FIFTH REPORT OF THE COMMITTEE

FOR THE TWO YEARS ENDING 30 JUNE 1982

Standing Committee on Structural Safety

CONTENTS

1 CONSPECTUS

The Standing Committee on Structural Safety was formed in the Spring of 1976. Four Reports have been issued and this is the fifth. The Committee always regarded its early years as experimental, since it was not possible, without operating experience, to predict the best way to use the time and effort available. Experience has now shown that there are at least two useful functions which such a committee could perform in the future. The first is to continue with the kind of work which has engaged the attention of the Committee since it began. The second is, when specifically called upon by the Institutions, to advise them on appropriate actions which they might take when a serious deficiency in the safety of a particular type of structure, or of a certain type of material used in structural construction, has appeared or is considered likely to appear. As far as the Committee is at present aware, there is only a small chance that such a fault will appear in the near future, but the probability can never be mathematically zero and the cost, if it should occur, could be very great, both in financial terms and in reputation.

There have, for example, recently been statements in the press that structural faults have appeared in some of our newest buildings - in particular hospitals. The circumstances appear to be somewhat complex and multi-disciplinary, and the faults may not be indicative of a trend, but the Standing Committee has no information beyond the press statements, nor does it know if, in some cases, litigation will follow. Presumably, if the faults are serious and costly, some form of enquiry will be established, requiring a substantial effort by the enquiring committee and by those who are asked to provide information.

The Committee is always prepared to discuss a structural failure in a specific case if something at issue appears likely to be general and therefore applicable to other cases. The identification of the cause of every failure is itself all important in the attempt to classify structural failure as falling into the several groups used in the classification in question (e.g. gross error in design; the use of faulty materials not known to be unsatisfactory when they are used; poor supervision of construction, either of procedures or in the use of materials; and control of labour). Such a classification, compiled and interpreted by experienced and practising engineers as was done in the recent BRE/CIRIA pilot survey of structural failures(1), would be of value to and worthy of study by all structural engineers.
Speaking of general conclusions by the Committee, it is worth emphasising that there has been wide agreement by members of the Committee who have worked in the construction industry that, from their own practical experience, a major cause of structural failure is human error (and sometimes indeed gross human error). The study of human error as a cause of lack of safety in the field of construction clearly leads to the consideration of other fields such as psychology and the behavioural sciences, and it impinges upon such subjects as insurance and litigation.

Discussions by the Committee and others on the subject in its general aspect, are at present at an early stage, and it would be a considerable undertaking to study the matter fully and particularly as to how the frequency of human error could be reduced. The Committee considered, however, that the potential benefits of such a study could be very substantial and of value in fields far wider than the construction industry itself.

It was also generally agreed within the Committee that few structural accidents could be traced to the required research information not being available somewhere. The amount of technical knowledge in the various parts of engineering is so large that the problem for all engineers is to keep in touch with what is already known, and to find the time and energy to study the flow of new, or supposedly new, information. No doubt the advances being made in information and retrieval systems will ease the problem, but meanwhile the quantity of information available inexorably increases. In practical matters of engineering design and construction, achievement and innovation do not necessarily require new knowledge. As in most professions, achievement and innovation often come from using old knowledge in new ways, sometimes creating new risks which are not instantly obvious.

The Committee has sometimes briefly considered suggestions that it should discuss various topics of a philosophical nature. For example, the education of engineers, the form and content of codes of practice and what considerations should determine the amount of inspection given to various types of existing structures. The Committee asked itself one beguilingly simple question applicable to all safety matters - is enough effort being given to safety? Most of these topics are controversial and some are indeterminate, but a few comments will be ventured.

The Committee has made little attempt to discuss the education, training and professional development of engineers. One third of the Finniston Report was about these important subjects, and one of the five working parties already established by the Engineering Council will also look at these matters. The Institutions themselves have the responsibility for monitoring qualifying degree courses. The inclusion of any teaching about safety matters in the formal educational courses of the budding engineer is something which the lecturers of the educational institutions should decide, having regard to the needs of the profession and to the world around them. However, when the young engineer starts his first job, his supervisor must guide him on many aspects of engineering practice, including an awareness of safety aspects and potential problems.

The Committee was never sure that it had a specific contribution to make on the production of Codes of Practice. Certainly, the engineering codes implicitly involve some aspects of safety, but the many attempts made to discuss Codes only seem to have agreed on precepts which are unexceptional but not very helpful (e.g. the need for clear writing, concentrating on the important points, and leaving out muddling details, etc). It is in the best interests of all concerned with structures that these matters should be sorted out. The fact that several other branches of engineering have similar difficulties shows that the problems are general. It is time steps were taken to identify the problems so that decisive action can be taken on a rational basis. Briefly, the Committee feels that until the form and content of the structural codes are matched to clearly defined purposes, uses and users, the difficulties will remain.

In theory, all structures should be regularly inspected to determine whether some fault is developing, but for understandable reasons there are many types of structure where inspection is either skimped or not made at all.

Often, a developing fault will make itself apparent before any damage is done. The Committee has at various times discussed several examples of structures where there is a case for some measure of inspection. The need for inspection of long-span public assembly buildings was discussed in the Fourth Report, and the corrosion of tendons in bridges was discussed in the Third Report.

Trouble is now arising on this score in some countries. The recent report by the Concrete Society on deterioration of tendons in structures(2) is commended by the Committee. In its Fourth Report, disquiet was expressed about the possibility that there might be a number of dams in the country where there is no inspection. A few of these dams might be in an unsatisfactory condition and, if at some time the weather is particularly wet, one or more might collapse. Such a collapse could be dangerous, depending on whether people were at risk or not. The Standing Committee suggested that local authorities should, at the very least, list the dams they had in their area and see if there were any potential hazards. The Committee understands this suggestion is now under active consideration.

Another inspection matter, discussed by the Committee in its Second and Third Reports, was the failure of claddings on buildings. The Committee has little to add to its earlier statements. In the last analysis it is not sufficient for the owner of a building merely to conform to the statutory requirements and to insure against losses. Modern buildings are often large complex structures subjected to a constantly changing environment, and professional advice should be obtained and followed on suitable inspection and maintenance requirements. The Standing Committee can do no more than give a warning that claddings are one of the features of a building which should be watched, and watched more carefully as they age.

The Committee has made a few enquiries about chimney structures, the results of which are summarised in this Report. The Committee suggests that all chimneys should be carefully inspected from time to time, and the most suitable time is probably when the chimney is being re-lined or when it is not in service.

In every activity of human life our behaviour is conditioned by considerations of safety and survival, and many of our actions are instinctive. However, many of the hazards today are not only new in this century, but are constantly changing. It is not to be expected that the total cost and the total safety provisions in the many parts of our daily lives can now be calculated. There are too many historic costs involved, and our present actions implicitly take account of past events and experiences. What it may sometimes be possible to do is to estimate the cost and the savings in life and finance resulting from a proposed new safety measure.

Decisions about the scale of effort to be applied to safety in the many groups and sectors of our society result from a concensus based on value judgements, influenced by accident and community experience. Legislation and inspection are often required. Here and there in our society, customs and practices are slowly introducing numbers which could be used in cost-benefit analyses of safety. Of course, it is unlikely that decisions about investing in safety will ever be made on cost-benefit arguments expressed solely in financial terms, but it does appear that some safety investments are orders of magnitude lesser or greater than others in financial terms for similar results in saving lives. Such information would give grounds for serious thought, particularly when new or extended safety measures are being considered.

Studies could be undertaken to determine the benefits to be derived from keeping statistical records in particular well-defined cases, but it maybe that the data would be inadequate for any useful conclusions to be drawn.

The Standing Committee on Structural Safety has spent much more of its time on structures which are complete than it has on structures which are under construction. The Committee cannot find many safety or damage statistics for structures classified in these two headings. The Health and Safety Statistics 1978-1979(3), give the number of people in the construction industry as 1.3M, the number of deaths from injuries as 149, and the number of injuries as 32 000. The number of deaths and injuries caused by the failure of completed structures in the UK is very small. No official records are kept, but checks have been made from time to time, and it appears that the average annual number of deaths in the last decade in the UK is less than 10. The annual costs of failures in structures in the course of construction and of failures in structures after completion are not known to the Committee, but both must be on a considerable scale since the output of new construction in 1981 was nearly £13 000M and, in addition, more than £8000M was spent on repairs and maintenance.

A problem of growing importance is the ageing of many structures, which must bring with it problems of safety.

Finally, a few words about the Committee. The Chairman and the members have felt for the last year or two that new blood was required. The sponsoring Institutions have accepted this view and have decided that the Committee is to continue with its work, under a new chairman and with a substantial injection of new members.

2 NEW TOPICS DISCUSSED DURING THE TWO YEARS ENDING 30 JUNE 1982

2.1 Deterioration in buildings and other structures

Bridges

In previous reports attention was drawn to the possible problem of corrosion of prestressing strands in bridges. A report produced by a working party of the Concrete Society[2] makes recommendations on improving practice in the design, construction and repair of prestressed concrete structures to ensure adequate durability.

The Committee recommends that the report should be given wide circulation in a form suitable for convenient reference and assimilation by practising engineers.

Buildings

The attention of the Committee was drawn to the possibility of loss of safety in structures, other than bridges, as a result of corrosion. Very few prestressed concrete building structures have been demolished in the UK, and there is very little evidence to show whether there is a need for action to change current design and construction practice. The recommendations of the Concrete Society report, which is mainly concerned with bridges, could no doubt be applied with benefit to buildings and other structures.

There is some evidence of deterioration in structural steelwork and reinforced concrete framed buildings. Prohibition of the use of calcium chloride and high alumina cement in reinforced concrete or in composite steel and concrete construction, and careful control of admixtures, will do much to avoid corrosion in future construction. Careful attention is also required to detailing and in construction to ensure that concrete or jointing mortar is properly compacted and of suitable quality, particularly where it is vulnerable to changes in humidity and temperature. In design, attention should be given to the possible consequences (including ingress of moisture) of failure of the weather envelope of the building, particularly at flexible seals and expansion gap covers. Many modern buildings are complex and sophisticated structures subject to constant changes in the internal and external environment, and it would be prudent for owners to obtain expert professional advice on appropriate inspection and maintenance. Following a recommendation in its Third Report, the Committee noted, in its Fourth Report, that resources were allocated by BRE for further research on the corrosion of cavity wall ties. The Committee is pleased to note that BRE issued a review of performance of cavity wall ties[4].

Reinforced concrete chimneys

A few small to medium sized reinforced concrete chimneys, built before the current high standards of design and quality control based on CP110[5], CP114[6] and the American (ACI) Code[7] were adopted in the late 1940s, have been reported as having deteriorated to a point where their safety was in serious doubt and they were demolished.

Corrosion of the reinforcement had occurred mainly at construction joints.

From evidence received from various sources (including consultants, building and demolition contractors, owners and users) it appears that very few cases of serious deterioration of modern reinforced concrete chimneys have been reported. Failure of flue linings is an entirely different matter. There have been a considerable number of failures of linings in the UK and abroad. Some of these have been spectacular and have arisen from interaction between the windshield and the lining, others from loss of material and loss of material strength caused by movement, thermal shock and acid attack.

A change in flue gas temperature, in fuel, or in the régime of use from those assumed by the designer, could accelerate corrosion, and expert advice should be obtained if changes occur or are planned.

It seems prudent to ensure that attention is paid, in design, to hygrothermal considerations (ventilation, drainage and condensation); in construction, to the quality of concrete at construction joints; and in service, to systematic and skilled inspection.

The Committee recommends that owners and users of large reinforced concrete chimneys should have them examined from time to time by someone with a skilled eye (say, every 2 or 3 years), and should keep a register of inspection and maintenance for each chimney. Inspection of the inside of lined single flue chimneys is made more difficult by the presence of the lining, although access to the inside face of multi-flue chimneys is often possible. Deterioration of a lining might be an indication of unfavourable conditions affecting the shell and/or any corbels. The opportunity should be taken of inspecting the inside of the shell when any of the lining is removed for replacement or repair.

Checks on the condition of the concrete shell should normally be fitted into shut-down periods when the chimney is not in service.

Proposals concerning inspection along the above lines have been included in draft codes of practice for reinforced concrete chimneys which are being prepared by BSI and also by the International Committee on Industrial Chimneys (CICIND). The Standing Committee feels this is the right approach to the problem rather than by way of statutory regulation. However, owners and users of chimneys might not become aware of the recommendations contained in design codes if not alerted to their existence. It is reported, for example, that although the BSI Specification for steel chimneys(8) recommends regular 1- or 3-year inspection of unlined and lined steel chimneys, this recommendation is practised in only about 50% of cases.

Some additional publicity is recommended to bring the need for inspection to the notice of owners and users.

2.2 The effect of complex and comprehensive codes on structural safety

A new generation of structural design codes is currently emerging. They tend to be more complex and comprehensive than the codes they are intended to replace. Practising design engineers and others have expressed concern at the difficulty of understanding and applying these more complex codes.

Although the Committee does not know of any cases of structural failure caused by such complexity, there are cases of failure where it may have been a contributory, but not a dominant, factor.

Increased complexity of codes may be a reflection of a more highly developed technology which cannot be expressed in the simple terms used in the more primitive codes.

Although it is obvious that code writers should, and indeed do, endeavour to simplify the presentation as much as possible, it appears that further simplification is difficult or impossible at the present time, because there is no clear definition of the uses to which a code is to be put or therefore of the optimum form and content. Currently, codes are used as multi-purpose documents (for regulation, litigation, design guidance, contractual purposes, specification, provision of data, etc.), and they speak with many different voices to many different users. They are therefore inevitably complicated and un-clear, and will remain so until they are drafted for specific purposes, users and uses.

Proliferation of detail in codes tends to distract the designer's attention away from the fundamental considerations which should be his main concern. It is probably better if codes are written as aide memoires sign posting the pitfalls for designers rather than as collections of standard calculation procedures or as quasi-legal documents.

There needs to be a greater awareness on structural code committees of the need for engineers to be allowed and encouraged to use their experience and to exercise engineering judgement, rather than to rely on compliance with specific clauses in a code. Linear text used to express technical ideas can be lengthy and confusing, particularly if it is drafted with a view to making it watertight for use in litigation. More diagrams could help to simplify the codes.

2.3 Structures in the nuclear power industry

The United Kingdom Atomic Energy Authority accepted an invitation from the Standing Committee to explain its philosophy with regard to the analysis of risk of failure in nuclear power structures.

For many structures, there are three possible ways in which the risk can be investigated: (a) using historical data, (b) using a deterministic approach, and (c) using a probabilistic approach.

There have been no major failures of a nuclear power structure, and it is therefore not possible to use (a). The deterministic approach (b) is an extension of (a). Previous experience is incorporated into codes and specifications which are then used in the design and construction of a structure. Approach (b) is also therefore not possible for nuclear structures.

This leaves approach (c) as the only appropriate method for nuclear structures.

A nuclear structure is conceptually divided up into a number of units, components or parts, and for each a statistical distribution is assessed for the risks. The overall risk to the structure is then estimated by mathematically combining all the risks into statements of what the risks are of a particular type of failure per unit time.

There are many variables to be considered: strengths of materials, stress and variable stress, temperature and variable temperature, potentially corrosive fluids, high radiation fields, etc. All available information is used, and in many cases R & D has been specifically undertaken (e.g. improving the understanding of fracture mechanics and improving the techniques of non-destructive testing of thick-walled steel structures). The 'leak before break' criterion has great importance in the risk analysis.

The Atomic Energy Authority also studies in depth the effects on people and on the environment of a structural failure, even though the chance of failure is estimated to be so small that for any other industry, the risk would be totally ignored. For example, in countries where earthquakes are familiar, nuclear structures must clearly be 'earthquake resistant'. In the UK, even minor earth tremors are infrequent, but, nevertheless, nuclear reactors are now being designed to withstand magnitudes of earthquakes, flood depths and wind speeds predicted to occur once in 1000 years and, for certain sites near airports or seaways, impact of aircraft or gas tanker explosions.

The Committee was supplied with some illustrative values in the risk analysis of some of the key parts of nuclear structures, such as pressure vessels, and large and small pipes. The Committee agreed that the line of approach was right and acknowledged the increased understanding of fracture mechanics resulting from investigations by the Authority. This work and that on non-destructive testing would prove valuable to many parts of industry beyond the nuclear industry.

The Committee was impressed by the UKAEA's thoughtful and responsible approach to a complex problem but was not able to express an opinion about the safety of particular nuclear structures on the basis of this present review.

2.4 Structural failures during construction

Numerous accidents occur on construction sites every year, but only a very small number from structural failures, and most of these are of temporary works.

In general, it appears that structural failures do not usually, as is sometimes supposed, result from a lack of refinement in our structural codes or in mathematical models and methods of analysis or from poor control of quality of material properties, but are commonly attributable to human error. Various recent studies[1,9,10] of structural failures in the UK and abroad show the need to avoid errors and omissions or, simply, to make sure that nothing relevant gets forgotten or overlooked.

A human being decides whether or not an unfavourable influence or hazard has to be taken into account on the basis of what he already knows, but he is not usually in the position to assimilate all the relevant information which has been generated and published on the subject in question.

This situation could present an opportunity to carry out some useful multi-disciplinary research into the causes and avoidance of errors and omissions. The potential benefits of a suitable study of the subject could probably outweigh its cost many times over.

2.5 Cases in which the Building Regulations may not provide appropriate safeguards for structural safety

Deterioration

A case has been reported to the Committee in which a building contravened the Building Regulations[11] by reason of the fact that it contained an excess of calcium chloride in the reinforced concrete frame. Although considered to be safe and serviceable at the time of construction, it was suspected that deterioration of strength could occur over a period of years.

In the absence of a system of conditional licensing, the local authority was apparently not prepared to exercise discretion in the matter and enable the building to be occupied on the condition that it was monitored regularly.

It is understood that in the London area, the District Surveyors are enabled to permit the use of a building, or part of it, for a limited period of time at the expiry of which an inspection to establish the structural condition and the need for repair or replacement is carried out. Re-licensing depends on the findings of the inspection. It has been suggested that ways should be found to extend this system outside the London area so that buildings known to be subject to deterioration may be used and monitored.

However, the Committee feels that there may not be sufficient cases of this sort to justify a change in the regulations. When such cases do arise, each should be dealt with on its merits by the local authority using judgement based on competent professional advice. The owner should be alerted to the need for subsequent reappraisals and in this connection attention is drawn to the Institution of Structural Engineers Report on Structural Appraisal of Existing Structures[12].

Concentrated loads and chipboard flooring

For a number of years, chipboard has been used as a flooring material for domestic, office, storage and industrial premises. It is either fully supported on a concrete sub-base or, more often, it spans across timber joints or concrete or metal beams.

The properties of chipboard are somewhat different from those of traditional flooring materials in that the critical mode of failure is more likely to be by punching or shear, particularly where there are heavy concentrations of applied load.

With such a material, the loading requirements of the relevant British Standard Code of Practice(13) may not be appropriate, and compliance with that code may not provide adequate safety.

Revisions of CP3 are being considered by BSI whereby, for the purpose of calculating crushing or punching effects, specified loads would be considered to be spread over the actual area of application (instead of over a 300 mm square as at present).

To put this into effect, it would be necessary to carry out tests on the flooring material, simulating the intended loading conditions. The tests would also need to take into account whether the actual load might be static or dynamic. With so many possible variations of load and area, standardisation of tests may not be appropriate.

Until such time as satisfactory arrangements can be formalised in the design and the loading codes and in the regulations, designers and checkers should ensure that proving tests based on a realistic assessment of the actual conditions of service are carried out.

Subsequent change of use of the building may invalidate such tests, and consideration should be given by the control authorities to the introduction of a requirement for structural re-appraisal upon change of use.

Consideration should be given to the preparation of a Guide or Code of Practice on the structural use of chipboard with proper regard to long-term load effects, deterioration, moisture, misuse, vibration, impact and local application of load.

In the meantime, there is an urgent need for the regulatory authorities to consider measures to prohibit the structural use of chipboard where its material properties render its use inappropriate.

Change of use of a building

Change of use of a building does not necessarily require structural re-appraisal (other than for structural fire precautions) under the Building Regulations(11) except where there is also to be a structural alteration. When the change is to public use, the local authority may require a check to be made.

However, there are powers for the local authority under the Public Health Acts, and in particular Section 58 of the 1936 Act states 'The local authority becoming aware that any building or structure is in such a condition or is used to carry such loads as to be dangerous to persons may apply to a Court of Summary Jurisdiction'. The Court may order the owner of the building to execute works or demolish.

As to what constitutes 'danger', it seems that the engineer concerned with any re-use of a building must satisfy himself on this issue, and in particular whether an encroachment into the factor of safety would necessarily constitute danger. In this respect, there appears to be no case law to assist engineers who might find themselves in this situation.

It cannot be assumed that every change of use will be in the hands of responsible people who would at all times take full cognisance of the British Standard Code of Practice on loading[13] or adhere to the spirit of the Building Regulations.

In order to ensure that proper action is taken, a local authority might have to prove that a building which was theoretically overloaded was in a dangerous condition. It could be extremely difficult to prove this to the satisfaction of a Court, and with the current delays in reaching Court it could be that a building could be in use, dangerously overloaded, for a considerable period. If, after such time, there were no signs of distress the difficulty would be even greater.

The Committee considers that in the interests of public safety there is a need for the Building Regulations, Part D, to be modified to allow for Change of Use and that a change in type of storage should be considered as a material change of use.

<u>General comment on building regulations and the importance of engineering judgement</u>

Attention is drawn to the Committee's view that rigid adherence to a code of practice without the proper exercise of judgement by a qualified engineer does not necessarily result in adequate structural safety, particularly when a change of use occurs. A small increase in initial cost of construction to allow for heavier loading than the minimum value required by the building regulations may considerably increase the potential for change of use.

2.6 <u>The use of resins in civil and structural engineering</u>

It is recognised that the use of resins is a subject of growing importance. In an earlier report, attention was drawn to the need for further research to provide a satisfactory basis for the safe use of resins in construction. The Committee is pleased to note that some promising research has since been carried out by the Wolfson Bridge Research Unit at Dundee University on the fatigue resistance of adhesive bonded intermediate steel stiffeners for steel plate girder webs.

Some concern has been expressed to the Committee that in the fabrication of laminated timber beams, imperfections and low strengths can occur which are difficult to detect. Load testing could cause incipient damage and give no indication of the margin of safety.

Secondary fixings can sometimes be used to improve contact between surfaces during glueing and hardening. It was suggested that BSI should consider the possibility of developing standard quality control tests for glued timber structures and the Committee endorses this suggestion.

The making of glued joints is more hazardous on site than in the controlled environment of a factory, so site glueing (particularly of timber structures) should be avoided if possible.

With other materials such as concrete and/or steel, site glueing may be necessary, in which case the formulation of the resin must take into account the technique of application, the method of construction, the programme of construction and the probable climatic conditions during construction and in use. Fire resistance and the possibility of wetting should be taken into account. If the actual conditions vary from those assumed, the need for reformulation must be considered.

There would be considerable disadvantages in adopting a selection of standard formulations in a BSI standard. However, in the interest of safety, there is clearly a need for standard methods of test, and the Committee welcomes the reported intention to issue such a standard as soon as practicable.

Surface preparation of the parts of the structure to be joined together must be clearly described in the concrete, steel and resin specification, and the work must be supervised carefully. Difficulty in achieving a good bond may occur if there are air pockets in the concrete or if the concrete has been repaired with weak mortar.

There is a lack of information on the long-term performance of resins, and because of this it is not considered prudent at present to use resins in a critical part of a structure except where it would be feasible and economical to effect replacement should unacceptable deterioration take place. The Committee feels the need for a programme of long-term testing on standard reproducible formulations within the wide spectrum of possible choices. The continuing development of new formulations adds to this problem.

3 ITEMS OF CONTINUING INTEREST

3.1 Earth dams

In its Fourth Report, the Committee reviewed the safety measures for earth dams in the UK and the relevant Acts. It concluded that the position was not satisfactory. Recommended remedial works were not always put in hand. There were sometimes long delays to such work, and little was known about the condition of privately-owned dams.

The Committee was pleased to note that in February 1982 the Department of the Environment circulated advice on the matter to the Chief Executives of District Councils, and Metropolitan and London Boroughs of England. The DoE also asked for various checks to be made and information supplied by those bodies to the DoE to ensure that all necessary precautions were taken and all persons and bodies were aware of their responsibilities and powers in the matter. In addition, the preparation of a register of earth dams in the UK is under active consideration.

3.2 Ground anchors

In its Fourth Report, the Committee recommended that the CIRIA Report 65[14] should be expanded and up-dated to cover the additional problems identified by the Committee. This was done and the revised edition published by CIRIA in October 1980.

3.3 Damage to bridges by impact

In its Second Report, the Committee drew attention to the risks to overhead bridges arising from impact by high vehicles and high loads. Most of the recommendations made by the Committee were acted upon by the Department of Transport.

Subsequently, trials were put in hand on a number and variety of height warning devices, and an analysis will be made to determine their effectiveness. Also, a White Paper was issued in 1981 following the Armitage report[15] proposing a height limit of 4.2 m on the heavier road vehicles and any container carried by them.

There has also been a survey in 1981 by TRRL[16] to determine the awareness of drivers with regard to the height of their vehicles and the meaning of road signs referring to height of clearance. Only about one third of the drivers questioned knew the height of their vehicle or fully understood the height restriction signs.

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APPENDIX 1 TERMS OF REFERENCE

The terms of reference for the Committee were determined by the Presidents of the Institutions of Civil, Municipal 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 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 2 LIST OF MEMBERS

Chairman:	The Rt Hon the Lord Penney OM KBE DSc PhD MA FRS
	C D Brown LLD BSc CEng FICE Mott Hay and Anderson
	Professor J B Burland PhD MSc(Eng) FEng MICE MIStructE FGS Imperial College of Science and Technology
	A Gordon CBE LLD DipArch PPRIBA Alex Gordon & Partners
	The Hon Mr Justice Graham High Court Judge (Chancery Division)
	Professor E F Happold BSc CEng FICE FIStructE FCIOB University of Bath
	D N Rogers BSc(Tech) CEng FICE FIMunE City of Birmingham
	R E Rowe CBE ScD MA FEng FICE FIStructE FIHE FACI Cement and Concrete Association
	A C E Sandberg BSc ACGI CEng MConsE MIMechE MIHE Messrs Sandberg & Partners
	R S Taylor BSc CEng FICE Taylor Woodrow Construction Limited
	R L Triggs BSc CEng FICE Consulting Engineer
	F Walley CB PhD MSc CEng FICE FIStructE Consulting Engineer
Secretary:	L S Blake PhD BSc(Eng) CEng FICE FIStructE FIHE CIRIA
Technical Officer:	J S Armitage BSc CEng MICE MIStructE CIRIA

APPENDIX 3 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 buildings

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