee will devote a good deal of its attention to improving site safety and reducing the risk of a serious multiple accident because of bridge-bashing.

The Institutions' Presidents and Committees will comment on this Report in due course and suggest new areas requiring examination by the Committee. However the Committee was established in order to provide individual members of the profession, and of the public, with the opportunity to express any concerns that they might have on aspects of structural safety to the Committee on a confidential basis.

The Committee welcomes all such comments and suggestions, which should be addressed to the Secretary of the Committee or to individual Committee members, if that is preferred.

5. REFERENCES

1. LEOPOLD, E. and LEONARD, S.
Costs of construction accidents to employers.
Amsterdam.
Journal of Occupational Accidents (Elsevier, Amsterdam) 1987 **Vol. 8** 273 to 294

2. Commission of Inquiry into the collapse of the Hotel New World
Report to the President, Republic of Singapore, February 1987
Singapore National Press Ltd.

3. LANSER, M., WOLDE-TINSAE, A.M. and GREIMANN, L.F.
Effect of lightning on concrete
Proc. Am. Soc. Civ. Engrs. - J. Struct. Div.
April 1984 **Vol. 110** (No. 4), 859 to 870

4. BRITISH STANDARDS INSTITUTION
Code of practice for the protection of structures against lightning
BS 6651: 1985

5. BRITISH STANDARDS INSTITUTION
Code of Practice for lattice towers and masts
BS 8100: 1986

APPENDIX 1 LIST OF TOPICS REPORTED ON BY THE COMMITTEE SINCE ITS INCEPTION IN MARCH 1976

1. The Final Report of the Advisory Committee on Falsework (Bragg Committee)
2. High pressure gas pipelines
3. Fires in schools and other buildings exempt from control under the Building Regulations
4. Maintenance and inspection of British Rail structures
5. Concrete Society working party on structural safety
6. Building Integrity Division BRE
7. Cladding failures
8. The influence of Building Regulations on structural safety
9. The influence of safety factors on overall structural safety
10. Investigation of structural failures
11. The relevance of Agrément Certificates to structural safety
12. The risk of brittle fracture in high tensile steel structures
13. Liquefied petroleum gas containers in dwellings
14. The stability and durability of timber roof trusses
15. Tolerances and accuracy in building
16. Responsibility of local authority inspectors
17. The strengthening of reinforced concrete bridges by attachment of resin bonded steel plates
18. Damage to bridges through impact by high vehicles and high loads
19. Welded structures
20. The Building Research Establishment, Garston
21. The use of chemical admixtures in concrete
22. Various factors influencing the structural safety of buildings
23. Safety of post tensioned concrete bridges : corrosion of tendons
24. The role of the Health and Safety Executive in building control
25. Cavity wall ties and metallic components
26. Ground anchors and reinforced earth

27. The use of pulverised fuel ash in structures

28. The stability of buildings during partial demolition and reconstruction

29 Failures of medium sized public assembly buldings

30. Earth dams

31. Lighting columns

32. Deterioration of buildings and other structures

33. The effect of complex and comprehensive codes on structural safety

34. Structures in the nuclear power industry

35. Structural failures during construction

36. Some cases in which the Building Regulations may not provide appropriate safeguards for structural safety

37. The use of resins in civil and structural engineering

38. Mis-use of computer programs in design

39. The safety of structures affected by alkali-silica reaction in concrete

40. The profession's reactions to some matters of public concern

41. Safety of demountable grandstands

42. Structural safety related to size and importance

43. Implications of some recent court decisions on structural safety

44. Implications of the introduction of fee-competition on structural safety

45. Collapse of brick cladding to the Plymouth Polytechnic Tower block

46. Collapse of the Carsington Dam during construction

47. The safety of large panel buildings

48. Corrosion of reinforcement and prestressing tendons in concrete bridges

49. Inspection and maintenance of railway structures

50. Inspection and maintenance of large dams

51. Damage to bridges by impact from vehicles and vessels

52. The use of resin bonded plates to repair reinforced concrete

53. Structural damage due to gas explosions

54. Safety on site

55. Collapse of the Ynysygwas Bridge West Glamorgan

56. Rising groundwater

57. Collapse of the New World Hotel, Singapore

58. The effect of lightning on reinforced concrete

59 Safety of chair-lifts

APPENDIX 2

2.1 TERMS OF REFERENCE

The terms of reference for the Committee were determined by the Presidents of the Intitutions of Civil and Structural Engineers 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 and to make recommendations.

To produce an annual report on its activities.

To seek, receive and authorise the expenditure of funds necessary for the implementation of these terms of reference.

To suggest to the two Institutions any changes to its terms of reference it considers to be necessary or desirable.

2.2 LIST OF MEMBERS - JULY 1987

Chairman : Sir Derman Christopherson OBE DPhil BA(Oxon) FEng FIMechE MICE FRS
University of Cambridge

C J Evans MA FEng FICE FIStructE
Wallace Evans & Partners

A Gordon CBE LLD DipArch PPRIBA
Alex Gordon & Partners

R F Hughes CEng MICE
Directorate of Civil Engineering Services
Property Services Agency

Professor E F Happold RDI BSc FEng FICE FIStructE FCIOB
University of Bath

D J Lee BSc (Tech) DIC FEng FICE
G Maunsell & Partners

P F Mead FEng FICE
John Mowlem and Company plc

D N Rogers BSc (Tech) CEng FICE FIHT
Mott Hay & Anderson

R E Rowe CBE ScD DEng MA FEng FICE FIStructE FIHT FACI
Cement & Concrete Association

A C E Sandberg BSc ACGI FEng FICE FIStructE MIMechE FIHT MConsE
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* R S Taylor BSc CEng FICE
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J Uff QC PhD BSc(Eng) CEng FICE FCIArb MConsE
Consulting Engineer

F Walley CB PhD MSc FEng FICE FIStructE
Ove Arup Partnership

Secretary L S Blake PhD BSc(Eng) CEng FICE FIStructE

Technical Officer R M Lawson PhD BSc(Eng) ACGI CEng MICE MIStructE
CIRIA (until July 1987)

E W Dore CEng FIStructE MICE
CIRIA (from July 1987)

* Until his death in January 1987