



Association for Structural Engineers of London Boroughs

OUTLINE OF: 'RECOMMENDATIONS FOR THE INSPECTION, MAINTENANCE AND MANAGEMENT OF CAR PARK STRUCTURES'

This document is intended only to give an outline of the 'Recommendations'. For more detail, background, definitions and interpretation, reference should be made to the full text of the 'Recommendations' published by Thomas Teffiord Ltd.

INTRODUCTION AND SCOPE

Many car park structures have a history of early deterioration, structural defects and safety shortcomings due to poor design and construction and low standards of maintenance and repair. They were designed to normal building standards. Experience has shown that they are subject to a much more severe environment, more akin to the exposure of bridges. As a result, deterioration, particularly reinforcement corrosion due to the effects of de-icing salt, has had a major impact on their durability. There have been a few partial collapses, and accidents involving vehicles breaking through edge protection barriers have also occurred. As a result, closures of car parks for costly repairs and/or rehabilitation have been required. These experiences have emphasised the need for improved performance and safety of existing car park structures. The Recommendations address the important implications of the past performance of existing car park structures for their safety and use in the future. They provide guidance on standards of care that are considered to constitute good practice.

Part 1 of the Recommendations is intended for use by Owners and Operators. Part 2 is intended for their professional engineering advisors. The Recommendations, as a whole, aim to assist both Owners and Operators and their professional advisors to provide safe car park structures and cost effective inspection and maintenance with minimum disruption.

The Recommendations as a whole, i.e. both Part 1, and Part 2, relate to all types of multi-storey car park found in the United Kingdom for use by the public. They do not specifically consider car parks using mechanical stacking systems or private access car parks where different standards may be considered acceptable.

The recommended principles and approaches to management given in Part 1 apply to car park structures generally. The more detailed technical recommendations in Part 2 relate mainly to concrete car park structures since they form a large majority of existing structures.

The Recommendations cover existing car park structures, i.e. primary structure, cladding and edge barriers. They are concerned, in particular, with the safety of these structures whilst the car park is in service and with the actions needed by Owners, Operators and their professional engineering advisors to maintain safety and serviceability.

PART 1: CAR PARK STRUCTURES,, RESPONSIBILITIES, MANAGEMENT AND PROCUREMENT

MAIN RECOMMENDATIONS FOR OWNERS/OPERATORS

To provide adequate standards of safety of a car park structure, the Owner/Operator is recommended to:

- (1) Appoint an appropriately experienced Engineer to advise on structural safety, inspection, maintenance and repair in accordance with industry recommended practice.*
- (2) Request the Engineer to establish a 'Life-care Plan' for each car park structure and the baseline for commencing implementation.*
- (3) Provide adequate resources for implementing the Life-care Plan for maintaining the car park structure in a safe condition fit for use by the public*
- (4) Arrange for records of the design, construction, inspections, maintenance, repair, rehabilitation and replacement to be kept, maintained up to date, and made available to the Engineer and others as appropriate, as the life-care process progresses.*

1. CAR PARK STRUCTURES

The majority of car park structures are freestanding independent structures, the internal space being devoted to accommodating parked vehicles and to their entry and egress. The car park may also be a part of a multi-use structure where other parts of the building are used for other purposes, e.g. retail premises, offices, or residential accommodation. Most multi-storey car parks in the United Kingdom are concrete column and deck structures. The types existing are based on different structural concepts. The main types are:

- Insitu reinforced concrete column and slab
- Insitu frame, precast prestressed deck
- Precast frame and deck
- Lift-Slab construction

2. RESPONSIBILITIES OF OWNERS AND OPERATORS

Multi-storey car parks should be safe for use by the public. They should also inspire public confidence and, to that end, they should provide a safe environment for the user.

The prime responsibilities for the safety of a car park structure, its cladding and edge protection lie with the Owner and Operator of the car park. The Owner/Operator should recognise that car park structures deteriorate over time, especially if not well maintained, and become unsafe in various ways unless appropriate actions are taken.

3. LEGAL OVERVIEW

Owners and Operators of multi-storey car parks have duties under law to provide and maintain their premises so that they do not pose risks to the safety of their employees, other persons using the premises as a place of work, visitors (including trespassers and children) and the public at large. Failure to discharge the various duties may give rise to criminal breach and/or civil liability, and may result in intervention by statutory authorities. The object of these Recommendations is to provide guidance on standards of care which constitute good practice and which should satisfy statutory and common law requirements. Advice should be sought on legal requirements that may be current at any particular time.

4. LIFE-CARE PLAN

Management

The Owner and/or Operator is strongly advised to appoint, an appropriate Engineer with particular experience of the deterioration of structures and knowledge of the materials science of deterioration processes to:

- Take overall responsibility for advice on the structural safety of the car park structure, cladding and edge protection,
- Determine and implement a Life-care Plan, and
- Advise accordingly.

Getting Started

A Life-care Plan should be in place for each car park. The main elements of a Lifecare Plan for an existing car park are indicated below. A baseline for implementation is provided by an up-to-date Structural Appraisal undertaken by the Engineer. This should be based on an initial Condition Survey which can be used to benchmark the Structural Appraisals needed at intervals during the remaining life of the car park structure, cladding and edge protection.

The transition from the existing arrangements for inspection and maintenance to an appropriate Life-care Plan can be made along the following lines:

- For some car park structures, a recent Structural Appraisal (within the last 8 years) may serve as a baseline provided the Engineer is satisfied that it is sufficiently comprehensive and structural safety is unlikely to have been prejudiced in the meantime.
- For others that are over 3 years old where there are no adequate records of the structure, cladding and edge protection and/or of a Structural Appraisal within the previous 8 years, then a Structural Appraisal should be undertaken **without delay**.
- For new structures (under 3 years old), the process can normally be started by a 'benchmark' Condition Survey at age 3 years leading, to a , Structural Appraisal as advised by the Engineer.

Life-care Plan: Inspections and Structural Appraisals

- Daily Surveillance and reporting of damage or operational problems by onsite staff.
- Routine Inspections, usually by an assistant.
- Periodic Initial Appraisal and Condition Survey at intervals by the Inspector or the Engineer. The Condition Survey may include a second stage, Structural Investigation, specified by the Engineer. In some cases, the Engineer may advise that the Condition Survey needs to be complemented by monitoring potentially sensitive parts of the structure at intervals over time in order to keep track and assess the changing condition of progressively deteriorating components in a cost-effective way.
- Structural Appraisals at intervals by an Engineer.

Life-care Plan: Maintenance, protection, repair and rehabilitation or replacement

- Routine maintenance, usually by on-site staff.
- Protective and preventive repairs carried out through contracts for the application of cosmetic treatments, of protective treatments to slow deterioration and/or to control, corrosion, and for structural repair', strengthening, rehabilitation or replacement.
- Recording of works undertaken.

Records

The Owner/Operator is recommended to arrange for:

- Records to be kept of the original design and construction, of the inspection on completion prior to handover, and of maintenance, repairs and modifications carried out since construction.
- Reports of Routine Inspections, Initial Appraisals, Condition Surveys, Structural Investigations and Structural Appraisals to be retained. including drawings prepared from surveys, photographs and, test reports.
- As-built drawings to be used to record repairs and to be kept up-to-date as part of the Life-care Plan.
- The safe keeping of calculations.
- All this information to be referenced in the Health and Safety file for the car park.

5. TYPICAL SEQUENCE OF KEY ACTIONS FOR INSPECTION, MAINTENANCE AND MANAGEMENT

Owner/Operator

- 1 For each car park structure, its cladding and edge protection appoint an Engineer to advise and to act as a single 'responsible person' for structural safety and the development and implementation of the Life-care Plan.
- 2 Where required, arrange appointment of an Inspector.
- 3 Make arrangements for records to be kept by a designated 'keeper'.
- 4 Provide the Inspector/Engineer with all records relating to the design and construction of the structure (including as-built drawings, calculations – if available - materials certificates and test results etc) and reports of previous Initial Appraisals, Condition Surveys, Structural Investigations and Appraisals.
- 5 Arrange provision of suitable checklist systems for Daily Surveillance by onsite staff and Routine Inspections by an assistant, the Inspector or the Engineer.

Inspector

- 6 Carry out Routine Inspections at specified intervals, or supervise this work being undertaken by an assistant (Alternatively depending on organisational arrangements, supervision may be by the Engineer), using the checklist prepared and agreed with the Engineer.
- 7 Carry out Initial Appraisal: Assess sufficiency of records and carry out any additional site measurement, inspection etc. deemed necessary. In discussion with the Engineer, identify all locations and details that are critical to structural integrity.
- 8 Carry out Condition Survey, i.e. a full visual inspection and sampling and testing, e.g. half cell, cover and chloride profiles, of the structure, recording deterioration with specific reference to the implications - deterioration affecting structural safety and condition to be separately recorded. Report.
- 9 In consultation with the Engineer, extend the Condition Survey by Structural Investigation to provide any further information needed to enable Structural Appraisal to be completed.

Engineer

- 10 Review Initial Appraisal and Condition Survey and advise on next steps.
- 11 Undertake Structural Appraisal giving evaluation of integrity and adequacy of structure, cladding and edge barriers. Produce summary of the results with assessed structural capacities being compared with those required at all critical locations.

- 12 Estimate residual life of structure, cladding and barriers and appraise the implications of further deterioration. Report to Owner/Operator.
- 13 If the structure is deficient in strength, provide costed options for interim measures, pending repair works, together with costed options for repair works as may be requested by the Owner/Operator.
- 14 Produce costed options for long-term inspection, maintenance and periodic reappraisal of the structure, cladding and barriers, following remedial works, with specific reference to ensuring continued structural safety and reducing rates of deterioration. Update Life-care Plan. Report to Owner/Operator.

Owner/Operator

- 15 Review reports from Inspector and Engineer and consider options. Select option in discussion with the Engineer.
- 16 Commission maintenance, and repair/rehabilitation works, if needed. Where repair proposals have been prepared by a contractor, ask the Engineer to review them prior to commissioning.
- 17 Consider proposed update of Life-care Plan and commission continuing actions on the basis of the update accepted.

PART 2: IMPLEMENTATION OF LIFE-CARE PLAN

MAIN RECOMMENDATIONS FOR PROFESSIONAL ENGINEERING ADVISORS

The Engineer is recommended, for each car park structure, to:

- (1) *Review current arrangements for inspection and maintenance in the light of these Recommendations.*
- (2) *Advise on getting started on implementing a continuous Life-care Process' in accordance with these Recommendations.*
- (3) *Where current inspection and maintenance arrangements are not to the standards of the Recommendations, recommend to the Owner/Operator the changes needed.*

6. STRUCTURAL DEFECTS AND DETERIORATION

Many car park structures, especially those built in the 1960s and earlier, have required remedial action after only a few years in service. Generally it is, early concrete structures that are now in the most deteriorated condition. This is due to their longer exposure to the aggressive environment (wetting and drying, freeze-thaw action and de-icing salt), and due to poor standards of design and construction relative to modern standards and requirements. Robustness of car park structures was often not considered explicitly in early designs, Edge, barriers have sometimes been fitted without considering how vehicle impact loads would be transferred back into the structural frame and with little concept of problems that could occur when reinforcement is damaged by chilling for fixings or corrosion occurs.

It may not be safe or cost effective to wait, until significant visible deterioration of a concrete car park structure is present before, take remedial action. It is the task of Initial Appraisal, Condition Survey (including Structural Investigation) to identify deficiencies, especially potentially vulnerable components and features that may be prejudicial to safety. It is the task of Structural Appraisal to diagnose causes and implications for safety and future use of the car park. The elements of a Life-care Plan are outlined briefly below.

7. DAILY SURVEILLANCE AND ROUTINE INSPECTION

Preparation

Suitable checklist systems, either paper or computer based, should be provided for making reports of structure damage, equipment breakdown, or incidents observed during Daily Surveillance and Routine Inspections. The checklists should be prepared in consultation with the Engineer.

Daily Surveillance

The Operator's on-site staff should be required to keep the car park and its equipment under Surveillance on a daily basis and to report any breakdown of equipment, obvious damage, e.g. to edge barriers, and any other untoward incidents in the use of the car park.

Routine Inspection

Routine Inspections, usually by an assistant working under the supervision of the Engineer or the Inspector should be carried out. Routine Inspections are visual and should cover the structural frame, cladding and edge protection.

8. INITIAL APPRAISAL, CONDITION SURVEY AND SPECIAL INSPECTION

Initial Appraisal of the Structure, Cladding and Edge Protection

The Initial Appraisal, essentially an overall structural and materials review by a desk study of records prior to a Condition Survey.

The Initial Appraisal is vital to the identification, by the Condition Survey, of the causes and extent of deterioration and, defects, especially active corrosion of reinforcement or freeze/thaw action at structurally sensitive details. A checklist should be prepared for use in the Condition Survey.

Condition Survey

The Condition Survey should be based on the Initial Appraisal of the structure, cladding and barriers and, in the first instance, is effectively a 'benchmark' survey.

Condition Surveys are usually visual in the first instance and based on a checklist developed during the desk study. Where the Survey is extended to include Structural Investigation, the scope of the required Investigation will need to be specified. A material and structural testing specialist should be employed to undertake the work.

The Condition Survey should include photographs and measurement of visible evidence of defects and deterioration. The risk of omissions in the work can be reduced by use of the checklist.

Special Inspection

Special inspection by an Engineer may be necessary at any time to examine damage to the structure.

9. STRUCTURAL INVESTIGATION

The Engineer may require the Condition Survey to be made more comprehensive by Structural Investigation, in particular through sampling of materials and tests to determine, for example, the reinforcement present and/or to diagnose the conditions within the structural components. The purpose is to determine details of the construction, and/or to confirm causes

or extent of deterioration as part of the process of bringing together Appraisal of structure sensitivity and damage due to deterioration.

The Engineer should specify all investigative work, including locations where samples are to be taken. Sampling and testing may be undertaken by a materials test house or a materials and repair specialist. The work should be undertaken by an organisation working to a relevant quality assurance standard for the work required, e.g. to BS EN ISO9001 or UKAS accreditation providing assurance of sound practice.

10. SUMMARY OF PRINCIPAL ACTIONS IN A TYPICAL INITIAL APPRAISAL AND CONDITION SURVEY

Following Initial Appraisal, the Condition Survey is often in two stages, the second being Structural Investigation used to extend the information gained in the first visual stage of the Survey. Actions should be taken as required by the Engineer. They will normally include:

- Studies of the records of design, construction and maintenance of the structure, cladding, edge barriers and fixings. Assessment of the sufficiency of the information and making any additional site measurement, inspection etc. deemed necessary. Where as-built drawings are not available, the relevant parts of the car park structure should be surveyed and drawings produced to record positions and extent of cracks and defects.
- Appraisal of the structure on the basis of the records and identification of all locations, details etc, that are, or may be, critical to structural integrity, including those where deterioration of materials may exacerbate criticality.
- Preparation of a checklist for the Condition Survey.
- A visual inspection of the structure, cladding, edge barriers and fixings recording visual deterioration and damage caused by impact with specific reference to the implications.
- Making any Structural Investigation necessary to provide further information needed to enable a Structural Appraisal to be completed.
- For a structure with a history of deterioration problems, monitoring of the progress of deterioration through regular testing and investigation may be in progress already or can be set up. The data collected over time can then be used to estimate remaining life before repair becomes essential to maintain safety.
- Where relevant as-built drawings do not already exist, preparation of as-built/as-found drawings of sensitive or deteriorated structural areas based on the results of the Survey. Drawings should include updated information on modifications and repairs, e.g. rehabilitation of barriers or holes cut for services, and on deterioration found.
- Reporting to the Engineer and the Owner/Operator giving details of the observed condition of the structure, cladding and barriers, the potential implications for safety and future use, and proposing further actions including prompt pre-emptive maintenance where appropriate. The development of more serious and costly deterioration in the longer term arising from, for example, leaking drains and expansion joints, ponding seepage through cracks, breakdown of waterproofing, rust staining and spalling, can be reduced and/or delayed by giving, priority to prompt pre-emptive maintenance. To avoid making deterioration worse and/or initiating it elsewhere, preemptive maintenance must be appropriate and correctly applied.

11. STRUCTURAL APPRAISAL

A Structural Appraisal, as part of the Life-care Plan, to evaluate the integrity and adequacy of the structure, cladding and edge barriers should be undertaken by the Engineer at intervals of not more than 16 years. Appraisal will generally be needed at intervals shorter than 16 years.

The Appraisal should be based on a review by the Engineer of all the information to hand from the Initial Appraisal and Condition Survey, including any Structural Investigation. The Appraisal may be assisted by data from monitoring of the progress of deterioration at sensitive locations to confirm diagnoses of causes and to enable prognoses of future condition to be formulated.

A partial or full Structural Appraisal may also be needed at short notice following a Special Inspection that indicates structural integrity may be in question. This Appraisal may also lead to a rescheduling of future Appraisals in the Life-care Plan.

On completion of an Appraisal, the Engineer should review inspection timescales and recommend to the Owner/Operator an appropriate schedule for the next Appraisal as part of an update of the Life-care Plan

12. SUMMARY OF PRINCIPAL ACTIONS IN A TYPICAL STRUCTURAL APPRAISAL

Actions should be taken as scheduled by the Engineer. They will normally include:

- Completion of appraisal calculations for the structure and production of a detailed summary of the results with assessed structural capacities (as-designed, as-built and as-found deteriorated) being compared with those required by design standards for all critical locations. The accuracy of as found deteriorated capacities may be low given the subjective judgements required in the calculations. These calculated values should therefore be used with caution. In some circumstances appraisal may be based on, judgement only without calculation, provided the basis of the judgement is given.
- The summary should identify any particular weaknesses, lack of robustness, or potential for progressive collapse. Standards, applicable at the time of construction are generally appropriate except where the structural configuration is not within their scope or clauses have been withdrawn subsequently for technical reasons, e.g. empirical rules for flat slab design. For shear in flat slabs, and Lift-Slab structures in particular, current standards should be used.
- Appraisal of the safety and integrity of cladding.
- Appraisal of the adequacy of edge protection and fixings for vehicle restraint by reference to published performance data, or testing where their adequacy cannot be determined with confidence. Appraisal of adequacy for protection of pedestrians should also be considered.
- Appraisal of the implications of trends in deterioration on the assessments above and the risks of accelerated deterioration, especially for details that are not easily inspected or are critical to structural safety. Where deterioration mechanisms are weakening the structure, criteria for minimum acceptable technical performance should be developed and applied bearing in mind the limitations in reliability of the condition assessment. The next Condition Survey and repair and strengthening works should be undertaken before minimum acceptable technical performance is reached.

- Arranging for monitoring of sensitive deteriorating parts of the structure, e.g. corbels or integrity of steelwork connections.
- If the structure is deficient in strength or unacceptably sensitive to partial or progressive collapse, provision of costed options for interim measures, pending remedial works, together with costed options for remedial works.
- Where the structure, cladding and/or edge barriers are unsafe, inadequate or substantially deteriorating, provision of costed options for interim measures and remedial works.
- Production of costed options for the long-term inspection, preventive and capital maintenance and periodic re-appraisal of the structure, cladding and barriers with specific reference to ensuring continued structural safety and dealing with deterioration that may not have safety implications.
- Reporting to the Owner/Operator giving the results of the Appraisal and proposing the future Life-care Plan, including options for future inspection, maintenance, repair and rehabilitation or replacement.

13. MAINTENANCE, REPAIR, REHABILITATION AND REPLACEMENT

The primary objective of maintenance, repair, rehabilitation, or replacement is generally to maintain the structure, cladding and edge barriers in a safe and serviceable condition at reasonable residual-life cost compatible with the Owners/Operators' requirements as reflected in the Life-care Plan. All proposals for repair should be subject to the advice of the Engineer.

Routine Maintenance

The primary purpose of routine maintenance is to keep a multi-storey car park clean and fit for use. The most important agents promoting deterioration of car park structures are de-icing salts and water brought into the structure by vehicles and the weather. A secondary purpose of routine maintenance is therefore to minimise the deteriorating effects by keeping the environmental conditions within the car park as dry as possible and reducing the amount of contamination i.e. maintaining good drainage, clean decks and falls.

A ban on the use of de-icing salt in the car park will reduce the risk of chloride induced corrosion although salt will still be imported onto the decks by vehicles in the winter months. Hazards from falling spalled concrete should be avoided by giving maintenance priority to the regular removal of loose surface concrete, especially in and over public areas.

The Operator's employees usually undertake routine maintenance. Responsibility for minor repairs, e.g. to drains, barriers, joints or waterproofing, may be placed with a third party who should be properly supervised. Those undertaking routine maintenance, should be trained appropriately to minimise risks of incorrect work that may make matters worse.

Protection, Repair and Rehabilitation

The protection and repair of concrete structures requires complex design and specification work. The basic principles for protection and repair of concrete structures subject to corrosion damage, or which are expected to need such measures to minimise future damage or deterioration are given in BS EN 1504 and elsewhere.

14. HEALTH AND SAFETY OF PERSONNEL ON SITE

Requirements for health and safety should be met for all inspection, investigative, maintenance and repair work on site. Appropriate assessments of risks should be carried out.

December 2002
ICP0213A