Low-Cost Maintenance Approach to High-Rise Buildings: A Critical Appraisal of Low-Energy Refurbishment Scheme in Birmingham

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Abstract: *During the 1960's a significant number of high-rise and medium rise walk-up blocks have been designed and constructed using prefabricated concrete cladding systems. It was estimated that a total of 6535 blocks were built in the UK; 848 blocks were built in the West Midlands; this counts for one eighth of those built in the UK as a whole. Most of these blocks were characterised by inferior quality material and poor workmanship, poor supervision and inadequate environmental services which subsequently deteriorated to a state of disrepair. The main culprits were condensation, water ingress and cold bridging effects due to low energy efficiency standards and lack of thermal insulation. At the end of their life span it was initially contemplated that these problems could be remedied by adopting a more 'high-tech' sophisticated components of composite cladding methods, and highly automated environmental services to improve the operational efficiency and optimise their long- term durability and life-cost cycle.*

However, the cost of these components has proved to be higher than expected and beyond clients' affordability. Attempts to optimise these buildings to meet the requirements of today's users and the current Building Regulations required rethinking of the whole process; therefore an alternative cost effective maintenance and energy efficient approaches need to be developed.

In an effort to address these issues this paper is being set out to investigate and critically evaluate the modus operandi of low-cost maintenance and refurbishment approach to high-rise buildings in Newtown South Aston area in Birmingham.

It is anticipated that this paper will highlight issues for open discussion amongst planners, decision makers and facilities managers that might increase the level of understanding and awareness between all those involved in the process of maintenance and refurbishment of buildings.

Keywords: Low-cost maintenance, Low-energy design, high-rise, refurbishment, cladding, whole life cycle costing.

1. Maintenance of Buildings

Maintenance of buildings is an invaluable process and plays an integral role in the design and construction of buildings. Its primary aim is to retain the value and the quality of a building as a place where users/occupiers can perform to their full potential The condition and quality of buildings in our built environment is so important to retain such value. This derives from the need to preserve the utility of buildings to the wider range of users activities and functions. Buildings which support individuals' needs socially, psychologically and intellectually is more likely to enhance performance; optimise efficiency and empower users to achieve their full potential and will be in greater demand.

It is obvious that real assets investment value relies primarily on supply and demand; in the absence of demand a building has no value to be maintained and neither the initial cost nor the standard of maintenance has any economic significance. Such a vicious circle If such a demand is established and any attempt to retain these assets should take into account the long-term financial consequences, occupational cost, running cost amongst many others and should not be based solely on initial costs.

The total costs of owning and using asset over its predicted life span can be calculated as below (Lee, 1995).

$$LCC = Ic + (Mc + Ec + Cc + Oc) + (Vc) - Rv$$

Ic = Initial cost,

Running Cost (Revenue Expenditure)
Mc = Maintenance costs,
Ec = Energy costs,
Cc = Cleaning costs,
Oc = Overhead and management costs,

Vc = Occupational Costs,
Rv= Resale value.

When such a demand exist, much of that will be affected by the quality of building design, specifications and durability of materials as much as on the level of energy and services cost which in turn determine the type and level of maintenance requirements. This particularly true in high-rise buildings. They represent a significant part of our building stock; they are valuable assets in our built environment.

It was estimated that a total of 6535 blocks were built in the UK; 848 blocks were built in the West Midlands; this counts for one eighth of those built in the UK as a whole. However, some of these blocks were characterised by inferior quality material and poor workmanship, poor supervision and inadequate environmental services which subsequently deteriorated rapidly to a state of disrepair. The main culprits were condensation, water ingress and cold bridging effects due to low energy efficiency standards and lack of thermal insulation amongst many others. Lack of maintenance and inadequate Routine inspection and repair have exasperated these problems further.

There are plethora of studies which have highlighted the gravity of the problems. Some of socio-economic repercussions including urban degeneration, dissatisfaction, social distress, vandalism and crimes amongst many others (Derbyshire, 1993; Lee, 1995) The knock on effect of such distress has led to a rapid depreciation of the actual value of the asset, creating unhealthy and most certainly unfit environment for human habitation; some of these building have to be demolished as they become unsafe and hazardous to the occupants. So what can be done to resolve these problems? What measures can be undertaken to optimise their asset value? What benefits can level of maintenance and energy efficient measures bring about and how can these be harnessed to reduce maintenance and energy cost? What roles can award authorities; investors, clients and occupiers play in achieving these objectives. It is anticipated that this paper will be focused on some of the key issues related to low–cost maintenance and low-energy design measures for the high rise.

1.1 Life Cycle of High-rise Buildings:

There is no clearly defined data about high-rise residential buildings but one can extrapolate from the many observations on high-rise buildings. Some rough estimations can be arrived at as shown in table 1. Clearly the range of average life span of the high rise varies considerably between countries with the highest in Britain and the lowest in Japan.

<table>
<tr><th>New Zealand</th><th>Australia</th><th>Britain</th><th>USA</th><th>Japan</th></tr>
<tr><td></td><td></td><td></td><td></td><td>20 Years</td></tr>
<tr><td></td><td></td><td></td><td rowspan="2" colspan="2">35 Years</td></tr>
<tr><td>50-60 Years</td><td>50-60 Years</td><td>60 Years</td></tr>
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Table 1: A *comparison of life cycle of high-rise buildings in different countries*

When a high-rise like any other building type building fail to respond to change either become redundant or obsolete which could be described primarily as physical, functional and financial; this might justify the need for a new building. This may occur particularly when maintenance cost becomes exceedingly greater than new construction cost. In establishing which course of action maintenance and facilities managers mangers have to work closely with other built environment professionals to assess the financial viability of new build; a meticulous cost- benefit- analysis is needed, this is based primarily on the capital Value of the cleared site for its best use less the cost of demolition and new construction. Otherwise they might decide to adopt a major improvement /renovation programme which will be measured in terms of the capital value of existing building and site minus the cost of conversion. In this case such major improvement would entail to bring the building to an acceptable standards.

Clearly there are no absolute standards, which would be equally acceptable, to every over a period of time. The fact is a high-rise building was initially designed and built at lower standards then the standards acceptable at the time when improvement carried out will be more likely to be higher than the initial design standards. There must be an element of improvement to justify such undertaking. It can be argued that such improvement should be performed to bring every part of the building to currently acceptable standards and new way of thinking in the 21 century, which would minimize future maintenance cost.

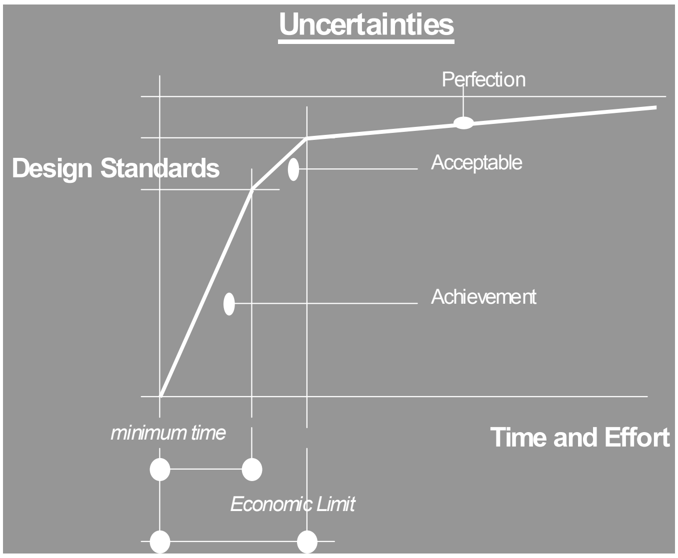

Figure 2: Acceptable vs. achievable standards

And increase the life span of the building considerably. This is particularly true given the end users and occupiers, mainly families who should be entitled to a humane environment as their right regardless of the added value such improvement might bring about.

Figure 3: High-rise has been demolished due to a higher value of the site.

2. Low-energy High-rise Buildings:

What constitutes Low-energy design or eco-design attributes? How are these manifested in high-rise buildings?

In Britain, the term low-energy design is much more widely used and is generally synonymous with the term eco-design. The emerging notions of 'eco-design' and 'green building' have received much greater publicity recently amongst many practitioners (e.g. architects, building surveyors, estate and facilities managers). This has echoed many descriptive and evaluative building studies over the last ten years or so (Evans, 1990; Forman, 1994; Brookes, etal, 1993; Stuart, etal 1993; Birkeland, 1996). However, these concepts are as old as the Greek atrium and Roman baths.

Figure 4: High-tech cladding has a higher capital cost value and might prove difficult to maintain.

There is no widely accepted definition of what constitutes a low-energy design solution, but it is commonly agreed that there is a wide range of eco- design characteristics and *ad hoc* environmental attributes which can be identified, depending on the building type (e.g. residential, commercial, office buildings); the usage of the building and the quality of technical services needed to sustain a building to an optimal level of performance (Logan, 2002).

These low-energy design characteristics might include some or all of the following, inter alia,

- Greater reliance on natural means of ventilation including chimney stacks, venting and cooling surfaces.
- Optimisation of natural heating and cooling methods such as thermal mass, solar heating and radiation, ventilated cladding.
- Efficient usage of natural and artificial lighting.
- Flexible use of the building spaces and resources and easiness of upgrading of the building envelope.
- Reuse and recyclability of building materials.
- Use of energy efficient materials and better specification.

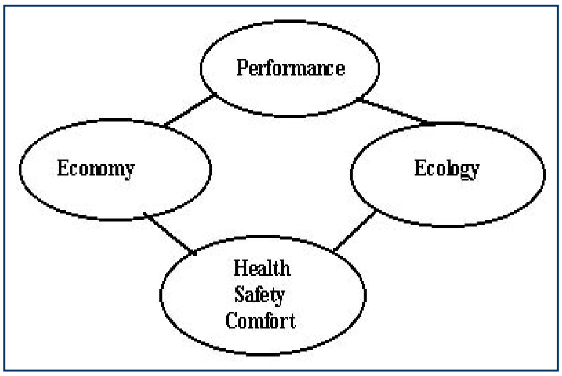

Figure 5: Objectives of low-energy design buildings.

To what extent can these characteristics be incorporated in the renovation of high-rise residential blocks? How can these be effectively achieved at low maintenance cost? What impact they have on the envelope and environmental requirements of the building? This is given that they are the most likely to change to meet different building Regulations?

2.1. External Envelope:

The external envelope of a high rise building should be designed to provide an efficient wall-to-floor ratio as this will influence not only the initial cost of the building but also its performance over time with regard to maintenance, running cost including heat losses and cooling. The wall-to-floor ratio is aimed at maximising the amount of floor area contained by 1 m2 of wall. Buildings, which are long and thin in plan, tend to have a high wall-to-floor ratio and consequently can be expensive to build and to operate as compared with tower blocks. This is almost entirely the case with Walk-up Blocks as compared to Tower Blocks (Clarke, 1990).

It is well documented the external walls of these blocks is of a higher U-value. This is particularly true in concrete infill panels with various finishes and U-values of 0.90-1.10 W/m2 K, which contribute to excessive heat losses.

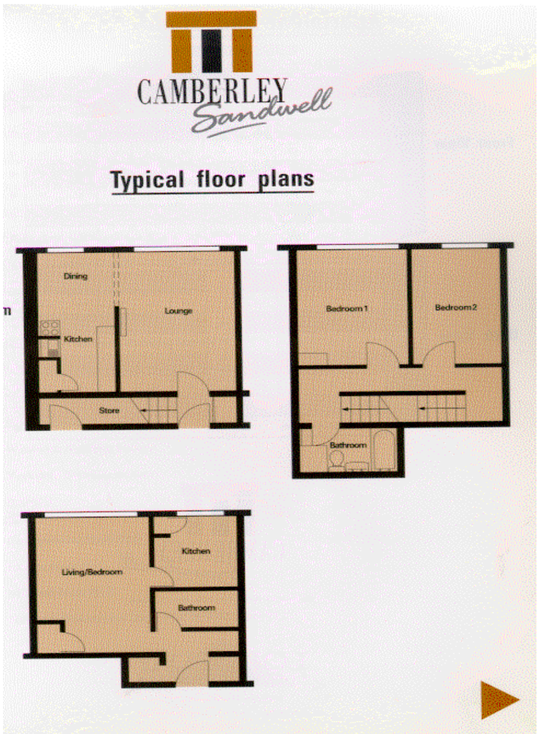

Figure 3: Tower blocks are more compact and have less floor-to walls ratio

Therefore any attempt to renovate the external fabric should aim to achieve affordable heating together with an improvement in energy efficiency at a U-value of 0.50-0.60 to keep it in line with the Building Regulations so that the fabric will be maintained at temperature and humidity that will prevent its deterioration[1]. This will equally reduce the chance of cold bridging and minimise the risk of mould growth and the likely health problem associated with it. Double skin façade can achieve a whole

[1] It is has been argued that the cost of upgrading thermal insulation by internal dry-lining is one quarter of the cost of cheapest external insulation but it is difficult to achieve suitable U-values (Clarke, 1990)

range of benefits and acts in tandem with other environmental aspects including improvement in building acoustics, allowing access for maintenance as well as improving the thermal performance of the building with a wider implications to level of thermal comforts.

However, thermal performance of double skin façade is highly affected by a whole range of factors (Williams, 2002).[2] Which is beyond the scope of this paper.

It becomes imperative that in any conversion scheme much greater emphasis should be given to take into account these factors to upgrade the average thermal performance of the external fabric to at least new-build standard and where possible higher.

2.2. Environmental Requirements:

A window is an important part of the design of the external skin of most buildings including high rise, for it needs to provide good outlook with comfortable conditions without glare or draughts. Many of the high-rise buildings were constructed using large concrete panel systems with relatively larger window sizes, most of which are single glazed within a metal frame. Whilst the main intention was to design windows for natural ventilation very little attention has been made in many high-rise developments to avoid excessive draughts, heat loss, excessive background noise level and discomfort.

The current Building Regulations stipulate that an external wall has a U- value of 0.45 W/m2 K. This can be achieved in a variety of ways including double glazed opening windows and insulated spandrel panels. Although the initial cost of providing a high performance external wall may be more expensive, it can provide cost benefits over the life span of a building.

The design of the external skin itself can provide high levels of insulation; it is also possible to improve its performance further by providing sun screening on exposed facades and highly glazed areas.

The most vulnerable facades for solar gain in building on sites in Britain are those facing south and west. Facades facing east are less susceptible to solar gain. However, there may be conditions on east-facing glazed facades where glare is the problem.

The design of external screening should take into account the elevation of the sun, which will be high in the sky on the south and require horizontal screens, whilst vertical screens are more appropriate to provide protection from the lower sun angles, which are experienced on the east and the west.

[2] Width of the skin. Shading. Air flow. Heat transfer. Absorptive and reflective qualities of the glazing and structural members. Orientation. Direction of prevailing winds. Mode of operation.

3. The Case Study:

Many technical and environmental problems have been identified as the result of the use of concrete in high-rise buildings, together with some design faults which will be examined, along with a critique on their impacts on the occupants of the high-rise.

Most of the high-rise blocks in Newtown South Aston in Birmingham were constructed with a reinforced concrete frame and floors and large concrete infill panels. Some were poorly built and defective. Poor workmanship can be attributed to poor quality, or inferior quality materials and construction detailing. For instance, poor insulation, incorrect use of the panels and defective sealant have led to subsequent problems of moisture and water logging.

Other technical problem related to roofs, walls and windows have been identified including the incompatibility of materials in the construction of walls and roofs, condensation, mould growth and leaking roofs. Windows were single glazed in steel frames. These problems have resulted in the present-day need for the refurbishment of the housing stock of the city. However the decision was solely based on two main factors.

Firstly to cater for new users requirement and to improve the performance of the tower block spatially and environmentally to meet the current building regulation requirement. Adaptability of the design layout to accommodate current users requirements and expectations was the main priority and hence different users groups were encouraged to be actively involved and participate in the early discussion, developing and refining internal design brief. Several design ideas about how best to cater for new requirements were explored and alternative layouts were developed accordingly which subsequently assessed leading to best- fit design layout.

3.1. The Roofs:

Most of the roofs of the tower blocks are slabs of pre-cast concrete, usually with an insulating agent bonded to their underside and covered by a waterproof membrane, usually of asphalt.

It has been suggested that the life of any flat roof is limited to around 10-15 years, which determines maintenance cycle. In high-rise building, problems have occurred mainly due to the effects of thermal movement; the slab moves at a different rate to that of the bituminous asphalt covering, therefore encouraging the separation of the slab and its covering allowing the ingress of water, the freezing of which can further split the waterproof membrane. On many of the low-rise maisonette blocks flat roofs have been replaced with traditional tiled pitched roofs, which are considered to be longer lasting; the pitched roofs are more aesthetically pleasing than flat ones and of longer life span.

Whilst the addition of pitched roofs to tower blocks would enable them to become, “primary, city-wide landmarks which can also enhance the area’s legibility and quality of ambience such improvements would create difficulties in the management and maintenance of pitched roofs at such a height. In other words, the pitch would have to be sufficiently high so as to allow the accommodation of lift gear, which is usually placed on the roof of high-rise blocks. On the refurbished units in Newtown, roofs have been left flat. The roof finish was stripped back and new vapour barrier and thermal insulation was added on the top to give a U-value of 0.40 W/m^2 K. This has been re-covered by two layers of bituminous felt finish in a suitably strong, yet malleable waterproof covering.

3.2 External Claddings:

External concrete panels have been identified in literature to be a major source of concern in high-rise buildings (Hinks, 1992; Ransom, 1995). ”Currently, Birmingham City Council is carrying out structural tests on 150 tower blocks following the discovery of serious defects in some large panel system building [Martin, 1999]. It is evident from the case study that the large steel reinforced concrete panels making up the outer skin of many tower-blocks are anchored via metal fixings; many of which may have become corroded over the years, or were simply incorrectly used during initial construction procedures. This is together with poor thermal insulation associated with dense concrete.

This has led to cracking which is usually treated by raking out the crack, thus removing loose debris, and infilling with either powder concrete or, in some cases, a polymer sealant in order to prevent the further ingress of water. In some cases, the replacement (re-cladding) of a panel has been undertaken; this can cause difficulty where the panels have been slotted into one another during initial construction and, in the case of the Bison design, the rear of panels has been infilled with cast-in-situ concrete to improve insulation.

An alternative solution has been utilised on the Five Towers where an additional twin-block “skin” has been built up around the tower, with the window frame moved out flush with the new cladding. Not only has this improved the sound and the thermal insulation of the building, but it has also proved to be more aesthetically pleasing once completed. The disadvantage of such a method is that it is expensive and can create dust and debris harmful to residents, most of whom were in residence while such works were carried out. Clearly higher cost of decanting has led to such health and safety hazards and disruption to the daily life activities of the occupants?

When tower blocks undergoing re-cladding; a further disadvantage to such an exercise was demonstrated during an interview with a tenant, who stated that she had “lost all privacy, and had to keep all of the lights on because the windows were covered up, increasing electricity bills. Such temporary inconvenience should be weigh against decanting cost and health and safety of the occupants. Another tenant complained of being burgled as a direct result of the scaffolding erected around his balcony.

3.3 The Windows:

Many of the windows were delivered as an integral part of a wall panel and were made of metal bonded into the concrete panels. The window units themselves created a “cold bridge” (Barry, 1992). Being removed from the panels, to which they were bonded, would have caused irreparable damage. Therefore, the ideal time to replace the windows was when the new cladding was being built around the blocks. The windows in the Five Towers have been replaced by maintenance-free UPVC double glazed units providing a U-value of 2.9 W/m^2 K and up to 32db sound reduction; the fact that cladding has been added to the tower blocks on top of the original panels has minimised the problems caused by the removal of the original window frames.

All of the previously open balconies have been infilled with double-glazed, sealed windows providing sun space, thus preventing the escape of any heat, reducing the background noise level while further improving the safety and security of the building.

4. Discussion:

Whilst many of these buildings were constructed shown to be short-sighted and short-lived. What was considered to be modern, low-cost and low-tech public sector housing at the time has proved to be deficient highly inadequate to 1990's users expectation and aspirations. No doubt, lack of long- term vision was one of the most contributory aspect to such dilapidations. Cutting cost at the initial design and construction stages has led to significant increase in the long-term cost of replacing faulty components and running cost. This deemed many high-rise energy inefficient. it proved to be costly option and very exasperating to occupiers. To maximize energy cost-effectiveness, thermal insulation together with re-cladding or double skin cladding proved to be beneficial in providing solar gain reduction and reducing heating loss; hence enhancing overall thermal performance which has contributed to occupant's satisfaction and comfort levels.

Element	Before Refurbishment	After Refurbishment
External Walls	Concrete infill panels 0.90-1.10 W/m^2 K	Twin-block "skin" has been built up around the tower added U-value 0.48-0.60 W/m^2 K
Internal Panels	of pre-cast or cast-in-situ concrete U-value 0.82 W/m^2 K	50 mm rock wool added U-value 0.32 W/m^2 K
Roof	Pre-cast concrete, with an insulating agent bonded to their underside	Thermal insulation added U-value 0.40 W/m^2 K
Windows	Single glazed steel windows U-value 5.4 W/m^2 K	Maintenance-free UPVC double glazed units providing a U-value of 2.9 W/m^2 K and up to 32db sound reduction.

Table 2: Energy Efficiency Improvements

The case study demonstrates that the major problem areas with high-rise buildings are poor quality materials and poor specification of the external envelope which encompasses roofs, walls and windows.

Because incompatible materials were used to construct the roofs, mingled with the poor quality of the concrete used in casting the roof slab and lack of regular planned maintenance, this has resulted in the present-day need to replace roof coverings with materials more suited to the task. The problems affecting the walls were the result of the use of concrete inappropriate for the facing of high-rise buildings together with lack of thermal insulation; the concrete used allowed the ingress of water and condensation. This has led to dampness being experienced internally and the loss of the facing of the concrete sections externally.

The window frames used in nearly all high-rise buildings were made of steel, which itself creates a “cold bridge” resulting in considerable heat loss from the dwelling and encouraged condensation internally, yet the remedies have proved to be a low-energy orientated and long-lasting.

Controlling and optimising the use of energy through effective environmental management must be the priority, and in that, high-rise have a critical role to play in terms of the amount of energy they consume which affect energy cost. This is a collective responsibility which requires a holistic approach by the profession as a whole to increase the overall performance of the housing stock to an acceptable level. The cost of introducing these low-energy design features should be justified on the basis of long-term energy cost saving and reduction of failures, lower maintenance cost and possible increase in property value. However, one should bear in mind that the actual value of any energy- efficiency measure is frequently determined by the perception of different stakeholders, owners, users and the general public at large.

The accumulated evidence over the last two decades has shown that these building are more prone to rapid decay and deterioration which can occur due to condensation and water penetration mingled with poor thermal insulation. Whilst the refurbishment should ensure the use of these buildings for a further thirty years to suite the changing users’ requirements, it is debatable whether this will, in fact, happen. Such improvements however, should create cost-effective, yet a sustainable living environment which, at the very least, perform thermally, socially and aesthetically in tune with their immediate needs and expectations.

5. The Way Forward:

While tower blocks could be considered to be an unsatisfactory method of providing housing, their new fabric should be carefully maintained; a comprehensive planned maintenance programme should be introduced. No doubt, proper maintenance management and work planning will be pivotal to ensure economic and rational use of resources. A number of principles or guidelines can be recommended as follows:

I. Greater reliance on refurbishment based on well thought through design and suitable materials and methods of construction will be a safeguard in extending the physical life of high-rise buildings. This remains to be a viable option by careful consideration of user-friendly materials, optimisation of the current techniques, judicious construction detailing and much greater emphasis on the mix and the composition of the surrounding landscape and infrastructure.

II. Adopting a more holistic whole-life performance approach based on life cost cycle analysis is needed embracing an assessment of components specifications together with durability of materials towards more accurately predicting their life cycle. Anticipation of failures through routine monitoring and inspection will be a safeguard for maximising their life span.

III. Clarity and appropriateness of procedures for prevention and rectifications of defects as and when they occur towards minimizing overall long-term maintenance cost.

IV. Providing adequate resources, which can be proactively deployed including, *inter alia*, cyclical responsive and planned preventive maintenance to reduce the level of physical and functional obsolescence and any subsequent financial depreciation.

V. Encouraging users participation in the design and management of their own asset toward better appreciation which might promote greater awareness via changing general public perception and attitudes towards the high-rise.

After years of neglect and inner city blight, the high-rise can only regain its prominence in the skyline of our cities in Britain, retaining their utility and value and redefining their role as focal points or landmarks, which bring harmony and pride and regenerate inner towns and cities.

6. References:

Allard, R. (2001) “Get a Whole Life”, Building Magazine, 4 May 2001.

Barry, R. (1992) “The Construction of Buildings”, Vol. 4, Third Ed. BSP Professional Books.

Birkeland, J. (1996) “Rethinking the Built Environment”, Proceedings of the Catalyst ‘95 Design& Environment Conference, University of Canberra, 13-16 July, Centre for Environmental Philosophy, Planning & Design.

Brookes, A. & Grech, C. (1993) “The Building Envelope”, Butterworth Architecture. City Challenge Newtown South Aston, (1997)“Succession Strategy”. Birmingham Housing Department.

Cook,G. & Hinks, B. (1997) “The Technology of Defects”.

Clarke, D. (1990) “Domestic Low Energy: 3 High-Rise and Walk-Ups”, *The Architects Journal,* 4 April, pp 71-74.

Cullingworth, J. B. & Nadin, V. (1997) “Town and Planning in the UK”.

Fitzpatrick, T. (1997) “Tale of Tall Cities”, The Guardian, 6 Feb., Technology Online.

Fordman, M. (1994) “Case Studies: Queens Building at De Montfort University”, Unpublished Paper.

Glendinning, M. & Muthesius, S. (1994) “Tower Block”, Yale University Press, MIT.

Lee, R. (1995), “Building Maintenance Management”, Blackwell Science.

Logan, S (2002), “High Rise, Low Energy”, Building Services Journal, March

Martin, I. (1999) “Fears over Brum Towers”, Birmingham Post, p.8.

Ransom, W.H. (1995), "Building Failures: Diagnosis and Avoidance", E & FN Spon.

Stuart, J., etal (1993), "Greener Buildings: Environmental Impact of Property", MacMillan.

Harrison, H. W. etal, “Overcladding: External Walls of Large Panel System Dwelling”, BRE Report, Case Study No. 1, pp 52-53.

Williams, C. (2002) “All Rise”, Building Services Journal, March.

APPENDIX TWO

Pictures of the refurbishment of Briarley continued

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