

Utilization of Fly Ash as a Concrete Additive Material in the Construction of Yard Flooring

Jack Widjajakusuma^{1*}, Muhammad Agil Faisal¹, Joshua Michael Sondakh¹, Viktoria Darlene Pelupessy¹, Septhew Ong¹

Program Studi Teknik Sipil, Fakultas Sains dan Teknologi, Universitas Pelita Harapan

Email Author: jack.widjajakusuma@uph.edu^{1*}

Kata Kunci:

Abu Terbang, Beton, Lantai Pekarangan, Pengabdian Masyarakat, Bencong Indah

Abstrak

Proyek pengabdian masyarakat ini bertujuan untuk memperbarui halaman warga RW 01, Kelurahan Bencong Indah, Kecamatan Kelapa Dua, Kabupaten Tangerang, dengan menggunakan bahan limbah sebagai campuran tambahan pada beton. Menanggapi kondisi lantai halaman yang rusak serta kurangnya pemahaman masyarakat mengenai bahan bangunan yang berkelanjutan dan hemat biaya, inisiatif ini berfokus pada pembangunan lantai yang lebih tahan lama sekaligus mendorong praktik konstruksi yang ramah lingkungan. Proyek dilaksanakan dalam tiga tahap: observasi awal lokasi untuk menilai kondisi dan kebutuhan halaman; identifikasi karakteristik konstruksi, pemilihan bahan tambahan, perancangan campuran, serta penimbangan dan pencampuran material; dan pengecoran lantai secara kolaboratif dengan partisipasi masyarakat setempat. Proses ini tidak hanya memperkuat hubungan antarwarga, tetapi juga memberikan keterampilan konstruksi yang bermanfaat bagi para peserta. Hasil proyek berupa halaman yang lebih kuat, dengan kuat tekan rata-rata 17,4 MPa pada umur 28 hari, sehingga memenuhi mutu rencana f'c sebesar 16 MPa. Selain itu, masyarakat memperoleh keterampilan praktis dan pengetahuan yang lebih mendalam tentang penggunaan abu terbang sebagai bahan bangunan. Dengan memilih semen berbasis abu terbang dibandingkan semen Portland biasa, proyek ini turut mendukung beberapa Tujuan Pembangunan Berkelanjutan, khususnya terkait kesehatan, air bersih dan sanitasi, pekerjaan layak, permukiman berkelanjutan, konsumsi dan produksi yang bertanggung jawab, serta penanganan perubahan iklim. Pendekatan ini juga sejalan dengan visi Asta Cita pemerintahan Prabowo-Gibran dalam mendorong ekonomi hijau yang lebih ramah lingkungan.

Abstract

Keywords:

Fly ash, concrete, yard flooring, community service, Bencong Indah.

The community service project revitalized the courtyard of RW 01 in Bencong Indah Urban Village, Kelapa Dua District, Tangerang Regency, by incorporating waste additives into concrete mixtures. In response to both the deteriorated courtyard floor and the community's limited awareness of sustainable, cost-effective building materials, the initiative sought to construct a more durable floor and promote environmentally friendly construction practices. The project was executed in three stages: an initial site observation to assess the courtyard's conditions and needs; identification of construction characteristics, selection of additional material specifications, mix design, and weighing and mixing of materials; and a collaborative floor-casting process involving residents. This process not only strengthened community bonds but also provided participants with transferable construction skills. The project resulted in a more durable pavement, achieving an average compressive strength of 17.4 MPa at 28 days, satisfying the design strength (f'c) of 16 MPa. Additionally, the community gained practical skills and enhanced understanding of fly ash utilization in construction. By selecting fly ash-based cement instead of traditional Portland cement, the project contributes to several Sustainable

Development Goals (SDGs), including Good Health and Well-being, Clean Water and Sanitation, Decent Work and Economic Growth, Sustainable Cities and Communities, Responsible Consumption and Production, and Climate Action. This approach also aligns with the Prabowo-Gibran administration's Asta Cita (Eight Missions), particularly its objective to promote a green economy.

Copyright © 2026 Jack Widjajakusuma

*This work is licensed under a **Attribution-ShareAlike 4.0 International (CC BY-SA 4.0)***

INTRODUCTION

The RW 01 area of Bencongan Indah Village, Kelapa Dua District, Tangerang Regency, is currently experiencing challenges in providing adequate public yard infrastructure. Improving the quality of environmental facilities in this area is essential and should be pursued through collaborative initiatives to create a cleaner, healthier residential environment (Purba, Widjajakusuma, Wibowo & Sumantri, 2025). Field observations indicate that the proposed design for yard paving and communal facilities requires cost-effective alternative construction materials that meet structural strength standards, in accordance with funding and concrete technology principles (Mulyono, 2004; Widjajakusuma, J., Bali, I., Ng, G.P., Owen, M., Wijaya, N., 2026).

To address these challenges, this community service program aims to optimize the utilization of industrial waste—specifically fly ash—as a filler material in concrete mixtures. The use of fly ash as a partial cement replacement has been technically validated and meets standard specifications for pozzolanic minerals in functional concrete mixtures (ASTM International, 2008). Furthermore, the use of fly ash helps accelerate progress toward the SDGs (Alfathy, Saputro, Sarwanto & Ramli, 2024; Wibowo & Widjajakusuma, 2025). In practice, material proportions must be calculated accurately in accordance with the standard code for normal concrete mix design (Badan Standardisasi Nasional, 2000) and aligned with national concrete mix design procedures to ensure optimal quality, durability, and workability (National Standardization Agency, 2000).

Beyond technical material readiness, sociological factors such as active resident participation and enthusiasm for cooperation represent key drivers for the program's success. Participatory community education approaches have demonstrated effectiveness in enhancing communal awareness and supporting the sustainable maintenance of constructed public facilities (Widjajakusuma, Sondakh, Buntoro & Tanuhendrata, 2025; Widjajakusuma, Waruwu, Rahayu & Wibowo, 2025). Accordingly, this community service initiative aims to deliver technical outreach and facilitate hands-on yard flooring casting with residents, thereby equipping the community with practical skills for independent maintenance and replication of this infrastructure.

The global construction sector remains heavily dependent on ordinary Portland cement, the manufacture of which is responsible for a substantial share of anthropogenic carbon dioxide emissions. In the Indonesian context, the rapid pace of settlement development in peri-urban regencies such as Tangerang has intensified demand for concrete-based infrastructure. At the same time, large volumes of coal combustion residue, in the form of fly ash, are generated by nearby steam power plants and remain underutilized. This paradox, in which a valuable pozzolanic by-product is treated as waste while communities struggle to finance basic concrete infrastructure, provides the central motivation for the present community service program. By reframing fly ash as a resource rather than a residue, the program simultaneously seeks to reduce the environmental burden of waste disposal and the economic burden of construction on a modest-income neighborhood.

Community empowerment through appropriate technology is most effective when it builds upon the existing capacities and social capital of the target population. Prior community service literature has emphasized that village-level innovation rooted in local wisdom and collective participation tends to be more sustainable than externally imposed solutions (Kapisa, Maulana & Sukirman, 2025). In RW 01 of Bencongan Indah Village, the strong tradition of cooperation, or *gotong royong*, precisely represents the kind of social capital that can be mobilized to internalize a new construction technique. The program therefore positions residents not as passive beneficiaries but as co-producers of the infrastructure, so that

the technical knowledge introduced during the activity is retained within the community after the service team has departed.

The initiative is further situated within the broader agenda of the Sustainable Development Goals (SDGs). Reusing industrial by-products in construction directly supports SDG 9 on industry, innovation and infrastructure, SDG 11 on sustainable cities and communities, and SDG 12 on responsible consumption and production. The alignment of grassroots community activities with these global targets has been shown to depend on supportive local frameworks and sustained institutional commitment (Kapisa & Sudrajat, 2025), as well as on integrating sustainability principles into higher-education-led outreach (Alfathy, Saputro, Sarwanto & Ramli, 2024). Universities, through their community service mandate, occupy a strategic position to translate laboratory-validated material technology into tangible neighborhood improvements while advancing these goals.

Environmental and infrastructure-oriented community service has a growing precedent in the Tangerang region, where academic teams have engaged residents in activities ranging from coastal mangrove replanting to mitigate erosion (Dewi, Khaerudin, Gandara et al., 2025) to sanitation and public-facility improvement (Purba, Widjajakusuma, Wibowo & Sumantri, 2025). This university has an established track record of participatory community programs, including independent water-closet and sanitation initiatives (Widjajakusuma, Pramono, Parhusip et al., 2021; Parhusip, Pramono, Widjajakusuma & Pinontoan, 2022), sports-facility upgrading (Widjajakusuma, Sondakh, Buntoro & Tanuhendrata, 2025), and the application of eco-paving-block technology (Widjajakusuma, Waruwu, Rahayu & Wibowo, 2025). The present activity extends this trajectory by focusing specifically on the use of an industrial by-product as a functional construction material.

Building on this foundation, the specific problem addressed here is twofold. The first is the physically inadequate condition of the communal yard in RW 01, an open earthen surface of approximately 12 m² that becomes muddy during the rainy season and dusty during the dry season, hindering the communal and economic activities that the space is intended to support. The second is the limited familiarity of residents with economical, standards-compliant alternative construction materials, together with a persistent perception of fly ash as mere waste. Accordingly, the objectives of this program are: first, to deliver technical outreach on the proper proportioning of fly ash in concrete; second, to construct a durable yard floor slab in collaboration with residents; and third, to equip the community with the practical competence required to maintain and replicate the infrastructure independently.

From a materials standpoint, fly ash is a finely divided residue carried by the flue gases of coal combustion and collected by electrostatic precipitators. Depending on its origin, it is classified under the ASTM C618 specification into Class F, which is low in calcium and derived from the combustion of higher-rank coals, and Class C, which contains higher calcium and possesses some self-cementing character. Both classes are dominated by amorphous aluminosilicate glass, which endows fly ash with its pozzolanic capacity. Because the physical and chemical characteristics of the ash vary with the coal source and the combustion conditions, verifying that a given supply satisfies the pozzolan specification is an essential precondition for its use as a partial cement replacement in structural applications.

Economical construction is a particular concern for community-scale infrastructure, where budgets are limited and residents, rather than contractors, often carry out the work. Sound concrete technology holds that a mixture must balance cost, workability, durability, and strength, and that these objectives can be reconciled through careful proportioning and material selection (Mulyono, 2004). Introducing a low-cost pozzolanic by-product into this balance is attractive precisely because it can lower material cost while, under appropriate conditions, improving workability and long-term durability. Communicating this balance to residents in accessible terms was therefore a central aim of the program's outreach component.

METHODS

Community engagement was treated as a continuous thread running through every stage rather than as a discrete preliminary step. From the initial site survey onwards, community leaders and residents were consulted so that decisions about the layout, dimensions, and scheduling of the work reflected local needs and constraints. This sustained dialogue was intended to build the sense of ownership that the empowerment literature identifies as decisive for the long-term maintenance of community infrastructure.

The final technical stage, comprising pouring and curing, was treated as a critical control point for quality. After the fresh concrete had been placed and finished, the surface was kept continuously moist during the initial hardening period to support the hydration reactions that underpin strength development. Representative cylinder specimens were cast from the same batch used in the field and cured under controlled conditions before compressive-strength testing at the standard age of twenty-eight days. Sampling the field batch in this way, rather than preparing an idealized laboratory mixture, ensured that the reported strength reflected the concrete actually placed by the residents and therefore provided a realistic measure of the constructed facility's structural adequacy.

The program adopted a participatory action research framework, in which the university service team and the resident partners jointly diagnosed the problem, planned the intervention, executed the construction, and evaluated the outcome. This methodological choice reflects a broader shift in community service practice away from one-directional aid delivery and towards collaborative, technology-mediated empowerment in which beneficiaries actively acquire transferable skills (Andriyanto, Muharni, Nugroho et al., 2025). The activity was carried out in a sequence of stages, each designed both to achieve a physical construction milestone and to create a concrete learning opportunity for the participating residents.

Consistent with good community service reporting practice, the program's success was assessed against measurable indicators rather than by physical completion alone. Two categories of indicators were employed. The first was social: the level of resident participation across the successive stages, and the observable change in residents' attitudes towards fly ash as a construction material. The second was technical: the compressive strength of the hardened concrete, evaluated through standard cylinder testing, together with the visual integrity of the finished slab. Taken together, these indicators allowed the team to judge both whether knowledge transfer had occurred and whether the constructed facility satisfied the structural requirements for its intended service loads.

Throughout the technical stages, the mix design and material-handling procedures were anchored in recognized standards. The proportioning of cement, fly ash, water, and fine and coarse aggregate followed the Indonesian standard procedure for normal concrete mix design (Badan Standardisasi Nasional, 2000), while the suitability of the fly ash as a mineral admixture was verified against the pozzolan specification of ASTM International (2008). Grounding the field activity in these references ensured that the economical mixture promoted to residents would nonetheless meet accepted feasibility and strength criteria. The detailed sequence of activities is summarised in the process diagram in Figure 1 and elaborated in the numbered stages that follow.

The Community Service (PkM) program is implemented through a participatory action research approach to integrate appropriate technology into sustainable community empowerment initiatives (Purba, Widjajakusuma, Wibowo, & Sumantri, 2025). This approach positions partner residents as active participants, engaging them from the initial planning phase through to monitoring (Widjajakusuma, J., Pramono, R., Parhusip, A. et al., 2021; Parhusip, Pramono, Widjajakusuma & Pinontoan, 2022; Widjajakusuma, Waruwu, Rahayu & Wibowo, 2025).

1. Field Observation and Community Approach: Direct surveys are conducted in RW 01 of Bencongan Indah Village to measure the dimensions of the public yard paving area, which covered approximately 12 m². A total of 36 residents were engaged as participants across the stages of the activity. During this stage, a participatory approach is adopted with community leaders to ensure active resident involvement in the process (Parhusip, Pramono, Widjajakusuma & Pinontoan, 2022; Widjajakusuma, Waruwu, Rahayu & Wibowo, 2025; Rijal, 2026).
2. Identification of Construction Characteristics, Selection of Additional Material Specifications, Mix Design, and Weighing and Mixing of Materials: The basic material requirements for field paving are analyzed using the principles of concrete technology to ensure the construction design remains economical while meeting feasibility and structural strength standards (Mulyono, 2004). Fly ash waste is used as a mineral admixture that meets the technical specifications for pozzolanic coal and ensures safety and suitability for partial cement substitution (ASTM International, 2008). The weight and volume composition of each material element forming the concrete—cement, fly ash, water, fine aggregate, and coarse aggregate—are calculated precisely according to the standard method for normal concrete mix design (Badan Standardisasi Nasional, 2000). Material-mixing procedures are implemented

directly on-site with residents and are guided by nationally standardized procedures to ensure the mixture achieves optimal field workability (Badan Standardisasi Nasional, 2000).

3. Concrete Pouring and Curing: The concrete mixture is poured onto the yard flooring area collaboratively. Following pouring, periodic concrete curing is conducted, and cylinder test samples are collected to evaluate compressive strength in the laboratory, ensuring that the final results meet infrastructure safety standards (Badan Standardisasi Nasional, 2000; Mulyono, 2004).



Figure 1. Diagram of the Floor Slab Construction Process

RESULTS

The program produced outcomes across three interrelated dimensions: social participation, technical performance, and environmental improvement. Each dimension is reported below in sufficient detail to substantiate the conclusions drawn and to allow other service teams to replicate the approach in comparable settings.

The implementation of the Community Service (PkM) program in RW 01, Bencongan Indah Village, showed very positive dynamics in terms of community participation and engagement. From the outreach stage to field execution, residents' enthusiasm and engagement were evident throughout. A total of 36 residents took part across the successive stages, representing about 30% of those invited. Because most working-age residents were away at work or school during the daytime activity, participation was dominated by retirees and homemakers. The participating residents not only acted as observers but were also directly involved in the entire construction process, from land preparation and assembly of wire-mesh reinforcement to the pouring process. This active involvement became an initial indicator of knowledge transfer, as residents began to understand the function and operating mechanisms of alternative materials in simple construction (Widjajakusuma, Pramono, Parhusip et al., 2021).

Technically, the main innovation in this activity was the application of a concrete mix design incorporating fly ash. In its implementation, the service team, together with the residents, directly practiced the formulation of fly ash substitution at 16% of the cement's total weight. This practice opened residents' eyes to the possibility of reducing dependence on conventional cement without sacrificing mix volume. This direct field education proved effective in changing the community's perception, from previously considering fly ash merely as combustion waste that pollutes the environment, to a highly valuable pozzolanic material capable of reducing the Budget Plan (RAB) for the construction of neighborhood facilities (Dewi, Khaerudin & Romli, 2026).



Figure 2. Preparation for Floor Slab Construction

From a structural quality evaluation perspective, the construction of this yard floor slab has met the construction feasibility standards for light-to-medium service loads. Three cylindrical specimens (150 mm diameter, 300 mm height) were cast from the field batch, cured, and tested in compression at 28 days following SNI 2493:2011 for specimen preparation and curing and SNI 1974:2011 for the compressive-strength test. The individual results were 17.2, 18.4, and 16.6 MPa, giving a mean of 17.4 MPa with a standard deviation of 0.9 MPa (Table 1). Because every specimen and the mean exceeded the design strength (f'_c) of 16 MPa, the slab was assessed as adequate and safe for accommodating residents' communal activities in the yard area and supporting operational loads within the Multipurpose Warehouse area. In addition, visual observations of the split tensile strength also showed no significant shrinkage cracks on the surface of the floor slab, proving that the addition of fly ash effectively increased workability and reduced the risk of micro-cracking during the hydration process.

Table 1. Compressive strength of concrete samples at 28 days

Specimen	Age (days)	Compressive strength (MPa)
Sample C-1	28	17.2
Sample C-2	28	18.4
Sample C-3	28	16.6
Mean	28	17.4
Standard deviation	—	0.9
Design strength, f'_c	—	16.0



Figure 3. Floor Slab Construction

As the final result of the social and physical changes, the RW 01 environment now has a much more adequate, neat, and clean yard infrastructure. The previous condition of the area, which was open ground susceptible to muddiness during the rainy season and dustiness during the dry season, has now been completely resolved. This success in the physical construction simultaneously demonstrates that community empowerment through the adoption of sustainable material technology can provide a dual solution: resolving local infrastructure issues through cooperation while also contributing to more environmentally friendly industrial waste management.

Beyond the headline strength figure, the field practice yielded several practical observations of direct value to the community. Substituting sixteen percent of the cement mass with fly ash noticeably improved the workability of the fresh mixture, making it easier for inexperienced resident volunteers to place and finish the slab by hand. The predominantly spherical morphology of fly ash particles, which act as micro-ball bearings within the paste, is a widely reported cause of this improved flow, and residents observed the effect directly as the mixture was worked into the formwork. This hands-on

demonstration reinforced the outreach message that the alternative material was not merely cheaper but, in several respects, also easier to work with.

The economic dimension of the result was equally salient for the partner community. Because a portion of the cement, the most expensive constituent of the mixture, was replaced with a by-product available at little or no cost, the material cost of the slab was reduced relative to a conventional mix of comparable volume, thereby lowering the neighborhood facility budget. At the same time, diverting fly ash from disposal into a durable structural application converted a waste-management liability into a community asset, so that a single intervention addressed both a local infrastructure deficit and a broader environmental concern.

Evidence of durable knowledge transfer emerged throughout the activity. In the early stages, several residents expressed skepticism, associating fly ash solely with the undesirable residue of combustion. By the pouring stage, the same residents were able to articulate the rationale for the substitution and to describe, in their own terms, how the material contributes to strength development. This shift from skepticism to informed advocacy is arguably the most important social outcome of the program, since it is the precondition for residents to adopt the technique in future construction within the neighborhood independently.

From a structural quality standpoint, the completed yard slab met the feasibility requirements for light-to-medium service loads. The compressive strength recorded at twenty-eight days was deemed adequate and safe for accommodating the communal activities in the yard and supporting the operational loads associated with the adjacent multipurpose warehouse area. The finished surface exhibited no significant shrinkage cracking on visual inspection, an outcome attributed to both the pore-refining action of the fly ash and the improved compaction achieved with the more workable mixture. These observations indicate that the economical mix promoted during the outreach did not compromise the serviceability of the finished element.

The process flow depicted in Figure 1 also functioned as a pedagogical aid during the activity. By presenting the sequence from site survey through needs assessment and construction preparation to floor-slab construction, the diagram allowed residents to locate each hands-on task within the overall workflow and to understand why the technical steps were undertaken in a particular order. This structuring of the activity helped to convert what might otherwise have been isolated manual tasks into a coherent, reproducible procedure that residents could later follow on their own.

The environmental dimension of the outcome was embodied in the site's physical transformation. The communal yard, previously an open earthen surface that turned to mud in the rainy season and raised dust in the dry season, was converted into a clean, level, and durable platform suitable for the neighborhood's communal and economic activities. Because this improvement was achieved by absorbing an industrial by-product that would otherwise have required disposal, the single intervention delivered a visible local amenity while also easing, in a small but concrete way, the wider burden of combustion-waste management.

DISCUSSION

The results of this program can be interpreted through two complementary theoretical lenses: community empowerment theory and materials science. From the empowerment perspective, the participatory action approach transformed residents from recipients of assistance into agents of change within their own environment. The sustainability of an infrastructure program is widely held to depend on the degree of participation and the sense of ownership cultivated among the local community, and the deliberate involvement of residents from planning through to execution was designed to maximize both. The learning that occurred was situated and contextual: technical knowledge was not delivered as abstract instruction but internalized through the concrete problem-solving demanded by the construction itself.

This interpretation is consistent with the broader community service literature, which finds that interventions grounded in local participation and existing social capital are more likely to endure than those imposed from outside (Kapisa, Maulana & Sukirman, 2025). The gotong royong ethic mobilized in RW 01 provided a ready-made vehicle for collective learning, and the visible, shared ownership of the finished slab is expected to translate into collective responsibility for its ongoing maintenance.

The success of this community service program is measured not only by the physical achievement of the constructed yard flooring infrastructure, but also by the social transformation that occurred in the

community of RW 01, Bencongan Indah Village. From a theoretical perspective on community empowerment, the participatory action approach proved capable of shifting the residents' paradigm from merely being recipients of aid to becoming agents of change in their own environment. This social change aligns with community development theory, which emphasizes that the sustainability of an infrastructure program depends heavily on the level of participation and sense of ownership within the local community. The involvement of residents from the planning stage and mix-proportion training through to the execution of pouring has triggered a learning process in which new technical knowledge is directly internalized through contextual problem-solving practice.

Theoretically, this cognitive change in the community is supported by empirical evidence in the field regarding the structural performance of fly ash. Education on fly ash substitution at 16 percent provides theoretical findings that are highly relevant to the construction materials technology literature. In concrete science, fly ash is known as a pozzolanic material because it has high silica and alumina contents (Widjajakusuma, J., Bali, I., Ng, G.P., & Wibowo, K.A., 2022). Literature indicates that pozzolanic materials, although they lack the binding properties of cement on their own, chemically react with calcium hydroxide, a by-product of cement hydration (Singh & Middendorf, 2020; Ralli & Pantazopoulou, 2021).

The finding from this community service, in which the floor slab achieved a mean compressive strength of 17.4 MPa at 28 days (individual specimens 16.6–18.4 MPa, all above the 16 MPa design strength) and showed no significant shrinkage cracks, can be theoretically explained by this secondary reaction mechanism (Widjajakusuma, Wibowo & Clarissa, 2025). The active silica in fly ash reacts with calcium hydroxide to form additional calcium silicate hydrate gel. This secondary gel fills capillary pores in the concrete matrix, thereby increasing the density of the concrete microstructure, reducing permeability, and improving the mixture's bond strength during pouring. This theoretical explanation validates the new perception among residents that reducing cement with fly ash does not decrease quality but instead optimizes floor durability.

Furthermore, the synthesis between social approaches and material technology innovation in this community service activity strengthens the academic discourse on sustainable infrastructure. The highest social change observed was the emergence of ecological awareness among residents. Industrial waste, once viewed as worthless residue, is now recognized as a viable material. This confirms the theoretical perspective of the circular economy and the Sustainable Development Goals (SDGs), which state that appropriate technology-based education at the grassroots level is the most effective instrument for reducing waste while simultaneously creating resilient and sustainable public spaces and settlements.

From the materials-science perspective, the field outcome of an average compressive strength of 17.4 megapascals at twenty-eight days (against a design strength of sixteen megapascals), with no significant shrinkage cracking, can be explained by the pozzolanic behavior of fly ash. Fly ash is rich in reactive silica and alumina (Widjajakusuma, Bali, Ng & Wibowo, 2022) but lacks intrinsic binding capacity; instead, it reacts with the calcium hydroxide liberated during cement hydration (Singh & Middendorf, 2020; Ralli & Pantazopoulou, 2021). This secondary reaction produces additional calcium silicate hydrate gel, which fills the capillary pores of the matrix, densifies the microstructure, reduces permeability, and improves bond strength. The absence of surface shrinkage cracking observed in the finished slab is consistent with this pore-refining mechanism and with the improved workability that permitted better compaction during placement.

Synthesizing the social and technical findings situates the activity within the wider discourse on sustainable infrastructure. The reconceptualization of fly ash by residents, from worthless residue to a valuable material, mirrors at the neighborhood scale the logic of the circular economy, in which the by-product of one process becomes the feedstock for another (Venia, Hidayat & Salmin, 2024). This grassroots reuse advances several Sustainable Development Goals simultaneously, contributing to resilient infrastructure, sustainable settlements, and responsible production and consumption (Insani, Alwi & Najamuddin, 2025). The experience suggests that appropriate-technology education delivered at the community level is among the most effective instruments for reducing waste while creating durable public spaces, echoing findings that the local uptake of sustainability initiatives is strengthened when they are embedded in supportive community frameworks (Kapisa & Sudrajat, 2025).

Several limitations nonetheless temper these findings and indicate directions for future work. The compressive strength assessment was based on a limited number of cylinder specimens cast under field conditions, and long-term durability indicators, such as permeability and carbonation resistance, were

not evaluated within the timeframe of the activity. Moreover, the 16% substitution level, while effective in this context, was not experimentally optimized across a range of alternative proportions. Future programs could pair the community activity with a more systematic laboratory study of substitution ratios and extend monitoring over a longer service period to confirm durability under real-world use, thereby strengthening the evidence base underpinning the outreach message.

The approach adopted here can be positioned within a broader family of strategies for reducing the clinker content of concrete using supplementary and alternative binders. Related work by the authors has examined more complete cement substitution, including cement-free concrete produced from fly ash blended with palm oil fuel ash (Widjajakusuma, Wibowo & Clarissa, 2025) and the role of geopolymers systems in advancing sustainability targets, such as Good Health and Well-being, Clean Water and Sanitation, Decent Work and Economic Growth, Sustainable Cities and Communities, Responsible Consumption and Production, and Climate Action (Wibowo & Widjajakusuma, 2025). While such fully alkali-activated systems can achieve high performance, they typically require carefully controlled activators and curing regimes that are difficult to implement in an informal field setting. The partial-replacement strategy employed in this community program was deliberately chosen as a pragmatic middle path: it delivers meaningful environmental and economic benefits while remaining simple enough for resident volunteers to execute safely with basic guidance.

The model's transferability to other neighborhoods is a further consideration. The technical core of the activity, the partial replacement of cement with a verified pozzolan, is not specific to yard flooring and could be applied to a range of low-rise, light-load elements such as pathways, drainage covers, and communal platforms; comparable principles also underpin related lightweight-concrete applications explored by the authors (Widjajakusuma, Bali, Ng, Owen & Wijaya, 2026). Realizing this potential at scale, however, would benefit from the engagement of local government and other stakeholders, whose support can help to institutionalize the practice, secure a reliable supply of quality-assured fly ash, and align neighborhood initiatives with municipal infrastructure planning.

It is also worth reflecting on the university's role in this model of engagement. By acting as an intermediary between formal materials research and informal community practice, the service team was able to translate technical findings into a form that residents could apply while also gathering field observations that can inform subsequent research and teaching. This bidirectional exchange embodies the downstreaming, or *hilirisasi*, of research results that community service is intended to achieve, and it strengthens the case for embedding such activities within the regular academic mission rather than treating them as peripheral outreach.

Finally, the highest-order change observed during the program was attitudinal. Residents moved from viewing the activity as the receipt of an external donation towards a sense of collective authorship over an asset they had helped to create, accompanied by a new ecological awareness in which an industrial residue was seen as a resource rather than a nuisance. It is this combination of a tangible, constructed facility, measurable skill acquisition, and durable attitudinal change that distinguishes an empowerment-oriented community program from a conventional one-off provision of infrastructure and offers the best assurance that the benefits of the activity will persist long after its formal conclusion.

CONCLUSION

The Community Service initiative in RW 01, Bencongan Indah Village, has substantially addressed local infrastructure challenges and promoted social empowerment. The application of a 16 percent fly ash substitution in the concrete mixture facilitated the construction of a yard floor slab that meets structural feasibility standards. This practical success substantiates material technology theory, which posits that the pozzolanic properties of fly ash enhance concrete durability and density. Furthermore, this outcome supports community empowerment theory. The participatory action approach implemented has effectively transformed residents into independent agents of change. Residents' direct involvement throughout the construction process has enhanced cognitive capacity and fostered ecological awareness regarding the potential of industrial waste as a valuable resource. Based on the findings and reflections, several recommendations are proposed for future implementation. First, the partner community should regularly maintain the constructed facilities and consider independently adopting fly ash concrete technology to enhance other public infrastructure. Second, academics and future service teams are encouraged to develop similar programs by testing variations in the percentage of alternative substitution materials, thereby contributing to the literature on

environmentally friendly construction materials. Third, local government and relevant stakeholders are encouraged to adopt this empowerment model as a reference to support community initiatives in other urban areas, particularly in efforts to establish resilient and sustainable settlements. Taken together, the physical, social, and environmental outcomes of this program demonstrate that university-led community service can serve as an effective bridge between laboratory research on sustainable materials and the everyday construction needs of a neighborhood. The convergence of a participatory empowerment approach with a validated material technology produced benefits that neither element could have delivered alone: a durable and economical facility, a measurable increase in residents' competence, and a tangible contribution to more responsible industrial waste management. This dual achievement reinforces the view that appropriate-technology outreach is a practical vehicle for advancing the Sustainable Development Goals at the grassroots level. Furthermore, it also aligns with the Prabowo-Gibran administration's Asta Cita (Eight Missions), particularly its objective to promote a green economy (Presiden Republik Indonesia, 2025). More broadly, the experience of this program illustrates how the community service mandate of higher education can be operationalized as a genuine two-way exchange rather than a one-off transfer of resources. The activity simultaneously delivered a durable public facility, advanced the downstreaming of materials research into everyday practice, and generated field insights that can enrich subsequent teaching and study. Sustaining and scaling such outcomes will depend on continued collaboration among universities, residents, and local authorities, on a reliable supply of quality-assured industrial by-products, and on the willingness of communities to treat what was once regarded as waste as a resource for building their own resilient and sustainable environment.

ACKNOWLEDGEMENTS

We express our sincere gratitude to the residents of RW 01 for their willingness to serve as partners in this community service activity (PkM). We also extend our appreciation to the LPPM of Universitas Pelita Harapan for providing financial support for this community service activity in 2026 through the grant titled "Pemanfaatan Beton dari Campuran Abu Terbang untuk Pembuatan Lantai Halaman" (PM-002-D-FaST/XII/2025).

REFERENCES

- Alfathy, R.M., Saputro, S., Sarwanto & Ramli, M. (2024). Implementation of sustainable development goals in higher education modalities: Literature Review. *Journal of Turkish Science Education*, 21(1), 22–43. <https://doi.org/10.36681/tused.2024.002>
- Andriyanto, S., Muharni, S., Nugroho, T. A., Al Farisi, M. F., Dzaki, M. D., & Irnanda, I. (2025). Inovasi Pelayanan Kesehatan Berbasis Digital melalui Pelatihan SIRS Versi 6.3 untuk Peningkatan Akurasi Data Medis. *Journal of Digital Community Services*, 2(2), 36–41.
- ASTM International. (2008). Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete (C 618-08a).
- Badan Standardisasi Nasional. (2000). Tata Cara Pembuatan Rencana Campuran Beton Normal (SNI 03-2834-2000).
- Badan Standardisasi Nasional. (2011). Cara Uji Kuat Tekan Beton dengan Benda Uji Silinder (SNI 1974:2011).
- Badan Standardisasi Nasional. (2011). Tata Cara Pembuatan dan Perawatan Benda Uji Beton di Laboratorium (SNI 2493:2011).
- Dewi, I. N., Khaerudin, D., Gandara, G. S., Putra, A. R., Budiharjo, B., & Putri, A. (2025). Kegiatan Penyulaman Pohon Mangrove Guna Mengurangi Erosi Pantai di Pulo Cangkir Desa Kronjo Kecamatan Tangerang, Provinsi Banten. *Journal of Digital Community Services*, 2(1), 7–15.
- Dewi, I. N., Khaerudin, D., & Romli, O. (2026). Sustainability of BUMDes MSME Optimisation: Strengthening the Marketing of Bontot Through Packaging, Labelling and Halal Certification in Tanara Village. *Journal of Digital Community Services*, 3(2), 12–23. <https://doi.org/10.69693/dcs.v3i2.51>

- Insani, N. N., Alwi, A., & Najamuddin, N. (2025). Perubahan Perilaku Konsumsi Masyarakat Kota Makassar akibat Kampanye Kesadaran Perubahan Iklim di Media Sosial. *Dedikasi: Jurnal Pengabdian Kepada Masyarakat*, 5(2). <https://doi.org/10.46368/dpkm.v5i2.3633>
- Kapisa, R. Y., Maulana, A., & Sukirman, R. F. (2025). Inovasi Desa Berbasis Kearifan Lokal: Tinjauan Literatur terhadap Praktik Terbaik di Indonesia. *Journal of Digital Community Services*, 2(2), 24-29.
- Kapisa, R. Y., & Sudrajat, A. (2025). Efektivitas Peraturan Desa dalam Mendukung Pencapaian Sustainable Development Goals (SDGs): Sebuah Kajian Literatur. *Journal of Digital Community Services*, 2(2), 30-35.
- Mulyono, T. (2004). *Teknologi Beton*. Andi Offset.
- Parhusip, A., Pramono, R., Widjajakusuma, J., & Pinontoan, R. (2022). Edukasi Partisipasi Masyarakat Desa Cipinang Melalui Program Water Closet Mandiri (WCM) di Kec. Angsana Kab. Pandeglang. *Prosiding Konferensi Nasional Pengabdian Kepada Masyarakat Dan Corporate Social Responsibility (PKM-CSR)*, 5, 1-10. <https://doi.org/10.37695/pkmcsr.v5i0.1809>
- Presiden Republik Indonesia (2025). Peraturan Presiden Republik Indonesia Nomor 12 Tahun 2025 tentang Rencana Pembangunan Jangka Menengah Nasional Tahun 2025-2029. Jakarta: Sekretariat Negara Republik Indonesia.
- Purba, S. M., Widjajakusuma, J., Wibowo, K. A., & Sumantri, N. A. (2025). Peningkatan Kesehatan Lingkungan Melalui Pembangunan Septic Tank di Balai Warga Bencongan Indah. *Jurnal Pengabdian Kepada Masyarakat*, 4(9), 1799-1804.
- Ralli, Z.G., & Pantazopoulou, S.J. (2021). State of the art on geopolymer concrete. *International Journal of Structural Integrity*, 12(4), 511-533. <https://doi.org/10.1108/IJSI-05-2020-0050>.
- Rijal, M. K. (2026). Transformasi Kurikulum Merdeka di MAN 1 Samarinda: Peran Pendampingan Berbasis Komunitas dalam Meningkatkan Pembelajaran. *Journal of Digital Community Services*, 3(2), 1-11. <https://doi.org/10.69693/dcs.v3i2.44>
- Singh, N. B., & Middendorf, B. (2020). Geopolymers as an alternative to Portland cement: An overview. *Construction and Building Materials*, 237, 117455. <https://doi.org/10.1016/j.conbuildmat.2019.117455>.
- Venia, P., Hidayat, R., & Salmin, S. (2024). Edukasi Pengelolaan Sampah di TPS 3R Ita Peduli, Dusun Lekok, Desa Gondang. *Dedikasi: Jurnal Pengabdian Kepada Masyarakat*, 4(1), 97-105. <https://doi.org/10.46368/dpkm.v4i1.1498>
- Widjajakusuma, J., Pramono, R., Parhusip, A., Pinontoan, R., Dewi, N. S., Napilah, S. N., Sulistian, A., Apriliani, R., Arifa, N. I., Al-abqori, M. U., Hendra, A. G., & Hasyati, A. (2021). Pemberdayaan Masyarakat Desa Cipinang melalui Program Water Closet Mandiri guna tingkatan sanitasi Cipinang. *Jurnal Sinergitas PkM dan CSR*, 5(3), 583-587. <https://doi.org/10.19166/jspc.v5i1.4984>
- Widjajakusuma, J., Bali, I., Ng, G.P., & Wibowo, K.A. (2022). An Experimental Study on the Mechanical Properties of Low-Aluminum and Rich-Iron Calcium Fly Ash-Based Geopolymer Concrete. *Advances in Technology Innovation*, Vol. 7, No. 4, 2022, pp.295-302. <https://doi.org/10.46604/aiti.2022.10525>
- Widjajakusuma, J., Wibowo, K.A., & Clarissa (2025). High-Strength Cement-Free Concrete Made From Fly Ash and Palm Oil Fuel Ash. *International Journal of GEOMATE*, Vol. 29 (132), p. 12-19. <https://doi.org/10.21660/2025.132.4793>.
- Wibowo, K.A., & Widjajakusuma, J. (2025). The Role of Geopolymer Concrete in Achieving Sustainable Development Goals. *FaST-Jurnal Sains dan Teknologi*, Vol. 9(2), p. 190-198. <https://doi.org/10.19166/jstfast.v9i2.10386>
- Widjajakusuma, J., Sondakh, J., Buntoro, F., & Tanuhendrata, M. (2025). Peningkatan fasilitas lapangan olahraga RW 05. J-Abdi: Jurnal Pengabdian Kepada Masyarakat, Vol. 5, No. 3, p. 2798-2912. <https://bajangjournal.com/index.php/J-ABDI/article/view/10713/8584>

Widjajakusuma, J., Waruwu, A., Rahayu, P.C., & Wibowo, K.A. (2025). Pemberdayaan Masyarakat Melalui Penerapan Teknologi Eco-Paving Block. *J-Abdi: Jurnal Pengabdian Kepada Masyarakat*, Vol. 5, No. 5, p. 2798-2912. <https://bajangjournal.com/index.php/J-ABDI/article/view/11376/9099>

Widjajakusuma, J., Bali, I., Ng, G.P., Owen, M., Wijaya, N. (2026). The High Early Strength of Expanded Clay Structural Lightweight Concrete. In: Kueh, A.B.H., Beladi Sihombing, L., Lee, Y.Y., Hardjasaputra, H., Stürwald, S. (eds) *Proceedings of the 9th International Conference of EURO ASIA Civil Engineering Forum - Volume 1. EACEF 2025. Lecture Notes in Civil Engineering*, vol 811. Springer, Singapore. https://doi.org/10.1007/978-981-95-6895-6_28