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Load Redistribution and Work-Stoppage Decision-Making during Temporary Earth-Retaining Structure Dismantling -Limitations and Lessons from the Dangjin H-Pile Accident-

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Abstract

Purpose: This study analyzes structural risks during temporary earth-retaining structure (TERS) dismantling and examines the limitations of monitoring-based safety management, focusing on a fatal H-pile dismantling accident at a railway subgrade construction site in Dangjin, Chungnam Province, Korea (August 2019). The research particularly investigates structural re-equilibration, load redistribution during brace removal, and the linkage between monitoring anomalies and failures in work-stoppage decision-making. **Results**: The analysis confirms that, in the Dangjin case, after sequentially cutting seven of eight welded connections between the H-pile and the waler, the final remaining joint could not withstand the highly concentrated load, fractured spontaneously, and caused the waler (H-300×300) to topple and fatally strike a worker. The accident represents a typical failure of structural re-equilibration, as no prior review of load-transfer paths for each cutting sequence had been conducted and no dismantling work plan had been prepared. In addition, although monitoring anomalies during dismantling can function as precursors to progressive collapse rather than simple displacement trends, these signals were not linked to any formal work-stoppage procedure, allowing the risk to escalate. **Conclusions**: This study conceptualizes TERS dismantling as an independent structural transition phase characterized by intensive structural re-equilibration and nonlinear load redistribution. It highlights the need for rate-of-change-based risk management criteria and for a monitoring-to-decision linkage system that explicitly connects monitoring anomalies to timely work-stoppage decisions in dismantling operations.

Keywords : Temporary Earth-retaining Structure (TERS), Load Redistribution, Stress Concentration, Changes in Load-transfer Paths, Work Stoppage, Progressive Collapse.

JEL Classification Code : L74, J28, K32

1. Introduction

Urban excavation works are among the most hazardous types of construction because they involve complex interactions among adjacent structures, groundwater level changes, ground heterogeneity, and changes across construction stages. Previous research and field safety management have primarily focused on controlling wall displacement and ground settlement during the excavation phase. Foundational studies such as Peck (1969), Clough and O'Rourke (1990), and Finno and Calvello (2005) contributed to establishing the theoretical basis for excavation-stage safety management. However, the dismantling phase of temporary earth-retaining structures, which is performed after excavation is completed, has often been regarded as a routine finishing operation, and relatively few studies have independently examined its structural risks.From the viewpoint of structural mechanics, the dismantling phase has risk characteristics fundamentally different from those of the excavation phase. During excavation, system stiffness generally increases as additional support members are installed, whereas during dismantling, the removal of the existing support system reduces structural stiffness and reorganizes load-transfer paths. In this respect, the dismantling phase should not be understood as a simple reversal of excavation procedures, but rather as an independent structural transition stage in which structural re-equilibration is concentrated. Yi et al. (2023) demonstrated through finite-difference analysis that improper strut removal can trigger progressive collapse in the sequence of kingpost, waler beam, strut, and retaining pile, indicating that even partial removal of support members may destabilize the remaining structural system.

The fatal accident that occurred during H-pile dismantling work in August 2019 at a railway subgrade construction site in Dangjin, Chungnam, is a representative example of such dismantling-stage risk. During sequential cutting of welded connections using an oxygen cutter, the load-transfer path associated with each cutting step had not been reviewed in advance, and no dismantling work plan had been prepared. After seven of the eight connections had been cut, the final remaining joint could not resist the concentrated load and fractured spontaneously, causing a fatal accident. Accordingly, this study analyzes the failure mechanism of structural re-equilibration and the limitations of monitoring-to-decision linkage during the dismantling phase, focusing on the Dangjin H-pile case, and proposes safety management measures specialized for dismantling operations.

Figure 1 presents a schematic comparison of changes in structural system stiffness across the different stages of temporary earth-retaining works.

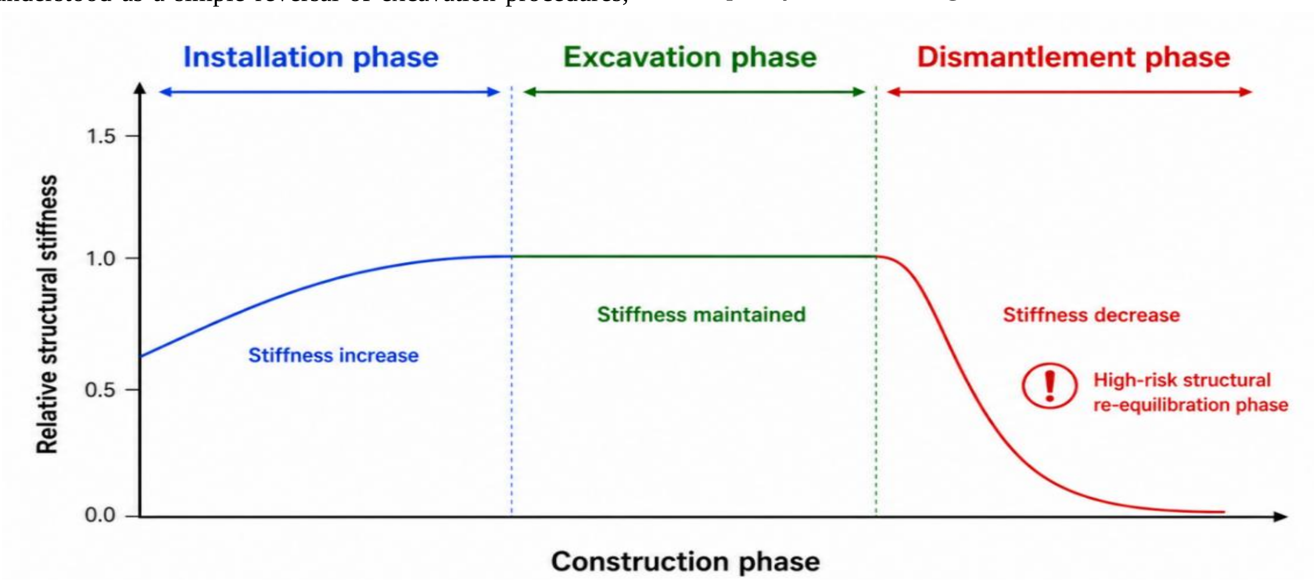

Figure 1: Schematic comparison of structural system stiffness changes at each stage of temporary earth-retaining works

2. Theoretical Background

2.1. Structural stiffness of temporary earth-retaining systems and the structural characteristics of the dismantling phase

Clough and O'Rourke (1990) introduced the concept of the system stiffness number and showed that maximum wall displacement increases nonlinearly as structural system stiffness decreases. Although their study focused on stiffness control in the excavation phase, the same principle can be applied in reverse to the dismantling phase. In other words, as support members are removed, structural stiffness decreases, and the displacement risk of the remaining system may increase in a nonlinear manner. Mana and Clough (1981) also analyzed braced excavations and showed that changes in bracing conditions directly affect wall displacement, providing a theoretical basis for understanding the structural consequences of support removal.

From this perspective, the dismantling phase has structural characteristics that are fundamentally different from those of the excavation phase. During excavation, the installation of additional struts or braces generally increases system stiffness, whereas during dismantling, the removal of the existing support system reduces stiffness and reorganizes load-transfer paths. Therefore, the dismantling phase should be understood not as a simple finishing process but as an independent structural transition stage in which instability may develop rapidly if the residual system is not properly assessed.

2.2. Progressive collapse and its application to the dismantling phase

Progressive collapse refers to a phenomenon in which local damage to a specific member or connection causes load redistribution to adjacent members, which in turn induces additional damage and eventually leads to collapse of the entire structural system. Zheng et al. (2021) experimentally investigated the load-transfer mechanism of braced and tied-back retaining systems and reported that when a particular strut or anchor fails, the load is transferred to a limited number of adjacent support members. Their results showed that as failure propagates, the bending moment of piles can exceed the critical level, resulting in large-scale collapse.

Yi et al. (2023) performed finite-difference analyses based on an actual collapse case and demonstrated that inappropriate strut removal can trigger a progressive failure sequence in the order of kingpost, capping or waler beam, strut, and retaining pile. Their study also confirmed that even local strut removal can induce substantial redistribution of internal forces within the residual structural system. These findings indicate that the dismantling phase of temporary earth-retaining systems is highly vulnerable to progressive collapse because the deliberate removal of support members itself functions as a trigger for load redistribution.

2.3. Limitations of monitoring-based safety management and decision linkage

Peck (1969) proposed the observational method as an integrated cycle linking design, construction, monitoring, and redesign. Dunnicliff (1993) emphasized that the purpose of instrumentation is to identify risk at an early stage and support decision-making. Finno and Calvello (2005) further argued that the observational method is a key practical means of responding to changing field conditions. However, previous studies on the observational method have mainly developed around displacement control during excavation, and they have not sufficiently addressed the possibility that monitoring anomalies during dismantling may function as warning signs of progressive collapse.

The official Committee of Inquiry report on the Nicoll Highway collapse stated that key inclinometers were not monitored daily during critical periods and that opportunities to detect unfavorable trends were missed (Committee of Inquiry, 2005). The report also identified the failure to stop work despite warning signs, under schedule and cost pressure, as a major management failure (Committee of Inquiry, 2005). In Korea, Jung and Lee (2018) showed through case analyses of anchored temporary retaining wall collapses that collapse may occur even when absolute displacement remains within the control range, if the displacement rate increases sharply. Their findings suggest the need to supplement conventional absolute-threshold management with rate-of-change-based criteria.

Taken together, these previous studies indicate that monitoring-based safety management in the dismantling phase should go beyond the simple confirmation of displacement values and be linked directly to work-stoppage decision-making. If no procedural linkage exists between abnormal monitoring signals and field decisions, early warning signs may be overlooked and structural instability may escalate into a serious accident.

3. Research Method

This study employed a single-case qualitative analysis based on the case study methodology proposed by Yin (2014). The main research questions were why structural re-equilibration failure occurs during the dismantling phase of temporary earth-retaining structures and why monitoring information fails to be linked to work-stoppage decision-making in that phase. The case selected for analysis was the fatal H-pile dismantling accident that occurred in August 2019 at a railway subgrade construction site in Dangjin, Chungnam, Korea.

The study used multiple data sources to improve analytical validity. These sources included accident education materials published by Safety First News (2019), industrial accident case materials from the Korea Occupational Safety and Health Agency, the official report of the Committee of Inquiry on the Nicoll Highway collapse

(Committee of Inquiry, 2005), and relevant academic studies such as Yi et al. (2023) and Zheng et al. (2021). By integrating accident case records, institutional materials, and prior scholarly research, the study attempted to interpret the Dangjin accident not as an isolated event but as a structural and managerial failure occurring within a broader risk mechanism.

For analysis, the study applied the eight-stage integrated risk mechanism model presented in Figure 2 as the main analytical framework. This framework was used to examine the sequence from support-member removal, reduction in structural stiffness, and load redistribution to possible monitoring anomalies, delayed work stoppage, and eventual accident occurrence. Through this approach, the study sought to identify both the mechanism of structural re-equilibration failure and the limitations of the linkage between monitoring information and field decision-making during dismantling operations.

Figure 2: Integrated eight-stage risk mechanism model for TERS dismantling and its application to the Dangjin case

4. Case Analysis: Fatal H-pile Dismantling Accident in Dangjin (2019)

4.1. Accident overview and sequence of events

In August 2019, a fatal accident occurred during the dismantling of H-piles and walers at a railway subgrade construction site in Dangjin, Chungnam, Korea. The dismantling work was performed by sequentially cutting welded connections between the H-pile and the waler using an oxygen cutter. After seven of the total eight welded connections had been cut, the final remaining joint failed under the concentrated load and fractured spontaneously, causing the waler (H-300×300) to roll down and strike a nearby worker, which resulted in one fatality at the scene.

The accident investigation identified three major management problems. First, no dismantling work plan had been prepared. Second, the load-transfer path associated with each cutting sequence had not been reviewed in advance. Third, the cutting work proceeded without temporary lifting or support measures.

4.2. Analysis of structural re-equilibration failure

The core mechanism of the Dangjin case is structurally consistent with the progressive failure path presented by Zheng et al. (2021) and Yi et al. (2023). From the first cut to the seventh cut, repeated load redistribution occurred as the number of remaining connections decreased and the load borne by each residual connection increased. Figure 3 illustrates this process step by step. At the final stage, when only one connection remained, that single joint was forced to

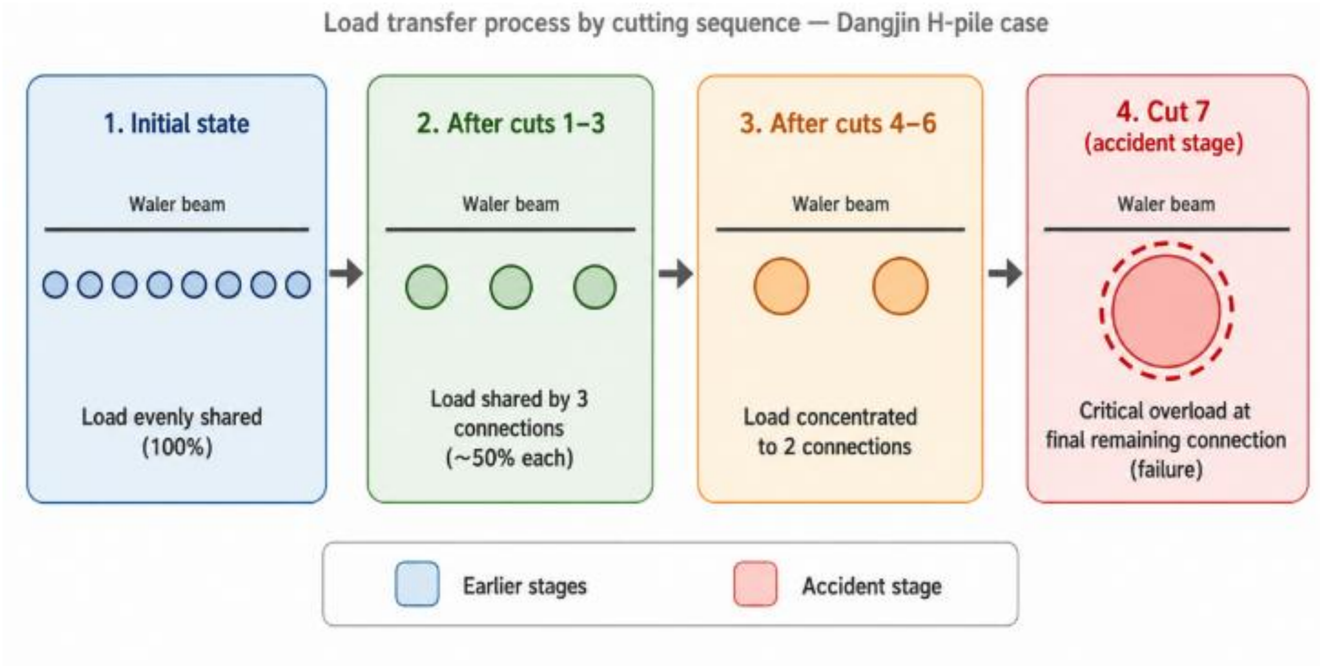

Figure 3: Dangjin H-pile case: schematic illustration of structural load-transfer processes according to cutting sequence

carry the load previously shared by the other seven locations, creating an extreme concentration of force. Unable to resist this concentrated load, the final connection fractured spontaneously, and the structural equilibrium of the system collapsed abruptly.

In the absence of temporary support, the remaining system became highly vulnerable to sudden instability as dismantling proceeded.

And Table 1 presents an analysis of the structural system changes at each cutting stage in the Dangjin H-pile case.

Table 1: Structural system changes by cutting stage in the Dangjin H-pile case

Stage	Cutting status	Structural system change	Key risk factor
Cuts 1–3	8 → 5 connections remaining	Gradual load redistribution	Onset of load concentration, no prior review of cutting sequence
Cuts 4–6	5 → 2 connections remaining	Sharp increase in stress on remaining connections	Approach to critical state, no temporary support provided
Cut 7	2 → 1 connection remaining	Extreme load concentration	Entire load carried by a single connection, imminent fracture
Fracture (accident)	Spontaneous fracture	Collapse of equilibrium → waler overturning	One worker fatally injured

This sequence shows that the accident was not a simple operational error but a typical case of structural re-equilibration failure during dismantling. Because the dismantling sequence had not been structurally reviewed in advance, the progressive concentration of internal force in the residual connection was neither predicted nor controlled.

4.3. Analysis of monitoring-to-decision linkage failure

In the Dangjin case, the failure of monitoring-to-decision linkage can be explained by two structural limitations. First, there were no monitoring criteria specifically designed for the dismantling phase. The existing management approach, which mainly relies on absolute displacement thresholds, is not sufficient to detect the rapid changes in structural stiffness reduction and load transfer that occur during dismantling. As Jung and Lee (2018) pointed out, structural instability may intensify even when absolute displacement remains within the control range, if the rate of displacement increases sharply.

Second, there was no procedural system linking abnormal monitoring signals to work-stoppage decisions. Similar to the findings of the Nicoll Highway Committee of Inquiry report, no explicit criteria, authority structure, or emergency response procedure for work stoppage had been established before dismantling began. As a result, even if abnormal signs had emerged during the dismantling process, there was no formal mechanism to translate such signals into immediate suspension of work. This limitation shows that accident prevention in dismantling operations depends not only on the presence of monitoring instruments but also on whether monitoring information is institutionally connected to field decision-making.

When the Dangjin H-pile case is expressed using the eight-stage risk mechanism model, it can be summarized as shown in Table 2.

Table 2: Eight-stage integrated risk mechanism model — application to the Dangjin H-pile case

Analysis item (stage)	Dangjin case	Remarks
Support removal (Stage 1)	✓ Confirmed	Sequential cutting at 8 connection locations
Decrease in structural stiffness (Stage 2)	✓ Confirmed	Nonlinear stiffness reduction as the number of cuts increases
Load redistribution (Stage 3)	✓ Confirmed	Concentration of the entire load on the final remaining joint
Increase in wall displacement (Stage 4)	△ Inferred	Cannot be identified in advance due to absence of a work plan
Expansion of ground movement (Stage 5)	N/A	H-pile cutting accident — ground settlement not applicable
Abnormal monitoring signs (Stage 6)	△ Inferred	Not identifiable due to lack of a monitoring–decision linkage system
Delay in work stoppage (Stage 7)	✓ Confirmed	No predefined work-stoppage criteria or authority
Progressive collapse and accident (Stage 8)	✓ Confirmed	One worker fatally injured

5. Improvement Measures

5.1. Mandatory establishment of an independent dismantling work plan

The most direct management gap identified in the Dangjin case was the absence of a dismantling work plan. At a minimum, such a plan should include the sequence of support-member removal and an analysis of load-transfer paths at each stage, a review of the stress state of the residual structural system through structural calculation or numerical analysis, a temporary lifting and support plan, an emergency backfilling plan, and monitoring items, measurement frequency, and control criteria. Although KCS 21 30 00 already requires stage-by-stage analysis and prior approval by the construction supervisor, the minimum required contents for practical implementation should be specified more clearly in relevant regulations or guidelines.

5.2. Introduction of rate-of-change-based work-stoppage criteria

Referring to the findings of Jung and Lee (2018), this study proposes a dual management system that uses both absolute-value criteria and rate-of-change-based criteria. Even when measured displacement remains within the control range, work should be stopped if the daily increase in displacement rises sharply or if acceleration in the same direction continues for three consecutive days. The specific quantitative thresholds should be adjusted according to ground conditions and construction methods at each site, and further quantitative validation is needed in future studies.

5.3. Establishment of a monitoring-to-decision linkage system

As the Nicoll Highway Committee of Inquiry report emphasized, the existence of monitoring instruments alone is less important than whether monitoring information is actually connected to decision-making procedures. Before dismantling begins, the authority responsible for work stoppage should be designated, and procedures should be established to ensure that abnormal monitoring signs automatically trigger suspension of work. In addition, monitoring review should be made mandatory before each dismantling stage begins, and the next stage should proceed only when the monitoring results remain within the caution threshold.

5.4. Institutional directions for improvement

Current occupational safety regulations provide detailed standards for the installation of retaining supports and excavation work, but they do not contain independent provisions for the sequence of support removal or for reviewing the stability of the residual structural system during dismantling. Sung and Shin (2011) pointed out, through an analysis of domestic retaining wall excavation accidents, that the absence of dismantling-stage safety standards is a structural reason for repeated accidents. Therefore, it is necessary to explicitly define the dismantling phase of temporary earth-retaining structures as an independent high-risk operation and to establish either new regulatory provisions or a separate KOSHA guideline requiring a dismantling work plan and prior review of stage-by-stage load transfer.

In more concrete terms, the differences between existing excavation-focused management and dismantling-phase-specific management can be summarized as shown in Table 3.

Table 3: Comparison between existing excavation-focused management and dismantling-phase-specific management

Category	Existing excavation-focused management	Dismantling-phase-specific management
Main risk	Wall displacement and settlement during excavation	Structural re-equilibration due to removal of support members
Risk assessment	Management centered on absolute displacement criteria	Dual criteria based on both rate of change and absolute values
Use of monitoring	Confirmation of exceedance of control limits	Linkage to work stoppage and decision-making
Work plan	Integrated into the general excavation work plan	Independent work plan for the dismantling phase
Management timing	Focused on the excavation phase	Includes the dismantling phase (before, during, and after dismantling)
Legal standards	Occupational Safety and Health Regulations and KCS provisions	Need for separate provisions specific to the dismantling phase
Management approach	Primarily reactive response	Primarily preventive risk management

5. Conclusion

This study analyzed the failure mechanism of structural re-equilibration and the limitations of monitoring-to-decision linkage during the dismantling phase of temporary earth-retaining structures, focusing on the fatal H-pile dismantling accident that occurred in Dangjin, Chungnam, in August

2019.

The analysis produced three main findings. First, the Dangjin case represents a typical failure of structural re-equilibration in which stage-by-stage load transfer was not reviewed during the sequential cutting of eight welded connections, and the final remaining joint fractured after seven connections had already been removed because it could not withstand the concentrated load. This mechanism is structurally consistent with the process of member-function loss, load redistribution, and progressive failure described by Zheng et al. (2021) and Yi et al. (2023). Second, the absence of dismantling-phase-specific monitoring criteria and of procedures linking monitoring information to work-stoppage decisions constituted a major structural background factor that allowed the accident risk to escalate. This pattern is consistent with the loss of opportunities to detect warning signs identified in the Nicoll Highway Committee of Inquiry report (Committee of Inquiry, 2005). Third, the analysis confirmed a regulatory gap in that current occupational safety regulations and KCS 21 30 00 do not define the dismantling phase as an independent high-risk operation.

The academic contribution of this study lies in conceptualizing the dismantling phase of temporary earth-retaining structures as an independent structural transition stage in which structural re-equilibration is concentrated, and in demonstrating this concept through the linkage between an eight-stage risk mechanism model and an actual fatal accident case. As key improvement measures, the study proposed mandatory establishment of an independent dismantling work plan, the introduction of dual work-stoppage criteria based on both displacement magnitude and rate of change, and the institutionalization of a monitoring-to-decision linkage system. However, this study is limited in that it is based on a qualitative analysis of a single case. Future research should therefore compare multiple dismantling accident cases and quantitatively validate rate-of-change-based monitoring criteria.

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