

CFA Guidance Note: Fixings and Fire

1 INTRODUCTION

There is a degree of misunderstanding with regard to the performance of fixings in fire situations especially the relative performance of certain types of fixing. There is also little published data on the performance of fixings in fire and a lack of definitive guidance as to how fixings may be specified for applications which may be exposed to fire.

This Guidance Note attempts to put the performance of the different types of fixing into perspective and offers a variety of approaches to overcoming the problem.

This advice is given as best practice at the time of writing. Please refer to the manufacturer before specifying any fixing for an application where a fire rating may be required.

2 SUMMARY

- ❑ *In fire tests most steel anchors and some resin anchors fail by steel failure of the bolt head or nut.*
- ❑ *The performance of resin bonded anchors in fire tests is only marginally lower than that of all-steel anchors.*
- ❑ *The load capacity of stainless steel anchors may be significantly better than that of carbon steel versions.*
- ❑ *At around 500°C concrete strength reduces by half as does the strength of most steels.*
- ❑ *Some anchors may be used unprotected with full Recommended Loads for exposures up to 30 minutes.*
- ❑ *For significant duration of exposure to fire (60 minutes or more) when using any anchoring system at full load special measures must be employed.*
- ❑ *A wide variety of anchor types, including resin bonded anchors, are available with certified performance at reduced loads for exposures up to 120 minutes.*

Section 4 outlines a variety of approaches including

For all anchor types:

- *Carry out dedicated fire tests for the complete application concerned.*
- *Apply fire protection to the fixings and surrounding areas.*
- *Specify anchors with loads certified from fire tests. Use stainless versions for higher loads.*

For resin bonded anchors

- *Use deeper embedment to delay temperature rise in the bond.*

3 PERFORMANCE OF FIXINGS IN FIRE

RESEARCH DATA

The performance of fixings in fire conditions is affected by a variety of influencing factors which are discussed in a CEB Report^[1.1]. However much of the consideration of Fire Exposure in this report is devoted to the performance of the different materials in isolation.

For instance:

- Concrete strength, both compressive and tensile, is reduced by half at around 500°C.^[1.2]
- The yield strength and Young's modulus of steel are also reduced to about half at 500°C.^[1.2]

Unfortunately the experimental research data relating to resin bond strength at elevated temperatures^[1.3] is derived from steady state tests which do not relate to the conditions pertaining in a fire. A theoretical model is discussed for bonded anchors^[1.4] in which steel and bond strengths are predicted to degrade to the point of failure at approximately the same time suggesting failure may be from either.

PRACTICAL TEST DATA

There are no commonly accepted procedures for the testing of fixings in fire conditions however some manufacturers have had their products tested in furnaces using standard ISO/DIN temperature/time curves as shown below.

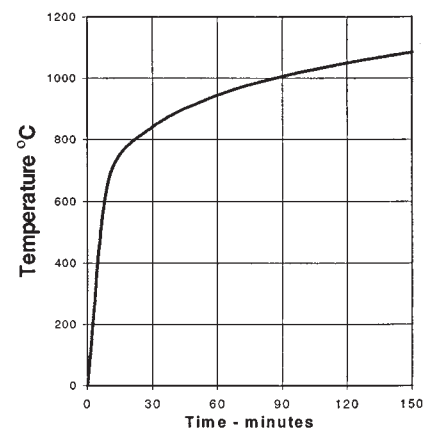
For the purposes of this Guidance Note the results of over 300 fire tests were made available by member companies. These results covered 17 different anchor types from ceiling fixings, drop-in anchors and through bolts to resin bonded, undercut and heavy duty expansion anchors. Anchors were loaded to various proportions of their Recommended Loads. 272 tests were carried out in cracked concrete the rest in uncracked concrete.

Modes of failure are reported only for the 272 tests in cracked concrete. In most cases the mode of failure for steel anchors was the nut or bolt head which was directly exposed to the heat.

For resin anchors the mode of failure was by steel failure of the nuts on larger diameters and by resin bond failure on smaller diameters at loads only marginally lower than for steel anchors.

Admissible Loads (reduced from Recommended Loads) resulting from one of these programmes of tests are identical for capsule type resin anchors and heavy duty expansion anchors for exposures of between 60 and 120 minutes.

ISO 834 Time/temperature curve



4 SPECIFYING FIXINGS FOR POTENTIAL FIRE APPLICATIONS

The following design approaches may be considered. Always involve the manufacturer's Technical Department.

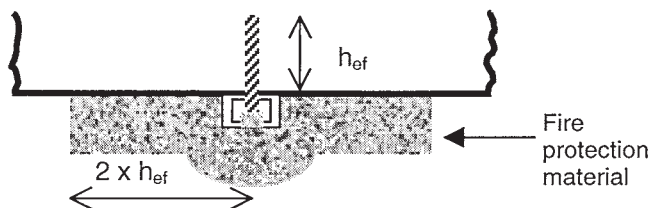
SOLUTIONS APPLICABLE TO ALL ANCHOR TYPES:

4.1 Carry out fire tests on the complete system including base material, fixture and anchoring system.

This solution is only feasible for major installations or repetitive installations where a complete system, such as a roller shutter door installation, needs validation. It is a very expensive solution and is obviously not practicable for most cases.

4.2 Specify anchors with additional fire protection.

There is little data available to quantify the improvement in performance which may be afforded to fixings by fire protection although the CEB report^[1,5] records tests of charring ablators which maintained a temperature difference of 40°C. Analytical studies^[1,4] suggest resistance may be increased by up to 30 minutes if the assembly is protected. Assistance in specifying fire protection should be sought, not only from the manufacturer of the fixings concerned, but also from the manufacturer of the fire protection being considered.



When applying fire protection the base material must be protected over the area used by the fixing for its strength. Fire protection should therefore extend to a radius from the fixing of at least twice its embedment depth, see above.

4.3 Specify anchors with load values checked against fire tests.

This is the most reliable solution as it is the only one with quantifiable data available. Different manufacturers have tests carried out to different criteria, some in cracked concrete others in uncracked. Tension tests carried out on two manufacturers' products using a standard time/temperature fire curve in cracked concrete with no additional protection show the following interesting results.

Heavy duty expansion and some capsule resin anchors can survive with loads close to or greater than normal (cracked concrete) recommended loads for 30 minutes in carbon steel versions and 60 minutes in stainless.

Heavy duty expansion and capsule type resin anchors can survive for 60 minutes with loads up to 21 – 29*kN, and for 2 hours with loads up to 8.0 - 12.0*kN (*M24 Stainless torque controlled resin capsule anchor).

Stainless steel load capacity may be typically twice that of carbon steel for the same exposure time.

Tests to fire curves represent more severe exposure than most practical cases. This is because fire tests involve loading in direct tension without a fixture whereas most applications involve shear loading (in itself less onerous) with a fixture in place which offers further protection.

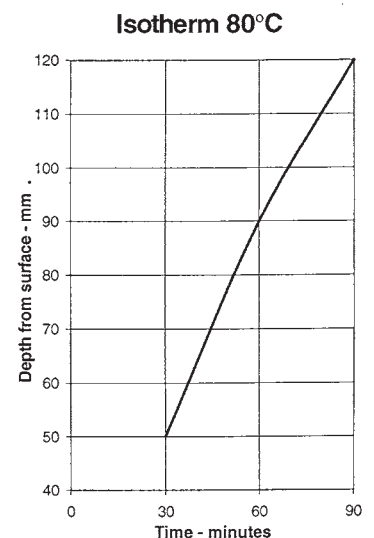
Specification of anchors with this certified data would normally involve calculating the allowable load performance for the chosen diameter, taking into account close edge distances, anchor spacing and any other influencing factors, and checking that the resulting load is no higher than the certified load value for the exposure required.

SOLUTIONS FOR RESIN BONDED ANCHORS ONLY:

4.4 Increase embedment depth to delay temperature rise in the bond.

The rate of temperature rise at depth within concrete is relatively slow so by setting the bond deeper its durability can be extended to match that of the nut/stud connection at the surface. Some manufacturers recommend this approach and use critical temperatures of between 80°C and 120°C, depending on the particular resin characteristics. The critical temperature is that above which bond strength is considered to weaken unacceptably. The adjacent curve is the isotherm for 80°C and comes from a series of curves^[2] of temperature vs depth at time increments from 10 to 90 minutes with a surface temperature of 1000°C.

The normal resin bond length must be set beyond the relevant depth to achieve the required delay. To extend durability beyond that offered by the connection at the surface additional fire protection will still be needed, see 4.2 above.



References:

- [1.1] Fastenings to concrete and masonry structures - State of the art report 1994. Comité Euro-International du Béton, Lausanne, Switzerland. Published in U.K. by Thomas Telford 1 Heron Quay, London E14 4JD.
- [1.2] CEB Report Chapter 28. Fire Exposure section 28.1.
- [1.3] CEB Report Chapter 27. Other Environmental Influences, 27.2 Temperature, 27.2.2 Bonded anchors.
- [1.4] CEB Report Chapter 28 Fire Exposure section 28.3.
- [1.5] CEB Report Chapter 28 Fire Exposure section 28.2
- [2] Dr Sell 1973.

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Construction Fixings Association
For more information contact: The Secretary
Construction Fixings Association
C/O Institute of Spring Technology
Henry Street
Sheffield
S3 7EQ
e-mail: info@fixingscfa.co.uk
Tel 0114 2789143
Fax 0114 2755573