BUILD, REPAIR & REFURBISH

ASSESSING CAR PARK STRUCTURES AHEAD OF THE EV TRANSITION

Specialist Report
2022 / 2023

Are our car parks fit for the vehicles of the future?

BUILDING TRUST

CONTENT

FUTURE OF CAR PARKS

FOREWORD
RUSSELL SIMMONS

BSc (Hons), MCIOB, CBuildE, MCABE, FCIHT, FBPA, AMICE
Chair of the British Parking Association, Parking Structures Group and car park specialist consultant at Stripe Consulting.

Car park structures are inherently at risk of degradation due to the level of exposure that they face and also the fact they are often under provided for, with regards to proactive repairs and protective measures.

Car parks often get 'forgotten' between elements infrastructure like bridges and structures such as shopping centres. Often they are the 'poor relation', not fitting in either category, despite being vital to our towns and cities and indeed to everyday life for many people.

For many years, organisations such as the Institution of Structural Engineers, Institution of Civil Engineers and the British Parking Association, along with individuals including myself and many of my industry colleagues; have been trying to raise awareness of the need to, and benefit of fully understanding the condition of car park structures. This is before putting in place a suitable, proportionate and sufficient life-care plan to ensure the structure remains safe and fit for use.

The need to ensure this message is received and acted upon by the nation's car park owners and operators increases year on year as the aging stock of car parks degrade at an exponential rate. Another factor to consider here is that cars in general are getting heavier and larger, which can increase the risk of impact and excessive load related stresses being imposed on these structures.

This report aims to increase awareness of the considerations that owners and operators (or those charged with the responsibility for the car parks serviceability) should be taking into account when putting in place a structured approach to ensuring their obligations are being correctly discharged.

If all car park structures were being correctly monitored and maintained, the net result would be that the UK's parking infrastructure would be of a better quality, would be safer, and would reduce the potential for premature failure or worse, collapse. This is why I am pleased to introduce this report and encourage all those with obligations connected to the upkeep of the UK's car parks to consider its contents.

CHAPTER ONE
CAR PARKS IN A MODERN WORLD

The UK has an ever-aging stock of Multi-Storey Car Parks (MSCPs), much of which were constructed from reinforced concrete in the 1960s and 1970s.

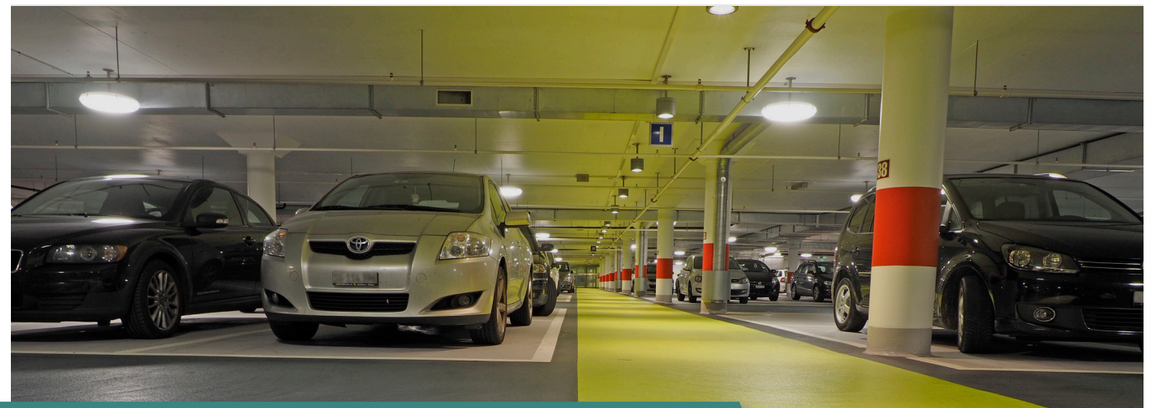
Although many of these structures still serve the public today, a large number have exceeded their original design life and require an ever-increasing level of investment to operate.

Although there are examples of well-built, well-maintained car parks, many have structural defects ‘baked in’ due to issues with design, materials and workmanship; all of which has been exacerbated by years of neglect and the increased demands placed on them by owners and operators.

In many cases, the maintenance and repair approach for these structures has been to patch-up the damage that can be seen as cheaply as possible and carry on, rather than adopting a whole life maintenance strategy.

This reactive maintenance does not always ensure that car parks are maintained to a good state of repair and, without treating the causes of the deterioration, can result in the need for much larger and more expensive interventions when maintenance issues snowball.

The cost of these repairs is exacerbated by the full or partial closures they entail, which has the knock-on effect of reducing footfall for surrounding businesses. The damage can be long-lasting, as valuable customers are lost to ‘competitor’ car parks and the businesses they support.



STATE OF THE NATION: THE UK’S CAR PARK SECTOR

- A 2020 study by Knight Frank shows that there are 103,000 public and private surface car parks across the UK, with around 38% of parking space (by area) owned by the public sector.
- The private sector is dominated by three companies – NCP, Apcoa and Q-Park, although the UK car park industry comprises 4,006 businesses employing 11,480 people.
- A significant proportion of MSCPs in the UK are in excess of 30 years old.

Sources: Knight Frank, IbisWorld, Russell Simmons – BPA

CHAPTER TWO
WEIGHING UP THE ISSUE

However, there's another challenge facing our Multi-Storey Car Parks in the UK – the rapid shift towards Electric Vehicles (EVs).

EVs are significantly heavier than Internal Combustion (IC) engine vehicles, with a new electric car being around 30% heavier than its petrol equivalent. What's more, if we take the average weight of the top five selling cars of the 1960s and compare this with the top five selling EVs in 2021, there is a 148% vehicle weight increase.

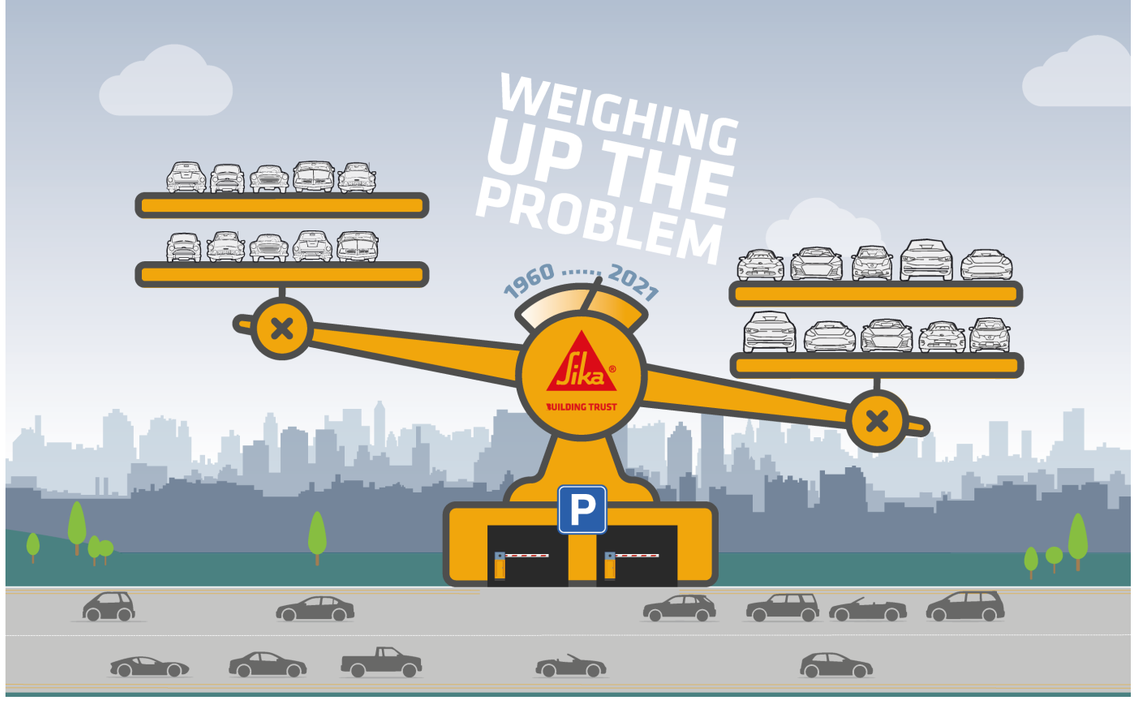
Why are electric cars heavier?

Electric vehicles are heavier because of their large batteries, the armour required to protect them, and the reinforced chassis and suspension required to support the battery weight.

An electric car's battery cells are the equivalent of a petrol car's fuel tank. While a petrol or diesel car can cover hundreds of miles with 60 kg of fuel on board, it would take around 500kg of batteries to do the same.

Put simply, Multi-Storey Car Parks built in the 1960s and 1970s were not designed for bigger, heavier modern IC vehicles, even without the issues laid out in chapter one, let alone the step change in load that EVs represent.

Best selling cars in the UK – 1960s	Best selling electric vehicles in the UK - 2021
BMC Austin/Morris 1100 (832kg)	Tesla Model 3 - second best-selling car overall in 2021 (1.726kg)
Ford Cortina Mark 1 (768kg)	Kia e-Niro (1.812kg)
Mini (635kg)	Volkswagen ID.3 (1.812kg)
Vauxhall Viva (770kg)	Nissan Leaf (1.580kg)
Ford Anglia (737kg)	Audi E-tron (2.351kg)



STRUCTURAL LOADINGS IN MULTI-STOREY CAR PARKS FALL INTO TWO MAIN CATEGORIES:

- Dead/static loads – Self-weight of the structural concrete elements of the car park, plus fixed items such as parapets, barriers etc. These loads lead to compressive (crushing), tensile (stretching) and shear (scissor action) forces, which act on the beams, slabs and columns and can lead to tell-tale concrete damage.
- Live/dynamic loads – Any load that moves including pedestrians and vehicles, whether parked or on the move. As these objects move around a structure, the various components (deck, beams, columns, ramps) are loaded and off-loaded, generating compressive, tensile and shear forces in excess of self-weight and static loads. This movement can also result in a degree of fatigue loading of these elements.

If you increase the weight of the vehicles using a Multi-Storey Car Park, then both of these load types and the corresponding stresses they place on the structure increase, even if the number of vehicles does not.

At present, car parks are designed to have an imposed load of 2.5kN / m2, but this is 'best case'. For example, the load that a car park can accommodate may have been reduced if the structure is 50 years old, has not been maintained correctly and has degraded.

This present best case of 2.5kN may not be sufficient because of the weight difference between EVs and IC engine vehicles. Of course, there are additional loads from the EV charging infrastructure too, but we have already seen this reduce as chargers get smaller and lighter.

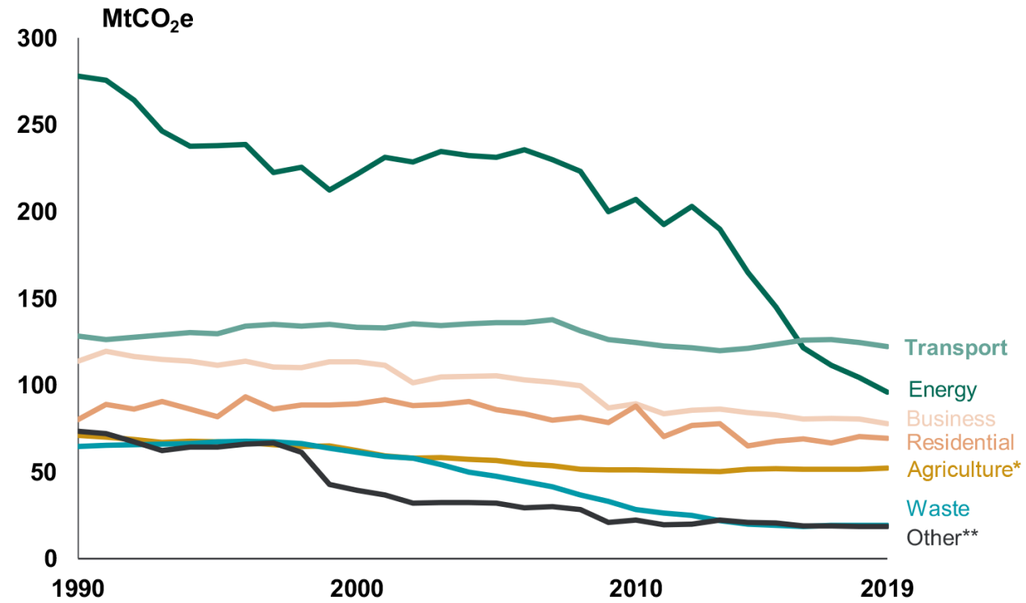
Due to design safety factors, the slabs, beams and columns of almost all MSCPs will be able to take the additional load represented by EVs at present due to the percentage of the UK fleet that they currently embody; but can they take the static and dynamic loads of a majority EV future without structural repair and strengthening?

Up to present, much of the focus has been on the challenges of EV charging infrastructure. However, it is likely that a significant proportion of the UK's transport network is simply not designed to cope with the additional loads generated by the increase in EVs that will be driving on our roads, over our bridges and – as this specialist report highlights - parking in ageing Multi-Storey Car Parks by the middle of the next decade.

The question being asked in this report is: If too little is done to address the current state of play both in terms of heavier vehicles, but also structural repairs and maintenance, are we putting the public at increased risk and potentially reducing their access to safe parking spaces?

CHAPTER THREE
THE RISE OF ELECTRIC VEHICLES

Figure 2: Greenhouse gas emissions by sector, 2019 (BEIS, 2021)



* LULUCF – Land Use, Land Use Change and Forestry
** Includes emissions from Public and Industrial Processes

This challenge is being made more difficult by the rise of electric vehicles as we move towards a lower carbon society. Achieving the UK's 2050 net zero target will require decarbonisation across all areas of the economy.

However, when you consider the government's most recent provisional figures, which show that the transport sector accounted for 31.1% of UK carbon dioxide emissions in 2019, making it the highest emitting sector of the economy, it is easy to see the need to tackle transport as a priority.

In addition, transport emissions have remained largely flat since 1990, unlike other sectors such as energy, business and waste which have seen significant falls.

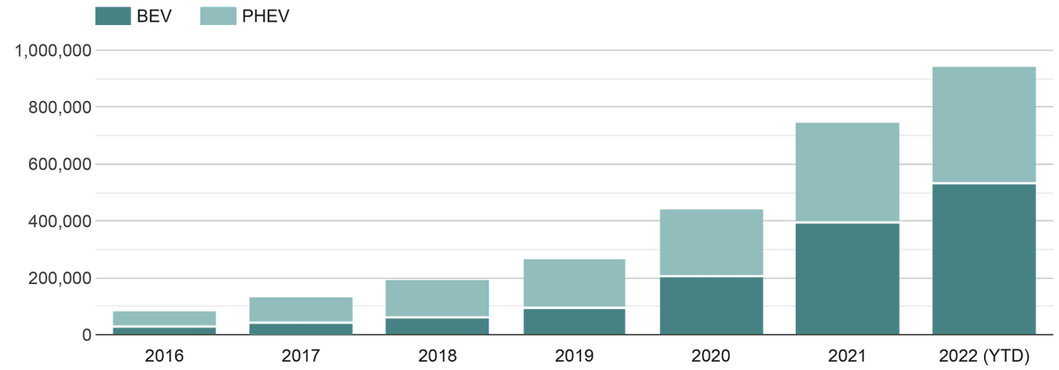
EVs have been identified as a key technology to minimise climate change and contribute towards the reduction in CO_2 as unlike petrol, diesel or hybrid vehicles they produce no tailpipe emissions.

The government has already set out plans to end the sale of new petrol and diesel vehicles by 2030 and for all new cars and vans to be fully zero emission at the tailpipe by 2035. This latter requirement will forbid the sale of new plug-in hybrid electric vehicles.

"THE FULL TRANSITION TO ELECTRIC VEHICLES (EVS) WILL BE ONE OF THE MOST IMPORTANT ACTIONS TO ACHIEVE THE UK'S NET ZERO TARGET."

The Climate Change Commission

Cumulative number of plug-in cars registered in the UK (2016 to date)



Source: SMMT, August 2022

Increased sales to support EV targets

Sales of electric vehicles are rising because of all the above factors, but also increased awareness and concern from the public about the climate emergency. Various incentive schemes have been used to encourage take-up, including the Plug-In Car Grant (PICG), which offered a grant towards the cost of new EVs, and the Electric Vehicle Homecharge Scheme (EVHS), which offered funding towards the cost of a home charger. Whilst these particular schemes have now closed, buying is still encouraged and tax incentives are available.

Figures at the time of writing show there are more than 911,000 battery and plug-in EVs on UK roads.

In 2021, more than 740,000 battery and plug-in EVs were registered – a 69% rise compared with 2020. Manufacturers such as Nissan, Tesla, Ford and more have all expanded their electric ranges in recent years and the volume of EV sales in 2021 was higher than the last five years combined.

CHAPTER FOUR
WHAT CAN BE DONE

The good news is that our car park structures can be returned to a good state of repair and strengthened when required, allowing them to cope with the increased weight of electric vehicles - all using proven technologies for repair, maintenance and improvement.

The key to understanding the risks is to establish the current position regards the car park structure by completing a structural appraisal in accordance with ICE recommendations.

An informed decision can then be made by a suitably qualified professional regarding the suitability of the building in its current condition, to be deemed structurally adequate or otherwise. In extreme cases it may be necessary to limit the weight of vehicles using the car park, or to spread the weight - for example by increasing bay sizes and, by doing so, reducing capacity.

Ultimately, the objective is to ensure that car park structures are safe, structurally sound and fit for purpose.

Fortunately, there are a whole host of innovative products and systems to ensure that this can be done in as cost and time effective way as possible.

This will involve taking stock of the asset in its current state, before looking at what needs to be done to strengthen and repair the structure and specifying the correct techniques and materials for the job.

Once the repair, protection and strengthening works are complete, there then needs to be a plan put in place to ensure that the asset is maintained into the future to prevent further deterioration and costly repairs.

VISUAL INDICATORS OF STRUCTURAL DETERIORATION:

- Water seepage – Water/rust staining of beam sides and deck soffits, often including the formation of stalactites. These features may indicate failed waterproofing, movement joints or drainage and present an increased potential for corrosion damage and coating failures.
- Concrete cracking – There are a myriad of causes, but cracking could indicate ongoing structural issues, and allows contaminated water to reach the steel easily. Often worsened by thermal expansion/contraction due to temperature changes.
- Spalled concrete with exposed steel reinforcement - Arises from expansive corrosion products (rust) forcing the concrete cover to fail. The corrosion is caused by de-icing salt ingress (decks or other wet areas) or carbonation (acidification) of the cover concrete, typically in drier areas.
- Deck coating wear and tear – Patches where coatings are delaminated or worn through due to application issues or tyre abrasion. Failed coatings lead to water ingress and the further issues this causes.

ASSESS - SPECIFY - REPAIR - MAINTAIN

ASSESS

Assess the structural performance of existing structures, to reflect their current condition, current loadings as well as future loadings. This is done via desk studies, site surveys and material analysis and will determine whether structural repair or strengthening is required to ensure that the structure is fit for purpose. This work will typically be carried out by a structural engineer.

Undertake a concrete condition assessment to quantify any damage and deterioration to the various structural elements, identify their causes and to determine their extent and seriousness (usually a combination of chloride sampling/analysis, half-cell potential mapping, cover depth and carbonation depth surveys, etc.). This work will typically be carried out by a specialist surveying and testing contractor.

This initial testing will allow the specifying engineer to determine what issues need to be addressed to ensure that the risk of further deterioration is reduced or removed. The results will also allow for prioritisation, to ensure that ‘big ticket’ items, critical to the car park remaining open, are addressed as a priority.

SPECIFY

It is therefore essential that the responsible engineers engage with materials manufacturers and suppliers to ensure that the correct products and product systems are specified for the project.

When this is done successfully, the products and systems will address most, if not all of the issues raised by the testing and surveys carried out. This ensures that the repairs have the longest possible lifespan and therefore represent a sound return on investment.

REPAIR

The techniques and products used to structurally repair a car park structure fall into three main categories:

Reinstate lost strength - Protect against future deterioration - Increase strength

REINSTATE LOST STRENGTH

There are a myriad of product categories which can be used to reinstate the strength of a car park structure which has been lost through corrosion damage, structural movements and excessive loading.

These include reinforcement primers, structural repair mortars & grouts, resin anchors and crack injection resins. These repairs may require new reinforcement to be installed to replace bars damaged by reinforcement corrosion.

The idea behind these kinds of repairs is that defective concrete is replaced by a durable material that is at least as strong as the existing concrete. This allows load paths to be reinstated and for further deterioration to be stopped.

There are subsets of products within these categories that are particularly useful in car park repair works. Fast-set, rapid strength gain products, usually but not always based on epoxy technology, can ensure a return to traffic-able surfaces within a few hours post-repair.

The guidance found in BS EN 1504 should be followed to ensure that high quality repairs are achieved.

PROTECT AGAINST FUTURE DETERIORATION

Car parks can provide very aggressive environments for concrete. This means that concrete protection in some form is often required to ensure the longevity of the structural concrete, including any repairs that have been made. These products generally fall into one of two categories:

PREVENT INGRESS

The aim of any coating on a car park is to prevent water penetrating into the concrete. On the car park decks and column bases, high-strength, waterproof and wear-resistant coatings prevent water laden with chloride salts from penetrating the concrete and causing reinforcement corrosion. On the columns, beams and soffits, coatings are also used to prevent moisture from entering, but also to prevent carbonation of the concrete. Carbonation is caused by atmospheric carbon dioxide (CO_2) penetrating into the concrete and reducing its pH. Once it reaches the steel reinforcement, this acidity destroys the passive oxide film on its surface and corrosion progresses leading to cracking, delamination and spalling. Specialist anti-carbonation coatings stop this process and provide a brighter more visually appealing environment.

Hydrophobic impregnants are applied to the concrete surface in either liquid or cream form. This group of products are designed to line the pores of the concrete, preventing water from entering and reducing the potential for freeze-thaw damage. Additionally, as water cannot penetrate the concrete, neither can chloride ions and so the corrosion risk is significantly reduced.

CORROSION CONTROL

To mitigate the risk posed by chloride ions in the concrete. These ions (from de-icing salts) diffuse through the cover concrete to the steel and amass at the surface. Once they reach a certain concentration, they destroy the natural oxide layer at the steel surface leading to reinforcement corrosion, cracking and eventually, delamination and spalling. Cathodic protection and prevention techniques use activated zinc or hybrid anodes to relocate the corrosion reaction to the anode and prevent reinforcement corrosion.

In addition to cathodic protection and prevention, corrosion inhibitors can be used to stop or prevent corrosion. These materials have been developed to diffuse into the concrete and prevent the corrosion reaction from occurring on the steel reinforcement. They are either spray applied or placed in drilled holes in the concrete at a spacing.

INCREASE STRENGTH

To ensure that the various elements of the car park can withstand current and future loads, it may be necessary to supplement their strength and therefore load-bearing capacity. Traditionally, this has been done using various forms of steel to supplement the reinforcement already buried in the concrete, for example:

BEAMS

Bolting or bonding steel plates to the bottom of the beam to increase the flexural capacity.

COLUMNS

Steel reinforcement cast into a concrete ‘jacket’ around the column, or a bonded/ bolted steel collar to provide the necessary confinement.

SLABS

Adding supplemental beams to the soffit, or additional reinforcement mesh and concrete overlay.

Whilst these techniques, when properly designed, undoubtedly achieve the aims of the strengthening, they increase the self-weight and therefore static load on the car park. Also, as they all contain ferrous materials, they represent a corrosion risk which must be mitigated by coatings and regular inspection and maintenance.

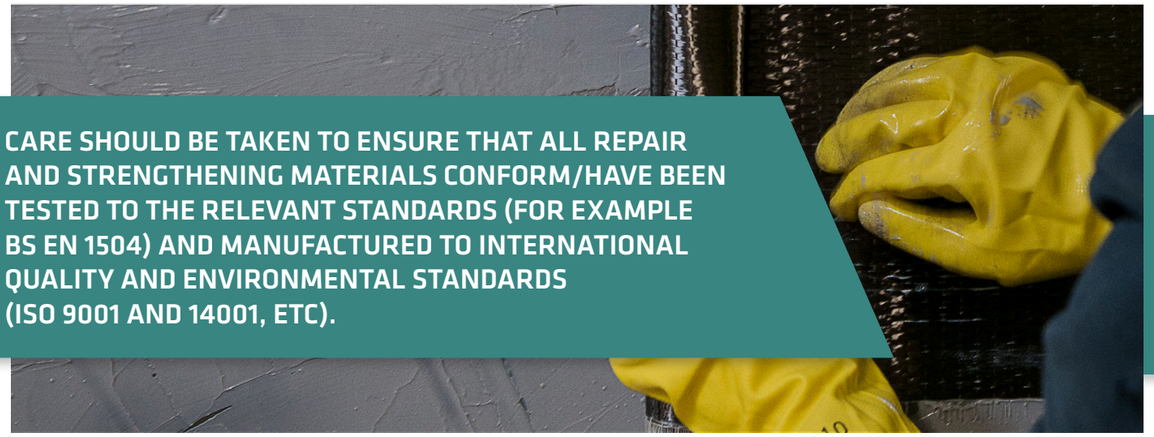
In the last 30 years, Carbon Fibre Reinforced Polymer (CFRP) products have been successfully employed to strengthen reinforced concrete structures. These materials generally come in the form of pultruded plates or as uni- or multi-directional fibres. These are then combined with an epoxy resin or adhesive on site to create a composite strengthening system.

The incredibly high strength of the carbon fibres, along with their low weight, means that much less material is required to achieve the same level of strengthening as steel. This means that a steel plate 10mm+ in thickness, weighing 100kg+ can be replaced by a ~1mm thick plate of CFRP weighing only a few kg. Similarly, a reinforced concrete column jacket 150mm thick can be replaced by several wraps of a CFRP fabric, which totals just 10mm.

The weight reduction alone reduces the risks around manual handling, the amount of labour required on site and removes the need for lifting/propping equipment. In addition, lengths of up to 50m can be applied in one go and there is no risk of corrosion.

CFRP PLATES AND WRAPS	STEEL PLATES OR BEAMS
PROS	**PROS**
Lightweight with very little manual handling risk	More widely understood and remains most common method, using common design codes
Uniform application of strengthening (no bolts)	Lower material/fabrication costs
Very little impact on headroom or column width	Simple surface preparation
Will not corrode	**CONS**
Straightforward and quick installation	Heavy to move into position and may need propping (which would cause closure of area below)
Can be hidden behind mortars, renders or coatings	Adds significant static loads to structures
CONS	Liable to corrosion
Higher initial cost	Point loads due to fixings and maximum length circa 5m
Cannot be fixed through or to	Reduced ceiling heights (beams) and increases width of columns
Fire resistance (only in certain circumstances)	Requires ongoing painting and inspection \maintenance

*It is important to note that any strengthening solution needs to be designed by a competent structural engineer to ensure that is fit for purpose and suited to the environment.



CARE SHOULD BE TAKEN TO ENSURE THAT ALL REPAIR AND STRENGTHENING MATERIALS CONFORM/HAVE BEEN TESTED TO THE RELEVANT STANDARDS (FOR EXAMPLE BS EN 1504) AND MANUFACTURED TO INTERNATIONAL QUALITY AND ENVIRONMENTAL STANDARDS (ISO 9001 AND 14001, ETC).

MAINTAIN

Life Care Plans

This holistic approach to structural refurbishment offers a lower-cost, more sustainable alternative to new build. Car park owners can refurbish their existing assets for a fraction of the cost of a new build, whilst also preventing the carbon footprint associated with constructing a new facility, including through construction methods and embodied carbon of building materials.

"WITH CAR PARKS, THE OWNERSHIP TENDS TO BE MORE VARIED (THAN BRIDGES) AND THERE AREN'T THE SAME OBLIGATIONS FOR FORMALISED PRINCIPAL INSPECTIONS ON A CYCLE WHICH YOU'D EXPECT FOR A BRIDGE STRUCTURE.

BUT A QUESTION THAT COULD BE LEGITIMATELY ASKED IS, IS IT NOW TIME TO MAKE IT MORE RIGOROUS AND MAKE IT MORE OF AN OBLIGATION FOR CAR PARK OWNERS TO HAVE GOOD PRACTICE AND FOLLOW RECOMMENDATIONS?"

-Structural safety campaigner, University of Edinburgh chair of future infrastructure and past ICE president Gordon Masterton – speaking after the partial collapse of a car park in Nottingham in 2017.

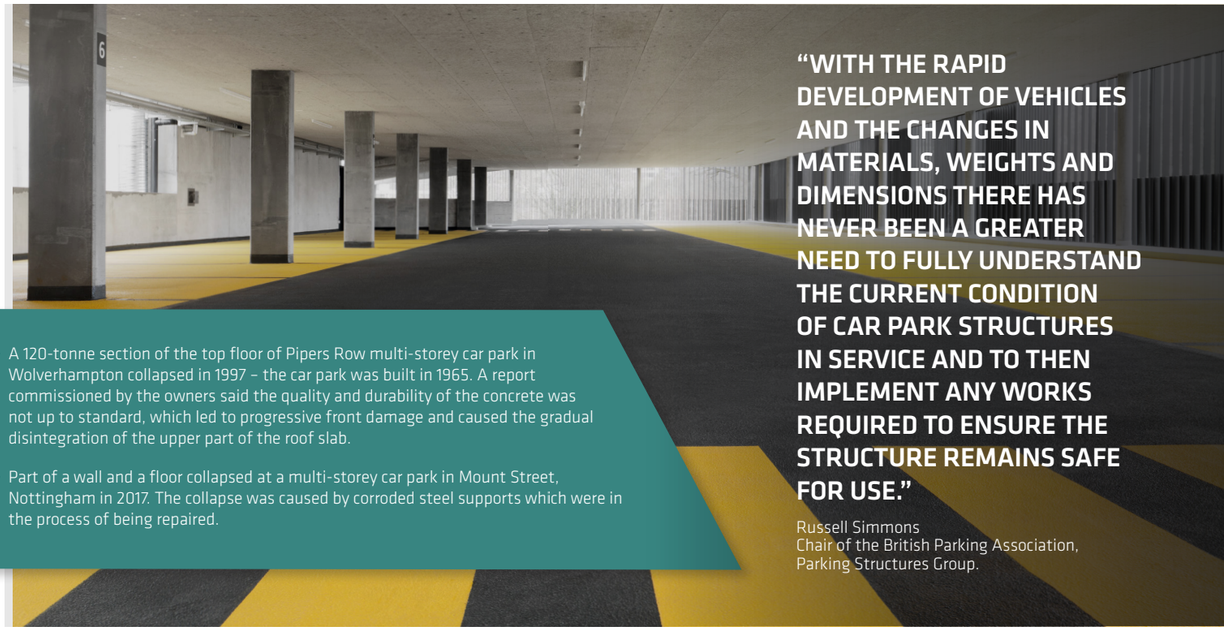
The bottom line

Above all else, car park owners and operators have a legal duty under the Regulatory Reform (Fire Safety) Order 2005 and the Health and Safety at Work Act 1974 to maintain the car parking facility to ensure that it does not endanger the people using it.

Operators also have a duty under s2(2) of the Occupiers Liability Act 1957 to take reasonable steps to ensure the reasonable safety of visitors, whether they are there legally or otherwise.

Unfortunately, there have been cases of catastrophic collapse in MSCPs and in most cases subsequent investigations have highlighted poor design, construction and/or maintenance of the structure.

Aside from regulations and legislation, it should be the aim of all car park owners and operators to provide facilities which make users feel safe and secure. Car park decking systems, protective wall coatings and marking systems are available in a vast range of standard colour and finish options which can significantly lighten and brighten parking facilities. This, when coupled with improved lighting and a proper cleaning, maintenance and repair plan, ensures that car park owners and operators can create safe and visually attractive parking environments for users.



- A 120-tonne section of the top floor of Pipers Row multi-storey car park in Wolverhampton collapsed in 1997 – the car park was built in 1965. A report commissioned by the owners said the quality and durability of the concrete was not up to standard, which led to progressive front damage and caused the gradual disintegration of the upper part of the roof slab.
- Part of a wall and a floor collapsed at a multi-storey car park in Mount Street, Nottingham in 2017. The collapse was caused by corroded steel supports which were in the process of being repaired.

"WITH THE RAPID DEVELOPMENT OF VEHICLES AND THE CHANGES IN MATERIALS, WEIGHTS AND DIMENSIONS THERE HAS NEVER BEEN A GREATER NEED TO FULLY UNDERSTAND THE CURRENT CONDITION OF CAR PARK STRUCTURES IN SERVICE AND TO THEN IMPLEMENT ANY WORKS REQUIRED TO ENSURE THE STRUCTURE REMAINS SAFE FOR USE."

Russell Simmons
Chair of the British Parking Association,
Parking Structures Group.

CHAPTER FIVE
SIKA SOLUTIONS

ABOUT SIKA

Sika has been transforming car park environments for over 40 years. It offers a single source solution, enabling refurbishment work to be carried out with minimum disruption. Operating globally from over 70 countries, it has an extensive product range, expert knowledge and technical support to assist with all car park refurbishment projects.

THE SIKA RANGE FOR CAR PARKS INCLUDES:

- **DECK WATERPROOFING SYSTEMS, FOR EXTERNAL AND INTERNAL DESK SURFACES, AND RAMPS**
- **OVERLAY SYSTEMS FOR EXISTING ASPHALT DECKS**
- **SEALING SOLUTIONS, FOR HIGH TO LOW MOVEMENT EXPANSION JOINTS**
- **ANTI-CARBONATION COATINGS**
- **JOINT SEALING FOR FACADES AND PRECAST CONCRETE**
- **CONCRETE REPAIR AND CORROSION PROTECTION**
- **SPECIALIST RAPID STRENGTH GAIN MATERIALS TO ENSURE A QUICK RETURN TO SERVICE**
- **FLOOR AND WALL COATINGS FOR ENTRANCE AREAS, WALKWAYS AND STAIRWELLS**
- **ANTI-GRAFFITI COATINGS**
- **BASEMENT WATERPROOFING SOLUTIONS**

Where applicable, Sika repair mortars, protective coatings and decking membranes been tested in accordance with the European standard BS EN 1504, along with a number of different standards.

SITE SURVEYS AND APPLICATION

As part of its service, Sika provides a free site survey and assessment before producing a complete specification with recommended product solutions and budget costings. Sika's specifications take into consideration the results of any specialist testing, where available. It is supported by a national network of contractors who are experienced in the application of Sika products.