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A Review of the Design Against Fire of the Principal Structural Materials

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BUILDING RESEARCH ASSOCIATION OF NEW ZEALAND

A REVIEW OF THE DESIGN AGAINST FIRE OF THE PRINCIPAL STRUCTURAL MATERIALS

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ABSTRACT

The paper outlines the state of development of fire engineering as a tool to model the real fire environment of an unwanted building fire, and in determining the response of structures to the associated high temperatures. It then reviews the methods used in achieving fire resistance with timber, steel and concrete in New Zealand buildings, and shows that to date there has been little use made of fire engineering. The paper urges engineers to regard fire as a load to be designed for.

KEYWORDS

Concrete, Fire, Fire Resistance, Fire Resistant Materials, Fire Tests, Steel, Timber.

1. INTRODUCTION

While this paper presents a general view, without too much detail, of the application of fire engineering to structural design, it assumes the reader has a working knowledge of what is meant by fire resistance and how this is currently applied to buildings by the Model Building Bylaw. The paper discusses the deficiencies of the current situation and explains developments in fire engineering which are leading to a more rational approach. It leads on to showing how these approaches may be applied to the fire protection of timber, steel, and concrete. References are given if the reader wishes to enquire in more detail.

2. BYLAW REQUIREMENTS

Current bylaw (1) requirements for fire resistance of structures are unsatisfactory for the following reasons:

(a) They are inflexible and may only be relaxed in special circumstances.
(b) Requirements are based on the results of an arbitary standard test which does not represent a real fire situation.
(c) Fire hazards may be significantly different between building uses, yet similar periods of fire resistance are required.
(d) The required fire resistance periods are arranged in steps which do not represent real situations.
(e) They provide a simple, but coarse control method.

No two building fires are the same. There will be differences as a result of the nature of the fire load density, the ventilation provided by the building and the effect of the building envelope on the course of the fire. Consequently a wide range of behaviour can be expected and it is an oversimplification to specify requirements from a tabulated situation when dealing with a complicated phenomenon. It is evident that the required periods of fire resistance have been selected to cover extreme situations and this undoubtedly results in the cost of fire protection being higher than it perhaps needs to be. While it will continue to be convenient to use an arbitary classification system to control the design of many buildings there are clearly cases where it will be worthwhile taking a fire engineering approach to design the fire resistance of a particular structure. Furthermore, this approach should be applied to rationalise the code requirements.

3. FIRE ENGINEERING

Engineers design structures to withstand a variety of loads. These include self weight, live loads created by the use of the building, external loads caused by the elements such as snow and wind, and the dynamic effects of earthquakes. Structural engineering has devoted an immense amount of effort to understanding these loadings and developing design methods in order to create cost efficient buildings to resist these loads. Fire engineering is doing the same thing by regarding an unwanted fire as a load on a building. To do this it is necessary to understand the nature of fire development and how it relates to a building. Fire engineering permits the specifying of fire protection by understanding the significance and severity of a real fire. Economies can therefore be realised because the fire load in many structures is low and the potential fire severity is also low.

The fire engineering approach to a building problem looks at three distinct factors: how hot the fire gets, how this heat affects the materials of the structure, and how stable the structure is under the effects of this heat.

3.1 THE HEATING CONDITIONS

It has been established that the course of a fire in a building is determined by the fire load, the ventilation conditions, and the characteristics of the building materials. The fire load is a measure of the amount of material, chiefly contents, which is available to burn. The rate of burning is determined by the disposition of the materials. The amount of ventilation provided to a fire has a marked effect on its speed of development together with the degree and rate of temperature rise. This effect can be calculated from the known geometry of window and door openings in relation to fire compartment size. The characteristics of the materials on the walls and floors surrounding the fire can have a marked effect on the fire development. Some materials will conduct heat away from the fire more readily than others, with the effect of keeping fire temperatures lower than where materials perform an insulating function.

3.2 EFFECT OF HEAT ON MATERIALS

A number of factors affect the way in which structural materials respond to fire conditions. Where the materials are non-combustible the effects are mainly temperature related and this applies to structural steel and structural concrete. Where the material is combustible the combustion characteristics become predominant and this applies to timber. These effects will be dealt with in more detail in the sections dealing with these structural materials.

3.3 STABILITY OF THE STRUCTURE

The way in which the fire affects the component materials of the structure, will in turn have a bearing on its stability during, and even after, the unwanted fire. Analysis of these stability effects is relatively straightforward for simply supported beams, but these are seldom used in real buildings. The effects of continuity and restraint render the problems much more difficult to analyse and so arrive at valid fire engineering solutions. This will also be dealt with in more detail in the sections on the three structural materials.

3.4 DESIGN PROCEDURES

During the last two decades substantial progress has been made around the world in the knowledge gained in the sciences of fire behaviour and of the effect of high temperatures on material properties. From this knowledge a number of methods of calculating structural fire endurance have been developed. When looked at collectively there appear to be three approaches to finding solutions to these problems i.e. empirical, engineering, and numerical.

3.5 EMPIRICAL SOLUTIONS

The empirical solutions are arrived at from comparative test data obtained by conducting standard time-temperature tests. Such solutions are constrained by the limitations imposed from the use of the standard time-temperature test, but nevertheless they provide means of determining fire resistance ratings of constructions similar to those actually tested. To be reliable, the empirical solution needs test data taken over a broad range of parameters in order to evaluate a particular type of protection. This solution has been developed recently as an important aid in the protection of structural steel and will be discussed more fully in that section.

3.6 ENGINEERING SOLUTIONS

In a number of countries design guides have been developed using a fundamental engineering approach to fire design problems. These give values for the design parameters over what is assumed to be a workable range of conditions. Some knowledge of fire engineering and judgement is necessary in the selection of the appropriate parameters both for fire performance and for structural behaviour. Calculations are based on reasonable and conservative assumptions and the calculations are continued until it is determined that some critical design condition results.

3.7 NUMERICAL SOLUTIONS

Numerical solutions provide the most accurate method of analysis. By nature of the whole fire process in which the temperature conditions are in a state of change and the material properties are temperature dependent, the analysis becomes very complex and necessitates the use of computers. The advantages of numerical solutions are that they permit allowance to be made for all these variables. Such solutions are generally based on examining the thermodynamic behaviour of the passage of heat through the fire protection system, if any, and the consequential heat buildup within the structural member. Finite difference methods are used by this means to calculate the temperature history and so failure can be determined when the method identifies that a predetermined failure criteria (such as a critical temperature) is reached. Development of such programs can be time consuming and expensive because they need validation by input of experimental data.

Numerical solutions for the interaction of the exposed structural member with the surrounding frame have been developed. These methods include consideration of restraint, composite action and redistribution of loads. The computer program is designed to take the known physical and mechanical properties of structural materials, and to apply design loads to the structural model so that stresses and strains can be determined at each joint. In addition the forces at the end of each member at a joint can be calculated and the resulting displacement of the joint determined. The program then applies the temperatures following the standard time temperature curve (or any other curve), and then calculates the effect of the heat flow into the member and the structural response, so that the resulting end forces can be checked against the ultimate moment capacity until a plastic hinge develops. The excess plastic moment at the point of the hinge is then redistributed and the whole process is continued in discrete time steps until sufficient plastic hinges have formed in other members and the structure is considered to be in a state of progressive collapse.

4. NEW ZEALAND APPLICATIONS

The descriptions above of the various solutions applicable to the fire resistance of structural members apply to situations in other parts of the world. What bearing therefore has all this on current and future methods in New Zealand?

The current state is that we do not go beyond empirical solutions. These almost solely evolve from stated requirements of fire resistance based on the traditional worldwide arbitrary scale of half hour fire resistance steps. The solutions needed by the building industry to these requirements, are obtained from empirical tables applicable to some of the more common building construction methods, and from the results of standard fire resistance tests conducted in New Zealand and elsewhere on special types of construction. The main source of information on New Zealand materials and constructions are contained in the SANZ MP9 Series (2). The current situation suffers from all the imperfections of being arbitrary, conservative and inflexible as outlined above.

There have been a limited number of attempts by structural engineers to break out of this system and apply some form of fire engineering to special structures. There are a number of identifiable problems in doing this, such as the engineer needs to acquire knowledge of fire engineering in order to carry out a valid design solution, sufficient information may not be known about NZ materials to make such an approach reliable, and approving authorities may be understandably cautious about accepting such solutions. Any fire engineering approach in NZ has been on a very limited basis and has been constrained within the empirical system. So far as is known no-one has yet attempted a full analysis of the fire environment followed by an analysis of the structural response. Certainly there has been no attempt yet to fully introduce numerical methods into this country.

To break out from traditional methods requires motivation and a will to overcome the difficulties. Two strong motivating influences are applicable. One is the evident attraction that a fire engineering approach can have in reducing costs of fire protection (because in some instances it can show that no protection is needed) and the other is the professional drive that engineers have to know and understand what they are doing. I suggest that all too often in the past engineers have abrogated their responsibilties in this area, in that the structure has been designed by the structural engineer after the architect has made enough of the basic decisions about the building to leave the engineer with little room to maneouvre. Engineers must start thinking of fire as load to be designed against along with the other more traditional types of loading. You will find that learning this will be expensive and that you will find it hard to justify for many of the more straightforward buildings. However, this has not stopped you in the past gaining a much clearer understanding of the influence of earthquakes and I suggest that you must face this development in fire engineering.

The remainder of the paper outlines how fire engineering solutions may be applied to the three main structural materials.

5. TIMBER

5.1 CHAR RATE

It would appear that of all the structural materials, timber is the one with least potential for the application of the third, or numerical, approach. An empirical solution has been used for some time in New Zealand, the principle basis being that covered in Part 8 of MP9. This approach uses a constant rate of 0.6 mm/min to determine the amount of loss of the external surfaces exposed to the fire. MP9 then permits a structural analysis of the remaining, uncharred, section to determine its capacity to carry load, with concessions on stress levels that recognise that fire attack is a low order of probability. It is evident this single constant value for char rate, which is independent of time, is too simple. Some researchers have suggested this value should be increased for time periods beyond an hour, and figures quoted vary accorded to species. For P. radiata, it has been established that the value of 0.6 mm/min is adequate, but only up to one hour. Beyond that, cracks and splitting encouraged an apparent faster average rate.

Research has shown that the behaviour of timber under fire attack is a complex process, involving not only the rate of char under a varying thermal environment, but also the related temperature and moisture gradients in the uncharred part of the cross-section. Changes in the mechanical properties of wood with a simultaneous increase in temperature and moisture content must also be taken into account. Petterson and Jonsson (3) have shown that it is possible to develop analytical models to include all three factors, but emphasise these are not adequately validated to become reliable numerical design methods. It seems likely it may be some years yet before this state is reached, certainly in New Zealand. For a more detailed understanding of the background, see references 4 to 7.

Although the char rate method is a simple approach, it is likely to be the only practical method available to New Zealand engineers for some years to come. Its principal limitation is that it should be applied only to "heavy" timber sections. This is usually taken to mean timber sections, either solid or laminated, with no dimension less than 100mm. It should not be applied to small sections such as 100 x 50, nor to thin sections of plywood.

5.2 ONSET OF CHAR

There are a number of empirical solutions available in New Zealand, involving the use of small timber sections insulated from the effects of fire. These are principally stud walls with linings of gypsum plaster board and engineers should be aware these are mostly tested not loadbearing. Even an elementary consideration of the way in which the studs char on the fire exposed side will show that if they are carrying load, they are likely to fail earlier, i.e. to provide less fire resistance. Some engineers have already fallen into the trap of designing loadbearing timber walls and then providing fire resistance by specifying layers of gypsum plaster board. This may not work, and care should be taken to ensure the loaded wall system has been fire tested as a loaded system.

Since few of these timber stud fire resisting wall systems have been tested carrying load, the empirical approach would require them to be retested, carrying a load. Since this is an expensive method (currently a loaded fire resistance test in New Zealand can cost between $6000 and $7000), an approach with some element of fire engineering has been under investigation by BRANZ. This is the "onset of char" approach which takes account of the fact that a gypsum board lining separates the timber from the fire temperatures so long as it continues to hold moisture and thereby keeping adjacent timber from exceeding about 100°C. Thereafter it is suggested little loss of strength by charring occurs until temperatures over 300°C are reached in the timber surface layers facing the fire. By monitoring the time to reach this critical temperature in a non-loadbearing standard furnace test it is suggested the likely time to failure under load due to loss of section may be predicted. The method has been described by Baber and Fowkes (8), but requires more experimental data to validate it. It is hoped it will become the basis for the application of method 8.2.1 (c) of MP9/8.

5.3 JOINTS

There is a growing faith in this country in the ability of heavy timber structures to resist fire, and this faith is well placed. However in the larger structures there exist problems of joints where metal connections are involved. Steel plates will absorb heat from a fire and may cause charring of adjacent timber. Also, bolts or nails provide a heat path into the interior, and these too may initiate charring with subsequent loss of grip, particularly where bending moment connections are involved. Currently in New Zealand engineers and the timber industry are paying too little attention to this problem, or are using protection details which lack validation by any identifiable fire engineering analysis. It is to be hoped the otherwise excellent reputation of heavy timber in fire is not to be changed by a disastrous failure because of bad engineering at the joints. This points to the need for research.

6. STRUCTURAL STEEL

6.1 RESEARCH

It is evident that around the world massive efforts have been devoted to understanding the behaviour of structural steel in fire situations. This has been done in research organisations created by the steel industry and also by others. Since this sort of research takes much time and money, industry funding has obviously aided progress, and results in the availability of a large volume of information on the fire engineering design of steel structures.

6.2 EMPIRICAL SOLUTIONS

Empirical solutions for particular protection systems have been available for many years, usually based on fire resistance tests sponsored by the manufacturers of these protection materials. This approach has been made to work, but has severe limitations such as many costly tests are needed, the results are limited to a restricted range of section shapes and sizes, and a lack of flexibility in adapting to new steel sections. In New Zealand this approach has been applicable to a number of protection systems, and the approved ones have been listed in MP9 Part 6. The limitations have been even more applicable here than overseas.

6.3 ENGINEERING SOLUTIONS

In the last 10-15 years there have appeared several engineering solutions which represent significant advances over empirical solutions. Countries where these have been issued include Sweden (9), Switzerland (10), USA (11), and France (12), and it appears most of these have been accepted by approving authorities as a means of establishing compliance with code requirements. No such engineering solutions have been available to structural engineers in New Zealand.

6.4 NUMERICAL SOLUTIONS

The research that has formed the basis for the fire engineering solutions mentioned above has, during the same period, been developed so that it is possible to use numerical methods to analyse the whole fire environment and the consequential structural response. The advantages of numerical analysis are that account can be taken of the dynamic character of fire attack, knowledge of heat transfer, variations in material properties with temperature, and the two or three dimensional response of a structure to the thermal conditions. These numerical methods require repeated application of finite difference methods and can extend into large computer programmes. It is claimed for these that they provide the most accurate method of analysis. It is, however, not known whether they have been validated by input of information from tests on structures, nor indeed whether it will prove possible to devise ways of doing so. As far as is known no such analysis methods are available here.

6.5 ENGINEERING SOLUTION FOR NZ PROTECTION SYSTEMS

At present, one step forward is being discussed in New Zealand. This involves adopting an engineering approach to the approval of protection systems to replace the empirical solution mentioned before. This approach is based on theory enunciated in 1967 on the mechanism of heat transfer into a steel member surrounded by fire.

An important parameter identified is the section factor, which is the ratio of the perimeter of the exposed surface of the member, to its cross-section area. This section factor is a measure of the capacity of a steel section to absorb heat, and is readily calculated for any cross-section, or can be listed in tables. Its magnitude has an important bearing on the time taken by a steel section to reach a predetermined critical temperature. A large perimeter will absorb more heat than a small one, and a large cross-sectional area will provide a greater heat sink than a smaller one. It follows that a small, heavy section (small section factor) will be slower to heat up over its whole section than a large, thin section (large section factor). Thus a section with a large section factor will take a shorter time to reach a critical temperature, or alternatively will need greater applied protection. Research has established that the yield strength of structural steels is reduced at elevated temperature. The reduction varies with steel type, but for most engineering analysis it can be taken to be 50% at 550°C. In principle, when the yield strength is reduced below the stress level, then a hinge will develop which can initiate collapse. Whether collapse will take place or not depends on the stress present at the time of heating. Most structural designs will be done to stress levels about 50% of yield, so this typical temperature of 550°C becomes critical.

An elementary engineering approach has now been developed in the UK which uses this critical temperature of 550°C as the basis for assessments of steel protection systems. A fire resistance test is needed to evaluate the behaviour of the system and to gather enough temperature data to input into an equation unique to that material relating time, protection thickness, and section factor. This equation can then be used to prepare graphs or tables which provide an engineering solution to the thickness of protection needed for a given steel section and for any required fire resistance period. In the UK this approach has now been applied to a large number of protection systems, and the results published in a manual (13). It is this approach which has been reviewed for use in New Zealand, and it appears likely it will find acceptance here. Adoption of it will provide manufacturers with an agreed method of obtaining approvals, local authorities will have less problems in obtaining proof of compliance with requirements, and engineers will be assured of the use of a rational design tool.

6.6 SACRIFICE TO SIMPLICITY

The UK engineering approach has been achieved only with some sacrifice to simplicity for practical application. Because it is based on one critical temperature it takes no account of steels which may have any other critical temperature, it also takes no account that the actual stress may be less than the nominal yield strength at the elevated temperature, nor does it permit allowance for the effects of restraint, both against expansion or from joint rotation. While it does make allowance for the influence a concrete floor slab may have on the steel beam (by modifying the section factor) it cannot allow for the composite action developed in New Zealand structures. Continuity is another factor not allowed for in this approach.

It is possible these factors can be taken into account in a more detailed engineering approach and the methods detailed in reference 9 certainly recognise most of them. However, considerable study of these very detailed procedures must be undertaken before they could be used and accepted in New Zealand.

6.7 BARE STEEL

Research investigations and results of fire tests have shown that unprotected steel can achieve worthwhile fire resistance under favourable conditions. The obvious cost savings of using bare steel should be an incentive for the application of fire engineering, although engineers should not expect to achieve fire resistance much in excess of ½ hour. To achieve this in building situations where the bylaw requires more than ½ hour would indicate the need to do an analysis of fire behaviour (to determine a realistic fire endurance time) and to use steel sections with low section factors. It may prove to be cheaper to use heavier, and unprotected, steel sections than to use sections designed only for the structural loads at ambient temperatures which require applied protection against fire.

6.8 EXTERIOR STEEL

Structural members are commonly regarded as being part of the structure containing the unwanted fire, so that beams and columns are considered to be totally, or at least partially, surrounded by a flaming fire environment. However, if external to the building envelope, flame and gas temperatures can be much lower than in an enclosed space and structural members may be surrounded by flames to a lesser degree, or may only be subject to radiation from flames issuing from the adjacent window openings. American Iron and Steel Institute has developed an engineering anlaysis (11) which is applicable, and it appears this can substantiate the use of bare steel members in many situations.

6.9 WATER COOLING

An ingenious application of heat transfer physics has evolved a method of fire protection which uses hollow steel members containing water. The method provides for the interconnection of the building members, usually with a header tank, so that on the impact of heat from a fire the water absorbes heat passing through the steel walls. A circulation is set up so that continuous cooling is provided to the heated members. Such a system seems to have the potential of coping with any fire intensity so long as water circulation is maintained. An engineering design method has been published by G.V.L Bond (14). Although a number of such buildings have been built in several countries, it seems doubtful if this method of fire protection will be extensively used because of the practical problems of ensuring the system is maintained in effective readiness throughout the life of the building (will corrosion inhibitors remain effective or might not the system develop a leak?).

6.10 CONCRETE FILLING

Another method of keeping hollow steel sections "cool" is to fill them with concrete. This can provide a mass capable of providing a heat sink. Again this method is amenable to heat transfer physics aimed at keeping the steel below a chosen critical temperature. British Steel Corporation (15) has published a useful design handbook on the design of hollow steel sections which contains a guide to fire resistant design of concrete filled columns.

6.11 COMPOSITE SECTIONS

A relatively recent development in Europe has been the use of columns and beams of wide flange sections, with these filled with concrete, so that both concrete and steel are exposed to view. The same heat sink effect applies as for hollow concrete filled sections. The development of engineering design solutions for this type of member has reached an advanced stage in Luxembourg and it is hoped information on this will be available in New Zealand soon.

7. STRUCTURAL CONCRETE

7.1 RESEARCH

Equally with structural steel, there has been much research effort in many parts of the world into fire engineering aspects of structural concrete. This has also been done in organisations financed by the concrete industry and by others. Again this has resulted in a large volume of published information on the fire engineering design of concrete structures.

7.2 EMPIRICAL SOLUTIONS

Notional recommendations for acceptable sizes, thickness and cover to reinforcing have been available here for many years, and these are included in MP9. All this information has been culled from a variety of overseas sources, mainly building codes, regulations and means of compliance. A recent examination of some of this information has revealed there is such a wide diversity in the recommendations as to throw doubt on their reliability. Nevertheless the writers of each of these documents have believed on the "best possible" evidence that their requirements are right. This is an inherent fault in any empirical solution, since it must use the safest, or most cautious, results. Thus New Zealand has been stuck with a set of recommendations for concrete which are in serious need of review. Building Research Association and Concrete Research Association have been endeavouring to undertake research into the response to fire of New Zealand concrete, but staff availability and research priorities in both Associations have permitted only slow progress. Initial work has been aimed at validation of the recommendations included in MP9.

7.3 ENGINEERING SOLUTIONS

During the last few years several design guides have been published overseas which provide the structural engineer with a means of applying some of the results of research. Two in particular are of interest, one from USA (16) and one from UK (17), but it is doubtful whether these should be regarded as full engineering solutions. The guide by CEB-FIP (18) comes more closely into this category because it includes an analysis of the real fire environment and leads on to the structural analysis of concrete members in elevated temperature conditions. This document is undoubtedly the most comprehensive and useful fire engineering solution available at the present time.

7.4 NUMERICAL SOLUTIONS

Not much information seems to be currently available here on full numerical solutions. Partial solutions can be applied, for instance the calculations of fire environment already mentioned above can equally apply to structural concrete buildings. Reference 18 contains charts which enable an engineer to determine the temperature at the position of the reinforcing at a given time. These charts result from a computer analysis of the transfer of heat in a concrete member, and thus result from a fire engineering analysis. However, after applying the charts to determination of the temperature, this is related to the arbitrary critical temperature of 550^{o}C, which firmly retains the analysis as an engineering solution rather than a fully numerical one. Perhaps because structural concrete is a more complex material than steel it is taking longer to arrive at a fully satisfactory numerical process which takes account of all the variables.

7.5 RESTRAINT

When any structural member is heated in a fire it will expand. If this member is built into the structure in the manner almost universally adopted in New Zealand, this expansion will be prevented or at least resisted, by the surrounding structure. The resulting buildup of forces can be beneficial in preventing collapse, and this is nowhere more apparent than in the common precast concrete floor systems on the NZ market. In these the protection provided to the steel reinforcing by the concrete is not enough to justify resistance to fire of more than $\frac{1}{2}$ to 1 hour, yet standard tests have shown them to be adequate for 2-3 hours. These results clearly arise from restraint against expansion, and to achieve a satisactory rational engineering approach to these situations continues to present a problem in New Zealand.

7.6 CONTINUITY

The benefits of continuity are recognised, but guidance on how to take advantage of it remains largely an ad hoc process. Clearly if a beam or slab is continuous over a support, the negative reinforcement is on top, in the cold zone (regarding the fire as applied underneath). It is therefore not subjected to the influence of high temperatures and can be expected to receive bending movement transferred to it from the positive reinforcement as it yields under the high temperature. The recommendations in references 16 and 17 help an engineer to make use of this, and no doubt these have been arrived at from the results of much research and testing. However, the only true way to recognise and make use of continuity will be to analyse the total structure by the numerical method referred to earlier. The size of the computer program involved in this method would appear to be at present a severe handicap to its application, but there is no doubt that the rapid development of computer technology will remove that obstacle before long.

8. CONCLUSION

Structural fire protection is still in its infancy in New Zealand. Very limited knowledge of fire engineering is available or applied by engineers here.

For timber, a simple empirical approach is used and the limitations of this have been listed.

For structural steel, engineers have mainly accepted manufacturers' technical information on applied protection systems, and used these systems to isolate their steel structures from the effects of fire without too much thought being given to how the structure may behave. Possible approaches to determining the need for protection, and the amount, have been listed.

For structural concrete, engineers have been tied to an empirical system of determining critical dimensions considered sufficient to meet the code fire resistance requirements. The existence of possible advances in the application of fire engineering knowledge are noted. Some engineers give scant regard to the design of concrete structures against fire - they seem to believe that because it does not burn, or does not yield like exposed steel, that all will be well. This view is no doubt reinforced by the apparently good record to date of concrete structures in fires in New Zealand. It is suggested that engineers who have this view are taking their responsibilities too lightly.

Above all, New Zealand engineers need to recognise that fire attack should be treated as a design load which is amenable to the application of sound fire engineering principles. Hand in hand with this, building controls must have a mechanism to permit engineers to put forward building designs based on these principles, and there must be adequate advice available to approving authorities to assist them to accept these designs as valid alternatives to code requirements. Are New Zealand Professional engineers willing to take up this challenge?

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