SPONTANEOUS FRACTURE OF GLASS DUE TO NICKEL SULPHIDE INCLUSIONS - RISK MANAGEMENT AND DEVELOPMENT OF A NON DESTRUCTIVE TESTING SYSTEM

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ABSTRACT

The spontaneous fracture of toughened glass used in building facade glazing can be a major problem for the owner of the affected building. This paper describes the approach taken by a major Australian Building Owner, AMP Society and its subsidiary company Resolve Engineering, when faced with spontaneous glass failures in the facade of one of the largest buildings in Australia.

The paper describes the approaches taken in relation to risk management and development of a non destructive testing technique to identify glass panels at risk of failure.

INTRODUCTION

The spontaneous fracture of toughened glass used in facade glazing was first thoroughly investigated in Australia by the CSIRO when it became a significant problem on a Melbourne building in the late 1950's (Ballantyne, 1961). The research concluded that the fracture was due to the presence of a very small spherical inclusion, Nickel Sulphide (NiS) , in the body of the glass.

In the case of Waterfront Place some 140 well documented spontaneous failures have occurred (outer and inner vision glass and spandrel glass) between March 1990 and February 1997 inclusive. On 68 occasions the NiS inclusion at the initiation point was recovered, analysed, photographed and measured.

Since Ballantynes original work, a number of other researchers have further investigated the phenomenon (including Mackenzie, 1978; Swain, 1981; Barry, 1993; Brungs and Sugeng, 1995). At least one major glass company, Pilkington, developed a "heat soaking" process for toughened glass to reduce the risk of spontaneous fracture in service. The majority of glass companies appear not to have supported the heat soaking process.

Despite what must have been considerable "in house" research by the glass companies over the years very little information is available from them and our experience is that they are reluctant to divulge any information. From what little is published it appears that glass companies have concentrated on the fracture mechanics associated with failure. Ongoing failure of toughened glass due to Nickel Sulphide suggests that the glass manufacturers have been unsuccessful in developing an identification process at the manufacturing stage.

Various case histories in Australia and overseas have shown that the failure rate of toughened glass due to NiS can vary significantly and there are many variables that appear to influence this rate. Further, a number of theories have been developed about failure mechanisms, rates of failure, effects of NiS inclusion sizes and locations, etc. which, in our experience, do not hold true in all cases.

Such uncertainty is not helpful to building owners and statutory authorities who have to face the very real issues of safety, tenant and public concern, potential risks of injury and property damage, potential for depressed asset values and high ongoing costs to remove and replace broken glass.

While various risk management strategies have been employed to reduce the risk of personal injury and property damage, the ongoing incidence of glass failures (particularly when glass falls from the building facade) has heightened the concerns of statutory authorities. They are now increasing pressure on building owners to take a more proactive approach to solving the NiS problem.

APPROACHING THE PROBLEM

Building owners whose properties are affected by spontaneous glass fracture have to face a number of important issues, including:

- Directors and Senior Officers liabilities
- Workplace Health and Safety legislation and associated obligations
- Affect on asset value
- Company image
- Property image and attractiveness to potential tenants
- Public and Tenant concerns
- Pressures from statutory authorities
- Media interest
- Insurance and potential damages claims

- High costs of risk management and glass replacement
- High costs of any litigation

Typical risk management approaches adopted or considered by building owners to date include:

- installation of physical canopies around the base of a building to reduce the risk of injury due to falling glass
- appointment of consultants to predict the scale of the problem and its likely duration
- replacing glass as it fails, possibly with an alternative type of glass
- restricting access to areas around the base of the building
- implementation of facade inspection programs
- visual inspection of glass to try to identify panes with NiS
- application of security type film to glass
- enveloping the facade in a protective frame or netting
- reglazing of the entire building facade

In our experience and opinion, none of these approaches is entirely satisfactory for various reasons including cost, aesthetics, impact on tenants and public, effectiveness, risk and reaction of statutory bodies.

RESEARCH AND DEVELOPMENT

Initially, we set out to determine if a method of finding NiS inclusions had been developed anywhere in the world. Literature searches and discussions with experts revealed little. AMDEL, an Adelaide based laboratory, had developed a visual inspection process many years ago for use on an Adelaide building. That inspection was restricted to spandrel panel examination only. It was not very effective because after replacement of suspect panels others continued to fail and still do so to this day.

In 1992 AMP and Resolve sought assistance from the University of Queensland and set out to develop a technique to identify NiS inclusions in glass. Various options were thoroughly investigated including:

- Ultrasonics
- Laser light scattering
- Stress identification with polarised light
- Refractive light
- Infrared
- Metal detection
- Visual inspection

The most promising of these options was a combination of the polarised light and visual inspection. A major inspection project was undertaken over a two year period. The results were disappointing, with a success rate of identifying panels with NiS calculated at about 30%, based on data from failures after inspection work had been completed.

From this experience Resolve determined that there were a number of factors contributing to the poor success rate including:

- the size of many NiS inclusions is on the threshold of vision (often in the region of 0.1mm diameter)
- operating in an unstable and often uncomfortable environment in a building maintenance unit, exposed to the elements, over the side of a building
- visual and physical fatigue after several hours in a building maintenance unit

To overcome these factors, work on a photographic technique commenced in 1995. The University of Queensland conducted exhaustive laboratory trials and site tests during late 1995 and early 1996 to confirm the effectiveness of the idea. A major inspection project was undertaken by us on Waterfront Place during 1996 using this technique. Since then Resolve has also been engaged by another major Building Owner to conduct a similar exercise on another building.

STATUTORY AUTHORITIES

In late 1991 Resolve's parent company AMP Society was served with a "Show Cause" notice from the Brisbane City Council as a result of several glass failures at Waterfront Place in Brisbane. A number of the risk management strategies outlined above were proposed and accepted by the Council at the time.

In early 1995 a number of glass failures occurred on four Brisbane buildings, all within a short period of time. This attracted significant media interest and resulted in greater public pressure on the Brisbane City Council to do something.

Council served another "Show Cause" notice in mid 1995 on AMP in relation to Waterfront Place. Despite all the work done to that date on research, canopies, restricted areas, facade inspections and the like, Council issued notice on AMP. An objection was lodged to the notice and the matter was referred to a Building Tribunal for determination. Their conclusions can be summarised as follows:

1. it was no longer acceptable to wait for glass to fail and then replace it

2. it was thought unreasonable to require total facade glass replacement

3. a vigorous research and development program was to be pursued to identify which panels were at risk of failure, and then replace them

4. all existing risk management measures were to remain in place until all faulty glass had been replaced

The position of the Queensland Division of Workplace Health & Safety was simple. The Building Owner has an obligation to ensure the safety of persons in and around the building. Regardless of risk management measures, if someone is injured it only proves that the measures were not effective and the building owner may face prosecution.

THE PHOTOGRAPHIC METHOD

The basic steps in the process are simple:

1. photograph the glass

2. magnify the developed negative many times so that an inclusion can be easily spotted - this is done in the comfort of an air conditioned office

3. examine identified inclusions in the glass to confirm what they might be and the likelihood of them causing future panel failure

4. produce a list of panels thought to be at risk of failure so that the building owner can replace them

It will be appreciated from earlier discussion that this process overcomes the limitations of the unaided visual techniques which until now were the most reliable methods available.

The principal features of the process include:

- specialised camera equipment for photography of reflective glass
- unique camera mounts to avoid vibration and movement, designed to suit the particular building facade
- unique identification of location on each negative at the time of exposure
- specialised film
- specialised and dedicated film developing equipment and chemicals
- reader based film examination to identify inclusions and their location in glass
- sophisticated database to handle inspection data and generate actual site coordinates of inclusion positions in glass
- quality control procedures, including duplicate examination of all film and computerised data entry checking

- microscopic examination of inclusions in glass to determine composition and risk category
- a final list of panes of glass recommended for replacement
- testing and inspection of replacement glass prior to installation

RESULTS

During the period June to December 1996 the photographic process was used to test and inspect a total of 14,753.35 square metres of external vision glass on Waterfront Place, Brisbane. The glass area represents 4194 individual panes of glass.

The process identified a total of 53,594 inclusions within the body of the glass, of which 291 were identified as Nickel Sulphide in 281 windows (i.e. 10 sheets of glass were found to contain 2 Nickel Sulphide inclusions). Each inclusion is identified by its location coordinates within the glass, and confirmed NiS inclusions were also measured to determine diameter.

From October 1996 to February 1997 inclusive, five external viewing panes spontaneously fractured. The location of the initiation point of fracture was in all cases exactly where the photographic process had identified a NiS inclusion.

CONCLUSION

Of all the issues a Building Owner may have to face during the life of a building, a facade problem is usually the most serious and frustrating. This is particularly so with spontaneous fracture of glass facade panels because there has not been a reliable method of identifying which panels are likely to fail.

Risk management through a combination of protective measures, application of the photographic method and replacement of glass likely to fail offer the Owner an effective alternative to total reglazing of a facade.

ACKNOWLEDGEMENTS

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