Whapples, Chris and McKibbins, Leo
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The main types of concrete-framed car parks are:

- in situ reinforced concrete frame and decks
- in situ reinforced concrete frame and precast prestressed decks
- precast concrete frame and decks
- prestressed and post-tensioned concrete construction
- lift-slab and other specialised system-build forms of construction.

2.4. Car parks below ground level were traditionally formed entirely in reinforced concrete owing to the additional fire protection requirements. However, with modern fire protection systems, other forms of construction can exist, especially in mixed-use developments.

2.5. Some older concrete car parks were constructed with in situ concrete on woodwool permanent formwork, voided slab decks and even beam and block decks. Sometimes the decks were supported on masonry loadbearing walls with little resistance to impact or disproportionate (progressive) collapse. In more recent times, new forms of construction have been used, including a small number of car park structures built with bonded post-tensioned concrete decks, in some cases with in situ post-tensioned beams using proprietary high-tensile steel bars which run through precast external columns. Following developments in technology, unbonded post-tensioned flat slabs have also been used in recent construction.

2.6. Structural steel-framed car parks have grown in popularity since fire protection requirements for the structure have been relaxed and coatings for corrosion protection have improved (Figure 2.2).

Figure 2.2 Typical steel-framed car park (courtesy of Milton Keynes University Hospital NHS Foundation Trust)

Chapter 3
Responsibilities of owners and operators

Chris Whapples, Andrew Rattray, John Carpenter, Ian Raybould and Peter Guest

3.1. All car parks should be safe at all times while in service, regardless of whether they are planned for partial withdrawal from service, for closure or for demolition. They should also inspire public confidence and to that end should provide a safe and pleasant environment for the user (Figure 3.1). Many multi-storey car parks meet these requirements, but some older ones do not.

3.2. The responsibility for safety and maintenance of a car park lies with both the owner and the operator. If the car park is leased the respective repair and maintenance obligations are normally defined within the terms of the lease.

3.3. **Owners/operators** should recognise and appreciate the characteristics of the car park structure for which they are responsible (Figure 3.2). They should also understand that car park structures deteriorate over time if not well maintained and can become unsafe in various ways unless appropriate action is taken.

Figure 3.1 Internal view of concrete-framed car park (courtesy of Queensgate Shopping Centre Peterborough)

10.3. Routine inspection

10.3.1. The next element of the **life-care plan** is **routine inspections**, usually by an **assistant** working under the supervision of the **engineer** or **inspector** and trained in the identification of defects in car park structures. **Routine inspections** are visual and should cover the structural frame, cladding and edge protection. They may also encompass other defined aspects of multi-storey car parks that are outside the scope of these recommendations, for example, security, lighting and traffic management.

10.3.2. **Routine inspections** should be scheduled regularly, at intervals recommended in the **life-care plan** that have been determined by the **engineer** in accordance with the guidance in Chapter 15, which provides a risk-based approach to determining appropriate inspection frequencies. Structures that are deemed by the **engineer** to present significant risks, for example, if there is evidence of potentially significant deterioration in key load-bearing areas, or based on factors including the age, robustness and vulnerability of the structure, will merit shorter intervals between **routine inspections**.

10.3.3. **Routine inspections** should be based on a checklist (usually prepared by the **inspector**) to identify all relevant items for inspection (Figure 10.1). The checklist should be developed on the basis of an assessment of safety risks determined in the **condition survey** (see Chapter 12). Defects highlighted by the checklist should be reviewed by the **inspector** or **engineer** and reported to the **owner/operator** where appropriate.

10.3.4. The recommended items of **routine inspection** of the structures of a car park include:

(1) Parking decks and ramps:

- Check drainage, especially bottom ramp drains and gully outlets (DETR Partners in Innovation Project, 2002), and report any blocked drains and/or ponding on decks.
- Use photographs to record any leakage through cracks in the decks or failing joint sealants and any consequential calcium carbonate deposits.

Figure 10.1 Routine inspection using a prepared checklist, while the car park is not in use. Checking the presence and condition of impact protection jackets that have been retro-fitted to structural steel columns (courtesy of Mott MacDonald Ltd)

11.5.14. Samples and cores should be taken from non-critical structural locations of components as far as possible, and as agreed by the **engineer**. Samples of materials (e.g. concrete, masonry, steel) for laboratory analyses can be obtained by a variety of drilling, sawing and cutting techniques. The inevitable damage caused by sample removal from the structure should be fully repaired in accordance with BS EN 1504 (BSI, 2008a). Damage to reinforcement or prestressing tendons must be avoided. Careful scanning in advance with a covermeter, radar or ultrasonic imaging device can reveal buried reinforcement and tendon ducts and enable these to be avoided in testing and sampling.

11.5.15. Many non-destructive and partially destructive test techniques, for example, pull-off tests, in fact cause some damage or residual mark to the tested component even after making good and cleaning. Owners and operators should be informed of any likely effects on the appearance of the structure and agree requirements and standards for making-good any such damage.

11.5.16. Testing should be undertaken by an organisation working to a relevant quality assurance standard for the work required, for example, to BS EN ISO 9001 (BSI, 2008b) or UKAS accreditation. Note that BS EN 9001 means only that a company is operating a quality assurance system that is reviewed externally, but UKAS accreditation is the formal recognition that an organisation is competent to perform specific processes, activities or tasks (which are detailed in a scope of accreditation) in a reliable, credible and accurate manner. Note that this accreditation is unlikely to apply to the full range of test methods that a company offers, so it is important to check the accreditation status of the particular test method required if this is desired.

11.5.17. Structural load tests may be required by the **engineer**. Load tests may be useful in some circumstances to determine the capacity of fixings of cladding panels, of an edge barrier system or of holding-down bolts (see Appendix D: 5). Such tests can provide useful data where reliable calculation of capacity is not possible. For car park decks, load-carrying capacity can generally be calculated.

Figure 11.4 (a) Multi-head half-cell testing (courtesy of Proceq UK). (b) Contour plot visualisation of the results of a half-cell survey of a deck slab (1-m grid) clearly distinguishing between locations with higher and lower corrosion risk

(a)

Table 13.1 Seven project phases for repair based on BS EN 1504-9 (BSI, 2008), adapted to the recommendations for car parks, summarising basic considerations and actions

Phase	Considerations and actions relevant to car parks
Phase 1	Competence of personnel and records
1.1	■ Engineer, contractor and inspector competent in protection and repair works
1.2	■ Quality system by contractor
1.3	■ Works inspection quality plan, including sampling regime
1.4	■ Document storage and management system
Phase 2	Information about the car park (operator-supplied **life-care plan**)
2.1	■ Condition and history of the structure
2.2	■ Documentation (inspection records – Chapters 10 and 11)
2.3	■ Previous repair and maintenance works
Phase 3	Process of assessment
3.1	■ Defects and their classification and causes – Structural defects (Chapter 8) – Non-structural defects (Chapter 9)
3.2	■ Safety/structural appraisal before protection and repair (Chapters 12 and 14)
Phase 4	Management strategy (Chapter 13)
4.1	■ Options
4.2	■ Principles
4.3	■ Methods
4.4	■ Safety/structural appraisal during protection and repair (Chapters 12 and 14)
Phase 5	Design of repair work (Chapter 13)
5.1	■ Intended use of products
5.2	■ Requirements
5.2.1	– Substrate
5.2.2	– Products
5.2.3	– Work
5.3	■ Specifications
5.4	■ Drawings
5.5	■ Safety/structural appraisal after protection and repair
Phase 6	Detail of repair work (Chapter 13)
6.1	■ Choice and use of products and systems and methods and equipment to be used
6.2	■ Tests of quality control
6.3	■ Health and safety (Chapter 14)
Phase 7	Acceptance of repair work (Chapter 13)
7.1	■ Acceptance testing
7.2	■ Remedial works
7.3	■ Documentation (Chapter 15)

13.1.7. The engineer is responsible for the design of all aspects of the protection and repair works. The engineer should ensure an appropriately skilled repair and protection contractor is appointed and puts in place a quality plan that fully complies with BS EN 1504 (BSI, 2005a). The engineer should set up appropriate hold points in the works, as part of the inspection quality plan, concentrating on critical components, as suggested in BS EN 1504 part 10 (BSI, 2003), and should ensure all relevant information is appropriately recorded. This is important because the process of repair often requires structural modification and so will be highly significant for any future works that may be contemplated.