Standing Committee on Structural Safety
Sixth report for the 3 years ending 30 June 1985

The Standing Committee on Structural Safety reports to the Presidents of IStructE and ICE. By publishing the sixth report of the Standing Committee, the President invites comments on its content and suggestions for further investigations. These should be sent in the first instance to the Institution, at 11 Upper Belgrave Street, London SW1X 8BH.

Conspicuously

The fifth report of the Standing Committee, issued in June 1982*, referred to the decision made by the Presidents of the Institutions of Civil, Municipal and Structural Engineers to reconvene the committee under a new Chairman, following the retirement of Lord Penney, who had been the committee’s Chairman for 6 years. Sir Derman Christopherson was subsequently appointed Chairman, and the committee started its work in November 1983.

This, the Sixth Report of the Committee, covers the period of 20 months, to June 1985.

The committee first reviewed the 37 topics studied by the previous committee, specifically to examine what effects the recommendations contained in its earlier reports might have had in averting or reducing risks which had been identified and to establish whether some further advice was required to take on board the light of new evidence or recent trends and innovations.

The most frequent cause of structural collapse was accidental damage by gas explosions and by vehicle impact. In its second report, the committee drew attention to the need to ensure that any voids, including ducts, in a building are vented to prevent accumulations of gas. It advised local authorities and the suppliers of the risk from the use of bottled gas in large panel high-rise dwellings which had not been strengthened following the Ronan Point inquiry. Suppliers of gas in refillable containers immediately gave appropriate advice to their agents to discourage the use of liquefied petroleum gas cylinders in dwellings above two storeys high, but the extent to which local authorities reacted to the committee’s advice is not known. The Department of the Environment issued similar advice to local authorities following the collapse of flats in Putney in 1985. The gas explosion in Putney resulted from the infiltration of gas from a fractured main. Collapse of these prewar flats illustrated that traditional construction, as well as large panel structures, can be vulnerable to progressive collapse.

Crack widths between 20 and 40 significant cases of structural damage each year, and they result in an annual average of 12-6 fatalities. The risk cannot be eliminated altogether, but wider acceptance of the committee’s earlier advice would result in a worthwhile reduction of this risk. The tragic gas explosion at the pumping station at Abbotsford in 1984 drew attention to a further and unexpected risk of large quantities of methane from the ground or groundwater penetrating pipelines. In its first and subsequent reports, the committee drew attention to the risk of structural damage to railway and highway bridges, including those of significant span and carrying vehicles with tall loads. The Department of

*see The Structural Engineer, 61A, No. 2, February 1983, p65

Transport accepted and implemented many of the committee’s recommendations and intensified their attempts to deal with this difficult problem. The Department of Transport has been taken to inform and educate transport firms and drivers, and various methods of bridge protection are under investigation. However, the risk remains, and although no loss of life or serious injury from bridge collapses as a result of vehicle impact, the collapse in 1985 of a footbridge over the dual carriageway A2 highway, struck by construction equipment on a low-loader, illustrates the potential significance of such accidents. The committee strongly recommends the Department of Transport and others concerned to accelerate their efforts to reduce this risk.

Another important recommendation in the committee’s first and second reports concerned the need to periodically inspect concrete and masonry claddings, particularly those abutting busy thoroughfares and areas of public concern. The committee recommended a图文 enhanced version of the brick cladding to the tower block at Plymouth Polytechnic might have given warning of potential collapse, but the incident illustrates the importance of the committee’s advice on this subject and the extent of the disaster which could have occurred if the adjoining cafeteria had been occupied.

The committee has frequently pointed to the importance for designers to take account of the potential for deicing road surfaces. The risk cannot be eliminated if structural failure is to be prevented. The committee therefore considered the need to periodically inspect concrete and masonry claddings, particularly those abutting busy thoroughfares and areas of public concern. The committee recommended the coordinated inspection of the safety of large concrete panel structures. This sixth report gives advice and recommendations on all of these subjects. The committee has also considered the structural safety implications of the collapse of the Ronan Point inquiry. The committee was pleased to find that such programmes of research were already in hand.

Although at present the number of structures affected by ASR is quite small in relation to the total national stock of buildings, bridges and other structures, it cannot be predicted whether ASR will become yet wider spread. So far, only one motorway bridge in the UK, in which ASR was implicated, has been demolished and rebuilt, but the work has been necessary on a number of other structures. Recent specifications and guidance notes to limit the alkali level in concrete should be sufficient to ensure against the effect of ASR in structures in the future, but the committee once again stresses the need for regular and adequate inspection of existing sensitive structures of all kinds. As with the case of reinforcement corrosion, programmes of research to establish effective methods of protection must be vigorously pursued, and structures exhibiting signs of ASR should be carefully monitored.

On the subject of the safety of earth dams, the committee concludes that the present plate knew about the condition of privately owned dams and, in cases where inspections had shown remedial works to be necessary, these works were not carried out. In 1982, the Department of the Environment circulated a report which the committee’s recommendations and intentions are in hand.

Several recent events have reinforced the committee’s concern that legal and insurance considerations now often preclude professional engineers from technical discussion with their peers on matters of safety. On a number of occasions, professional engineers have appeared to the public and to clients as having different opinions on technical matters which may impinge on safety, such as on the Severn Bridge, Great Ormond Street Hospital, Caxton’s Dam, Ronan Point, and other high-rise large panel structures. In no case has it been possible to give an authoritative statement reassuring the public and clients.

The committee believes that there should be no obstruction to communication or discussion between professional experts concerned with a project. Wherever matters of safety are concerned, professional engineers should be able to decide, if necessary after discussion with other engineers, the actions necessary to ensure the safety of a structure and to present their recommendations to their clients and others concerned without recourse to lawyers or to litigation.

The committee was pleased to learn that the Presidents of the two Institutions have already put in hand the programme of research and the programme’s feasibility on both of these points.

The committee is also concerned that the courts’ interpretation of professional liability, coupled with the fast expanding extent of litigation,
The output should be carefully checked for ambiguities in the internal and external force distributions and for all large displacements. A plot of the member geometry and the output displacements often assists in interpreting the many parameters available from the computer solution. Checking by an alternative program may show up any discrepancies.

Safety of structures affected by alkali-silica reaction in concrete

The phenomenon of alkali-silica reaction (ASR) in concrete has been known for more than 40 years. The reaction takes place in concrete only when the following three conditions occur together:

1. A reactive form of silica in the aggregate
2. A sufficient concentration of sodium, potassium, and hydroxyl ions to produce a sufficiently alkaline pore solution in the concrete
3. Moisture within the concrete, or which can be absorbed

ASR is a long-term reaction resulting in the formation of a gelatinous alkali silicate hydrate which causes the concrete to expand, and, in extreme cases, to crack. The actual crack formation depends on the nature and level of stress in the structure, its geometry, and the detailing of the reinforcement. The signs of ASR are usually apparent about 10 years after construction.

In the UK, nearly all cases have been limited to the use of Trent Valley sand or sea-dredged aggregates from the Bristol Channel or Isle of Wight areas. The precise number of cases where ASR has been attributed to be the major cause of cracking is not known. The number is somewhere between 50 and 100, all built between 1930 and 1975, and represents a very small proportion of the total volume of construction during that period. The implications of ASR on the safety of structures are as follows:

- Because it occurs relatively slowly, it can usually be recognised before the strength of the member is seriously affected. To this extent, it is a serviceability problem which can be fixed by normal inspection procedures. When definitely identified and the scale of the potential (but finite) expansion assessed, it may be necessary to evaluate the loadcarrying capacity (depending on the type of structural member, the climatic, and other moisture conditions) and to check on the possibility of secondary deterioration from corrosion. Depending on the outcome of this assessment, remedial action may be necessary, ranging from continued surveillance to effecting the repair once the reaction has ceased. In extreme cases, it may be necessary to replace certain elements. Each case requires expert judgement and sound engineering judgment.

- As the reactions can take place only in the presence of moisture, concrete foundations, beams, and areas of buildings exposed to high humidity, may be most affected. Loss of integrity of the concrete can cause structural weakening, particularly in shear and bond. Examples of structural elements that may react include girders, columns, corbels and halving joints, flat slabs, and pile caps. There is also a risk to foundations and other parts of the structure that cannot be easily examined, in that cracking resulting from ASR may not be detected.

The limitation of damage from ASR in new structures is covered by specifications such as those issued recently by the Department of Transport and the Concrete Society. The provisions in these documents are still under review, as more data become available from research and in situ tests. The emphasis in these specifications is on limiting the alkali level in the concrete from whatever source, but mainly the cement. Attention is also given to the use of aggregates with proven good performance.

It is felt that ASR is unlikely to become more widespread in new construction if this type of specification is followed.

Regarding the 'fail-safe' economic structures and buildings, there is a clear need for periodic inspection, particularly of bridges and sensitive buildings such as swimming pools and others in which high humidity can occur from industrial processes or through ineffective air-conditioning. High priority should be given to R&D, with the object of improving methods of identifying ASR and assessing its effects, methods of prevention by coatings or other means of control and effective remedial measures. There is also a continuing need to review specifications to limit damage by ASR in new construction.

Safety of demountable grandstands

Temporary grandstands are a relatively common feature at most sporting and open-air events. The failure of a temporary grandstand during filming of a BBC programme in May 1982, and the all-too-frequent failure of scaffolding systems, have highlighted the importance of the safety of such structures to the attention of the committee.

In a paper to the Institution of Structural Engineers the following main factors contributing to the 'fail-safe' economic structures were stated:

- Slender members subject to compression
- Importance of lateral support by bracing
- Possible large openings in the framework
- Access
- Flexibility of the joints (depending on the systems used)
- Possible omission of joint couplings or damage to members
- Lack of indemnity for 'hand' analysis
- Possible dynamic response leading to overload

There was also a strong possibility of 'unzipping' or progressive collapse following failure of one element. The most vulnerable members were usually at the rear of the structure.

The committee supported the Institution of Structural Engineers' initiative to produce a guidance document on the subject, and it recommended that the manufacturers should carry out appropriate testing and analysis to determine the stability of these structures with representative bracing patterns.

Structural safety related to size and importance

The importance of size and scale of a structure is not considered specifically in Codes of Practice. The basis of the treatment of risk in structural design is presented as follows.

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The factor $\gamma_c$ may itself be divided into two parts, depending first on whether partial or complete failure can occur without warning, and second, on the social and economic implications of failure. A parallel system may be defined as one in which redistribution of load occurs among adjacent elements at failure, and a series system is one where failure of one element leads to complete failure (e.g. loss of bearing).
The number of people affected by failure is usually related to the scale of a structure. The risk of failure is likely to be affected in various ways:

- Knowledge about spatial distribution of loads on large areas is limited (e.g. asymmetrical loads)
- Large structures demand more accurate analysis than smaller structures and can justify a greater proportion of the design fee
- Larger structures may develop greater movements (e.g. from temperature, shrinkage, creep, etc.)
- As structures become larger and more slender, they are more influenced by instability and dynamic effects.

The committee felt that the implication of size and importance of a structure should be reflected in Codes of Practice, so that the above effects could be treated in a more rational way in design. This could be achieved by an introductory section in the major structural Codes, and the committee recommends that this action should be proposed to the British Standards Institution.

**Implications of the introduction of design-fee competition on structural safety**

Tendering for design of structures on the basis of fee competition, rather than on structural safety, could lead to a more conservative approach to design by not refining the structure to its most economic form, which would eventually be more costly to the client than any fee saved.

In all competitive tendering, the onus would be on the client to specify the design requirements clearly, so that competition for design would be on a common basis and would result in safe structures. Advice to clients on the form and scope of fee competition should be given in the Codes of Practice, and the committee believes that guidance should be given on the procedures to be followed by a professional expert reporting on some aspect of a project to ensure adequate communication with other experts concerned to be followed by a professional expert reporting on some aspect of a project to ensure adequate communication with other experts concerned with the project.

**Collapse of the Carsington dam during construction**

The Carsington dam in Derbyshire failed during construction in June 1984. The 1250m-long 35m-high earthfill dam developed a massive slp failure over nearly half its length. The Secretary of State for the Environment, Sir Stan Hoare, commissioned an independent expert to inquire into the cause of the collapse. The committee cannot comment further until the report is released and they have had time to consider whether there are any matters of structural safety that need to be drawn to attention.

However, the committee felt that press reports, following the collapse, left an impression with the public that construction of dams could not be controlled. The committee believes that guidance should be given on the procedures to be followed by a professional expert reporting on some aspect of a project to ensure adequate communication with other experts concerned to provide suitable means of resolving any disagreements.

The committee wishes to emphasise that safety should take precedence over all other considerations in the event of disagreement between the parties or their representatives concerned.

**The safety of large panel buildings**

The stability of high-rise large panel buildings under normal and extreme loads, including fire conditions, was considered by the committee. This could not agree on the technical questions involved and further, they did not discuss these questions with each other. The committee believes that guidance should be given on the procedures to be followed by a professional expert reporting on some aspect of a project to ensure adequate communication with other experts concerned to provide suitable means of resolving any disagreements.

**Corrosion of reinforcement and prestressing tendons in concrete bridges**

The mechanism of corrosion of steel embedded in concrete is complex. However, it is known that corrosion occurs only when the chloride content of the cement matrix falls below 3% or if chlorides are present at a level sufficient to cause depassivation of the steel, leading to an electrolytic action between anode and cathode. The corrosion cell can be very localised, and it normally requires oxygen and water to be present at both the cathode and the anode so that ferric oxide (or rust) can be formed at the anode. In saturated conditions, corrosion can occur even in very much the presence of oxygen and water. General corrosion of a large area of reinforcement may occur relatively slowly, but it is pitting corrosion, or localised loss of steel (sometimes without much rust staining), that is more serious.
There are about 60,000 reinforced concrete bridges in the UK, of which 6000 are relatively long-span, over 400 m. Where corrosion has occurred, it is most serious on bridge abutments, piers, and decks, exposed to salt spray or dripping water. Corrosion of bridge decks in the UK is far less common than in the United States, in large part because of the absence of substantial, massive expansion joints, which in the UK is not the usual practice to provide a waterproof layer above the deck. In the UK the worst problems seem to occur at leaky expansion joints whose water is not properly drained. This has affected not only the concrete reinforcement, but also the bridge bearings.

However, current design of bridges stipulates positive drainage of joints, and continuous maintenance and in the rate of renewals, the preponderance of joints, are often preferred. Control of ingress of chlorides by surface coatings is being actively studied both in UK and overseas, as is the use of alternative deicing methods.

The long-term performance of post-tensioned concrete bridges, of which there are about 600 of relatively long span in the UK, was reported in the third report of the Standing Committee. The results of the post-tensioned bridges were presented, and since then a further two bridges have been investigated. Although voids have been found in the grouted ducts containing the tendons, little corrosion has been found. The committee concluded that the overall level of safety was relatively insensitive to the loss of one tendon and that there was a sufficient safety margin, after first cracking, to give adequate warning of failure.

The committee concluded that corrosion of reinforcement or prestressing tendons created a serviceability problem rather than one likely to cause catastrophic failure. Nevertheless, it was essential to maintain adequate procedures for inspection and repair. High priority should be given to R&D to improve methods of detecting corrosion and to provide effective methods of prevention and repair.

**Items of continuing interest**

**Inspection and maintenance of railway structures**

In 1976, the committee examined the procedures adopted by British Rail for the inspection of railway structures and for making repairs and replacement. In the committee's first report, it was concluded that British Rail's policy for inspection and maintenance was satisfactory and that, in spite of budgetary cuts on maintenance and in the rate of renewals, the present condition of railway structures gave no cause for immediate concern.

At that time, the maintenance budget was £35m on stations, bridges, and tunnels, which had a replacement value in 1976 of about £20,000m. It is understood that the maintenance budget has been kept at about the same relatively low level in real terms over the past 9 years. Without any reason to alter its earlier conclusion on the safety of railway structures, it is concerned that the effect of a prolonged period of restricted maintenance will inevitably reduce their margins of safety.

**Inspection and maintenance of earth dams**

In its fourth report, the committee drew attention to the unsatisfactory position with regard to the inspection and maintenance of earth dams in the UK, particularly those in private ownership. At that time, the 1975 Reservoirs Act enforcing inspection and maintenance of dams had not been implemented.

The committee went on to note that the 1975 Act is now being implemented, but points to the further need to include, within the Act, similar requirements for inspection and maintenance of canal banks and of tailings dams operated by the mining and quarrying industries.

In the case of the safety-critical dam collapse at Stave, Italy, underlines the importance of this recommendation.

**Damage to bridges by impact from vehicles and vessels**

The incidence of damage to bridges through impact by vehicles with tall loads was pointed out in the committee's first report, and recommendations made to the Secretary of State for Transport and subsequently endorsed by the Presidents.

Many of the committee's points have been covered in amendments to the Motor Vehicles (Construction and Use) Regulations, No. 1017 (1986), and the committee has noted work by the Transport & Road Research Laboratory to examine means of reducing the incidence of vehicle impact. However, it is considered that the measures taken to date had had too limited effect and that the risk of serious accidents, involving structural bridge damage followed by train derailment or multiple traffic accidents, remains unexpectedly high.

The committee reiterates its recommendation for a statutory limit on height and weight limits on the impact and loadings by vehicles, including organisations concerned with the transport of construction plant.

The importance of the problem is illustrated by the fact that, by 1985, all footbridges over a dual carrage section of the A1 in Kent, following impact by the bucket of an excavator on a line-loader. Fortunately, in this case, no multiple traffic accident resulted and no lives were lost.

With regard to the added risk, pointed out in the fourth report, of parapets being inadequate to withstand impact from the very heavy vehicles, the committee was pleased to find that the Department of Transport had issued a memorandum requiring more substantial parapets over railways.

**Use of resin bonded plates to repair reinforced concrete structures**

The committee reported some conclusions on the use of resins in civil and structural engineering in the fifth report. Subsequently, the use of epoxy resin to bond steel plates to the soffit of reinforced concrete sections was brought to the attention of the committee. This technique had been used with apparent success to strengthen a number of bridge decks and beams, but the committee advised against its wider application until its long-term performance had been proven. Epoxy resins are also used in the construction of segmental bridges, but are not required to have long-term durability.

Resin bonded plates have also been used recently as a repair method for a multi-storey car-park which had developed cracks in its principal beams between columns shortly after construction. The composite plate-concrete section had been designed to provide the additional factor of safety required to resist the subsequent imposed loads on the floor.

In this particular case, the committee was satisfied that adequate arrangements had been made to control the application and to monitor the performance of the resin bonded plates. Furthermore, because of the relatively low probability of severe fire in this type, which has been recognised in the fire regulations, the fire resistance of the resin bonded plates was not critical. However, for this and other applications, it is important to draw attention to the loss of strength of resins at relatively low temperatures. In a fire, the unprotected plate might deform, while laquered, petrolatum-coated, and if it fell, but also the structural strength of the beams would rapidly reduce. The use of such bonded plates in other forms of structure with a higher period of fire resistance remains suspect. In the case of performance under long-term loading is not well known. However, most buildings and bridges receive only relatively little permanent service load, and therefore creep strains may not be significant. Nevertheless, the loss of moisture and fungal growth were felt to be possible further hazards. The resin manufacturers should be encouraged to carry out long-term load and indicative fire tests. In situ monitoring of the performance of structures where this repair technique had been used was also emphasised as a prerequisite to its wider acceptance.

**Structural damage caused by gas explosions**

The death of eight people in an explosion causing progressive collapse in a block of flats in Putney, London, on 6 January 1985 drew attention again to gas explosions as the most common cause of structural failure in buildings in the UK. Since the Ronan Point incident in 1968, the number of mains gas explosions causing structural damage of varying severity ranged from 20 to 40 p.a., with fatalities averaging 12-6 p.a.9

The Putney flats were of traditional brick wall and concrete floor construction, built in the 1930s, and it has been reported that leaks of gas from a fractured main accumulated in a service duct and underfloor void before ignition. The effects suggest that a range of building types—not just large panel structures—are at risk of progressive collapse in the event of severe gas explosions or bomb explosions. In its third report, the committee:

- emphasised the need to ensure adequate venting of confined spaces, including ducts and basements
- advised the Local Authority Associations in 1978 to consider prohibiting the introduction of refillable liquefied petroleum gas cylinders into buildings particularly at risk.

In 1984, the Department of the Environment took similar action to warn the local authorities, and the committee now recommends that guidance notes should be prepared and widely circulated to assist in reducing the risk of severe explosions and in reducing the structural effects of explosions in buildings.

The Abbeyestead valve house explosion10 in May 1984, which resulted in 16 people killed and 28 injured, has drawn attention to other matters which need to be publicised throughout the civil and structural engineering professions.

An investigation by the Health & Safety Executive concluded that the explosion was caused by ignition of a mixture of methane and air. The methane, of ancient geological origin, percolated, either in gaseous form or dissolved in water, through the walls of a tunnel and thence into the valve house during pumping operations. The valve house was vented, but the pressure from the explosion was such as to lift the roof and then refurbish concrete beams and slab from its supports and cause several of the roof beams to fall into the chambers below.

The Abbeyestead explosion highlights the need to ensure the emergency of confined spaces or underground construction into which methane...
could permeate in gaseous form or in solution. Further, the designer and operator should ensure that all such ventilated paths are clear throughout the life of the structure and are not affected by changes in operation or of machinery therein.

References

2. Department of Transport: 'Interim specification to avoid alkali-aggregate reactions', DTP: Bridge Engineering Standards Division, July 1983
8. Department of Transport: 'The design of highway bridge parapets', Technical Memorandum (Bridge), No. 85, 4th revision, April 1984
10. Health & Safety Executive: 'A report of the investigation by the Health & Safety Executive into the explosion on 23 May 1984 at the valve house of the Lune/Wyre Water Transfer Scheme at Abbeystead', HMSO, 1985

Appendix 1. Terms of reference

The terms of reference for the committee were determined by the Presidents of the Institutions of Civil and Structural Engineers as follows:

To study trends and innovations in design, construction and maintenance of structures from the safety standpoint
To consider where further research and development work, or some warning of risk, appears desirable from the safety standpoint
To report to the two Presidents and to make recommendations
To produce an annual report on its activities
To seek, receive, and authorise the expenditure of funds, necessary for the implementation of the terms of reference
To suggest to the two Institutions any changes to its terms of reference it considers to be necessary or desirable.

Appendix 2. List of members

Chairman: Sir Durman Christopher, KT, OBE, DPhil, BA(Oxon), FEng,
FlMechE, MICE, FRS
University of Cambridge
C. J. Evans, MA, FEng, FICE, FIStructE, FCIarb, FIHT
Walter Evans & Partners
A. Gordon, CBE, LL.D, DipArch, FIRA
The Alex Gordon Partnership
H. B. Gould, CEng, FIStructE, FICE
Property Services Agency (until 1 January 1985) G Maunsell & Partners (from 1 January 1985)
Professor E. F. Hapgood, RDI, BSc, FEng, FIStructE, FICE, FCIob, HonFIRBA
University of Bath
D. J. Lee, BScTech, DIC, FEng, FIStructE, FICE, FIHT
G Maunsell & Partners
P. F. Mead, FEng, FICE
John Mowlem & Co. plc
D. N. Rogers, BScTech, CEng, PICE, FIHT
Mott, Hay & Anderson
R. E. Rowe, CBE, MA, ScD, DEng, FEng, FIStructE, FICE, FIHT, FACI
Cement & Concrete Association
A. C. E. Sandberg, BSc, ACGI, CEng, FIStructE, MIMechE
Mears Sandberg & Partners
R. S. Taylor, BSc, FEng, FICE
Taylor Woodrow Construction Ltd.
J. Uff, QC, PhD, BSc(Eng), CEng, FIStructE, MIMechE
Consulting Engineer
F. Walliday, CB, PhD, MSc, FEng, FIStructE, FICE
Consultant to the Ove Arup Partnership
Secretary: L. S. Blake, PhD, BSc(Eng), CEng, FIStructE, FICE, FIHT, CIRIA
Technical: R. M. Lawson, PhD, BSc(Eng), ACGI, CEng, MInstMechE, MICE, FICE, 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 and fire protection
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. Arched 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 & 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
38. Misuse of computer programs in design
39. The stability of structures affected by alkali-silica reaction in concrete
40. The profession's reactions to some matters of public concern
41. Safety of demountable grandstands
42. Structural safety related to size and importance of structures
43. Implications of some recent court discussions on structural safety
44. Implications of the introduction of design-free competition on structural safety
45. Collapse of brick cladding to the Plymouth Polytechnic tower block
46. Collapse of the Cansington dam during construction
47. The safety of large panel buildings
48. Corrosion of reinforcement and prestressing tendons in concrete bridges
49. Inspection and maintenance of railway structures
50. Inspection and maintenance of earth dams
51. Damage to bridges by impact from vehicles and vessels
52. Use of resin bonded plates to repair reinforced concrete
53. Structural damage caused by gas explosions

Continued from page 26 provided a number of analytical problems for us to solve at Christmas, which our readers tackled with various degrees of success. He now asks a question of a different kind:

Simply—the problem

A concrete ground-floor slab is cast on a polyethylene sheet, on a well-compactved granular sub-base. On the basis that the slab does not support load, and is shrinking, the only resistance to contraction is the friction to the underside of the slab/top of polyethylene (due to the self-weight of the slab).

What coefficient of friction \(\mu\) would you initially use in a calculation to determine the resistance to contraction in order to calculate the area of reinforcement to resist shrinkage forces?

Response required

Make an immediate note in the Journal of the \(\mu\) value you would use. Then check this value in next month's issue.

We are grateful to Martin Ashmead for his letter and will publish his comments next month.

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