ENHANCING THE CAPACITY OF CONSTRUCTION WORKERS THROUGH INTEGRATED TRAINING ON THE SUBSTRUCTURE OF EARTHQUAKE-RESISTANT HOUSES IN PANDEGLANG

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ABSTRACT

Pandeglang Regency is one of the earthquake-prone areas in Indonesia, dominated by soft soil deposits that make simple houses highly vulnerable to seismic damage. Most houses are constructed by local masons who rely solely on experience, with limited knowledge of earthquake-resistant construction, particularly in the substructure. This community service program aimed to enhance the competence of construction workers through integrated training covering five aspects: soil conditions, ground improvement, substructure elements, construction methods, and foundation implementation. The two-day training combined participatory approaches, visual instruction, and hands-on practice. Evaluation results demonstrated significant improvements: understanding of soil conditions and cone penetration tests increased from 33 to 76.7 (+132%); ground improvement from 28.3 to 81.7 (+189%); substructure knowledge from 24.7 to 81.7 (+231%); construction methods from 35 to 70 (+100%); and foundation implementation from 27 to 80 (+196%). Overall, post-test scores ranged from 70 to 82. The integrated training model proved effective in enhancing both technical knowledge and practical skills, and it holds potential for replication in other earthquake-prone regions as part of community-based disaster risk reduction initiatives.

Keywords: Earthquake-resistant Housing, Substructure, Construction Workers, Pandeglang, Community Service.

1. INTRODUCTION

Indonesia is one of the countries with the highest vulnerability to earthquakes, as it lies at the convergence of three major tectonic plates: Indo-Australian, Eurasian, and Pacific. Pandeglang Regency in Banten is classified as an earthquake-prone area due to the presence of the Cimandiri and Lembang Faults, as well as volcanic activity from Mount Anak Krakatau. The geological condition of Pandeglang, dominated by Quaternary alluvial deposits with soft soils, makes simple houses in this region highly susceptible to earthquake damage (Purnama, 2022; Setyaningrum, 2022). Earthquake surveys consistently reveal that houses built on rock or dense soils tend to be more resistant, while those founded on soft soils suffer the most severe damage (Villalobos & Romanel, 2019)

Most simple houses in Pandeglang are constructed by local masons without civil engineering design. Builders typically rely solely on experience, with very limited understanding of earthquake-resistant standards. As a result, many houses collapse due to failures in the substructure (foundations, tie beams, and working floors) when subjected to seismic shaking (Desiana & Nabila, 2021; Vidayanti et al., 2025).

The main problems identified cover five critical aspects. First, construction workers have limited understanding of soil conditions for foundations, which often leads to inappropriate foundation choices. The introduction of simple soil investigation methods, such as the cone penetration test (CPT), has proven effective in improving workers' understanding of soil behavior (Bela & Sianto, 2022; Waani et al., 2022). Although, in practice, combining field data (SPT, CPT, DMT) with laboratory testing is essential to determine soil parameters and ensure the safety of shallow foundations (Jarushi et al., 2025; Tanuwijaya et al., 2019). Second, workers lack knowledge of simple ground improvement techniques to increase the bearing capacity of soft soils, which is particularly necessary in Pandeglang. Third, they have little understanding of the basic principles of earthquake-resistant substructures, especially the function of tie beams (sloof) and foundation connection systems (Vidayanti et al., 2025). Fourth, their knowledge of standardized construction methods for substructures is very limited, for instance in reinforcement work and concrete production (Gunasti et al., 2023). Fifth, workers are not accustomed to proper foundation implementation procedures, starting from setting out (bouwplank), excavation, reinforcement assembly, concrete casting using a mixer, to tie beam installation (Rosdiyani & Sari, 2021). These conditions highlight the need for intervention through a community service program (PkM).

This program was designed to enhance the competencies of construction workers in Pandeglang through a series of training activities covering five key aspects: (1) improving knowledge of foundation soil conditions, (2) training in basic ground improvement techniques, (3) strengthening understanding of earthquake-resistant substructure elements, (4) improving knowledge of standard substructure construction methods, and (5) training in proper implementation procedures for earthquake-resistant foundations. Accordingly, this community service program not only expanded workers' technical knowledge but also equipped them with practical skills and raised their awareness of the importance of earthquake-resistant construction. The capacity building achieved through this training is expected to reduce the vulnerability of simple houses to earthquakes while simultaneously improving workers' welfare through more professional skills.

2. METHOD

This community service program was conducted over two days at Universitas Mathla'ul Anwar (UNMA) in Pandeglang, Banten. The partners included PT Tunas Lima Warna and the Civil Engineering Study Program of UNMA. Sixteen construction workers participated, aged 23–60 years, most of whom had only elementary to junior high school education.

2.1 Training Design

The training applied a participatory and practice-oriented approach, considered effective in previous studies on earthquake-resistant construction (Gunasti et al., 2024; Herman et al., 2017).

Activities consisted of:

1. Preliminary survey and focus group discussion (FGD) with local worker representatives and UNMA lecturers to identify training needs.
2. Development of training modules covering five aspects:
   - soil conditions and simple field tests (CPT),
   - ground improvement techniques (layered compaction, sand replacement, basic drainage),
   - substructure elements of earthquake-resistant houses (foundations, tie beams, and connections),
   - standard construction methods,
   - step-by-step foundation implementation.
3. Classroom sessions using visual presentations, discussions, and earthquake animations.
4. Field practice, including soil compaction with local tools, reinforcement bending using a bar bender, concrete mixing with a 500 L mixer, and tie beam installation.
5. Evaluation through pre-test, post-test, observation of practical skills, and a signed commitment sheet confirming workers' willingness to apply the training outcomes.

Table 1. presents the two-day schedule of training activities, combining classroom instruction with field practice. The program was designed to progressively build knowledge and skills, starting from basic understanding of soil and construction concepts to hands-on practice in foundation implementation.

Table 1. Training activities for construction workers

Day	Activities
Day 1	- Introduction to earthquake hazards in Pandeglang and the importance of earthquake-resistant housing - Soil conditions: explanation of soil types and their relation to foundation depth; simple CPT demonstration with audiovisual media - Ground improvement: theory of layered compaction, sand replacement, and gravel drainage - Substructure: role of tie beams (sloof), foundation depth, sloof–column connections, reinforcement anchorage (≥40D), concrete mix (1:2:3) - Construction methods: proper procedures for shallow foundations and occupational safety (OHS) - Foundation implementation: construction sequence using a simple Work Breakdown Structure (WBS).
Day 2	- Brief review of Day 1 theory - Soil compaction practice using simple tools and local materials - Reinforcement assembly for sloof and bar bender practice - Concrete mixing for K-200 quality using a concrete mixer

Day	Activities
	- Complete foundation construction: setting out (bouwplank), excavation, stone masonry (1:4), reinforcement, formwork, and concreting of tie beams - Reflection and simulation of construction sequence using WBS to strengthen understanding

Figure 1.(a) Classroom session on earthquake hazards in Pandeglang and the importance of earthquake-resistant housing, (b). Review of Day 1 materials before field practice on the second day.

2.2 Tools and Materials

The training used:

- Presentation equipment: laptop, projector, teaching modules.
- Construction tools: 500 L concrete mixer, bar bender, shovels, buckets, formwork, and excavation tools.
- Materials: Portland cement, sand, gravel, river stones, 8–10 mm reinforcement bars, binding wire, and clean water.
- Personal protective equipment (PPE): helmets, safety vests, gloves, and safety shoes.

Figure 2. Training equipment: (a) 500 L concrete mixer; (b) bar bender.

Figure 3. Construction materials: (a) sand; (b) gravel with 2–3 cm diameter.

2.3 Evaluation Method

Evaluation combined three indicators:

- Quantitative – improvement in pre- and post-test scores and practical performance, with targets of at least 50% improvement and ≥80% skill attainment.
- Qualitative – changes in behavior, including adherence to safety procedures and ability to prepare a simple Work Breakdown Structure (WBS).
- Contextual – participants' signed commitment to apply the training outcomes, supported by continued engagement from the industry and academic partners.

This combination ensured that the evaluation captured not only improvements in knowledge and skills but also behavioral changes and the potential for replicating the training model in other earthquake-prone regions.

Table 2 outlines the evaluation framework used to measure the effectiveness of the training program. The indicators cover quantitative, qualitative, and contextual aspects, ensuring that success is assessed not only by improvements in knowledge and practical skills but also by behavioral changes and long-term commitment from both participants and partners.

Table 2. Indicators of training success for construction workers

Aspect	Indicator	Success Measure
Quantitative	Knowledge score (pre–post test) Practical field skills	≥50% improvement ≥80% of participants achieve standard skills
Qualitative	Changes in work attitude and behavior Compliance with occupational safety (PPE) Ability to prepare simple work sequences (WBS)	Majority of participants consistently use PPE Participants able to explain work sequences correctly
Contextual	Commitment of workers and community Support from partners (industry & university)	Signed commitment statements from participants - Partner support for training replication

3. RESULTS AND DISCUSSION

3.1 Soil Conditions

Workers were introduced to local soil types in Pandeglang and their implications for foundation design. They also practiced simple cone penetration testing (CPT). Evaluation results showed an increase from 33 to 76.7 (+132%), demonstrating that workers could better understand soil conditions when explained through practical tools and demonstrations.

3.2 Ground Improvement

Training on ground improvement focused on basic techniques such as layered compaction, sand replacement, and drainage layers. Scores improved from 28.3 to 81.7 (+189%), and participants successfully applied these methods in field practice. This indicates that simple, low-cost techniques can be easily adopted by workers to enhance the bearing capacity of soft soils.

Figure 4. Ground improvement training: explanation and demonstration of soil compaction for shallow foundations.

3.3 Substructure

The training emphasized the importance of substructure components, particularly the role of tie beams (sloof) in connecting foundations and columns, reinforcement anchorage of at least 40D, and concrete mixing with a ratio of 1:2:3. Post-test scores rose from 24.7 to 81.7 (+231%), representing the highest increase among all aspects. The combination of visual explanation and hands-on practice enabled workers to recognize the critical role of substructure elements in preventing building collapse during earthquakes.

Figure 5. Substructure practice: (a) concrete mixing with a 1:2:3 ratio; (b) reinforcement bending with 40D anchorage length.

3.4 Construction Methods

Participants were trained in standard construction practices, including proper formwork installation, continuous concrete pouring, curing, and handling of construction joints. Safety measures such as the use of personal protective equipment (PPE) and safe excavation practices were also emphasized. Scores improved from 35 to 70 (+100%), accompanied by greater awareness of occupational safety and health practices

Figure 6. Construction methods: (a) proper installation of tie beam formwork; (b) instruction on the use of personal protective equipment (PPE).

3.5 Foundation Implementation

Workers practiced the complete sequence of foundation construction: setting out (bouwplank), excavation, stone masonry, reinforcement assembly, concreting, and tie beam installation. Scores improved from 27 to 80 (+196%), while direct observation confirmed that at least 80% of participants achieved competency in practical tasks. The introduction of a simple Work Breakdown Structure (WBS) helped workers understand construction stages more systematically, reinforcing both technical skills and quality awareness.

Figure 7. Foundation implementation: (a) field practice of shallow foundation construction following correct procedures; (b) reflection and discussion on construction sequence using Work Breakdown Structure (WBS).

3.6. Summary of Training Outcomes

Across all five areas of training, significant improvements were recorded in both knowledge and practical skills. Figure 8 presents a comparison of pre-test and post-test scores, highlighting consistent gains across all aspects. The largest increase occurred in substructure training (+231%), followed by foundation implementation (+196%), ground improvement (+189%), soil condition testing (+132%), and construction methods (+100%). These results confirm that the integrated training model effectively improved the competence of construction workers in earthquake-prone areas.

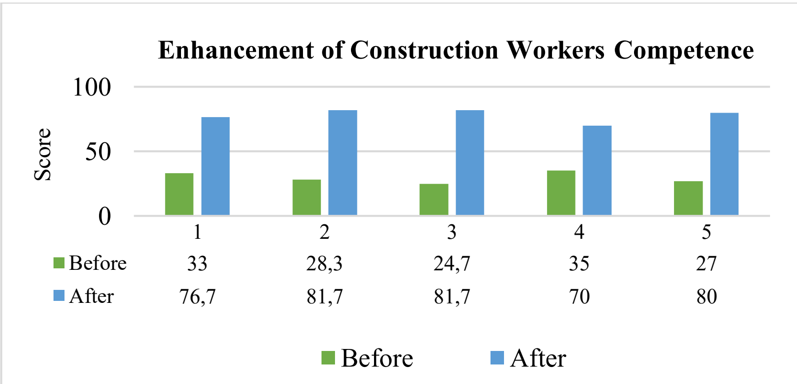

Figure 8. Improvement of construction workers' competence across five training aspects (Aspect 1: Soil Conditions and CPT; Aspect 2: Ground Improvement; Aspect 3: Substructure; Aspect 4: Construction Methods; Aspect 5: Foundation Implementation).

At the end of the program, participants signed a commitment sheet to apply earthquake-resistant construction practices in their work. This action served as evidence of achieving the contextual indicator, demonstrating their willingness to transfer training outcomes into practice.

Figure 9. Signing of commitment sheets by participants to apply earthquake-resistant construction practices in their future work

4. CONCLUSION

The integrated training on earthquake-resistant housing substructures in Pandeglang proved highly effective in enhancing the competence of construction workers. Evaluation results showed significant improvements across five aspects: knowledge of soil conditions and CPT increased from 33 to 76.7 (+132%); ground improvement from 28.3 to 81.7 (+189%); substructure knowledge from 24.7 to 81.7 (+231%); construction methods from 35 to 70 (+100%); and foundation implementation from 27 to 80 (+196%).

Beyond technical knowledge and skills, the training model successfully combined geotechnical, structural, and construction management perspectives. It emphasized practical learning through visual instruction, field exercises, prototypes, and simple Work Breakdown Structures (WBS), while also strengthening safety awareness and systematic work practices.

These findings confirm that integrated training can serve as an effective strategy to improve construction workers' capacity in earthquake-prone areas. The model holds strong potential for replication in other regions of Indonesia as part of community-based disaster risk reduction and to support national policies on workforce competency development in the construction sector.

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