IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Enhanced Pile Head Removal Process For Safer And Efficient Bored Cast-In-Situ Pile Construction

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ABSTRACT

The normal way of chipping off contaminated concrete from bored cast-in-situ piles is by using either manual or pneumatic hammers, making it a very laborious and time-consuming process. This traditional approach poses very real occupational hazards such as high levels of noise pollution, air pollution, hand-arm vibration syndrome (HAVS) due to long tool use and ergonomic discomfort to workers. Furthermore, the large amount of debris produced results in reduced productivity of the site and increased cleaning time. To this end, a new approach has been proposed that incorporates two major changes: (1) The use of synthetic foam-based sleeves to prevent reinforcement from bonding with concrete above the cutoff point and (2) The use of hydraulic splitters for precise pile head cutting. The foam sleeves allow the reinforcement to move relatively easily with respect to the concrete, thus easing the process of removing them after curing.

On the other hand, hydraulic splitters which are placed in the pre-drilled holes, induce controlled fractures that enable easy separation of the pile head into one piece with minimal need for manual force. This detached section is then safely lifted using a crane, thereby leaving a clean pile head that can be easily incorporated into the pile cap. A field trial was conducted to validate the effectiveness of this method on a 1.2 m diameter pile with a 1.5 m removable section. It was observed that there was a significant decrease in fatigue, noise, and dust exposure among the workers, and at the same time, there was a great enhancement in the efficiency of the process. This innovative approach increases safety and sustainability in the workplace. It improves project management and execution, which makes it a suitable technique to be adopted as a sustainable method of removing pile heads.

KEYWORDS:

Hand-Arm Vibration Syndrome (HAVS); Ergonomic Discomfort; Pile Head Removal; Workplace Safety

INTRODUCTION

India, now the most populous country in the world, faces a growing demand for infrastructure development to accommodate its expanding population. Changing demographics and evolving economic priorities have intensified the need for enhanced housing, sanitation, digital infrastructure, and efficient freight systems, with a significant portion of infrastructure investments directed toward these areas. The construction industry plays a pivotal role in this development. However, workplace safety remains a critical concern. Swuste identifies the construction sector as one of the most hazardous industries. According to the Industrial Global Union, India witnessed at least 240 workplace accidents in the infrastructure sector in 2024, resulting in over 400 fatalities and 850 serious injuries.

Additionally, a DW Report (2024) highlights that, on average, three workers lose their lives daily in Indian industries due to inadequate safety measures. These statistics underscore the urgent need for stronger workplace safety regulations and enforcement mechanisms. The accident process in construction is shaped by distal factors like project type, construction method, site restrictions, design complexity, subcontracting, and building height, which create underlying safety risks (**Zou et al., 2007**). Proximal factors, such as manual operations, site congestion, time pressure, workforce fragmentation, and working at height, directly influence accident likelihood. Sustainability is another growing concern in the construction industry, with CO_2 emissions and waste generation posing significant challenges. While a substantial portion of construction waste can be recycled, improper disposal remains prevalent. Additionally, emissions and noise from machinery contribute to worsening air quality and noise pollution (**Coventry and Woolveridge 1999; Khalili, 2020**).

Foundations serve as the fundamental support system for structures and require careful consideration in the construction industry. As a type of deep foundation, pile foundations play a crucial role in meeting the industry's demand for tall and heavy structures such as skyscrapers, elevated corridors, bridges, and offshore platforms. These piles, constructed from reinforced concrete, act as elements that transfer structural loads to deeper, more stable rock layers beneath the ground. In construction terminology, "Pile Driver" is used to describe both the pile-driving equipment and the skilled workers who operate it. Classified as part of the carpentry trade, pile driving is a demanding job where workers face harsh outdoor conditions such as extreme weather, noise, and difficult terrain (**Dasgupta, 2012**). Pile breaking/chipping involves the removal of the upper section of a concrete pile above ground level to expose reinforcement for structural integration or to adjust its length as per design requirements. This process becomes necessary when piles reach their intended capacity, require modifications, or need repositioning due to construction or demolition needs. Equipment such as jackhammers and cutting torches are commonly used for pile breaking. However, this procedure presents challenges, including excessive dust, noise pollution, worker fatigue, and potential structural damage. Ensuring effective planning, adherence to safety protocols, and skilled execution is essential for minimizing risks and maintaining efficiency in pile-breaking operations.

Researchers examining pile drivers' work patterns adopted the PATH (Posture, Activities, Tools, and Handling) tool, a structured observational technique designed for non-routinized and variable-cycle tasks, allowing for an in-depth analysis of posture and handling-related risks. The common observation was that the construction industry, particularly pile chipping, presents significant ergonomic challenges, including Manual Material Handling (MMH), awkward body positioning, and excessive kneeling, which often result in Musculo Skeletal Disorders (MSDs) affecting various body parts, such as the spine, shoulders, and knees. Pile drivers, while chipping, frequently struggle with protective boots in poor ground conditions, knee strain, and mobility issues due to muddy and slippery surfaces, increasing workplace risks (**Dasgupta, 2012**). The continuous vibration from pile chipping tools like jackhammers can lead to Hand-Arm Vibration Syndrome (HAVS), characterized by vascular constriction, nerve impairment, and joint degradation. Workers frequently exposed to these conditions may experience chronic pain, loss of dexterity, and bone necrosis, making safety interventions essential for preventing long-term occupational injuries [Iwanicka]. This paper focuses on overcoming the challenges faced by pile drivers while removing pile heads through two unique approaches, namely foam sleeves and hydraulic splitters.

PRACTICES IN PILE CHIPPING

Bored cast in-situ piles, as per IS 2911 (Part 1/Sec 2), are formed by drilling a borehole and filling it with reinforced concrete. The upper portion, known as the pile head, is connected to pile caps or beams, with the cutoff level indicating the section where excess concrete must be removed.

IS 2911 RECOMMENDATIONS

IS 2911 (Part 1 - Sec2) recommends that chipping should only be carried out after seven days of concreting using manual or pneumatic tools, ensuring structural integrity. To maintain precision, a 40 mm deep groove must be manually carved around the pile before chipping.

CURRENT INDUSTRIAL PRACTICES

Pile breaking using handheld light breakers or plant-mounted pneumatic heavy breakers is one of the simplest methods. Still, it can result in significant safety concerns and structural damage if not executed properly. It is crucial to allow piles to cure before excavation and trimming, with extended curing for high cement replacement mixes. Pneumatic breakers should not be applied vertically to avoid splitting the pile shaft and damaging the concrete below the cutoff level. Moreover, heavy impact breakers should not be used on small-diameter or lightly reinforced piles, as they increase the risk of integrity test failures. The conventional approach to pile chipping, involving manual or pneumatic tools, leads to excessive noise pollution and airborne dust, making it environmentally unfriendly. The accumulation of concrete debris further challenges sustainability efforts.

PROPOSED APPROACH FOR SAFE & SUSTAINABLE PILE CHIPPING

Pile head removal puts the safety of the workers and sustainability at stake. The proposed approach was carried out in two phases.

SYNTHETIC FOAM-BASED SLEEVE

Firstly, a flexible cover material must be identified that can take the green concrete pressure but does not cling to the reinforcement. After the concrete is set, the material is still flexible and easily allows relative movement of ribbed reinforcement and concrete. A synthetic foam-based sleeve was chosen as a reinforcement cover material based on studies and trials.

HYDRAULIC SPLITTERS

Secondly, the breaking and detaching process of the concrete block above the cutoff level should be expedited with the use of suitable mechanical equipment. Based on the field references, it was found that the splitter used for the rock breaking can be used for the pile head breaking process. Accordingly, the hydraulic splitters can be fitted to the holes (two or three holes at diametrically opposite directions/ equally spaced along the perimeter) drilled using a concrete drilling machine and operated to split the unwanted pile head concrete block from the pile just at the cutoff level.

STUDY AREA

To envisage the benefits out of the idea proposed, a trial cum implementation program was planned at the Katni grade separator project site, Madhya Pradesh.

PILE SPECIFICATIONS

Table 1 shows the piling specifications for which the pile chipping was carried out.

TABLE 1 – PILE SPECIFICATIONS

PILE PARAMETER	SPECIFICATION
Pile material	Concrete
Pile Type	Bored Cast In-Situ Pile
Pile Diameter	1.2 m
Pile Length Above Cutoff Level	1.5 m
Chipping Requirement	Remove excess 1.5 m before pile head casting.

SITE EXECUTION

A six-step approach was followed to complete the trial and implementation work. Figure 1 shows the methodology involved in the execution of approaches.

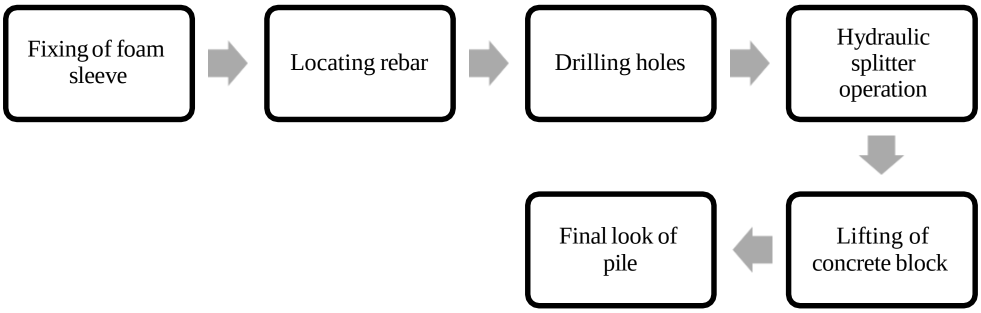

FIGURE 1- EXECUTION METHODOLOGY

Step 1: Fixing the foam sleeve

Debonding foam sleeves are attached to reinforcement rods above the cutoff level during cage fabrication. Figure 2A shows the fixing of the foam sleeve.

Step 2: Locating rebar

The reinforcement cage with the foam sleeve is lifted, positioned in the pile hole, and followed by concreting. Figure 2B displays the positioning of the reinforcement cage.

Step 3: Drilling holes

The rebar location is scanned, three drill points are marked, and holes are drilled just above the cutoff level. Figure 2C indicates the drill hole marking and drilling.

Step 4: Hydraulic splitter operation

Three hydraulic splitters are fixed and operated to create horizontal cracks, separating the upper concrete block from the pile. Figure 2D shows the fixing of the hydraulic splitter and its operation.

Step 5: Lifting of concrete block

A lift hook is installed, and the detached concrete block is lifted as a whole using a crane. Figure 2E shows the concrete block lifting process.

Step 6: Final look of the pile

The pile appears clean and ready for further structural work. Figure 2F shows the finished look after the operation.

A. Fixing of Foam Sleeve

B. Locating Rebar

C. Drilling Holes

D. Hydraulic Splitter Operation

E. Lifting of Concrete Block

F. Final Look of Pile

FIGURE 2- EXECUTION PROCESS

RESOURCES CONSUMED

The newly introduced pile head chipping method was implemented at the Katni Grade Separator Project, ensuring that the cost remained comparable to conventional execution. To enhance productivity, specific resources were deployed on-site, optimizing efficiency while maintaining the integrity of the process. Table 2 shows the minimal resources employed for the process.

TABLE 2 – ADOPTED RESOURCES

RESOURCE TYPE	DETAILS
Workforce	3 workers (for locating rebar, drilling, splitter operation)
Equipment	Rebar locator, Drilling machine with bit, Rock splitter, Crane
Material	Foam sleeve

RESULTS AND DISCUSSION

A simple modification in the construction process with the alternative material/approach improves the quality of the work, productivity, time, and cost savings for the construction project. Figure 3 shows the working of synthetic foam-sleeve which eases the removal of concrete without any involvement of manual labour.

(a) Without Foam Sleeve (b) Concrete Detachment with Foam Sleeve (c) Exposed Concrete
(d) Finished Look

FIGURE 3- PILE HEAD REMOVAL PROCESS

Above all, the ergonomic discomfort of the pile drivers was reduced drastically. Pile head removal and sustainability can be achieved. Table 3 compiles the observed benefits by adopting the techniques.

TABLE 3 – OBSERVED BENEFITS

MPROVEMENT PARAMETER	TANGIBLE BENEFITS	REMARKS
Productivity	New method of pile head chipping: 1 Hr. / pile	Conventional pile breaking with Pneumatic breaker: 6 Hrs. 30 mins.
Quality	Rebars are not affected. Clean working site after removing pile head	Concrete chunks are spread all around the pile after conventional chipping
Cost	20% cost savings	Quality is not compromised in spite of cost- saving
Delivery	Early completion of the pile head chipping process makes the pile ready for the pile cap construction process and subsequent works.	Cost reduction for the project can be achieved.
Safety	Reduced Manual Material Handling (MMH), awkward body positioning, and excessive kneeling	No provision for Hand-Arm Vibration Syndrome (HAVS)
nvironmental, Social and Governance)	Noise, air pollution, debris disposal, and vibration exposure to workmen can be reduced.	Sustainability concerns can be resolved.

CONCLUSIONS

- The proposed pile head removal method, using synthetic foam-based sleeves and hydraulic splitters, significantly enhances safety by reducing ergonomic risks like Manual Material Handling (MMH) and Hand-Arm Vibration Syndrome (HAVS) for workers.
- The new approach improves productivity, reducing pile head chipping time to 1 hour per pile compared to 6 hours and 30 minutes with conventional pneumatic breakers, as observed in the Katni Grade Separator Project trial.
- Quality of execution is elevated, with clean pile heads and unaffected rebars, minimizing concrete debris and ensuring a tidy worksite, unlike the scattered chunks produced by traditional methods.
- Cost efficiency is achieved with a 20% cost saving while maintaining quality, enabling early completion of pile head chipping and facilitating subsequent pile cap construction.
- Environmental sustainability is enhanced by reducing noise, air pollution, and debris, addressing ESG concerns and promoting a cleaner, safer construction process.
- The successful field trial on a 1.2 m diameter pile with a 1.5 m removable section validates the method's efficacy, making it a viable, safer, and sustainable alternative for bored cast-in-situ pile construction.

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