FIRST REPORT OF THE COMMITTEE
FOR THE YEAR ENDING 31 MARCH 1977

Standing Committee
on Structural Safety
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REPORT OF THE STANDING COMMITTEE FOR THE YEAR
ENDING 31 MARCH 1977

1. MEETINGS

The first meeting of the Standing Committee on 22 March 1976 was followed by a further seven meetings during the 12 months period ending 31 March 1977.

2. METHOD OF WORKING

The Committee took note of suggestions made by the Interim Committee* and selected for discussion with organisations and individuals a number of topics which might possibly indicate areas of risk. It should be emphasised that, at this early stage of the Committee's work, the topics were selected as much to help the Committee develop a method of working as to investigate known or believed areas of risk. Nevertheless, through the series of seven discussions held to date, the Committee has been able to identify a number of potential problems which justify further investigation and some which require action.

In addition to these discussions, the Committee has noted the limited statistics available on the occurrence of structural failures and has kept under review the major incidents, including those overseas, reported during the year. Research in the UK

* Report of the Interim Committee on Structural Safety June 1974
relevant to structural safety has also been noted.

Relatively few suggestions for topics requiring investigation have been received from members of the profession, but it is expected that this aspect of the Committee's work will increase as the Committee's existence and purpose become better known. It is also hoped that useful contacts can be established with organisations overseas concerned with structural safety.

3. TOPICS DISCUSSED DURING THE 12 MONTHS ENDING 31 MARCH 1977

The Standing Committee had confidential discussions on the following topics with individuals or representatives of the appropriate organisations:

The Final Report of the Advisory Committee on Falsework (Bragg Committee)
May 1976

Safety Considerations applied to High Pressure Gas Pipelines
July 1976

September 1976

Maintenance and Inspection of British Rail Structures
October 1976

Concrete Society Working Party on Structural Safety
November 1976

Building Integrity Division, BRE
January 1977

Claddings
February 1977

Reports of the discussions, together with the Committee's conclusions, are given on pages 3 to 31.
In addition, the Committee has discussed the following:
(a) DOE Research Report No 3 - Structural Safety
(b) Statistics on structural failures
(c) Safety considerations applied in the siting of chemical work and containers of high energy materials
(d) Brittle fracture in welded high tensile steel structures

The Committee has noted several major failures which have occurred in various countries during the year, but has not found it necessary to take immediate action on any of these.

THE FINAL REPORT OF THE ADVISORY COMMITTEE ON FALSEWORK (Bragg Committee)

May 1976

Introduction

The first action by the Bragg Committee had been to examine actual failures to consider, in each case, what went wrong, why the errors had not been noticed and how such mistakes could be avoided next time.

In general, no evidence of technical "unknowns" had been found; failures occurred because the known rules were not applied. Common faults which could be identified were:

- Insufficient allowance for horizontal loads and general lateral and longitudinal instability
- Lack of appreciation of the possibility of progressive collapse
- Actual vertical loads being different from design assumptions
- Inadequate foundations
- Lack of support to beams, and inadequate allowance for their deflection, particularly in the third dimension
- Instability of grillages
- Eccentricities and lack of fit during erection (tolerances not specified)
Faulty setting out
Defective or inadequate materials
Incorrect procedure for dismantling.

Considerable effort had been spent in collecting case histories of falsework collapses and the Report had strongly recommended some means of collating this type of information, even if individual case histories had to be kept confidential until all litigation had been completed.

The questions of checking and of responsibility had been considered in great detail and the Bragg Committee concluded that although that prime responsibility must remain with the designer of the falsework the designer of the permanent structure should also carry out a check. Many accidents had occurred on small sites for which architects were the responsible designers but, at present, architects are unwilling to be involved in falsework checking.

Discussion
The standard of knowledge and experience of falsework in small firms is lower than it should be, particular in understanding the loads involved. In the USA, the situation should be better because of the greater use of proprietary trestles and, for larger work, it is a statutory requirement for a licensed engineer to sign drawings.

The use of a design checking procedure raises the difficulty of assigning responsibility. The man who misses a mistake, however, should be less culpable than the man who makes it.

Architects generally assume that their consulting engineers carry out all the necessary checks on falsework. However, this assumption may not be true in all cases.

The Bragg Report's pleas for better education and training leads into a very complex situation, involving among other things,
industrial relations. Some of the recommendations about training will be very difficult to put into practice. For example, there is no such thing as a "falsework operative" and falsework is often erected by carpenters and others in a team which seldom keeps together.

The Building Regulations do not refer specifically to falsework and, contractually, the stability of the falsework is always considered in relation to the safety of the permanent works, not to the safety of the individual constructing it.

Better liaison between the designers of the permanent works and the temporary works would help. The permanent works designer needs to consider that falsework erectors may have a relatively low level of skill and, therefore, his design should make the falsework design and erection as simple as possible.

Standing Committee's conclusions

In the longer term there is a need to improve the standard of education and competence in the industry.

It is important that all parties understand the allocation of responsibilities. In the case of falsework, the responsibility for the design and construction should remain with the contractor. However, the designer of the permanent works has a professional duty of care regarding all activities on the site, insofar as his skills are involved.

The collection of case histories, in a standard form, is very desirable.

No new statutory regulation is necessary.
SAFETY CONSIDERATIONS APPLIED TO HIGH PRESSURE GAS PIPELINES
July 1976

Introduction
The British Gas Corporation supplies about 4000M cu ft of natural gas per day to 14M consumers through a system of high pressure pipelines built during the past twelve years. Gas is transmitted to 12 regions through a national grid of 2600 miles of pipeline at pressures up to 1000 psi. Bulk transmission around the regions is usually at pressures below 550 psi, most of it being between 350 and 100 psi. The total length of the high pressure (above 100 psi) system is about 8000 miles.

Local distribution systems all operate below 100 psi. Street mains generally operate at much lower pressures, the majority at less than 1 psi.

The high pressure system has been built for continuous duty well into the 21st century. It consists generally of 36 in diameter steel pipes buried at a depth of 3 ft 6 in, except where it is impractical to do so. The pipes are coated and provided with cathodic protection in order to minimise corrosion. The cost per mile of high pressure pipeline is about one third of that of a dual-carriageway road.

The Corporation's experience with high pressure pipelines dates from 1964 for distributing methane. Overseas experience, particularly American and French, dates back further and has been drawn on when British codes of practice and specifications have been produced. The Institution of Gas Engineers committee responsible for "Recommendations on Transmission and Distribution Practice IGE/TD/1 - Steel Pipelines for High Pressure Gas Transmission" is in permanent session to ensure that the code is kept up to date with experience and research.
The British Gas Corporation's current budget allocation for research and development in the high pressure transmission system is over £6M per year.

Design considerations
Gas pipelines differ from building and civil engineering structures in that the major element of the pipeline, the pipe, may be subjected to destructive prototype testing and to hydraulic testing on installation. If a failure occurs during either of these tests, an element of the pipe may be replaced with relative ease. As 95% of the system is straight pipe, quality control and maintenance are of greater importance than safety factors on their own.

Pipes are designed for a limit state condition of no brittle fracture and no propagation of a ductile fracture. Thus, if the limit state is reached, the pipe would leak rather than rupture. In addition to withstanding pressures, the pipeline requires protection against external corrosion and accidental damage from earthmoving equipment etc. Where possible, pipelines must withstand small ground movements. Special precautions are taken when subsidence is likely.

In suburban areas (population greater than one person per acre) the maximum pressure is reduced to 350 psi and in towns 100 psi is not exceeded. In areas of greatest risk, such as road and river crossings, additional protection is provided by increased wall thickness and sleeving.

The principal hazard on leakage of gas is fire, but explosion could also occur if gas leaked into a building.

Natural gas supplied to the pipeline system is practically free from oxygen, water and sulphur.

Current practice for design, control and maintenance
Materials specifications are based on those of the American Petroleum Institute with various improvements, notably concerning
the weldability and fracture toughness of the steel and in quality control.

The maximum hoop stress permitted by the design code is 72% of the yield stress. In practice, however, the maximum design hoop stress (based on the minimum pipe wall thickness) has not exceeded 65% of yield and this was a local peak value. Bends, valves and other fittings are designed to much lower mean stresses.

Strength of the high grade X60 steel used for the pipes is controlled by tensile tests. Flattened strip specimens are usually used, but a ring tension test on a section of pipe is an alternative. The correlation between the results of the two tests is known.

Weldability is controlled through chemical composition (< 0.35 carbon equivalent) and by welding trials on full lengths of pipe under field conditions. Fracture toughness is examined by drop weight tests at 0°C and Charpy tests; inclusions, particularly of manganese sulphide, are strictly controlled. These tests are carried out on two samples from every 50 pipes or every batch, whichever is more frequent.

Seam welded pipe is made in the mill by longitudinal submerged arc welds. It is then expanded under hydrostatic pressure in a die to achieve circularity. The die is then removed and the pipe subjected to test pressure. Every pipe is ultrasonically examined for laminations and weld defects.

Construction of the pipeline is subject to careful inspection, in particular visual inspection of welding, coating and wrapping operations. Visual inspection of welds is backed up by 100% radiographic examination and this is supplemented by magnetic crack detection on parts of the heat-affected zone. Faults are cut out and the repair re-radiographed until a satisfactory weld is achieved. Inspectors are specially trained and qualified; considerable effort has been put in to achieving the appropriate standards of competence and a strict approval scheme is in force. The scheme is becoming recognised internationally and British Gas inspectors are now in demand from other operators.
Before being put into service, pipelines are tested under hydrostatic pressure for 24 hours at a stress as close to true yield as possible. Usually, about 2 miles of pipeline are tested at a time.

The entire high pressure pipeline network is monitored continuously. A sophisticated control system scans the network every 30 seconds, monitoring pressure and flow of the gas. In the event of a pressure or flow difference, or a failure in the control system, an alarm is given and rapid action is taken. All the control systems are duplicated.

**Performance of the pipeline system to date**

Standards of quality control have improved greatly since the system was started. When, in 1967, the hydrostatic test pressure was first raised to the level of the yield stress, there was a case of 11 breaks being found in a 7 mile section. There has been a progressive improvement since then; there has been only 1 failure under test since 1970 and none since October 1972. The present level is better than 1 failure in 1000 miles. For comparison, the overall US average is 1 failure in 50 miles. Most of the failures were due to faulty welding in longitudinal pipe seams.

Since the accident reporting system came into operation in 1970, there have been 6 significant incidents involving loss of gas. All were caused by digging machinery. One of the incidents led to the rupture of a 30 in diameter pipe, but the remainder involved small diameter pipes (up to 4 in). British Gas monitor many more incidents of much less significance (such as coating damage). There have been no fatalities or injuries to the public due to accidents involving the pipelines, neither has there been any damage to public property.

**Discussion**

The British Gas Corporation felt that, as far as possible, they had ensured that the pipelines would last until known natural gas supplies ran out, well into the 21st century. The possibility of
external corrosion was of concern, but considerable care had been
taken by coating and cathodic protection. Pipes were also coated
internally although the gas contained little or no water or oxygen.
Research was in progress to establish pipe wall thicknesses required
to resist damage from most digging machines.

British Gas liaise directly with land users to determine if any
works are about to be carried out near pipelines.

The monitoring system would detect major leaks (pipe fractures)
as a pressure difference between offtakes. Minor leaks are
detected by regular patrolling of the pipelines, both by foot and
by helicopter. Leaks often show on the surface by changing the
colour and condition of the vegetation.

In the event of future land developments approaching high pressure
pipelines, policy would be to divert the pipeline or to provide
additional protection to the pipe. Similarly, if mining subsidence
were likely to reach an unacceptable level in a particular area,
the pipeline would be shut off and diverted; liaison is maintained
with the National Coal Board.

In open country, where there is a choice of route, pipelines are laid
in stable ground conditions. As soil loads can be reacted through
large areas of pipe, the resulting stresses are not considered to
be significant. Although the maximum permitted hoop stress due
to pressure is 72% of yield, the normal design limit has been 65%;
where the pipelines approach populated areas, the maximum is
reduced to 55% of yield and, generally, stresses are considerably
lower than this. The maximum hoop stress in bends is 55% of yield.

At points where external loads may be significant, where there is
a tee or branch connection in the pipeline, or where the pipeline
goes above ground to a compressor or pressure reduction station,
the individual design is analysed in detail. Generally, the
limiting condition has been the need to avoid plastic growth at the test pressure; this criterion has been found to be more onerous than stresses produced by reaction, temperature etc.

In most of the pipeline system, pressure variations are small (causing stress variations of less than 10% yield) so that the risk of fatigue effects is also small. US experience also gives no indication of any fatigue problems.

There are no statutory regulations covering safety factors except that the Gas Act lays responsibility for standards on the British Gas Corporation. In general, the standards applied to pipelines in the UK are more stringent than in the USA.

Although it is intended to inspect and test pipelines in service, this is not yet a routine and is applied only when there is some doubt about integrity. A considerable amount of research and development effort is currently being expended in developing suitable ultrasonic or magnetic equipment to enable integrity to be assessed without the need for hydrostatic pressure tests. For the next financial year (1977/78), the budget for this project is £4.5M.

Improvements in steel quality to reduce tearing and increase toughness and wall thickness are likely to allow some changes and greater freedom in design.

Further enquiries

Following the discussion, the Committee raised a number of further points with the British Gas Corporation.

In order to avoid the risk of internal corrosion to the pipeline system, suppliers of natural gas are required to meet British Gas Corporation's specification and have installed extensive purification plant. The gas is monitored for impurities at entry to the system and, in addition, throughout the network.
Equipment which will detect external and internal corrosion is due to enter service in 1977.

Tee and branch connections and valves are designed using finite element techniques and limit analysis under hydrostatic test pressure conditions. Serviceability requirements often dominate the design of valves. Test conditions (such as capping-off) are determined so as to simulate in-service conditions. When sections of pipeline are subjected to hydrostatic test, as many fittings as possible are included in the test section. Specifications for fittings are very detailed, much more so than for other types of pipeline.

Research by the National Coal Board has shown that a buried pipeline behaves compositely with the soil when ground movements occur; the pipeline is analogous to a filament of a beam and is thus subjected to axial loads (tensile or compressive). Rotations are small and the pipeline is sufficiently flexible to make bending stresses negligible. There have been no cases of pipes failing in tension, but compressive buckling has occurred in subsidence areas.

Standing Committee's conclusions

The Committee concluded that, on the basis of the information provided, the British Gas Corporation has made a careful and thorough investigation of the problems likely to arise in the design and construction of high pressure gas pipelines. Moreover, the Corporation endeavours to ensure high quality construction and, within the limits of present technology, to monitor the installations in service.

Through steady improvements over the years, the Corporation has achieved a high level of control over the quality of materials and workmanship consistent with the design approach adopted.

The Corporation is conscious of the need for improved techniques for inspecting and monitoring pipelines in service and is carrying out appropriate development work.
FIRE IN SCHOOLS: AN INVESTIGATION OF ACTUAL FIRE DEVELOPMENT AND BUILDING PERFORMANCE (BRE Current Paper CP4/76)

September 1976

Introduction
The Fire Research Station has undertaken a survey of 25 fires in modern schools, and reported on 14 fires in 1974-75. A team of three carried out site investigations based upon evidence of the fires, verbal or written reports of fire brigades and eyewitnesses, and information regarding structures and contents from local authority staff. Results were discussed with FRS specialist staff and comprehensive reports were prepared for each fire, amplified by plans and photographs.

In 1965, reinstatement of fire damage cost £0.5m compared with £9m in 1975. The total expenditure on school building work now exceeds £10m per year. The number of cases of malicious damage has increased by a factor of 10 from 1965 to 1975, but the number of fires due to other causes has also risen.

The most common route of serious fire spread was through ceiling voids which had no fire barriers. However, the extent of such spread was influenced by the airtightness of the void and the nature of the materials enclosing it. Other aspects contributing to fire spread were the poor performance of suspended ceilings under fire attack, failure to provide proper protection to service ducts, inadequate firestopping, and door details.

Uncased lightweight steel roof trusses sagged if the supporting columns were protected, but the whole structure collapsed inwards if the columns were not protected. Fire damage was the major problem but very considerable damage was caused by smoke to finishes and contents.

The Fire Research Station report concludes by commenting on practical measures to reduce fire spread. The possibilities of venting a fire through a non-fire resisting roof deck or by PVC roof glazing should be considered. Plan layouts should allow
for some compartmentation and avoid flammable external wall linings opposite windows in 'courtyard' situations. Open plan areas should have ceilings sub-divided into smoke reservoirs and some limitations placed upon highly flammable contents of such areas.

If attention is given to these matters and other fire weaknesses detailed in the report then a high standard of fire protection might be achieved at little additional cost.

Discussion

A rising number of fires in schools are caused maliciously. No children's lives have been lost, but four adults (including one fireman) were killed between 1971-74. About 75% of deaths due to fire occur in private homes, and the Fire Research Station intends to report on this in 1977.

Regarding the cost of providing additional fire protection to existing schools, it may be more effective to spend the money combatting vandalism.

There is no breakdown available of how much of the reinstatement cost is due to smoke damage, but it is a significant proportion of the total. The provision and proper sealing of fire barriers should drastically reduce the amount of such damage. It is understood that the Department of Education and Science have called upon local school authorities to comply with the general provisions of the Building Regulations on a voluntary basis.

In 1973, DES required void barriers to be built into all future schools - thus severe fire spread in ceiling voids should not occur in schools built since that date.

School buildings are becoming more widely used by the general public out of school hours. The provision in some existing schools of a standard of fire protection appropriate for such use may be too costly to be justified in the present economic situation.
Standing Committee's conclusions

The measures recommended to the Department of Education and Science in BRE Current Paper CP4/76 would reduce the damage by fire in future school buildings and no action need be taken by the Committee on this point at the present time. However, in view of the increasing use of school buildings by the general public out of school hours and the potential fire spread hazard in many existing buildings, the attention of the appropriate Licensing Authority should be drawn to the importance of ceiling void divisions, the proper sealing of fire barriers and other matters dealt with in Building Regulations.

MAINTENANCE AND INSPECTION OF BRITISH RAIL STRUCTURES
October 1976

Introduction

The inspection of railway structures is carefully organised and planned from Board level down using standardised procedures. Design staff are deliberately involved in maintenance and inspection in order to achieve a totality of approach.

The permanent way staff are required, in the course of their duties, to be on the look-out for and to report anything they think might be wrong or which gives them cause for concern.

Regular inspections of structures are carried out by examiners who are specially trained tradesmen. Common standards are achieved by internal training courses, guidance handbooks and standard report forms.

Most bridges and buildings are inspected by such specialist examiners every three years and this includes the taking of photographs. Tunnels are inspected every year by engineers.
Structures for which access is difficult or uneconomical on a three-year basis (designated 'special structures') are inspected every six years. The action taken on the resulting reports is influenced by the longer interval between examinations. Wagon-mounted hydraulic platforms have been developed to inspect the piers and soffits of underbridges from the track to help minimise the number of 'special structures'.

The examiners' reports are assessed by the engineers who then decide what action should be taken. In the case of bridges, a marking system has been devised to provide a common basis for assessment and allocation of priorities for any necessary remedial work.

Stresses in bridge members are calculated, based on actual measurements of corroded sections and upon current loading standards. Detailed drawings of all structures are kept and so are the original designs, if they are available. Having calculated stresses, specialist teams then make assessments with particular regard to problems such as fatigue.

The procedure outlined does not, however, cover accidental damage to structures, in particular bridges, often caused by road vehicles. The DOE are making progress with British Rail over the problem of vehicles striking parapets, but the problem of high vehicles or loads causing impact on bridges under the railway appears to be far from satisfactory resolution.

There has been surprisingly little interest by British industry in developing hydraulic inspection platforms for bridges and so British Rail have had either to import them or develop them themselves.

Discussion
Most bridges and buildings erected before the last War were designed for an indefinitely long life and there is evidence that, given good maintenance, they can generally be kept in
service, economically, far longer than might be expected, despite increased axle loadings and the increased incidence of maximum loading. Wagon axle loads are now of the same order as those of locomotives and research is indicating that traction and braking forces are greater than they had previously been taken to be. The high ratio of live load to dead load stresses in bridges carrying railways means that questions of fatigue assume a special importance. The new high speed train presents no serious loading problems on bridges, but regard has to be paid to aerodynamic effects, particularly in tunnels.

Out of the 3000 metal bridges in one Region which are at least 78 years old, an average of 10 to 15 is being renewed each year. It was feared by British Rail that the rate of replacement would soon have to be sharply increased as structures reached a point where they could no longer be economically maintained, but this has not yet been found to be necessary. A programme for the replacement of the cast iron underbridges still in service in the country is being adhered to and the most highly stressed bridges are being dealt with first.

When a specialist examiner has inspected a structure and reported it "satisfactory", there is normally no follow-up action by engineers. The degree of reliance and trust therefore placed upon the examiners is such the BR engineers have to be closely aware of each examiner's capabilities and limitations, and to pay special attention to their selection and training. The examiners have the knowledge and powers to stop trains immediately, or take other appropriate action if they encounter a bridge or structure which they consider to be unsafe for the loads it has to carry.

At present, £35M is spent each year on the maintenance of stations, bridges and tunnels, which have an estimated total replacement value of the order of £20 000M. Financial constraints prevent all the maintenance scheduled for attention in any year being carried out. Of the work considered desirable
in 1976, 30% could not be undertaken and the estimated figure for 1977 is 36%. However, after due allowance is made for the removal of redundant structures, there is no immediate concern that degradation is out-running renewals to the extent of putting safety at risk. Maintenance of structures is carried out as required, not as routine.

In the event of the discovery of a serious defect due to a particular type of design detail, a special check of all structures incorporating similar details is instituted and appropriate action taken.

Estimates of maintenance costs are made when comparative designs are being studied, so that relative costs of different designs are assessed, not only on first cost, but also on the likely total cost over the life of the structure, suitably discounted. Design always takes account of the avoidance of details which may become "maintenance sores" and ease of access for inspection and maintenance.

The cost of construction of railway structures is higher than that of other similar structures because of the over-riding need to minimise interference with railway traffic during the course of the work.

Railway engineers tend to be wary of new materials, insisting upon their being thoroughly tested and proved before acceptance. This policy seems to have enabled British Rail largely to avoid recent problems in the construction industry, such as those involving high alumina cement and calcium chloride.

A new development is for architects responsible for the design of new buildings to prepare a maintenance manual for each one. Inspection and maintenance of buildings is generally carried out by civil engineers, architects being involved only in certain major new buildings; in the latter case, routine maintenance is generally managed by a man operating in the role of maintenance supervisor.
A growing number of railway buildings and structures is "listed" as being of historical interest, to the extent that their proper maintenance could distort the allocation of available funds.

Wherever possible, piers of overbridges are designed to deflect de-railed railway vehicles and there is preference for structurally redundant designs which will tolerate the removal of a column without collapse. The risk of such an accident is small.

The Railways Board is, however, concerned over the incidence of road vehicles striking bridges under the railway. As yet, there has been no serious accident to a train from this cause, but they have occurred abroad and there have been several cases in this country when a bridge has been seriously damaged but it has been possible to stop trains in time. Similar problems occur with canal and motorway bridges and they are not limited to bridges of less than standard clearance. There are length, width and weight restrictions on road vehicles, but none on height; neither is there any requirement for the height of the vehicles to be recorded in the driver's cab. Lorries carrying mechanical plant or containers are the cause of the majority of accidents of this nature. Better road signing and the painting of black and yellow stripes on a bridge face to delineate its outline do not seem to provide adequate counter-measures. The use of height gauges involves many problems but the possibilities in this respect are being studied further.

Further enquiries into damage to bridges from road vehicles
The Committee was disturbed by the incidence of damage to bridges by impact from road vehicles and requested more detailed information from British Rail and the Department of Transport.
**Additional information from British Rail**

There are about 400 cases per year of bridges under the railway being struck by road vehicles. Of these incidents, 10% (40) are considered serious (i.e. damage which could endanger a train) and 36% are considered potentially serious (i.e. damage which could, if repeated, put the bridge into the serious category). In the remaining 54% of cases, damage was slight (i.e. superficial).

The distribution of heights of bridges struck appears to correspond to the distribution of heights of British Rail's bridges. There is no trend towards more lower bridges being struck; bridges of up to 22ft (6.7m) clearance have been damaged.

Typical instances of serious damage are as follows:

- Bricks chipped out of the compression rings of arch bridges
- Flanges of steel girders 'sliced' through
- Light bridges moved bodily sideways

At least two railway bridges have had to be reconstructed in the last year due to severe damage from road vehicles.

The principal road vehicles involved in serious damage incidents are lorries carrying containers and low loaders carrying contractors' plant. The increasing number of such loads now on the roads is a cause for concern. While the number of incidents per year appears to be reasonably static, the damage caused is increasing in severity.

The following actions to reduce damage to bridges have been proposed, but objections have been raised to most of them by at least one of the interested parties (other than British Rail):

- Notices in vehicle cabs stating the height of the vehicle and/or load (warning signs on bridges are meaningless unless a driver knows his vehicle's height)
- Regulations directing that contractors' plant be chained down to the vehicle to prevent the jib or arm rising during transit
Speed restrictions at low bridges
Signals and gauges to warn drivers that their vehicles exceed the maximum height
Energy-absorbing beams to prevent high vehicles/loads from passing under the bridges
Better and more effective height limit warning signs and strategically placed diversion signs
HGV licence endorsements for drivers carelessly hitting bridges
Better administration of planning controls to prevent, for example, an industrial estate being built with sole access through a low bridge
Traffic lights controlling one-way movements through arch bridges (in particular, those over S-bends)
Regulations restricting vehicle heights
Revision to the insurance liability for damage to property.

Additional information from the Department of Transport
Incidents involving bridges carrying roads and footpaths over roads are not so well documented as those for railways. However, there are about 4 incidents per year analogous to British Rail's 'serious' category. Of the last 40 serious incidents, 35 involved footbridges and 5 involved road bridges. In at least 11 of the incidents involving footbridges, bridge spans fell into the road. Damage to road bridges varied from minor soffit damage to shattered prestressed concrete beams.

The principal vehicles involved in serious damage incidents were low loaders carrying contractors' plant.

All the bridges involved in incidents reported to the Department of Transport had clearances greater than the standard 16ft 6in (5.0m)

There is no indication that the number of incidents per year is increasing.
Standing Committee's conclusions

British Rail has a satisfactory policy for inspecting and maintaining structures and, in spite of budgetary cuts on maintenance and in the rate of renewals, the present condition of railway structures gave no cause of immediate concern. However, it could not be inferred that the rate of degradation will not increase as a result of heavier loads and changes in design and construction over the years.

The emphasis placed on designing for ease of inspection and maintenance, and the policy of organisationally combining design, inspection and maintenance, is to be commended.

The incidence of damage to structures by impact from road vehicles was a disturbing feature and the present lack of control over vehicle heights was especially worrying. Although it would be impossible to prevent all damage to bridges from road vehicles, the following measures would improve the situation:

(a) Amendment of the regulations defining abnormal loads to include vehicles or loads over the standard height (16ft 3in)

(b) Circularising contractors, road hauliers, plant hirers and other appropriate bodies making clear the current situation and emphasising the risk to public safety.

CONCRETE SOCIETY WORKING PARTY ON STRUCTURAL SAFETY

November 1976

Introduction

Membership of the Concrete Society is drawn from all branches of the construction industry. The Society is controlled by the Council, but responsibility for technical matters rests with the Technical Executive Committee, which controls a number of standing committees. Of these, the Structural Committee covers all structural matters, including regulations, standards and codes of practice.
The Society arranges meetings and visits and produces publications; an Export Group has been formed recently.

The Working Party on Structural Safety was set up "to study recent examples of structural inadequacy of temporary works and permanent construction in concrete which have led to public concern and to advise appropriate action; to consider whether in the light of recent knowledge other dangerous situations may develop and to propose action in case incidents should occur; to consider the overall balance between greater safety and cost; to act as the liaison between the Society and the Standing Committee on Structural Safety".

The Working Party was set up because the Society was concerned by the lack of public confidence in the industry, in particular the effects of this lack of confidence on the image of concrete, and the cost of measures to enhance safety. The Working Party is studying failures of materials to comply with specifications as well as collapse failures. The Working Party has links with the BRE and the technical press.

Communication and responsibilities have been identified as the main areas for concern. Changes of attitude and practice with regard to a number of topics have been suggested and amongst those referred to were the following:

Responsibilities

Difficulties can arise in work under the Joint Contract Tribunal (JCT) form of contract, in which it would be helpful to include and clarify the position between the parties owing contractual responsibilities (eg the architect, the contractor) and those owing a duty of care (eg the consulting engineer, the local authority). A formal register of engineers might help to improve this situation.
Maintenance

Many problems are caused by lack of maintenance. Buildings should be designed for ease of inspection and maintenance. A maintenance manual should be prepared for each building, and should be available readily to the owner and user. Possibly, arrangements could be made for the designer to have a maintenance contract, as is increasingly being done with building services.

Code Revisions

Changes of design rules in codes of practice need to be handled carefully in order to avoid what may subsequently be seen as unnecessary expenditure of time and resources. Some revisions have been made in such a way as to imply that the structures designed to the earlier version of the code appeared to be "unsafe", implying an often unjustified need for a check of all such structures.

The Concrete Society attaches great importance to safety and is anxious to assist the Committee in any way it can.

Discussion

The Working Party has found that administrative problems are more important than technical matters. Failures are usually caused by a sequence of mistakes; a single error is unlikely to be catastrophic on its own. The Concrete Society is attempting to make a statement on the current situation in the industry; it has no power to effect any changes. The Society intends to produce booklets on aspects of safety, the booklets being similar in size and approach to the Cement and Concrete Association's 'Man-on-the-job' series.

The present construction contract arrangements do not clearly allocate the responsibilities of all parties nor do they identify the individuals who hold the responsibilities.
Codes of practice are becoming more lengthy and complex as margins of safety are being refined and reduced. The Working Party accepts the principle of having codes of practice as deemed-to-satisfy documents, but the codes should be limited to basic principles. Design recommendations and formulae, which are often up-dated and amended, should be given in non-mandatory handbooks.

The cyclic expansions and recessions in the construction industry and consequent movements of personnel into and out of the industry counter attempts to improve communications and quality of personnel and their work. A greater consistency of workload would provide a more stable base from which improvements in standards and safety could be made.

**Standing Committee's conclusions**

The Committee noted the Concrete Society's comments and suggestions and agreed that it should liaise with the Society on matters of mutual concern.

The discussion had highlighted several areas of concern which would be considered for further investigation and, in particular, the Committee noted the needs expressed for easier inspection and maintenance and also the view that widely varying workload was an important factor adversely affecting quality of workmanship.
Introduction

The terms of reference of the Building Integrity Division relate to buildings, but it is not intended to disregard problems associated with other forms of structure. Initially, the Division will not be concerned with minor serviceability failures (such as leaking roofs) but will try to identify possible major hazards before they occur. After conferring with many organisations a number of subjects have been suggested to the Division for consideration.

The Division intends to study systematically the development of structures and their elements and the development of codes and regulations governing their design and construction. Ten wide-span public building structures have collapsed in the last three years and the possible need to survey such structures is being explored.

Initially the Division is organised in two teams, an analytical team and a field team, and staff includes a mathematician/operations researcher, a structural engineer, a chemist/construction materials technologist and a scientific assistant. It is hoped to increase the staff to about 10 persons in the near future.

Discussion

The Division is exploring the use of hazard analysis as one of its tools. This is a form of reliability analysis used by UK Atomic Energy Authority and others to establish safety factors based on the consequences of failure. 'Fault trees' can be developed which outline the possible effects of environmental factors on the performance of components and interactions between components. Similar 'trees' can be produced to show combinations of events leading to failure.
Secondary effects and properties of structural elements (i.e. those properties in addition to those specified in the design) will be studied. Present design trends are often to neglect these effects which have provided additional safety margins in the past.

The hazard analysis approach does not take account of gross design errors and incorrect design assumptions, which can be a major cause of structural failures. Techniques need to be developed to reduce the occurrence of hazards due to such errors.

The estimated cost of building defects is approximately one fifth of the annual expenditure on maintenance (between £200 and £300 million). This figure does not include fire damage; there are 750 fatalities each year due to fire. This compares with 6 deaths due to structural failure. The Division will not ignore fire, but this area is well covered by others.

To evaluate all possible hazards would be outside the Division's current capacity and budget, so methods are being developed to concentrate on the major hazards. The Division is unlikely to carry out experimental work itself. Such work would be done either by another BRE specialist division or by an outside organisation under contract.

Enquiries indicate that no other countries have established organisations similar to the Building Integrity Division, although some countries have expressed interest in forming such a body. The EEC Commission has working groups on structural safety and on fire; any output of the Commission can become incorporated in the laws of the member countries.

Cooperation between the Standing Committee and Building Integrity Division

Both bodies are still in their formative stages, so firm proposals for mutual cooperation would be pre-emptive. However, close contact will be maintained between the Standing Committee and the Division.
BRE agreed to keep the Standing Committee informed of their current work relating to safety and of the activities of the Building Integrity Division.

**Standing Committee's conclusions**
The Committee appreciated the public and parliamentary concern over the integrity of buildings and agreed that BRE were correct in responding to this concern. It was important that the Building Integrity Division's programme of work should be effective in matters of both safety and economy.

The Committee would like to keep themselves fully informed of the Division's activities and would arrange further discussions with BRE.

**CLADDINGS**
February 1977

**Introduction**
The history of claddings to modern buildings falls into three periods - the decades commencing 1950, 1960 and 1970. The claddings considered here are large precast concrete panels, brickwork or blockwork, masonry or precast concrete panels and tiles and mosaics.

In the 1950s, the techniques were new and many mistakes were made. Failures were due to insufficient provision for movement, insufficient allowance for construction tolerances, the use of materials subject to corrosion, fixings poorly constructed or omitted, inappropriate or degradable materials and failure of adhesion of mortars. Traditional techniques were often used in inappropriate circumstances; problems became apparent only after construction - too late to correct the design. Towards the end of this decade, standards began to improve and the first bylaws controlling claddings were introduced in Inner London in 1957.
This improvement continued gradually throughout the 1960s, partly due to the introduction of bylaws and also because of the large cost of remedial work.

By the 1970's a code of practice had been introduced; this, as well as guidance notes from other authorities, gave a situation where sufficient information was available for a satisfactory standard of design and construction to be maintained. However, it is apparent that the information is not always reaching the appropriate persons. Architects resist the use of movement joints on aesthetic grounds and do not always consult their structural engineer on the design of claddings. The standard of workmanship on site is not improving, yet the need for increased supervision (or any supervision) is not recognised.

Both designers and builders often fail to inform building owners of the need to inspect and maintain cladding. There is a reluctance among all parties to take any action until a failure occurs.

Discussion
Failures are more likely to appear in stone or precast concrete cladding. Brickwork generally may have more flexibility provided supports and ties are adequate.

Cladding failures do not always appear immediately after construction; a period of 10 or 15 years may elapse before claddings fail. 1965 may be regarded as the 'turning-point' in cladding design and construction. Before this date, many designs and methods of fixing were experimental and the risk of failure was relatively high. Most later designs were based on sufficient background knowledge and experience to provide a much greater reliability. However, there is still a need for education of designers, owners and contractors to give a full awareness of the implications and problems of the cladding system they are using.

A very severe winter or very hot summer is still likely to
produce cladding failures; new and old buildings are equally susceptible to these circumstances.

Although the GLC Bylaws control the design and construction of claddings in the Inner London area, The Building Regulations, covering the remainder of England and Wales, do not refer specifically to claddings.

The need to inspect and to maintain claddings again highlights the need for the production of a maintenance manual for each building to allow the owner or occupier to avoid expensive remedial works and putting himself and the public unnecessarily at risk.

Annual inspections of claddings for the first five years of a building's life and every five years subsequently may be an appropriate programme.

When subject to careful control, the fixings of storey-height precast concrete panels do not usually give problems. However, ill-considered surface finishes may not provide sufficient protection to the reinforcement, and the surface concrete may not be sufficiently durable. Joints between panels are not always designed to throw off water, thus providing an additional corrosion risk.

Although brickwork may appear to be satisfactory, ferrous angle supports may be corroded. These are difficult to inspect, being hidden behind the brickwork, and, even when galvanised, cannot be regarded as having a life of more than 20 years. The fixing of brick slip-tiles remains a perennial problem.

Standing Committee's conclusions
Claddings form an area of structures which is likely to give trouble for several years to come. There are many different kinds of problems which occur, however, the following common points are already evident:

The need to encourage building owners and users to carry out regular inspections
The need for guidance on methods and objectives for carrying out inspections
The need to draw attention to the information already available on the design and erection of claddings
The need to make provision for easy inspection and repair of fixings and other important features.

In view of the diversity of the subject, the Committee agreed to have further discussions with other interested parties in order to obtain a clear and well-balanced view.

4. ACTIONS

The Committee has identified a number of problems from its discussions during the year and has taken the following actions.

The Committee has made suggestions to the Secretary of State for Transport regarding the control of road vehicle heights with the object of reducing both the risk to public safety and the increasing severity of damage caused by vehicles hitting bridge structures.

From its discussions on fires in schools, the Committee has suggested to the Secretary of State for Education and Science that the attention of the appropriate authorities should be drawn to the fire protection requirements of the Building Regulations when they consider permitting the general public to use school buildings.

The Committee has also informed the Presidents of the three Institutions of some unsatisfactory features which are becoming apparent in existing claddings to various types of building. The Committee intends to make more investigations and hold further discussions on this matter.
There are a number of other problems brought to the Committee's attention during the year which it has decided to investigate further before making any recommendations.

5. PROPOSALS FOR THE YEAR COMMENCING 1 APRIL 1977

For the coming year, the Committee has already planned the following discussions but would always welcome suggestions on any additional matters requiring attention.

- Safety problems from the Building Regulations point of view
- Systems for investigating structural failures
- Safety implications of limit state design methods

In addition, it will continue to investigate some of the topics listed in Section 3 and deal with other matters presented to it.

6. SUMMING-UP

It is of course too early for the Committee to present anything but tentative conclusions on the subject of structural safety but, based on the Committee's work to date, there are indications as follows:

In many cases, failure results from the lack of application of existing knowledge, from divided responsibility or poor communication.
Commercial pressures and, especially, the very variable work load on the industry makes training and the development of skills more difficult than in most other industries.

Wider publication of case histories on failures and risks would help towards a better understanding by all concerned.

Another need is to ensure that responsibility for the various aspects of design and construction are clearly and appropriately placed and understood and that the building owner clearly appreciates what he can or cannot do with his building.

Increasing the quantity of statutory regulations would generally not seem to help in the problems investigated to date and, indeed, might have an adverse effect on the quality of work in the industry.

The above will have implications for education and training at all levels of the profession and industry.

Although structural failures continue to occur, the Committee wishes to emphasise that the British record for structural safety is good, especially with regard to injuries caused and loss of life. However, the number of failures and their consequent cost must continue to remain matters of public and professional concern.

Finally, the Committee would like to record its gratitude to the several organisations and individuals who have provided information and given opinions so frankly and willingly during the year.
APPENDIX 1 SUMMARY

The Committee, which was set up in February 1976 by the Presidents of the Institutions of Civil, Municipal and Structural Engineers, has held eight meetings during the year ended 31 March 1977. It has examined a number of reports, taken note of the limited statistical information available on structural failures and held discussions with seven organisations or individuals on a variety of topics including falsework, the design and construction of high pressure gas pipelines, railway structures, fire risks in schools and claddings to buildings.

Some of the topics were selected for discussion more to help the Committee develop a method of working than to investigate real or assumed areas of risk. The Committee has been impressed by the readiness of the individuals and organisations concerned to provide them with information and frank opinions.

Although structural failures will continue to occur, the British record of structural safety is good, especially in terms of personal injuries and loss of life. The Committee, in its work to date, has found evidence which indicates that, in some cases of structural failure, the cause can be traced back to lack of appreciation of existing knowledge, to unclear or divided responsibilities or to inadequate communication. These are not new points, and the lesson must be the continuing need to improve training and education at all levels and to ensure that responsibility for the various aspects of design and construction are clearly and appropriately placed and understood.

The Committee believes that, through its discussions to date, it has been able to give some help to the individuals and organisations concerned and it has identified some matters requiring attention.
Suggestions have been made to the Secretary of State for Transport regarding the control of vehicle heights with the object of reducing the growing number of incidents in which vehicles have caused severe damage to bridge structures. Following the discussion on fires in schools, the Committee has written to the Secretary of State for Education and Science on the point that the current fire protection requirements of the Building Regulations may not always be fully taken into account when the appropriate authorities are considering permitting the general public to use school buildings. The Committee has also informed the Presidents of the three Institutions of some features of claddings on buildings which may cause trouble in the future. The Committee intends to pursue this subject further to see if any recommendations may be made.

Finally, The Committee wishes to make known that it will welcome views and information relevant to its work from any source in the UK or overseas.
APPENDIX 2 TERMS OF REFERENCE

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 three 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 three Institutions any changes to its terms of reference it considers to be necessary or desirable.
APPENDIX 3 LIST OF MEMBERS

The Rt Hon Lord Penney OM KBE MA PhD DSc FRS (CHAIRMAN)
S L Bragg MA MSc CEng FIMechE FRAeS
Vice-Chancellor & Principal, Brunel University
C D Brown BSc CEng FICE
Mott Hay & Anderson
J A Derrington BSc(Eng) DIC CEng FICE FIStructE
Sir Robert McAlpine & Sons Ltd
A Gordon CBE LLD DipArch PPRIBA
Alex Gordon & Partners
The Hcn Mr Justice Graham
High Court Judge (Chancery Division)
Professor E F Happold BSc CEng FICE FIStructE
University of Bath
Professor J Heyman MA PhD CEng FICE
University of Cambridge
J N Rogers BScTech CEng FICE FIMunE
City Engineer, Birmingham
R E Rowe CBE MA ScD CEng FICE FIStructE FIHE FACI
Cement & Concrete Association
R L Triggs BSc CEng FICE
Edmund Nuttall Ltd
F Walley MSc PhD CEng FICE FIStructE
Property Services Agency, Department of the Environment

SECRETARY L S Blake BSc(Eng) PhD CEng FICE FIStructE FIHE CIRIA

TECHNICAL OFFICER J C Mason MA CEng MIStructE
CIRIA

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APPENDIX 4 STATEMENT OF COSTS AND ESTIMATES FOR 1977/78

Summary of expenditure for the fifteen month period 1 January 1976 to 31 March 1977

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
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<tbody>
<tr>
<td>CIRIA staff time and overheads</td>
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<tr>
<td>Expenses to Committee members</td>
<td>420</td>
</tr>
<tr>
<td>Press Conference, Committee luncheons</td>
<td>484</td>
</tr>
<tr>
<td>Room hire, etc.</td>
<td></td>
</tr>
<tr>
<td>VAT @ 8%</td>
<td>510</td>
</tr>
<tr>
<td>TOTAL</td>
<td>6,882</td>
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</tbody>
</table>

Budget for twelve month period 1 April 1977 to 31 March 1978

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIRIA staff time and overheads</td>
<td>6,714</td>
</tr>
<tr>
<td>Expenses to Committee members</td>
<td>600</td>
</tr>
<tr>
<td>Committee luncheons room hire, etc.</td>
<td>360</td>
</tr>
<tr>
<td>VAT @ 8%</td>
<td>614</td>
</tr>
<tr>
<td>TOTAL</td>
<td>8,288</td>
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