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Rehabilitation of brownfield sites using the Gyropiler to remove existing bored cast in-situ concrete piles

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ABSTRACT: Reinforced concrete deep foundations are typically abandoned after a building is demolished. This is a particular problem in highly developed cities, such as London, as they undergo redevelopment cycles. Many London sites are now in their third generation of deep foundations. The previous foundations present significant economic, environmental and safety challenges for subsequent developers, as the ground is increasingly more congested with piles; this is clearly not sustainable. Reuse of existing piled foundations is particularly difficult as insurance cannot be easily obtained. The piling industry has adopted construction methods to core out existing piles, only to replace them with larger diameter or deeper concrete piles. This paper explores the use of the Giken Gyropiler to overcore and remove concrete piles in their entirety. This technique, combined with more sustainable foundations could rehabilitate sites that have been polluted with piles, and has the potential to improve the value of brownfield sites.

1 BACKGROUND

Bored cast in-situ concrete piles have been used widely on commercial buildings in London for over 50 years. Therefore, a large proportion of brownfield sites are now on their third generation of piled foundations, and the ground is becoming increasingly littered with man-made infrastructure, see Figure 1.

RuFUS (Butcher *et al.*, 2006) published guidance and a number of case studies relating to the 'Reuse of Foundations in Urban Sites', however there is still little appetite amongst developers to reuse existing concrete piles as, amongst other factors, it is difficult to assess their condition. Consequently, new piles are often installed in favor of reusing existing piles, which cannot be easily removed, during redevelopment.

A high profile example of a bored piled foundation polluted site is illustrated in Figure 3. The Shard development in Southwark, central London, was previously home to a 26 storey structure which had been founded on underreamed piles. The previous development, Southwark Towers, had limited basement space, therefore the structures had been founded on relatively shallow piles (Moazami & Slade, 2013). Aerial views comparing the Southwark Towers and the Shard development are presented in Figure 2.

Consequently, the piles could not be reused and the presence of the underream bell eliminated the option to remove the piles. The new piles were therefore positioned in between the existing underream piles, as shown in Figure 1.

Loads from the Shard superstructure was vastly different from those that had been imposed on the underream foundations from the Southwark Towers. Therefore, to accommodate these loads, additional, deeper piles were required. Importantly, none of the existing piles were mobilised, and still remain in the ground as obstructions to future developments.

The scheme comprised the installation of over 100no. bearing piles 1.8m in diameter constructed to depths of over 60m deep, through the London Clay and where founded in Thanet Sands (Beadman et al., 2012).

2 INTRODUCTION

If the situation remains where developers do not reuse existing piles, a solution must urgently be sought to enable the efficient and economic removal of existing piled foundations. Failure to do so, would inhibit the future development potential of large cities, ultimately reducing the value of such areas.

Current pile removal techniques rely on a large piling rig, typically weighing over 120 tons, to core out existing piles, which can range in diameter from 450mm up to 1800mm or more. This process involves

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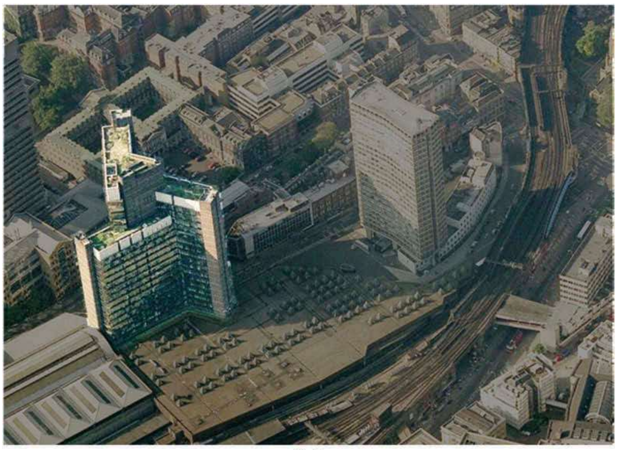
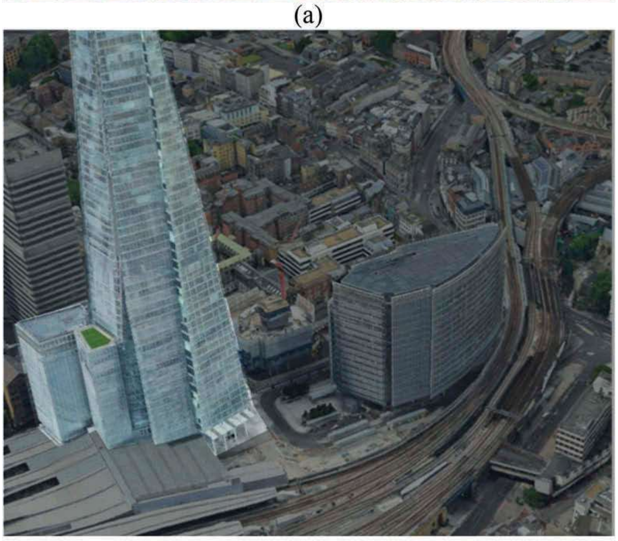
Figure 1. Géotechnique artist impression of sub-surface congestion (courtesy of Keller).



(a)



(b)

Figure 2. Aerial views of (a) Southwark Towers and (b) the Shard, post development.

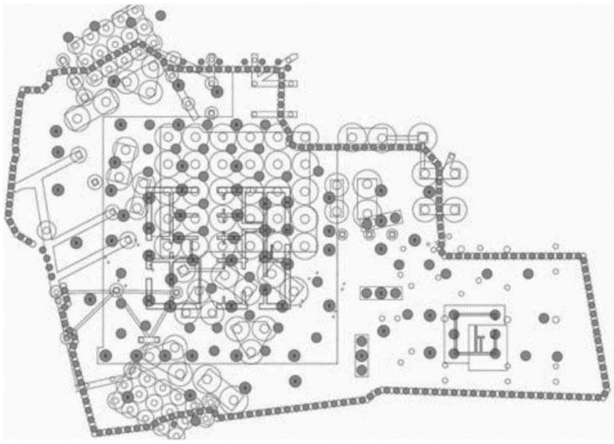


Figure 3. Existing underreamed piles from Southwark Towers and new pile layout (shown in dark grey) adopted at the Shard, shown as dark circles (Moazami & Slade, 2013).

the use of a segmental casing, with 50mm thick walls, with cutting teeth. The piling rig repeatedly advances the casing along the length of the pile to grind through existing obstructions and remove sections of the unwanted pile in short segments, as shown in Figure 4 and Figure 5. This is a laborious, time consuming, high maintenance and expensive process. The environmental concerns arising as a result of these coring operations are also significant; as noise, dust and vibration levels are frequently excessive.

The construction industry is generally keen to consider the use of new technology to establish a competitive advantage over other contractors, and thereby maintaining and expanding on a significant market share.

As a vast majority of brownfield development sites in London have already been littered with pile foundations, there is an urgent requirement for an efficient and reliable procedure for removing existing piles. This paper investigates the suitability of the Gyropiler to develop a bored cast in-situ piled removal process.

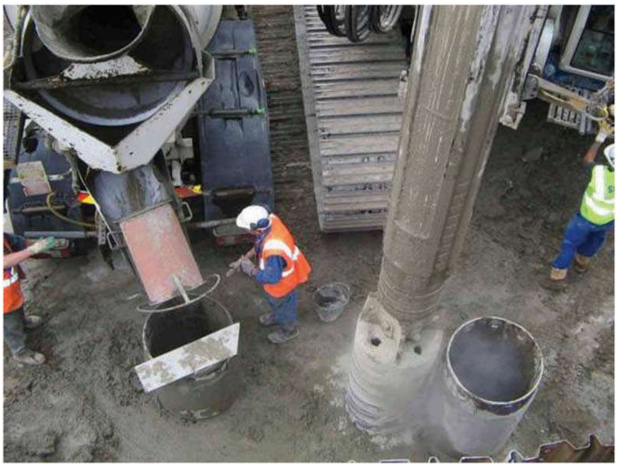


Figure 4. Pile removal on 900mm diameter piles.

Figure 5. Pile coring in progress on 1800mm diameter piles.

This project considers the removal of existing concrete bored piles through a series of centrifuge model tests (Gorasia *et al*., 2013). A bespoke auger was designed to drive through the soil. The purpose of this tool was to remove the soil directly adjacent to the piled foundation, as well as the bored element, in its entirety.

3 GIKEN GYROPILER

Giken (Giken, 2018) recognizes that infrastructure projects heavily rely on concrete construction, which are constructed without regard for future developments and are therefore inherently difficult to remove at demolition stage; this all contributes to a congested subsurface environment.

The Giken Gyropress Method (Giken, 2018) has the potential to resolve the deep foundations industry by reimagining new construction method concepts. The Gyropress, shown in Figure 6, enables the installation of tubular piles with cutting teeth attached to the pile toe. The piles are rotated and jacked simultaneously. This technique respects the “Five Construction Principles” (Giken, 1994).

Expansion for the applicability of the Giken Gyropress into the pile removal market aligns with the “Five Construction Principles”. This application would further enhance the Giken offering, as significant improvements would be realized in environmental

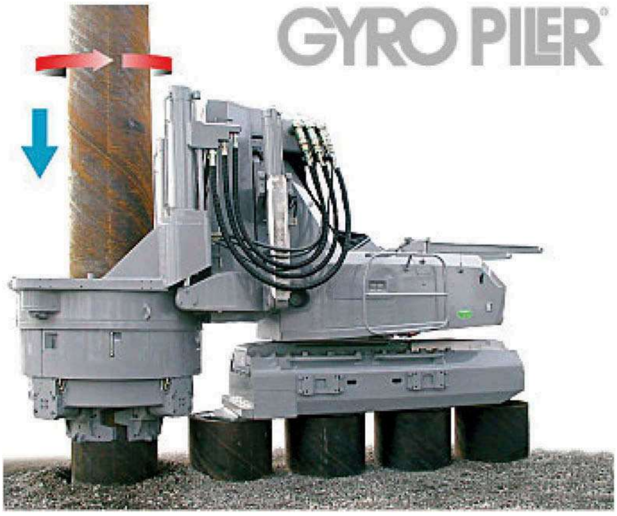


Figure 6. Giken Gyropiler (Giken, 2018).

Environmental Protection	Construction work should be environmentally friendly and free from pollution.
Safety	Construction work has to be carried out in safety and comfort with a method implementing the highest safety criteria.
Speed	Construction work should be completed in the shortest possible period of time.
Economy	Construction work must be done rationally with an inventive mind to overcome all constraints at the lowest cost.
Aesthetics	Construction work must proceed smoothly and the finished product should portray cultural and artistic flavour.

Figure 7. General construction principles (IPA, 2016).

protection, safety, speed and economy, as construction practices would move away from inefficient, slow and hazards incremental pile breaking methodologies, to more effective solutions.

4 GYROPILER BESPOKE PILE REMOVAL AUGER

This discussion paper seeks to explore an experimental technique for bored pile removal that has been developed by City, University of London. This technique has been trialed in laboratory model tests and aims to allow for the removal of complete piles by over excavation and remolding of the soil from the pile annulus using a specially developed auger, as shown in Figure 8.

Figure 8. Over coring auger for model tests on bored pile extraction.

In principle, the results from previous tests (Gorasia *et al.*, 2013) showed that the cutters reduced the applied torque force between approximately 20-30%.

The auger was designed to remove a small annulus of soil from around an existing concrete pile. The tool is advanced along the full depth of the pile before being twisted to shear the soil just below the pile toe.

Special consideration was given to developing a means of ensuring that the pile could be removed as a complete element. 'Cheesegrater' cutting teeth (visible in Figure 9) allow for a small annulus of soil to also be removed along the face of the pile. Without this modification, the Gyropiler would easily shear lightly reinforced piles as friction between the inside face of the tube and the pile would exceed the structural capacity of the piled element (McNamara *et al.*, 2013).

If a pile was sheared in this way, the removal process would be incredibly time consuming and laborious, as the Gyropiler would be required to repeatedly lift the cutting auger which would then need to be cleaned, before repeating the activity to the toe of the pile.

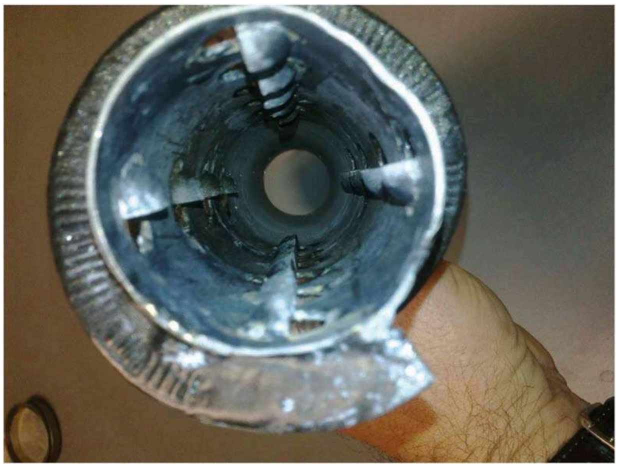


Figure 9. Pile over coring auger showing 'cheese grater' type cutters inside a steel tube.

The auger is effective because the cutting teeth scrape some of the soil from around the pile, remolding it and forcing it to the outside of the tube where it can be removed on the flights. This allows the tube to advance over the length of the pile with very little friction acting on the inside of the tube and leaving a concrete column that is no longer in contact with the soil along its shaft and that can be lifted out of the ground using a crane.

If similar principals could be applied to tubular steel piles then it may be possible to remold the soil around the base of an advancing pile with careful design of the tip. If the soil is remolded then structure or fabric may be removed during rotation of the pile and this could contribute to an overall reduction in vertical jacking force required.

5 APPLICABILITY TO BROWNFIELD SITES

The operation of the Gyropiler relies on tubular driven piles on which it is supported. The tubular piles provide reaction to both driving forces and extraction forces.

Brownfield sites are characterized by many unknown and known obstructions in the ground. These include the piles to be removed and also other old shallow foundations, redundant buried structures and both live and disused services.

Whilst the Gyropiler is easily capable of penetrating such ground conditions and obstructions, the removal of existing obstructions would nonetheless be time-consuming as temporary tubular steel piles would be required to provide the necessary reaction forces to implement the Gyropiler in its current configuration. Furthermore, on congested sites in well-developed urban areas, previous pile layouts will have been designed to avoid existing buried infrastructure. Therefore, the installation of temporary tubular piles may impinge on such infrastructure which would make the Gyropiler a non-viable method of extracting existing concrete piled foundations.

The obvious solution to ensure the successful deployment of the Giken Gyropiler for all applications on brownfield sites would be to develop or adapt existing tracked piling rigs to accommodate the Gyropiler system.

This approach to pile removal would complement a new concrete piled foundation that may be adopted on a site remediation development. The bespoke Gyropiler mechanism could be attached to a tracked piling rig and would be capable of removing existing foundations. The same piling rig could either be used to extend the newly bored pile, or continue to drill or extract piles across the site without the need for other pile removal machinery, importantly, negating the need for environmentally damaging percussive methods.

Benefits of this adaptation include limiting the number of items of heavy plant on site, which is particularly important in helping to manage safety and logistics on piling sites.

This process greatly improves on current practice, where piles are cored, backfilled with lightly cemented concrete, only to be drilled through and replaced with a structural concrete pile. The environmental impact of this process is catastrophic and adds considerable time to the construction program. The Gyropiler mechanism, combined with a tracked piling rig, would enable site teams to remove existing concrete piles and construct new piles in continuous single operation.

In addition, a piling mat would be already be required for the installation of concrete bored piles. Consideration would need to be given to the existing piling mat design to ensure sufficient bearing capacity for the Gyropiler attachment when extracting existing foundations.

6 PILE REMOVAL SEQUENCE

Removal of existing piles would be carried out using the following process, as illustrated in Figure 10:

i. Drill through the centre of pile to the pile toe
ii. Resin the end of the bar to provide a method of lifting the pile out of the bore; see (a)
iii. Install Gyropiler attachment; see (b)
iv. Use conventional segmental casing to advance Gyropiler attachment; see (c)
v. Extend Gyropiler attachment below existing pile toe; see (d)
vi. Attach pile cropped to top of casing and lift pile head from central bar; see (e)
vii. Continue to lift pile from bore and incrementally crop, resulting in concrete falling away from central bar; see (f)
viii. Extend pile bore if required
ix. Extract segemental casing and Gyropiler to competent ground conditions; see (g)
x. Place reinforcement and structural concrete to complete construction of new textured pile; see (h).

7 IMPLICATIONS FOR THE PERFORMANCE OF FUTURE BORED CONCRETE PILES

During a previous experimental trial (McNamara et al., 2013), two piles were cast in a clay sample and over-cored with one straight shafted tubular cutter, and the other with a profiled tubular cutter.

Upon removal the plain pile shaft was especially clean and no clay had adhered to the tubular cutter. The profiled pile cutter plugged at the base and a significant amount of clay had adhered to the surface, as illustrated in Figure 11.

Figure 12 shows the profile of the straight tubular pile cutter, whilst Figure 13 clearly shows a more textured bore profile arising as a result of using the profiled tubular cutter. The implication of such a pile bore surface is that the pile newly constructed in this bore would possess a much improved adhesion factor, compared with a standard bored pile.

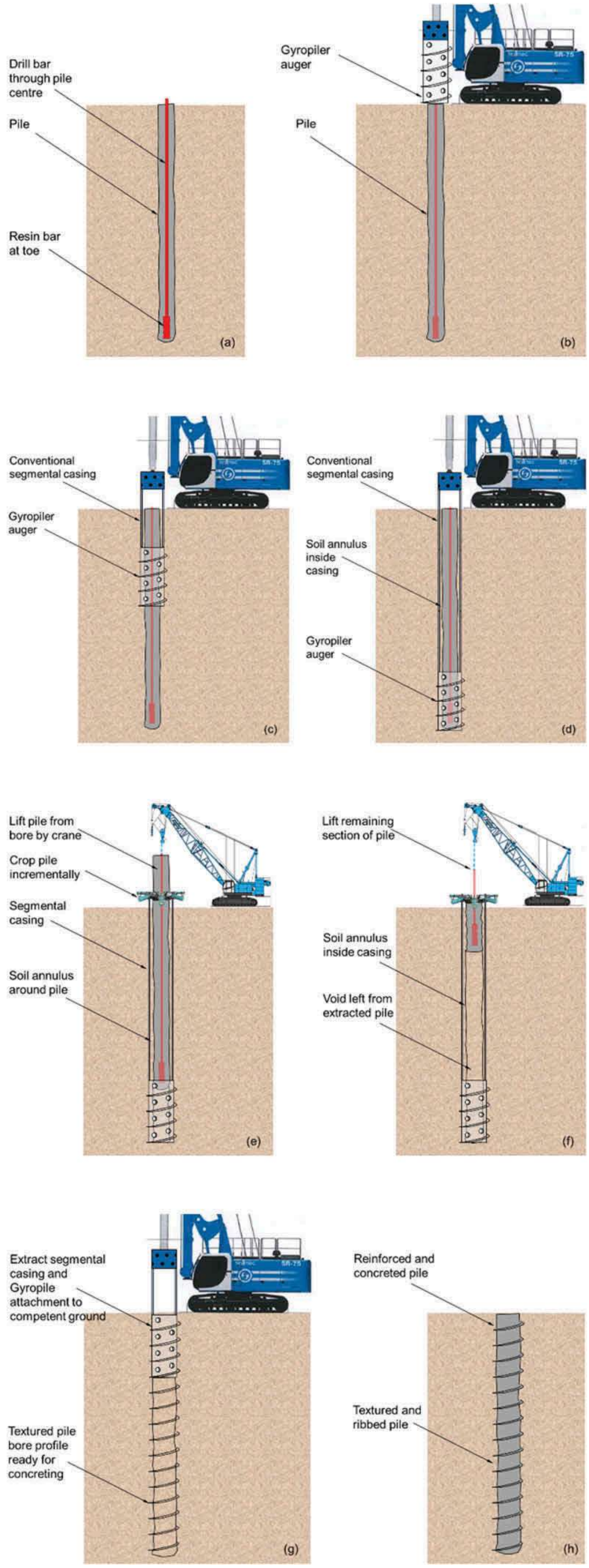


Figure 10. Gyropiler pile extraction sequence.

Figure 11. Adhered clay on the surface of the profiled pile (McNamara et al., 2013).

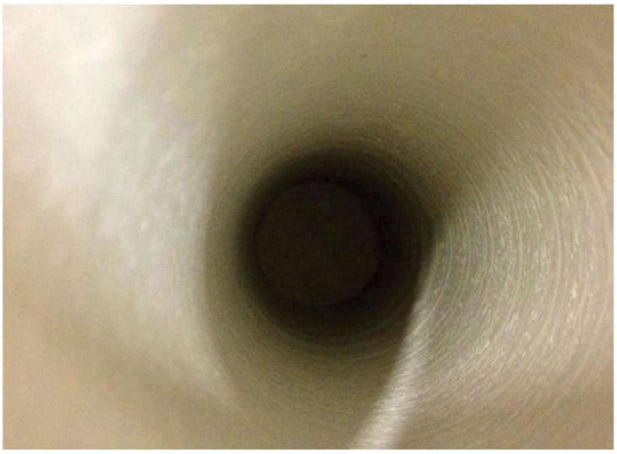


Figure 12. Photograph of clay surface after removal of plain tubular pile (McNamara et al., 2013).

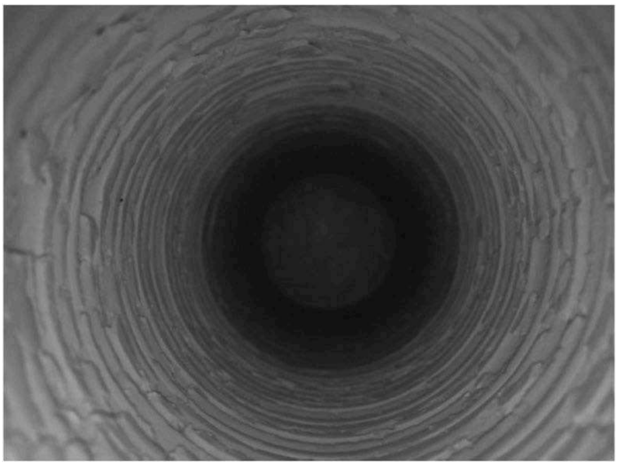


Figure 13. Photograph of clay surface after removal of profiled tubular pile (McNamara et al., 2013).

8 CONCLUSIONS

There is an urgent need to develop new systems and approaches to brownfield site remediation.

A potential method of removal of existing bored concrete cast in-situ piles has been proposed using Gyropile technology.

The method has potential to allow removal of deep piled foundations whilst also creating enhanced shear capacity at the soil-pile interface.

The processes described in this paper extends the application of Giken plant to sites where tracked machinery is required.

A feasible construction sequence has been outlined which has considered the practicalities and typical site limitations likely to be experienced. The process has genuine potential to improve health and safety in construction, reduce the environmental impact of demolition works, and accelerate construction programs.

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