AUTOMATED MAINTENANCE MINIMIZES BUILDING DEFECTS

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ABSTRACT

With the enormous expenses associated with the construction of a new building, it is necessary to take every possible precaution to see that the building endures for the longest possible period, with the minimum of unscheduled maintenance and repairs. The need to eliminate unforeseen problems, from unscheduled machinery downtime, to major concrete cancer type problems is paramount. Added to this is the need to minimize the cost of altering or upgrading the building through-out its lifetime. The correct choice of initial materials and systems, aided by constant automated assessment of the various elements of and within the building, will help in this process.

1. Introduction

In the past a lack of planning for maintenance of a building has been all too common. Today many building owners are demanding that their buildings last much longer than previously, and plan for at least one major renovation of the building during its lifetime. It is essential that the long term maintenance of the building be designed and built in to the structure at the start to maximise the economic life of the structure and minimise the cost of maintenance and repairs throughout the life of the building.

2. Modern Buildings

Building owners are used to dealing with unwanted problems even before their building has commenced construction - design problems, local authority intransigence and then the inevitable building cost variations during construction. The problem they do not need is the unexpected one that may occur within months of occupying the building. That is to find it is falling to pieces. In Melbourne in the mid 1950's, one of the first multi-storied, glass facade building was constructed for ICI. Within months, a person was nearly killed when a pane of glass fell out onto the pavement, bearley missing a passer by. Within days the building was surrounded by protective hoardings and major reworking was being undertaken to the facade.

Today we are faced with buildings which are larger and taller than ever before. Only recently the tallest building in the world was announced for the United States of America by Mr. Donald Trump, to exceed the 443 m Sears Tower in Chicago.[4] Within 100 m of the Sears building a 482 m high building - but with only half the actual floor area - has commenced construction, due for completion in 1992. The Sears building already has plans prepared to add 16 stories to the existing building. There are plans in New York City for a building of 150 stories, currently on hold for financial reasons, not structural.

We have the technology to construct these buildings, including the ability to transport the men and materials to their final destinations via hoists, cranes and pumps. We have learnt how to resist the wind loading which would result in swaying of many feet at the top of the building, where the occupants would tend to develop sea-sickness before lunch. Even movement as small as 50 mm (2") is enough to produce a queasy stomach after several hours.

The majority of these building are clad with aluminium and glass facades, concealing a structural frame of either concrete, concrete encased steel or bare steel with fire spray protection. These have led to ever increasing heating or cooling loads being applied to our buildings. Various attempts have been made to improve the thermal loading by use of mirrored glass, which in turn has led to the need for further controls when the reflections started to cause more problems to the neighbours than the glass solved for the occupiers. In addition there is the need for more artificial lighting in our offices now darkened by the treated glass in the windows.

We are requiring the materials used in our buildings to do more, without really knowing if they are capable of doing the extra work for the proposed life of the building not withstanding with the very sophisticated testing available today. The life expectancy of the building is a matter to which I will return shortly. With facade materials we generally look for four features - appearance, light weight, ease of fixing, long life. Each is in many ways dependent upon the other.

Using new materials, or old materials in a new fashion in itself is not a problem. The problem arises from a lack of testing of the planned system or process in the actual circumstances that will be met in practice. In many instances this is impossible and empirical calculations are made or computer modeling used to simulate the anticipated conditions. It is obvious from the disasters found in buildings that many of these models are decidedly flawed. This is not always the fault of the supplier or the builder. The example of a new building sheltering an existing building and creating a light problem or a heat load problem being but one example.[5] Add to this a new building creating a change in pressure - from wind tunnel affect for instance, and thus causing a previously virtually dry facade to become almost permanently wet during rain periods. The change in the demand made on the cladding may be quite radical. For five years, the original building may have resisted the solar problems, but after this period of time may not be able to adjust to resist the new water problem - a break down of the window seal may create noise from wind, which whilst this is annoying, is as nothing compared to the problems as a result of the now developed ingress of water.

We must look at our buildings in a broader light. We must consider that buildings will have a longer life than many designers previously envisaged.[6] Many people are talking of 50 years and more. This will require more care in the structure itself and much better detailing of the external fabric and internal finishes, including the building services. This is especially true with respect to the replacement of various parts of the building, either from changing architectural fashions, or technological advances in services.

The cost of the modern building is growing ahead of general inflation. In Melbourne the published cost increases between 1978 and 1988 were consistently higher than the consumer price index by a factor of between one fifth in 1978 to over one third higher in 1988.[7] This is a result of a number of factors, including increases in wages in the building industry, generally amongst the highest in industry - a crane driver today can expect to receive well in excess of $500 gross per week, compared to the average wage rate of $280 per week. The increase in materials has also been high during this period, especially components with high labour content.

A further area of high cost is in the building services. The growth of the "intelligent" or is it now "smart" buildings, is both a cause and a result of this increasing cost. The growth of the use of computers, facsimile machines, highly advanced telecommunication systems, security systems, high speed elevators and/or personnel conveyor systems, airconditioning systems and high quality lighting are all adding to the cost and complexity of our buildings. Many of these services are linked to central computers which monitor the state within the building at all times.[3] Computer programmes supplying simple information as to whether the equipment is running, through to knowing a person is in the building, their whereabouts and then controlling the lights, airconditioning and even the elevators to suit, reducing the use of building services to the minimum, are now readily available.

A number of steps have been taken to try and contain the rising costs. These include more efficient construction methods ranging from jump forming service cores, to a greater use of precast concrete, especially in industrial situations. Currently it is rare to see standard brickwork in either commercial or industrial building facades. Other changes include better management techniques and greatly improved financial planning. The growth of cost planning for efficient building designs reflects this trend. The use of computer modeling is a growth field only at the periphery of what will occur in future years.

With all the effort and money being put into the planning and construction of our buildings, there is still insufficient emphasis being given to building maintenance.

3. Maintenance

Maintenance falls into several different categories. These are:

- Regular service maintenance,
- Periodic running maintenance,
- Long term replacement maintenance

and the one we would all hope to avoid,

- Crisis or emergency maintenance.

3.1 Regular Service Maintenance

The first of these is straightforward. Regular service maintenance includes the supply of toilet paper, soaps, regular cleaning of floors, rubbish removal and the tasks that affect day to day running of the building.

This type of maintenance is gradually being computerized, including the fitting of sensors to equipment to register a fault condition - a dispenser out of paper, waste bins full, or hand driers not operating. Purchasing, scheduling and staff wages can be computerized and there are any number of computer programmes available for this type of work.

3.2 Periodic Maintenance

This is planned maintenance of existing equipment. It can be readily computerized and there are a number of programmes available to permit notification as to when this periodic maintenance is due. This includes such areas as cleaning or changes of filter for airconditioning systems, greasing or oil changes. It should extend to checking such items as door locks and handles, toilet cisterns, light tubes and the numerous other myriad items which wear out within a building.

3.3 Long Term Maintenance

This should include the plan to replace specific items when their economic life is expended. A simple example is fan bearings. It is possible to estimate fairly accurately the life expectancy of a given bearing, emergencies excepted. A good replacement programme, devised and maintained, will, in the long run, save money. All too often, if the economy calls for savings, it is in the maintenance arena. A poorly serviced airconditioning system will result in poor performance of the plant, usually increasing running costs, increased noise and a lowering of the efficiency of the system - running hot or cold.

3.4 Building Fabric Maintenance

As well as machinery maintenance, the building fabric requires maintenance. This area receives even less consideration than the internal systems. A typical situation has occurred with the Sydney Opera House. The sails , which form the roof, are covered with tiles. These are mounted on a frame on top of the concrete sub-frame. There was no provision built into the Opera House during construction to permit regular inspection of the roof covering or its sub-frame.

A number of problems have arisen with the concrete structure elsewhere in Opera House. The generic term of "concrete cancer" is often used for these problems. That is a break down of the concrete, generally through degradation of the steel reinforcing, with the resultant expansion of the steel during rusting, forcing the concrete surface to delaminate. The Opera House is basically sitting in the water of Sydney harbour with some salt content. A lack of correct specification during construction - today we would use a much denser concrete and possibly a different reinforcing - epoxy coating perhaps - and more importantly virtually no maintenance of the concrete since its construction, has led to a situation where $A80 million dollars is being spent, to repair the existing condition - excluding the roof. It has been estimated that a further $A80 million dollars will have to be spent every five years to maintain the building, not allowing for any improvements or upgrading of the facility. Back to the roof.

It was decided in 1987 that it was essential to inspect the whole of the sail area, to locate faulty tiles and replace them. No provision had been made to do this in the original design. Considerable research and money went into developing a special remotely controlled devise to travel over the roof and permit human access. There is only one draw back. During the first trial use of the machinery, it was found that the damage which had occurred to the sub-frame and the tiles was such, that the sails would not take the load of the device. It has now been moth-balled indefinitely.

Nauru House, Exhibition Street, Melbourne.

Another example, which is all too common around the world today is the degradation of precast facade panels. In this case it is Nauru House in Exhibition Street Melbourne. The panels were acid etched to provide the desired finish. Today there are a large number of these panels which require replacement. The panels have delaminated and the reinforcing has become clearly visible. The original cost of the building in the 1970's was some $80 million dollars. The present quote for repairing and replacing the facade panels as appropriate is at least that value. The Nauru Government is repairing the panels where possible as the money is not readily available for wholesale replacement.

3.5 Crisis or Emergency Maintenance

This is where machinery or other items break down unexpectedly and require immediate service or replacement. Failure of a door closer, or the tripping of a circuit breaker being but two examples of this problem. No amount of pre-planning will eliminate all these problems, but it can kept to a minimum.

4. Early Warning Systems

As a method of providing an early warning of problems with the building, sensors can be built into the fabric. These should be installed in exposed concrete units and can detect early changes in the conductivity of the concrete and any signs of electrolysis developing in the panels. Not every panel requires the sensors, but those most exposed to the prevailing weather and at points around the building which may be subject to specific problems - in the Sydney Opera House this would include the area around the lower concrete structure in the vicinity of the harbour waters.

Similar sensors can be placed in strategic points around glass clad facades to detect early signs of moisture penetration. These could have been installed in the roof spacing of the Sydney opera House. When combined with the use of robots as discussed below, these would have picked up the problems when they first started to develop, permitting quick, and certainly much cheaper repairs.

The sensors should be connected to the central monitoring computer.

5. Robotics

Robotics are not new in the building construction industry. They are widely employed in off-site operations as in most manufacturing processes. What is new is the use of Robotics on the construction site. Robots used in industry fall into two categories. The first is generally the pre-programmed unit which is typically installed on the production line and has specific pre-set movements. They may carry out simple operations - spot welding of window frames, to quite complicated operations which require a number of sensors to permit delicate movements, such as picking up glass products.

The second type is the remote hand controlled unit. At the 6th Annual Conference held in San Fransisco in 1989 we were shown the concrete finishing machine being developed by Shimizu Corporation of

Japan, and then undergoing evaluation at the University of Texas in the United States of America.

We were also shown other developments include robots designed to be mounted on the outside of a building and guided over the surface to inspect the condition of the facade cladding - glass seals, ceramic tiles and similar items. There are at least two such robots now under development, both suspended by cables from the roof, but able to move over the surface by use of suckers onto the surface.

A further development by Kumagai Gumi Co. of Japan is the facade painting robot. This is basically a suspended unit which is able to move over the surface, including quite complex shapes and applies an even coating to the surface. A similar robot can be employed to clean the facade.

Thus the modern building will be able to make use of these remote devises in their initial design. The need for suspended scaffolding devices for facade cleaning and general inspection may soon be superseded by these mechanical devises.

6. Computer Aided Drafting (CAD)

Another area of automation is the development of computer aided drafting. Whilst well known in architectural offices for the initial design/construction drawing from architects to the engineering requirements, owners are now taking the use of CAD one step further. They are now taking the original CAD programme for their building and including all the various alterations for future reference. A typical use is the relocation of partitions. Most offices change their layouts a number of times during the life of a building. Each move will involve some new penetrations to the slabs and even to fixed internal walls. It is much cheaper and quicker, as well as better for the structural integrity of the building to reuse as many of the existing holes as possible. A.M.P. Assurance,[2] one of Australia's largest insurance companies and property investors, is making use of this facility, not only in their new buildings but have an active programme of putting all existing buildings onto CAD, thus giving them instant access to a vast arrange of information about their buildings.

They have taken the next step and have devised a computerised data base which will replace the old card system, detailing every action taken on any building. This will cover every piece of machinery, type, brand, maintenance items and so forth. Eventually this will permit widespread comparisons across all buildings. It is anticipated that the reliability of specific items of equipment from toilet paper dispensers to major airconditioning plant will be instantly available. This data will then be incorporated in new projects, gradually eliminating the inefficient items from the building, with the obvious economic advantages.

7. Summary

The increase in the size of our buildings and the need for a longer economic life, requires that the building by maintained in its optimum condition. The use of remote sensors linked back to a central monitoring computer will provide early warning of developing problems, permitting early detection and much cheaper remedies, than currently possible. The use of remotely controlled robots permits inspections of areas, such as the facade, which previously were either inaccessible or if accessible were both difficult and expensive.

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