A Structural Assessment Of
The Non-Traditional Tarran Houses
Owned By Rotherham Metropolitan Borough Council
In Maltby, Rotherham

For

Rotherham Metropolitan Borough Council
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By

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Date: December 2004

Amendment Record

Date	Description of Amendments	Comments
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06.01.05	Costs updated, appendices added & structural details added	Draft Issue 2
28.01.05	Privately owned property numbers amended	Draft Issue 3
18.02.05	Final Issue	Final Issue

Curtins consulting

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1.0 INTRODUCTION TO THE INVESTIGATION

Curtins Consulting Engineers were commissioned by Rotherham Metropolitan Borough Council on 1st December 2004, to undertake investigations of the council owned Tarran properties located in Maltby.

These investigations involved a combination of visual inspections and intrusive exploratory works in order to assess the current structural condition of the properties.

In addition to the investigations described above, consideration has also been given to the previously undertaken condition survey together with the comments made by The Audit Commission.

On this basis, costs and recommendations have been prepared in respect to the following alternative options.

a) Identify repair and upgrade works required for the properties to achieve full mortgageability status.
b) Also identify alternative repair schemes to achieve a limited form of mortgageable status. (A limited number of building societies are prepared to offer mortgages on properties with a life span of approximately 30 years.)
c) Identify repair and upgrade works required to ensure a life span of 30 years and satisfy the requirements of the Decent Homes Standard.

It is understood that there are 86 Tarran properties on the estate, 70 of which remain in the ownership of Rotherham Metropolitan Borough Council. The estate layout is shown in Appendix A.

2.0 INVESTIGATION STRATEGY

2.1 Background

A previous assessment of the condition of these properties was undertaken in February 2004, making recommendations on their future lifespan and need for repair. The report suggested that the external PRC structure should be removed and replaced with a new insulated cavity wall on extended foundations.

The purpose of this supplementary investigation is to undertake a more extensive and representative sampling pattern consisting of external visual surveys of all properties combined with intrusive surveys of void properties.

2.2 Methodology

The table below lists the properties where intrusive surveys were undertaken.

Street	***Property Nos***
Braithwell Road	59, 61, 63, ***65***, 69, 71, 73, 75, 77, 81, 83, ***85***, 87, 91, 93, 95, 97
Chadwick Drive	1, 3, 4, ***5***, 7, 8, ***9***
Newlands Avenue	***1***, ***2***, ***3***, 4, 5, ***6***, ***7***, 8, 9, 10, 11, 12, 14, ***15***, 16, 17, 19, 21, 23, 24, ***25***, ***26***, 27, 28, 29, ***30***, 31, 32, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, ***51***, 52, ***53***, 55, 57, 59

The properties where inspections were undertaken as part of this assessment are highlighted in ***bold italics.*** The site layout shown in Appendix A indicates the location of the council properties on the estate.

In all instances, intrusive investigations were undertaken within void properties to minimise disruption to tenants.

The present risk assessment is confined to consideration of the principal structural elements. The condition of non structural elements, such as doors, windows, guttering, rainwater goods, canopies, outbuildings and external fixtures and fittings, together with gas, water and electrical services, central heating, flues, bathroom and kitchen fittings and internal decorations are all excluded from consideration.

Opening up work to expose hidden elements was carried out in those areas considered most likely to be suffering from degradation or deterioration. The results obtained are used as the basis of the recommendations and are given as being representative of the stock as a whole. However, as the entire structural fabric of every building cannot be inspected, there is no guarantee that the worst or most aggressive areas of degradation have been identified.

Whilst sub-soil investigations were excluded from the investigations, small trial pits were dug to assess the size and form of the existing strip footings. Moreover, evidence of structural movement associated with foundation instability was recorded during the visual inspections, if present. Whilst many of the foundation solutions adopted at the time of construction would not comply with current standards, it is most likely that any settlement due to inadequate foundation size or depth would have already occurred. However, this does not exclude the potential risk of future movement, for example, as a result of flooding or drainage failure.

The structural risk assessments exclude items of a geotechnical and environmental nature.

No testing for asbestos has been carried out during the preparation of this report, nor any assessment, comment or testing for levels of toxic mould.

2.3 Background to Corrosion of Concrete in PRC

Deterioration associated with reinforced concrete elements relates to corrosion of the steel reinforcement and degradation of the concrete matrix either independently or as a result of the steel corrosion. Concrete is inherently alkaline and this alkalinity protects the encased steel reinforcement from corrosion. However, the protection can be reduced by the action of acidic gases present in the air (such as carbon dioxide and sulphur dioxide). This process is called carbonation. If the depth of carbonation is greater than the concrete cover surrounding the reinforcement steel, the risk of reinforcement corrosion increases, reducing the integrity of the concrete and leading to a reduction in structural capacity. The corrosion process can be exacerbated by the presence of high levels of chloride ion in the concrete. This was sometimes used during the construction process.

The following characteristics need to be assessed in order to determine the structural condition and future durability of the concrete.

- Chloride Content
- Cement Content
- Carbonation Depth
- Cover to Reinforcement

2.3.1 Chloride Content

The chloride content of concrete is measured by potentiometric titratiun in accordance with BS1881: Pt 124; 1998. A concrete dust sample is obtained by drilling a unit and collecting the material for analysis.

In total 132 concrete samples were taken.

2.3.2 Cement Content

The dust samples are tested under laboratory conditions to establish the percentage of cement by weight of concrete dust. This can then be used to express the chloride ion content as a percentage by weight of cement.

2.3.3 Carbonation Depth

The depth of carbonation in concrete is determined by spraying the surface of the drilled hole with Phenolphthalein indicator. This liquid turns uncarbonated concrete purple, such that the colourless zone can be measured to determine the carbonation depth.

2.3.4 Cover to Reinforcement

Electronic cover meters can be highly inaccurate especially when determining cover in relatively thin units that may be held in position with ferrous metal nails / screws. For this reason cover was established through opening up of the units and drilled holes.

2.3.5 Linear Polarisation Corrosion Rate Monitoring (LPCRM)

Curtins experience indicates that whilst high levels of chloride ion may be present in a concrete element, the rate of corrosion may not necessarily be high. Projections of remaining component life span using only the levels of chloride ion can therefore give pessimistic (i.e. short) results. A more specialist testing approach can be undertaken, which measures the actual rate at which the reinforcement is corroding. This allows a more targeted assessment of the future performance of the structure to be assessed.

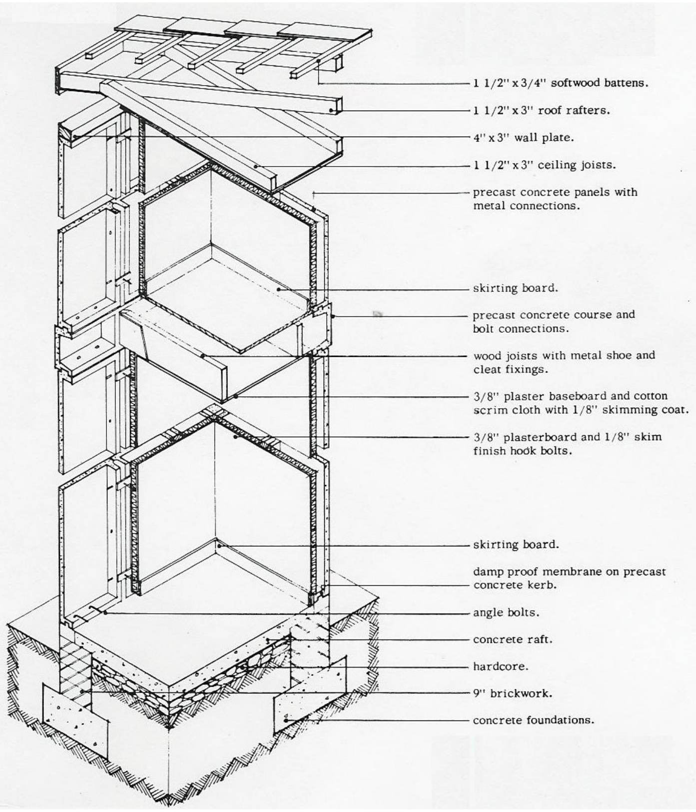
3.0 DESCRIPTION OF ORIGINAL CONSTRUCTION

3.1 General

Robert Greenwood Tarran, a building contractor in Hull in the 1930's, developed a modular building system of storey height concrete wall panels, which was adopted by the government in 1944 for use as temporary houses. Subsequently, the design was developed into a number of variants, including the Tarran Newland. Whilst the properties in Maltby are classified as Tarran houses, they should not be confused with one of the many variants developed by Tarran.

The Tarran Newland system is classified as defective by Part XVI of the Housing Act of 1985.

3.2 Structural Form



The Newland system of construction comprises precast reinforced concrete storey-height tray-shaped panels, which are joined by precast reinforced concrete columns at corners and party walls. Steel channel floor units are bolted together to form a continuous steel ring beam.

The panels and corner columns are clamped together and are located at ground level on precast reinforced concrete kerb units. At first floor level the steel channel ring beam is fixed to the upper and lower storey wall panels with hook bolts. Timber bearing plates are sandwiched between the ring beam and wall panels.

The vertical joints between wall components are caulked internally and mortar pointed externally.

At eaves level a timber wall plate is bolted to the panels.

The roof is a steel truss design constructed from steel angles. It is fixed down to the timber wall plate and is clad with profiled asbestos cement tiles.

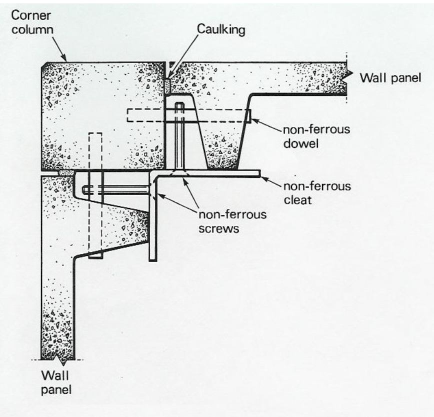
At first floor, the prefabricated steel-channel floor units span from the front and rear walls to the centre of the house where they are supported on tubular steel columns. Where the steel channels of the floor units abut other units, (ie. at the centre of the house over the support wall and at junctions between adjacent units) the back-to-back channels are bolted together to form an "I" section.

The floor therefore comprises a complete steel grillage with the periphery channels forming the ring beam for the external walls.

3.3 Overall Stability

The construction of a pair of Newland semi-detached houses is unusual insofar as two separate concrete box structures are formed by clamping together adjacent panels, which are additionally connected by the steel ring beam at first floor level and a wall plate at roof level. The stability of each house therefore relies upon the wall units remaining connected and forming a box, which will carry the vertical loading and withstand horizontal forces.

The steel grillage provided at first-floor level provides an effective diaphragm which should eliminate the possibility of local lateral failure of the walls, and will distribute vertical loads onto adjacent wall panels should individual panels become weakened by reinforcement corrosion.

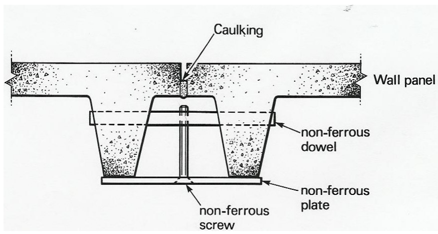


3.4 Corner Columns

The storey-height columns are reinforced with stirrups and four ¼ in. (6mm) diameter steel rods. Holes are cast in the columns to take the fixing dowels from the panels. The columns share the vertical loading with the panels but their prime function is to tie the corner wall panels together providing continuity to the external wall. If deterioration of the post occurs such that the continuity of the concrete box is lost, the steel ring beam at first-floor level and the wall plate at eaves level should prevent immediate further damage.

3.5 Panels

The reinforced panels are of a thin section and corrosion of the steel resulting in spalling and disruption of the panel will reduce its load-bearing capacity. Disruption of the concrete between the clamping members of the fixing could put the fixing under strain or if the concrete fails, the fixity could be lost.



3.6 Kerbs

The precast reinforced concrete kerbs provide support and location for the wall units. Disruption due to corrosion of the reinforcing steel could result in lifting or dropping of panels putting increased load on the fixings and causing distortion of the ring beam.

4.0 INVESTIGATION FINDINGS

4.1 Concrete

Generally the concrete elements were found to be in reasonable condition on all properties. Carbonation tests and reinforcement cover depth checks were undertaken on the concrete elements at each property. This revealed that the average depth of carbonation is between 0 – 10mm and is not greater than 15mm in any of the elements tested. This is not considered to be excessive, particularly given the age of the structure and suggests that the concrete is particularly dense. However, the cover to the reinforcement in a number of the existing concrete columns is particularly low and it is therefore considered that the carbonation front is at, or approaching the embedded reinforcement in a number of locations. Consequently, a number of the existing columns, particularly corner columns, were observed to be spalling as a result of corrosion of the embedded reinforcement. This corrosion has occurred as a result of the carbonation front reaching the reinforcement and it is considered that an increasing amount of reinforcement corrosion will occur with time, if appropriate repair works are not undertaken.

The analysis on the samples retrieved from the reinforced concrete elements found that the chloride ion content varied between 0.6% and 1.1% as a percentage of the total cement content, with an average content of 0.75%.

In accordance with the Building Research Establishment (BRE) Digest 444 Part 2, it is possible to assess the risk category of corrosion to reinforcement, which is dependent upon chloride content, carbonation depth, environment and concrete cover (Figure 4 in BRE Digest 444 Part 2 refers). *In this instance, an average chloride content by weight of cement less than 0.6% is not considered to pose a significant risk of corrosion of the reinforcement. Chloride levels up to 1.0% can be tolerated, providing the concrete remains dry. It is therefore considered that the levels of chlorides recorded do not present a significant risk of corrosion of the reinforcement.*

On the basis of the above, it is considered that deterioration of the concrete frame is attributable to a combination of the reinforcement being displaced or poorly placed during the original construction and variability of the concrete mix. As a consequence of the reduction in the alkalinity of the concrete through carbonation, corrosion of the embedded reinforcement has begun.

The present state of corrosion is not considered sufficient to materially affect the overall stability of the structures providing steps are taken to stabilise the environment surrounding the PRC components.

4.2 Trial Pit Excavations

Trial pits were excavated to expose the foundations at four properties to establish their depth, dimensions and condition, together with condition of the underlying strata. The excavations at 5 Chadwick Drive indicate that the foundation is approximately 150mm deep and the formation level is approximately 400mm below ground level. The remaining excavations at 6 Newlands Avenue, 7 Newlands Avenue and 85 Braithwell Road indicate that the external walls are built off the existing rock strata.

The British Geological map sheet 100 indicates that the underlying stratum is the Lower Magnesian Limestone overlain by boulder clay.

4.3 Linear Polarisation Corrosion Rate Monitoring (LPCRM)

Linear Polarisation was undertaken in three locations on all void properties listed in Section 2.2, namely the corner post, lintel and wall panel. The tests indicated that the embedded reinforcement is in reasonable condition and that the rate of corrosion is in the region of 0.1mm per year, which is considered to be low.

Where the concrete cover is particularly low and corrosion of the reinforcement is currently ongoing, it is not practical to measure the rate at which corrosion is occurring.

The full LPCRM report provides full details of the tests undertaken on site and can be found in the appendices of this report.

5.0 RECOMMENDATIONS

5.1 Present Condition

These investigations indicate that the properties have remained in a safe structural condition to date. Evidence of concrete spalling and reinforcement corrosion is apparent to some corner posts and wall panels. This is considered to be attributable to a combination of the reinforcement being displaced or poorly placed during the original construction and variability of the concrete mix.

Further investigations of the embedded reinforcement suggest that the rate of corrosion is low. Therefore, providing the concrete is kept dry, the structure should continue to perform adequately if they are to be retained.

Foundations exposed during the investigations do not meet current standards with respect to depth, width and quality of concrete. In some instances, the external walls are built directly off the existing rock strata. However, they appear to have performed adequately to date without showing signs of differential settlement. Continued long term performance cannot be guaranteed as they could be affected by flooding, drainage failure or by the addition of extra load from a change in wall construction.

There are localised, non structural defects that any refurbishment works should address. These include localised deterioration of timber fascias, window units, door frames and rain water goods.

On the basis of the investigations undertaken, it is considered that the properties are in reasonable condition but have begun to deteriorate. Whilst the test results indicate that the concrete is in reasonable condition, it is clear that there are a number of areas where poor quality construction techniques could cause further reinforcement corrosion. Consequently, it is considered that as further moisture ingress occurs, so the number of instances of reinforcement corrosion will occur. It is therefore not possible to guarantee the future performance of these properties without undertaking repair works.

5.2 Recommended Repairs

Based on the results of these investigations it is considered that providing the concrete is kept dry, these properties will continue to provide a safe structural life for a further 30 years. However, there are a number of options for increasing the useful life of these properties, depending upon the level of repair required.

5.2.1 Full Mortgageability

The nature of the existing construction is such that none of the major lending institutions will provide a mortgage on these properties in their original condition. **In order to obtain full mortgageability on these properties, it is necessary to undertake a PRC licenced repair scheme, such as PRC Licence Repair Scheme 081, designed specifically for the repair of Tarran houses and intended to attract the widest range of mortgage providers.**

Typically, these schemes involve the removal of the existing PRC frame, which is replaced with a traditional cavity wall construction, thereby guaranteeing a future life in excess of 50 – 60 years.

Whilst these repair works will ensure a future life of the properties in excess of 50 – 60 years, they are reasonably complex and dictate that alterations are undertaken to existing drains, foundations, rainwater goods and services. It is usually necessary for tenants to be relocated temporarily during such extensive works.

5.2.2 Alternative Mortgageable Repairs

Rather than undertake a full PRC licenced repair scheme, it is possible to achieve a more limited mortgageable status by adopting a reduced repair specification. Curtins Consulting, together with panel of three consulting engineering practices, prepared the Non Traditional Homes Appraisal Scheme (NTHAS), in conjunction with some of the major lending institutions. This aimed to repair non-traditional properties in an appropriate and cost effective manner, by considering the current condition of the property.

Generally, NTHAS involves extensive testing of the existing concrete to verify its condition and implement appropriate repair works. A statistical analysis of the results is undertaken to ensure that a 95% confidence level can be guaranteed. These results are then compared with the five pre-determined repair categories designed to achieve a minimum 30 year life expectancy.

From the results of these investigations, the properties fall into NTHAS Category 4, which dictates that the PRC elements should be removed, in a similar fashion to the repair scheme described in Section 5.2.1 above. **It is therefore considered that an NTHAS repair solution offers no benefit in this instance.**

Whilst the PRC Licenced Repair Scheme and NTHAS are generally recognised as mortgageable repairs, some lenders are now willing to provide limited mortgages on overcladding schemes that retain the existing PRC elements. Basically, the scheme requires that a bespoke repair solution is developed and offered to CU2000 Insurance Providers, to ensure that they are satisfied with the proposed repair scheme. Providing the repair scheme is approved, a CU2000 insurance policy is granted on the scheme in a similar fashion to NHBC, and a number of lenders will normally provide mortgages at restricted rates. Whether or not mortgages are taken up, the repair scheme is intended to provide a life of at least 30 years but with the likelihood of a much longer life.

In addition to the installation of an overcladding system, it will also be necessary to undertake various internal upgrade works to ensure the internal PRC elements are also kept dry and warm. These include new double glazing complete with trickle vents and appropriate ventilation to toilets and bathrooms.

5.2.3 Decent Homes Repairs

The following section provides a brief overview of the application of the Decent Homes Standard to the Tarran Newland houses in Maltby, and is based on the findings of Curtins intrusive and visual inspections only. For further details of the general requirements of the

Decent Homes Standard, refer to Section 6.0.

Given that Curtins investigations were undertaken within void or decommissioned properties, the comments made should be used as guidance only. Clearly, void properties will not satisfy the requirements of the Decent Homes Standards.

It is considered that in their current condition, the properties satisfy the structural requirements of the Decent Homes Standard. However, it is considered likely that within the foreseeable future deterioration of the frame will occur to such an extent, that the properties would no longer be considered structurally stable and would subsequently not satisfy the requirements of the standards. It is therefore recommended that the concrete elements should be kept dry and warm to avoid further deterioration of the frame.

If mortgageable status is not required, the overcladding specification can potentially be reduced, thereby reducing costs. In order to satisfy the Decent Homes Standard, it is recommended that an insulated over render system be applied to the properties.

The provision of an insulated render system will clearly also improve the thermal performance of the properties.

The standards offer guidance on the nature of the heating systems adopted within properties and the associated levels of insulation required. It is recommended that the council review its records to determine the nature of the heating systems provided within these properties. It is considered however, that the provision of an insulated render system should provide sufficient insulation to satisfy the requirements of the standards.

In addition to the above considerations, it will also be necessary to consider the condition of facilities such as kitchens, bathrooms, heating, electrics etc and determine if these need replacing to satisfy the Decent Homes Standard. The assessment of these facilities is considered to be beyond the scope of this report. However, for the purposes of preparing budget costs, it has been assumed that the following works will be undertaken, as used within the original condition report.

- Replacement / Upgrade of Central Heating System
- Replacement Kitchens
- Replacement Bathrooms
- New External Doors
- New Windows
- Electrical Re-wire

5.2.4 Demolition

In addition to costs for the repair works recommended above, consideration has also been given to the costs of demolishing the properties. The costs for buy back of properties where tenants have previously exercised their Right To Buy and now own the properties, are considered to be beyond the scope of this appointment. Preliminary demolition costs are included in Section 7.0.

6.0 DECENT HOMES STANDARD

The following section provides a brief interpretation of the requirements of the Decent Homes Standard. This section is intended as guidance only and any recommendations made to comply with the Standard, with the exception of those relating directly to the structure, are considered beyond the scope of this report.

Requirements of the Decent Homes Standard

The government has established a target to *"ensure that all social housing meets set standards of decency by 2010, by reducing the number of households living in social housing that does not meet these standards."*

The Decent Homes Standard is a minimum standard that all social housing should meet by 2010. However, landlords are not expected to make a home decent if this is against a tenant's wish.

It should be noted that landlords are not expected to undertake only that work which contributes to making homes decent, and should address elements not considered within the standard but may be considered high priority in some areas (i.e. environmental works, security etc).

A decent home is described as one, which is wind and weather tight and has modern facilities and should meet the following criteria, as outlined within the standards:

It meets the current statutory minimum standard for housing.

The current minimum standard for housing is the Fitness Standard (Section 604, Housing Act 1985 as amended). Dwellings deemed unfit under this legislation fail this criterion. In summary, the requirements constitute the minimum deemed necessary for a dwelling house to be fit for human habitation. They are that a dwelling house should:

- be free from serious disrepair
- be structurally stable
- be free from dampness prejudicial to the health of the occupants
- have adequate provision for lighting, heating and ventilation
- have an adequate piped supply of wholesome water
- have an effective system for the drainage of foul, waste and surface water
- have a suitably located WC for exclusive use of the occupants
- have a bath or shower and wash-hand basin, with hot and cold water
- have satisfactory facilities for the preparation and cooking of food including a sink with hot and cold water

The Fitness Standard applies to both houses and flats, but the legislation also states that flats can be considered unfit if the building, or part of the building outside the flat, fails to meet any of the following requirements:

- the building or part is structurally sound
- it is free from serious disrepair
- it is free from dampness
- it has adequate provision for ventilation
- it has an effective system for the drainage of foul, waste and surface water

The government intends to replace the Fitness Standard with the Housing Health and Safety Rating System (HHSRS), which will assess the health and safety risks in dwellings. The system is unlikely to come into force before 2005. Guidance on the use of HHSRS has been prepared by the Office of the Deputy Prime Minister, in order to assist landlords in the assessment of their housing.

It is in a reasonable state of repair

Dwellings deemed as failing to meet these criterion are those where either:

- One or more of the key building components are old *and*, because of their condition, need replacing or major repair; or
- Two or more of the other building components are old *and*, because of their condition, need replacing or major repair

Key building components are those which, if in poor condition, could have an immediate effect on the integrity of the building and cause further deterioration in other components. They are the external components plus internal components that have potential safety implications and include external walls, roofs, windows and doors, chimneys, central heating boilers, gas fires, storage heaters and electrics. If any of these components are old and need replacing, or require immediate attention or repair, then the dwelling is not considered to be in a reasonable state of repair and remedial action is required.

Other building components are those that have a less immediate impact on the integrity of the dwelling. If two or more of these components are old and need replacing, or require immediate attention or repair, then the dwelling is not considered to be in a reasonable state of repair and remedial action is required.

A component is defined as '*old*' if it is older than its expected or standard lifetime. The Decent Homes Standard offers guidance on component lifetimes to be used in the disrepair criterion.

Components are deemed to be in '*poor condition*' if they need major work, either full replacement or major repair. The Decent Homes Standard offers guidance on definitions of poor condition of various components, to be used in the disrepair criterion.

It should be noted that one or more key components, or two or more other components, must be both old and in poor condition to render the dwelling non-decent on the grounds of disrepair. Components that are old and in good condition, or those in poor condition but not old, would not, in themselves cause the dwelling to fail.

It has reasonably modern facilities and services

Dwellings deemed as failing to meet these criterion are those which lack three or more of the following:

- a reasonably modern kitchen (20 years old or less);
- a kitchen with adequate space and layout;
- a reasonably modern bathroom (30 years old or less);
- an appropriately located bathroom and WC;
- adequate insulation against external noise (where external noise is a problem);
- adequate size and layout of common areas for blocks of flats.

In some instances there may be limiting factors such as physical or planning restrictions that make improvements necessary to meet this criterion impossible. A dwelling would not fail this criterion where it is impossible to make the required improvements to components for planning reasons.

It provides a reasonable degree of thermal comfort

This criterion requires dwellings to have both effective insulation and efficient heating

Efficient heating is defined as any gas or oil programmable central heating or electric storage heaters or programmable LPG/solid fuel central heating, or similarly efficient heating systems that may be developed in the future.

Due to the differences in efficiency between gas/oil heating systems and the other heating systems listed, the level of insulation required differs.

For dwellings with gas/oil programmable heating, cavity wall insulation, or at least 50mm loft insulation is deemed to offer an effective package of insulation.

For dwellings heated by electric storage heaters / LPG / programmable solid fuel central heating, a higher specification of insulation is required; at least 200mm of loft insulation *and* cavity wall insulation.

The Decent Homes Standard offers guidance on effective means of improving energy efficiency. Where new heating systems are being installed, the standards recommend that measures be taken to increase the energy efficiency of the dwelling, wherever possible.

7.0 BUDGET COSTS FOR REPAIR SCHEME

The table below indicates the costs suggested within the original Audit Commission report. The costs have been adjusted to reflect the nature of structural works involved in each of the repair schemes. Additionally, alternative costs have been provided for refurbishment works such as kitchens and bathrooms, to reflect the difference the specification of these elements can have on the final cost of the works.

	Original Audit Commission Report Costs	***PRC Licenced Repair Scheme***		***CGU 2000 Mortgageable Repair Scheme***		***Decent Homes Repair Works***	
		Original Audit Commission Report With Alterations To Structural Costs	Budget Costs Based On Actual Current Contractors Costs	Original Audit Commission Report With Alterations To Structural Costs	Budget Costs Based On Actual Current Contractors Costs	Original Audit Commission Report With Alterations To Structural Costs	Budget Costs Based On Actual Current Contractors Costs
Central Heating	£ 3,200.00	£ 3,200.00	£ 3,200.00	£ 3,200.00	£ 3,200.00	£ 3,200.00	£ 3,200.00
Kitchen	£ 2,700.00	£ 2,700.00	£ 4,225.00	£ 2,700.00	£ 4,225.00	£ 2,700.00	£ 4,225.00
Bathroom	£ 1,500.00	£ 1,500.00	£ 2,500.00	£ 1,500.00	£ 2,500.00	£ 1,500.00	£ 2,500.00
External Doors	£ 1,200.00	£ 1,200.00	£ 1,200.00	£ 1,200.00	£ 1,200.00	£ 1,200.00	£ 1,200.00
Windows	£ 1,900.00	£ 1,900.00	£ 1,500.00	£ 1,900.00	£ 1,500.00	£ 1,900.00	£ 1,500.00
Electric Re-wire	£ 1,800.00	£ 1,800.00	£ 2,750.00	£ 1,800.00	£ 2,750.00	£ 1,800.00	£ 2,750.00
Demolish & Prop	£ 1,700.00	£ 1,700.00	£ 1,750.00	£ -	£ -	£ -	£ -
Foundations	£ 1,400.00	£ 2,000.00	£ 2,000.00	£ -	£ -	£ -	£ -
Walls	£ 8,750.00	£ 15,000.00	£ 15,000.00	£ -	£ -	£ -	£ -
Party Wall	£ -	£ 3,000.00	£ 3,000.00	£ -	£ -	£ -	£ -
Roof / Drains	£ 2,200.00	£ 2,200.00	£ 2,000.00	£ -	£ -	£ -	£ -
Scaffold	£ 1,000.00	£ 1,000.00	£ 1,200.00	£ 1,000.00	£ 1,200.00	£ 1,000.00	£ 1,200.00
Externals	£ 1,000.00	£ 1,000.00	£ 1,000.00	£ -	£ -	£ -	£ -
Plaster and paint/decoration	£ 900.00	£ 2,000.00	£ 3,000.00	£ -	£ -	£ -	£ -
Concrete Repairs		£ -	£ -	£ 1,000.00	£ 1,000.00	£ -	£ -
Structural Cladding		£ -	£ -	£ 11,000.00	£ 11,000.00	£ -	£ -
Concrete Repairs		£ -	£ -	£ -	£ -	£ 1,000.00	£ 1,000.00
Over Render		£ -	£ -	£ -	£ -	£ 7,750.00	£ 7,750.00
Re-roof		£ 4,500.00	£ 4,500.00	£ 4,500.00	£ 4,500.00	£ 4,500.00	£ 4,500.00
Asbestos Removal (Roof)	£ 12,000.00	£ 2,000.00	£ 2,000.00	£ 2,000.00	£ 2,000.00	£ 2,000.00	£ 2,000.00
Asbestos Removal (Internal)		£ 2,000.00	£ 2,000.00	£ 2,000.00	£ 2,000.00	£ 2,000.00	£ 2,000.00
Management to 2010	£ 2,800.00	£ 2,800.00	£ 2,800.00	£ 2,800.00	£ 2,800.00	£ 2,800.00	£ 2,800.00
Annual Repairs	£ 3,600.00	£ 1,000.00	£ 1,000.00	£ 3,600.00	£ 3,600.00	£ 3,600.00	£ 3,600.00
Total per property	**£ 47,650.00**	**£ 52,500.00**	**£ 56,625.00**	**£ 40,200.00**	**£ 43,475.00**	**£ 36,950.00**	**£ 40,225.00**
Total for 70 properties	**£ 3,335,500.00**	**£ 3,675,000.00**	**£ 3,963,750.00**	**£ 2,814,000.00**	**£ 3,043,250.00**	**£ 2,586,500.00**	**£ 2,815,750.00**

The above costs exclude professional fees, disturbance allowance/decanting, VAT, contractors preliminaries etc.

£2,000 cost for foundations is considered to be an average, as some dwellings may not need extra foundations if walls are built directly off the existing bedrock.

£15,000 external wall cost is based on the construction of a new cavity wall with insulation.

The Audit Commission findings have also requested that costs of demolition works be considered. Whilst the costs for re-acquisition of privately owned properties is considered beyond the scope of this assessment, the cost of all demolition works are listed below.

The original condition survey report assumed demolition costs of £3,500 per property. However, it is considered that the following costs should be used when making an assessment of any demolition proposals.

Preliminary Demolition Costs

Demolition Works*	£4,500
Asbestos removal (internal)	£1,500
Asbestos removal (roof)	£2,000
Disconnection of services	£1,200
Total	**£9,200 per property**
Total (for 86 properties)	**£791,200**

* Demolition works includes removal of slabs and foundations, re-grading of gardens etc, and disconnection of services.

The above costs exclude professional fees, disturbance allowance / decanting, VAT, contractors preliminaries etc.

The following costs for acquisition of 14 private have been transferred directly from the re-calculated costs contained in the Audit Commission report dated 11 November 2004. Costs for home loss compensation and disturbance costs have been transferred directly from the original condition report.

	Property Value £22,000	***Property Value £44,000***	***Property Value £55,000***	***Property Value £62,000***
Acquisition of 16 private properties	*£352,000*	*£704,000*	*£880,000*	*£1,056,000*
Home Loss Costs	*£266,000*	*£266,000*	*£266,000*	*£266,000*
Disturbance Costs	*£43,000*	*£43,000*	*£43,000*	*£43,000*
Demolition	£791,200	£791,200	£791,200	£791,200
Total	**£1,452,200**	**£1,804,200**	**£1,980,200**	**£2,156,200**

The above costs exclude professional fees, disturbance allowance / decanting, VAT, contractors preliminaries etc.

The costs shown in italics above have been taken directly from the original reports as discussed above.

8.0 CONCLUSIONS

On the basis of the investigations undertaken, it is considered that the properties are in reasonable condition but have begun to deteriorate. Whilst the test results indicate that the concrete is in reasonable condition, it is clear that there are a number of areas where poor quality construction techniques could cause further reinforcement corrosion. Consequently, it is considered that as further moisture ingress occurs, so the number of instances of reinforcement corrosion will occur. It is therefore not possible to guarantee the future performance of these properties without undertaking repair works.

There are three repair schemes considered within these report, each of which will ensure a minimum future life of 30 years and meet the requirements of the Decent Homes Standards. The choice of solution is primarily a financial one and depends upon the individual circumstances of the local authority or RSL. If finance were available, it is recommended that a PRC Licensed Repair Scheme be adopted. This scheme removes the PRC elements and effectively converts the dwellings into traditional houses, with a projected lifespan of at least 60 years, but in all probability up to 80 years. However, it is possible that many more tenants will exercise their right to buy once the costly work has been undertaken.

If financial constraints exist, either of the two alternative schemes will provide a life span of at least 30 years. The render finish provided under the CGU scheme tends to be more robust than that used in the basic scheme. Whilst mortgages are available from some mortgage lenders, future sales of the properties, in say 20 years, may prove problematic.

Foundations exposed during the investigations do not meet current standards with respect to depth, width and quality of concrete. In some instances, the external walls are built directly off the existing rock strata. However, they appear to have performed adequately to date without showing signs of differential settlement. Whilst the continued long term performance of any foundations cannot be guaranteed, as they could be affected by flooding or drainage failure, the risk of any future movement is considered to be low

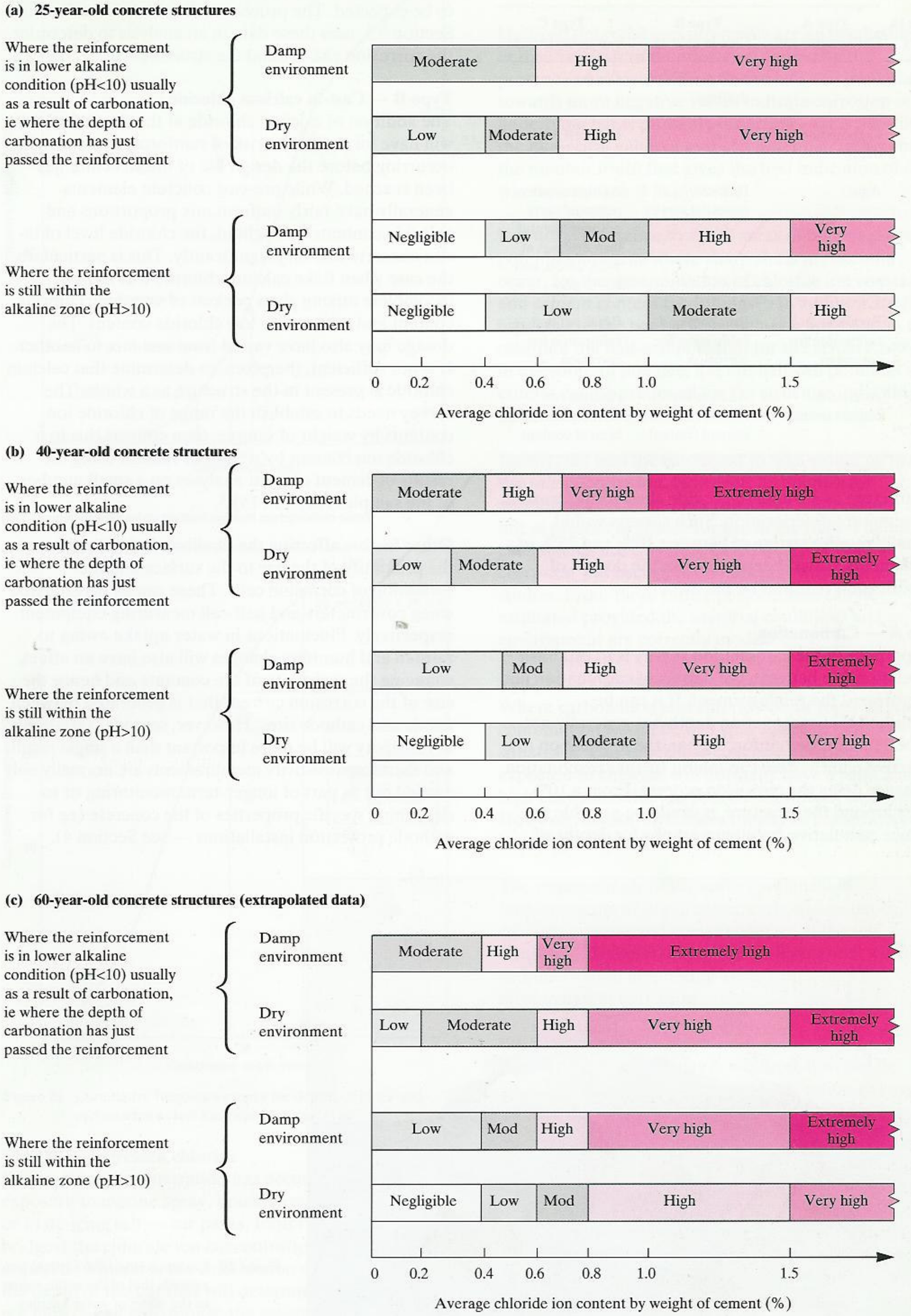
It is recommended that a proportion of the annual repair budget is used to inspect the drains adjacent to the dwellings and relay any damaged pipes as necessary.

Appendix A – Maltby Estate Site Layout


Salisbury House
BM 115.63m
Pumping Station
Manor Hotel (PH)
117.3m
BRAITHWELL ROAD
NEWLAND AVENUE
BEVAN CRESCENT
116.4m
116.7m
CHADWICK DRIVE
TCB
LB
El Sub Sta
BM 117.35m

Appendix B – Building Research Establishment (BRE) Digest 444 Part 2, Table 1

Table 1 Estimated risk of corrosion in concrete structures with estimated cube strength of 35 N/mm² or above, relative to carbonation, chloride content and environment



Appendix C Site Photographs

Curtins consulting

Photograph 1 – Typical Front Elevation of Tarran Newland House

Photograph 2 – Vertical Cracking Of Corner Post

Photograph 3 – Spalling Of Corner Post

Photograph 4 – Linear Polarisation Corrosion Rate Monitoring

Appendix D Laboratory Analysis Results

Sample Ref	Address	Member Type	% Cement Content	% Chloride Content	% Cl in Cement	BRE Categorisation, Risk Due to Chloride Content in Cement		
1	26 Newland Avenue	Corner Post	16.37	0.136	0.83	.	MEDIUM RISK	.
2	26 Newland Avenue	Long Panel	15.39	0.126	0.82	.	MEDIUM RISK	.
3	26 Newland Avenue	Short Panel	15.39	0.136	0.88	.	MEDIUM RISK	.
4	26 Newland Avenue	Long Panel	15.39	0.087	0.57	.	MEDIUM RISK	.
5	26 Newland Avenue	Lintel	15.39	0.143	0.93	.	MEDIUM RISK	.
6	26 Newland Avenue	Corner Post	16.37	0.143	0.87	.	MEDIUM RISK	.
7	26 Newland Avenue	Long Panel	15.39	0.126	0.82	.	MEDIUM RISK	.
8	26 Newland Avenue	Long Panel	15.39	0.126	0.82	.	MEDIUM RISK	.
9	26 Newland Avenue	Long Panel	15.39	0.101	0.66	.	MEDIUM RISK	.
10	26 Newland Avenue	Long Panel	15.39	0.126	0.82	.	MEDIUM RISK	.
11	26 Newland Avenue	Long Panel	15.39	0.136	0.88	.	MEDIUM RISK	.
12	26 Newland Avenue	Long Panel	15.39	0.098	0.64	.	MEDIUM RISK	.
13	26 Newland Avenue	Ring Beam	15.39	0.094	0.61	.	MEDIUM RISK	.
14	26 Newland Avenue	Long Panel	15.39	0.094	0.45	.	MEDIUM RISK	.
15	26 Newland Avenue	Short Panel	15.39	0.105	0.50	.	MEDIUM RISK	.
16	26 Newland Avenue	Plinth	19.1	0.091	0.43	.	MEDIUM RISK	.
17	30 Newland Avenue	Long Panel	15.39	0.103	0.49	.	MEDIUM RISK	.
18	30 Newland Avenue	Short Panel	15.39	0.119	0.77	.	MEDIUM RISK	.
19	30 Newland Avenue	Corner Post	16.37	0.066	0.31	LOW RISK	.	.
20	30 Newland Avenue	Plinth	19.1	0.052	0.25	LOW RISK	.	.
21	30 Newland Avenue	Long Panel	15.39	0.101	0.48	.	MEDIUM RISK	.
22	30 Newland Avenue	Long Panel	15.39	0.101	0.48	.	MEDIUM RISK	.
23	30 Newland Avenue	Short Panel	15.39	0.098	0.64	.	MEDIUM RISK	.
24	30 Newland Avenue	Ring Beam	15.39	0.136	0.65	.	MEDIUM RISK	.
25	30 Newland Avenue	Lintel	15.39	0.206	0.98	.	MEDIUM RISK	.
26	30 Newland Avenue	Long Panel	15.39	0.126	0.60	.	MEDIUM RISK	.
27	30 Newland Avenue	Ring Beam	15.39	0.077	0.37	LOW RISK	.	.
28	5 Chadwick Drive	Plinth	19.1	0.087	0.46	.	MEDIUM RISK	.
29	5 Chadwick Drive	Long Panel	15.39	0.047	0.31	LOW RISK	.	.
30	5 Chadwick Drive	Corner Post	16.37	0.062	0.38	LOW RISK	.	.
31	5 Chadwick Drive	Long Panel	15.39	0.048	0.31	LOW RISK	.	.
32	5 Chadwick Drive	Short Panel	15.39	0.035	0.23	LOW RISK	.	.
33	5 Chadwick Drive	Short Panel	15.39	0.06	0.39	LOW RISK	.	.
34	5 Chadwick Drive	Lintel	15.39	0.056	0.36	LOW RISK	.	.
35	5 Chadwick Drive	Long Panel	15.39	0.043	0.28	LOW RISK	.	.
36	5 Chadwick Drive	Ring Beam	15.39	0.089	0.58	.	MEDIUM RISK	.
37	9 Chadwick Drive	Long Panel	15.39	0.043	0.28	LOW RISK	.	.
38	9 Chadwick Drive	Short Panel	15.39	0.048	0.31	LOW RISK	.	.
39	9 Chadwick Drive	Corner Post	16.37	0.047	0.29	LOW RISK	.	.
40	9 Chadwick Drive	Lintel	15.39	0.105	0.68	.	MEDIUM RISK	.
41	9 Chadwick Drive	Plinth	19.1	0.015	0.07	LOW RISK	.	.
42	9 Chadwick Drive	Ring Beam	15.39	0.062	0.30	LOW RISK	.	.
43	9 Chadwick Drive	Short Panel	15.39	0.056	0.27	LOW RISK	.	.
44	9 Chadwick Drive	Long Panel	15.39	0.085	0.40	.	MEDIUM RISK	.
45	53 Newland Avenue	Plinth	19.1	0.021	0.11	LOW RISK	.	.
46	53 Newland Avenue	Corner Post	16.37	0.052	0.25	LOW RISK	.	.
47	53 Newland Avenue	Ring Beam	15.39	0.079	0.38	LOW RISK	.	.
48	53 Newland Avenue	Long Panel	15.39	0.039	0.19	LOW RISK	.	.
49	53 Newland Avenue	Short Panel	15.39	0.041	0.20	LOW RISK	.	.
50	53 Newland Avenue	Long Panel	15.39	0.079	0.51	.	MEDIUM RISK	.
51	53 Newland Avenue	Lintel	15.39	0.12	0.57	.	MEDIUM RISK	.
52	53 Newland Avenue	Short Panel	15.39	0.058	0.28	LOW RISK	.	.
53	51 Newland Avenue	Plinth	19.1	0.012	0.06	LOW RISK	.	.
54	51 Newland Avenue	Ring Beam	15.39	0.029	0.14	LOW RISK	.	.
55	51 Newland Avenue	Short Panel	15.39	0.064	0.42	.	MEDIUM RISK	.
56	51 Newland Avenue	Long Panel	15.39	0.052	0.34	LOW RISK	.	.
57	51 Newland Avenue	Long Panel	15.39	0.052	0.34	LOW RISK	.	.
58	51 Newland Avenue	Corner Post	16.37	0.014	0.09	LOW RISK	.	.
59	51 Newland Avenue	Lintel	15.39	0.133	0.86	.	MEDIUM RISK	.
60	51 Newland Avenue	Long Panel	15.39	0.03	0.19	LOW RISK	.	.
61	25 Newland Avenue	Long Panel	15.39	0.051	0.33	LOW RISK	.	.
62	25 Newland Avenue	Short Panel	15.39	0.05	0.32	LOW RISK	.	.
63	25 Newland Avenue	Ring Beam	15.39	0.077	0.50	.	MEDIUM RISK	.
64	25 Newland Avenue	Plinth	19.1	0.055	0.29	LOW RISK	.	.
65	25 Newland Avenue	Short Panel	15.39	0.059	0.38	LOW RISK	.	.
66	25 Newland Avenue	Long Panel	15.39	0.027	0.18	LOW RISK	.	.
67	25 Newland Avenue	Corner Post	16.37	0.083	0.51	.	MEDIUM RISK	.
68	25 Newland Avenue	Lintel	15.39	0.118	0.56	.	MEDIUM RISK	.

Sample Ref	Address	Member Type	% Cement Content	% Chloride Content	% Cl in Cement	BRE Categorisation, Risk Due to Chloride Content in Cement		
69	15 Newland Avenue	Short Panel	15.39	0.053	0.25	LOW RISK	.	.
70	15 Newland Avenue	Ring Beam	15.39	0.046	0.22	LOW RISK	.	.
71	15 Newland Avenue	Long Panel	15.39	0.031	0.15	LOW RISK	.	.
72	15 Newland Avenue	Long Panel	15.39	0.036	0.23	LOW RISK	.	.
73	15 Newland Avenue	Short Panel	15.39	0.036	0.17	LOW RISK	.	.
74	15 Newland Avenue	Lintel	15.39	0.069	0.33	LOW RISK	.	.
75	15 Newland Avenue	Corner Post	16.37	0.015	0.07	LOW RISK	.	.
76	15 Newland Avenue	Plinth	19.1	0.013	0.06	LOW RISK	.	.
77	7 Newland Avenue	Ring Beam	15.39	0.036	0.23	LOW RISK	.	.
78	7 Newland Avenue	Long Panel	15.39	0.065	0.31	LOW RISK	.	.
79	7 Newland Avenue	Lintel	15.39	0.067	0.32	LOW RISK	.	.
80	7 Newland Avenue	Short Panel	15.39	0.065	0.31	LOW RISK	.	.
81	7 Newland Avenue	Plinth	19.1	0.032	0.15	LOW RISK	.	.
82	7 Newland Avenue	Long Panel	15.39	0.053	0.34	LOW RISK	.	.
83	7 Newland Avenue	Short Panel	15.39	0.044	0.29	LOW RISK	.	.
84	7 Newland Avenue	Corner Post	16.37	0.005	0.03	LOW RISK	.	.
85	5 Newland Avenue	Ring Beam	15.39	0.061	0.40	LOW RISK	.	.
86	5 Newland Avenue	Lintel	15.39	0.096	0.62	.	MEDIUM RISK	.
87	5 Newland Avenue	Short Panel	15.39	0.126	0.82	.	MEDIUM RISK	.
88	5 Newland Avenue	Long Panel	15.39	0.061	0.40	LOW RISK	.	.
89	5 Newland Avenue	Corner Post	16.37	0.031	0.19	LOW RISK	.	.
90	5 Newland Avenue	Lintel	15.39	0.134	0.87	.	MEDIUM RISK	.
91	5 Newland Avenue	Long Panel	15.39	0.057	0.37	LOW RISK	.	.
92	5 Newland Avenue	Plinth	19.1	0.038	0.20	LOW RISK	.	.
93	1 Newland Avenue	Long Panel	15.39	0.009	0.06	LOW RISK	.	.
94	1 Newland Avenue	Lintel	15.39	0.067	0.44	.	MEDIUM RISK	.
95	1 Newland Avenue	Short Panel	15.39	0.061	0.29	LOW RISK	.	.
96	1 Newland Avenue	Plinth	19.1	0.011	0.05	LOW RISK	.	.
97	1 Newland Avenue	Corner Post	16.37	0.017	0.08	LOW RISK	.	.
98	1 Newland Avenue	Ring Beam	15.39	0.055	0.26	LOW RISK	.	.
99	1 Newland Avenue	Short Panel	15.39	0.093	0.60	.	MEDIUM RISK	.
100	1 Newland Avenue	Long Panel	15.39	0.076	0.36	LOW RISK	.	.
101	6 Newland Avenue	Ring Beam	15.39	0.019	0.09	LOW RISK	.	.
102	6 Newland Avenue	Lintel	15.39	0.127	0.60	.	MEDIUM RISK	.
103	6 Newland Avenue	Corner Post	16.37	0.03	0.14	LOW RISK	.	.
104	6 Newland Avenue	Plinth	19.1	0.024	0.13	LOW RISK	.	.
105	6 Newland Avenue	Long Panel	15.39	0.054	0.26	LOW RISK	.	.
106	6 Newland Avenue	Short Panel	15.39	0.048	0.23	LOW RISK	.	.
107	6 Newland Avenue	Long Panel	15.39	0.048	0.23	LOW RISK	.	.
108	6 Newland Avenue	Short Panel	15.39	0.050	0.24	LOW RISK	.	.
109	2 Newland Avenue	Ring Beam	15.39	0.036	0.23	LOW RISK	.	.
110	2 Newland Avenue	Lintel	15.39	0.164	1.07	.	.	HIGH RISK
111	2 Newland Avenue	Long Panel	15.39	0.104	0.68	.	MEDIUM RISK	.
112	2 Newland Avenue	Short Panel	15.39	0.057	0.37	LOW RISK	.	.
113	2 Newland Avenue	Plinth	19.1	0.019	0.10	LOW RISK	.	.
114	2 Newland Avenue	Corner Post	16.37	0.042	0.26	LOW RISK	.	.
115	2 Newland Avenue	Long Panel	15.39	0.061	0.40	LOW RISK	.	.
116	2 Newland Avenue	Short Panel	15.39	0.081	0.53	.	MEDIUM RISK	.
117	85 Braithwell Road	Ring Beam	15.39	0.034	0.22	LOW RISK	.	.
118	85 Braithwell Road	Lintel	15.39	0.058	0.38	LOW RISK	.	.
119	85 Braithwell Road	Short Panel	15.39	0.098	0.64	.	MEDIUM RISK	.
120	85 Braithwell Road	Long Panel	15.39	0.174	1.13	.	.	HIGH RISK
121	85 Braithwell Road	Short Panel	15.39	0.108	0.70	.	MEDIUM RISK	.
122	85 Braithwell Road	Long Panel	15.39	0.050	0.24	LOW RISK	.	.
123	85 Braithwell Road	Corner Post	16.37	0.019	0.09	LOW RISK	.	.
124	85 Braithwell Road	Plinth	19.1	0.013	0.06	LOW RISK	.	.
125	65 Braithwell Road	Ring Beam	15.39	0.019	0.09	LOW RISK	.	.
126	65 Braithwell Road	Short Panel	15.39	0.123	0.80	.	MEDIUM RISK	.
127	65 Braithwell Road	Long Panel	15.39	0.098	0.47	.	MEDIUM RISK	.
128	65 Braithwell Road	Lintel	15.39	0.118	0.56	.	MEDIUM RISK	.
129	65 Braithwell Road	Corner Post	16.37	0.013	0.06	LOW RISK	.	.
130	65 Braithwell Road	Plinth	19.1	0.030	0.14	LOW RISK	.	.
131	65 Braithwell Road	Long Panel	15.39	0.040	0.26	LOW RISK	.	.
132	65 Braithwell Road	Short Panel	15.39	0.038	0.18	LOW RISK	.	.

Appendix E

Linear Polarisation Corrosion Rate Monitoring Report Prepared by Messrs BGB

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Corrosion Rate Survey
For Curtins Consultants
Maltby

December 2004

Corrosion Rate Measurements Taken by Dr. K. Hladky
Report Written By Dr. J. P. Broomfield

Report No. JPB/0501/001

1.0 Introduction

Broomfield Consultants were requested by Mr. Ray Anderson of Curtins Consultants to undertake a survey of system built houses at Maltby Near Rotherham. Arrangements for access and for labout to break out steel was made by Mr Neil Parkinson of Curtins Leeds office. Previous surveys undertaken by Curtins had revealed the presence of chlorides in the concrete and carbonation to, or approaching, reinforcement depth. Both can lead to reinforcement corrosion. In combination the likelihood of corrosion is enhanced.

The survey was undertaken using the Bigfoot Polarisation Resistance Probe (small probe) which measures the instantaneous corrosion rate of reinforcing steel embedded in concrete. A brief description of the equipment, its use and interpretation of results is given in Appendix 1.

There are 86 Tarran houses on Newland Avenue, Braithwell Road and Chadwick Drive. They are precast concrete single family houses. A total of thirteen were the subject of this investigation.

2.0 Investigation,

The following houses were surveyed on 14 and 15 December 2004:

1, 2, 2, 15, 25, 26, 51 and 53 Newland Avenue
5 and 9 Chadwick Drive
65 and 85 Braithwell Road

A reinforcing bar in an external column, beam (window lintels) and a panel was exposed at each location by Curtins appointed personnel. All measurements were external. The condition of the steel was recorded. An electrical connection was made to the steel and the reference electrode potential (half cell potential) recorded. The polarisation resistance was recorded by the equipment and then converted to a corrosion rate in micrometres per year (µm/y) steel section loss as described in Appendix 1. Measurements were made at three locations on each of the 15 houses

Vertical upright - Either front or back, corner measured if possible. Measurement was not on the corner rebar, as it was often with very low cover and corroded, but on one of the other accessible bars. Two or three readings were taken in a vertical run above and below the excavation. It is possible that some of these hit horizontal ties. The bar was very thin (assumed to be 5mm) in all of them. Overall little corrosion, occasional small rust spotting.

Panel - Adjacent to the vertical. There is a reinforcement round the edges of the panel, again very thin. Took 2-3 readings on a vertical above and below the rebar connection opening.

Window lintel - Curtins advised that they had measured high chlorides in these units. Steel exposed by drilling to one corner in each. Usually a thicker rebar (assumed to be 8mm) found there. Measurements taken at 2-3 locations near the rebar connection.

All the reinforcement was very soft steel, sometimes with a 'twist' profile. On all the houses with visible corrosion this is due to very low cover (typically believed to be 1-2 mm). Those measured usually had a better cover (approximately 10 mm). On one of the houses the vertical had split in a number of places, probably due to a leaky gutter over many years. Curtins also did their own chlorides and carbonation tests (typical carbonation depth 10-15 mm).

3.0 Results and Discussion

The results of the corrosion rate, reference electrode potential and visual observations are recorded in Table 1, along with the steel diameter which was used to correct the reading for the surface area over which the corrosion current is measured. Table 2 records the statistics of the results. There is a high correlation between bars showing rust and measurements of 1.0 µm/y section loss or more (highlighted in red in Table 1).

Simple arithmetic shows that at the highest corrosion rate recorded it will take 1000 years for a corrosion rate of 5 µm/y to corrode through a 5mm diameter reinforcing bar. Even allowing for only 25% section loss for structural purposes there is still 250 years to reach a critical level.

While the rate of section loss is not likely to lead to structural problems in the foreseeable future, there is a risk of cracking and spalling of concrete which would happen sooner and lead to potential hazards of falling concrete, unsightly appearance and ingress of the elements into the structure. However, as described in Appendix 2, we can predict the time to first cracking and the time to spalling from the corrosion rate, steel diameter, cover depth and concrete compressive strength.

The results may be summarised as follows:

Cover	25 mm	25 mm	12 mm
Bar Diameter	5 mm	8 mm	8 mm
Compressive Strength	25MPa	25 MPa	50 MPa
Time to First Crack	**25 y**	**20 y**	**1.2 y**
Time to Spall	**27 y**	**22 y**	**3.2 y**

Thus it can be seen that using the worst corrosion rate measured, the time to cracking is 20 to 25 y for a 25 MPa concrete but only 1.2 y for a harder and therefore more brittle 50MPa concrete. The time to spalling is around 22 to 27 y for the 25MPa concrete reducing to 3.2 y for a 50MPa concrete with only 12mm cover.
The equations used were developed in the laboratory and have had only limited field validation. They do not take into account the geometry of the reinforcement, e.g. corners, or closely spaced bars which could accelerate cracking, delamination and spalling.

It can therefore be concluded from the corrosion rates measured and the information available that if the cover is generally 25mm there is a reasonable time to cracking and spalling of the concrete at the observed corrosion rates, assuming that they are representative of the average corrosion rate throughout the year. However, in locations where the cover reduces to 12 mm or less, the time to cracking could be as low as one year, with spalling in 3.2 years.

However, if we look at a more typical high corrosion rate of say 1 μm/y the figures increase by a factor of 5 giving a worst case time to cracking of about 6 years and a time to spalling of 16 years.

Measurements were taken at locations that had not cracked or spalled and were the cover was beyond 1-5 mm. Therefore to rehabilitate the houses it will be necessary to conduct repairs of damaged concrete and control ingress of moisture by cladding and waterproofing to bring the remaining service life up to useful levels. These corrosion rates are low (see Appendix 1) and should be controllable by conventional repair and enclosure. However given that the carbonation depth has reached the steel in many locations, extensive repairs will be needed.

4.0 Conclusions

1. Corrosion rate measurements were undertaken at 126 locations lintels, columns and panels in 13 "Taran" precast concrete houses in Maltby, Rotherham.

2. Corrosion rates ranged from 0.1 to 4.7 μm/year section loss per year.

3. Even at the highest corrosion rate the time to structurally significant section loss would be hundreds of years.

4. However, times to cracking and spalling would be only a few years if the cover is 12 mm or less at the highest corrosion rate, and 6 to 16 years to cracking and spalling if a typical high corrosion rate of 1 μm/year section loss is used. This rate was measured at 19% of the locations.

5. Extensive concrete repairs and efforts to enclose the concrete to protect it from moisture ingress will be required to preserve the houses for any significant useful life.

TABLE 1 – REFERENCE ELECTRODE POTENTIALS (E_{CORR}) AND CORROSION RATE

Ecorr [mV Ag/AgCl]	Est. Diameter [mm]	Rate Corrected [um/year]	Location	Comments
1 Newland Avenue				
17.3	5	***2.3***	Vertical	Some very slight rust spots
24.8	5	***1.5***	Vertical	
1.5	5	***1.8***	Vertical	
76.6	5	***1.8***	Vertical	
78	5	***2.0***	Panel	Slight rust spots
16.8	5	***1.5***	Panel	
39.6	5	***1.8***	Panel	
38	5	***1.5***	Panel	
65.7	5	***0.3***	Lintel	Clean steel
65.3	5	***0.3***	Lintel	
3 Newland Avenue				
88.2	5	***0.8***	Vertical	Clean steel
101.3	5	***0.8***	Vertical	
123.1	5	***0.7***	Vertical	
22.8	5	***0.2***	Panel	Clean steel
71.2	5	***0.2***	Panel	
90.5	5	***0.4***	Panel	
124.5	8	***0.4***	Lintel	Slight rust spots
147.8	8	***0.5***	Lintel	
6 Newland Avenue				
-29.7	5	***1.5***	Vertical	Slight rust spots
-14.6	5	***1.5***	Vertical	
-10.6	5	***1.7***	Vertical	
39.5	5	***0.8***	Panel	Clean steel
39.3	5	***0.7***	Panel	
45.4	8	***0.5***	Lintel	Clean steel
64.3	8	***0.4***	Lintel	

Table 1 Continued

2 Newland Avenue				
-13.3	5	***0.8***	Vertical	Slight rust spotting
-11.4	5	***0.4***	Vertical	
-49.3	5	***0.6***	Vertical	
120.5	5	***0.3***	Panel	Slight rust spots
123.7	5	***0.3***	Panel	
78.8	8	***0.1***	Lintel	Clean steel
60	8	***0.2***	Lintel	
7 Newland Avenue				
123.7	5	***0.2***	Vertical	Clean steel
118.6	5	***0.2***	Vertical	
110	5	***0.2***	Vertical	
22.8	5	***0.2***	Panel	Clean steel
40.9	5	***0.1***	Panel	
33.2	5	***0.2***	Panel	
-175.5	8	***0.5***	Lintel	Clean steel
-188.2	8	***0.3***	Lintel	
-190.6	8	***0.6***	Lintel	
15 Newland Avenue				
46.8	5	***0.6***	Vertical	Slight rust spots
71.6	5	***0.4***	Vertical	
30	5	***0.1***	Panel	Clean steel
68.3	5	***0.1***	Panel	
149.7	8	***0.1***	Lintel	Clean steel
93.4	8	***0.1***	Lintel	
25 Newland Avenue				
-20.7	5	***1.8***	Vertical	Some very slight rust spots
-37.2	5	***1.3***	Vertical	
-26	5	***1.0***	Vertical	
126.5	5	***0.8***	Panel	Some very slight rust spots
130	5	***0.6***	Panel	
137.1	5	***0.6***	Panel	
76.4	8	***0.3***	Lintel	Clean steel
73.5	8	***0.3***	Lintel	

Table 1 Continued

26 Newlands Avenue				
-105.2	5	***1.9***	Vertical	Slight rust spots
-72.5	5	***1.0***	Vertical	
-32.7	5	***1.1***	Vertical	
-55.9	5	***0.3***	Panel	Some very slight rust spots
-41.9	5	***0.3***	Panel	
-33.5	5	***0.3***	Panel	
-74.3	8	***0.3***	Lintel	Clean steel
-49.7	8	***0.3***	Lintel	
-8.3	8	***0.2***	Lintel	
30 Newland Avenue				
128.7	5	***1.1***	Vertical	Slight rust spots
136.3	5	***1.6***	Vertical	
147	5	***0.8***	Vertical	
99.9	5	***0.3***	Panel	Clean steel
124.3	5	***0.3***	Panel	
126.4	5	***0.2***	Panel	
38	8	***0.4***	Lintel	Clean steel
55.9	8	***0.2***	Lintel	
67	8	***0.2***	Lintel	
51 Newland Avenue				
-173.1	5	***1.0***	Vertical	Some very slight rust spots
-180.6	5	***0.8***	Vertical	
-164.5	5	***1.1***	Vertical	
4.3	5	***0.1***	Panel	Clean steel
53.2	5	***0.1***	Panel	
87.3	5	***0.2***	Panel	
125.4	8	***0.2***	Lintel	Clean steel
118.4	8	***0.1***	Lintel	
53 Newland Avenue				
192.1	5	***1.5***	Vertical	Rust spots
256.3	5	***4.7***	Vertical	
208.9	5	***1.2***	Vertical	
35.8	5	***0.2***	Panel	Clean steel
44.9	5	***0.2***	Panel	
27.9	5	***0.2***	Panel	
44.7	8	***0.3***	Lintel	Clean steel
27.7	8	***0.2***	Lintel	
48.6	8	***0.3***	Lintel	
5 Chadwick Drive				

Table 1 Continued

-92	5	***0.4***	Vertical	Some very slight rust spots
-74.5	5	***0.3***	Vertical	
-87	5	***0.4***	Vertical	
49.9	5	***0.2***	Panel	Clean steel
79.7	5	***0.2***	Panel	
75.6	5	***0.2***	Panel	
-96.9	8	***0.2***	Lintel	Clean steel
-99.3	8	***0.1***	Lintel	
-38.6	8	***0.1***	Lintel	
9 Chadwick Drive				
55.6	5	***0.4***	Vertical	Some very slight rust spots
68	5	***0.4***	Vertical	
70	5	***0.3***	Vertical	
70.7	5	***0.2***	Panel	Clean steel
66	5	***0.1***	Panel	
20.6	5	***0.1***	Panel	
15.6	8	***0.0***	Lintel	Clean steel
115.2	8	***0.2***	Lintel	
106.3	8	***0.2***	Lintel	
65 Braithwell Road				
97.3	5	***0.9***	Vertical	Some very slight rust spots
102.7	5	***0.9***	Vertical	
105.1	5	***0.7***	Vertical	
120.3	5	***0.5***	Panel	Some very slight rust spots
113.4	5	***0.4***	Panel	
160	5	***0.3***	Panel	
45	8	***0.2***	Lintel	Clean steel
64.1	8	***0.2***	Lintel	
109.9	8	***0.2***	Lintel	
85 Braithwell Road				
115.7	5	***0.8***	Vertical	Some very slight rust spots
109.2	5	***0.7***	Vertical	
113.9	5	***0.7***	Vertical	
127	5	***0.5***	Panel	Some very slight rust spots
153.9	5	***0.5***	Panel	
170.3	5	***0.6***	Panel	
140	8	***0.2***	Lintel	Clean steel
110.2	8	***0.1***	Lintel	
143.8	8	***0.1***	Lintel	

Table 1 Continued

Table 2 – Statistics of corrosion rate measurements.

Average	0.6 μm/y
Maximum	4.7 μm/y
Minimum	0.1 μm/y
Number of Measurements	126
Number >1.0 μm/y	24
Percentage $\geq$1 μm/y	19%

APPENDIX 1

Measuring the corrosion rate of reinforced concrete using linear polarisation resistance

Concrete Society Current Practice Sheet 132

See Also Concrete Society Technical Report 60
Electrochemical tests for reinforcement corrosion

APPENDIX 2 – CONVERSION OF SECTION LOSS RATES TO TIME TO CRACKING AND TIME TO SPALLING

Section loss to achieve first crack is given by:

$x_o = 83.8 + 7.4c/d - 22.6f_{c,sp}$ See reference 1 – Gonzalez et al. 1996

where x_o = radius reduction (= ½ of section loss)
c = cover (mm)
d = bar diameter (mm)
$f_{c,sp}$ = tensile splitting strength = 0.3(compressive strength)$^{2/3}$ (Ref. 2).

However, 1st crack is not a delamination or a spall. Typically spalling occurs when cracks are over 0.1mm wide.

This can be calculated from the formula

$w = 0.05 + B[x - x_o]$ See reference 1 – Gonzalez et al. 1996

were w = crack width ≤1mm
B = 0.01 for top cast steel and 0.0125 for bottom cast steel
x = bar radius reduction for crack width w
x_o = bar radius reduction for 1st crack as above

Therefore

$x = x_o + (w - 0.05)/B$

Therefore Time to first cracking is $2x_o/S$
Time to spalling is $2x/S$

Where S is the corrosion rate in micrometres section loss per year

REFERENCES

1. Rodriguez, J. Ortega L. M. Casal J. and Diez J. M. Corrosion of Reinforcement and Service Life of Concrete Structures. 7th Intl. Conf on Durability of Building Materials and Components. 1996; Stockholm.

2. Neville, A. M. Properties of Concrete. 1995; 4th Edition. pp309, 310.