Automated Bar Bending Schedule and Reinforcement Procurement-Waste Estimation for Apartment Pile Caps: an Excel-Macros Case Study

Putri Lynna A. Luthan[1*], Nathanael Sitanggang[2], Syahreza Alvan[1], Mena Fadilia Lukman[2], Fathinah Muthiah Sari[1]

1- Construction Management Study Program (D4), Faculty of Engineering, Universitas Negeri Medan, Indonesia.
2- Building Engineering Education Study Program (S1), Faculty of Engineering, Universitas Negeri Medan, Indonesia.

* putri.lynna@unimed.ac.id

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Abstract

Waste material in construction projects is a major challenge that leads to increased project costs and inefficiency. One material that often experiences significant waste is reinforced concrete, primarily due to inefficient steel cutting, errors in the planning of bar lengths, and discrepancies between the working drawings and field conditions. Accurate reinforcement take-off and procurement planning are important for controlling construction waste, but spreadsheet automation is frequently reported without a clear distinction between theoretical material demand and actual site scrap. This study evaluates an Excel-macro-assisted bar bending schedule (BBS) workflow for three pile-cap group (P1-P3) in an Indonesian apartment construction project using project drawings, reinforcement schedules and procurement quantities collected during May-July 2025. The reconstructed BBS indicates reinforcement requirements of 825.53 kg for P1, 1,105.01 kg for P2 and 9,746.84 kg for P3, totaling 11,677.38 kg when the displayed subgroup values are summed. Reported procurement is 12,158.56 kg, giving a mass difference of 481.18 kg and a procurement surplus ratio of 3.9575% relative to ordered mass (approximately 3.958%). This figure represents an estimated a procurement-demand balance, not an independently measured disposal rate. The contribution is a traceable case-study workflow linking detailed bar schedules to quantity aggregation and a clearly defined surplus indicator, rather than a demonstrated new cutting-stock optimization algorithm. Further validation requires bar-level stock allocation, reusable-offcut records, independent calculation checks and field measurements.

Keywords: bar bending schedule, Excel macros, pile caps, procurement surplus; construction material waste.

1. Introduction

In the construction industry, material efficiency is crucial to the success of a project. However, many projects still experience material waste, particularly in the use of concrete reinforcement. Pile cap work is one type of reinforced concrete construction that has three components: casting, reinforcement, and formwork, which contribute 50-60% of the project cost [1]. Of these three components, steel reinforcement is the component that has the most significant impact on total construction costs, accounting for 38.5% in European countries, 26% in the USA, and 25.67% in Indonesia [2–4]. The high cost of reinforcing steel in construction work must be taken seriously, so it must be calculated carefully to avoid producing large amounts of reinforcing-steel waste, which would result in project cost overruns. The emergence of material waste during the implementation of construction projects in the field is inevitable, caused by the suboptimal utilization of reinforcing-steel offcuts in pile cap work.

Material waste is referred to as leftover material due to poor planning, low material quality, and inadequate material storage, resulting in wasted time, costs, and environmental impacts [5, 6]. Waste material in reinforcement is caused by inadequate worker skills, reinforcing-bar cutting errors due to inappropriate pattern guidelines, information on the latest technology that has not been optimized, and estimates that do not match the actual work [7]. However, these pieces actually still have the potential to be reused in smaller reinforcement work or as part of reinforcement splices. Reusable reinforcing-steel offcuts can be incorporated into cutting and material management strategies to reduce waste and improve material utilization [8]. Furthermore, empirical evidence from reinforced-concrete construction projects indicates that systematic

planning and the reuse of suitable reinforcement remnants can contribute to lower material waste in structural elements such as column, beams, and slabs [9]. Material waste from ironwork can be minimized by creating a list/model of rebar bending using the Bar Bending Schedule method. However, this method can only provide information on the length, quantity, and shape of the iron, thereby avoiding errors in bending, but it cannot minimize the waste produced, which results in steel offcuts that cannot be reused.

Reinforcing-steel quantities for pile caps depend on structurally approved geometry, load effects, bar arrangements, development lengths, anchorage and detailing requirements. Consequently, materials planning cannot be separated from the actual project design. The construction-waste literature identifies design coordination, fabrication planning and procurement as relevant control points [5], [7]. Meanwhile, automation can improve the traceability of quantity take-off, but improvements in cost, runtime or scrap reduction require explicit comparison data [10].

With the rapid development of digital technology under Industrial Revolution 4.0, software tools have become widely available and are used by planning consultants and construction contractors to perform calculations quickly and accurately. One of the available software programs is the Excel macro feature, which is used to calculate the estimated material requirements for a building construction [10]. The Excel macro are programmable routine within Microsoft Excel, which can save time, reduce labor, minimize errors, and be used in an automated manner to calculate material leftovers. Industry 4.0 and Society 5.0 encourage the construction industry to develop a skilled workforce to face the era of automation, which can increase competitiveness, work quality, project timeliness, and new services for customers [11].

In construction projects, reinforced-concrete pile cap play a crucial role as a link between the foundation piles and the upper structural elements. One important aspect in the planning and implementation of pile cap work is the estimation of concrete reinforcement requirements, which must be calculated accurately to ensure structural strength and project cost efficiency [12]. Inaccuracies in concrete reinforcement estimates have a direct effect on potential material waste and potential project delays caused by over-ordering or material shortages [13]. A study conducted by Tam et al. shows that reinforcement materials contribute a significant percentage to total construction waste, making their control an important aspect of project management [14]. Previous research includes Excel-macro cost estimation [10], BIM-enabled quantity take-off, special-length prioritization and mathematical cutting-stock optimization [15]. The contribution of the present study is to document a reproducible, pile-cap-specific BBS to procurement reporting sequence in a conventional spreadsheet environement, and to audit the distinction between steel demand and nominally purchased steel. Neither an optimal cutting pattern nor a measured waste reduction is asserted without the corresponding records.

The study asks: (RQ1) What is the reinforcement mass required by each pile-cap group and bar diameter in the case project" (RQ2) How large is the difference between reported stock-bar procurement and the calculated mass requirement? (RQ3) Which additional operational data are required before the calculated procurement surplus can be interpreted as physical cutting waste?. This study investigates the ABC Building construction project in AAA City, which has a main structure of reinforced concrete and uses various types of plain and threaded reinforcement. This project shows a difference between the quantity of reinforcement ordered and the reinforcement used in the field. This study is limited to pile cap work using the Bar Bending Schedule modeling approach and Microsoft Excel Macros. The case study therefore provides a project-specific account of reinforcement quantity estimation and procurement surplus, with potential practical implications for similar workflows.

2. Theoretical Background and Methodology

Digitalization has reshaped construction workflows through data centric, iterative and automation ready practices often grouped under Construction 4.0. Reviews highlight accelerating adoption of BIM, IoT, analytics and automation to raise accuracy and reduce waste across the project lifecycle. These studies also stress that benefits materialize only when technology is coupled with process redesign and collaborative mechanisms [11]. Automating quantity take off (QTO) directly improves cost/quantity accuracy, shortens feedback loops, and limits reinforced concrete (RC) over ordering. Empirical and implementation studies report that BIM enabled QTO reduces discrepancies versus manual workflows and supports waste prevention decisions (i.e., order batching, clash prenvention and schedule linked pours). Recent research documents automated extraction of zone based concrete volumes and formwork quantities from BIM and real project QTO standardization, while systematic or bibliometric reviews map the evolving capabilities and barriers. These insights anchor the rationale for automating rebar and waste computation in RC works even in non BIM settings using fit for purpose tools such as Excel [15].

Accurate automation depends on codified detailing rules and dependable sectional and weight data. Practitioner manuals and standards summarize bar shapes, hooks, and bending details that govern cutting and fabrication lists. For weight or mass calculation, consolidated rebar tables provide mass per length, a critical

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input for automated quantity and waste formula. Together, these sources underpin machine readable rules and lookup tables that Excel macros can invoke to generate bar schedule, lengths, and mass (kg/m) consistently [16].

Pile caps are D regions with complex 3D stress fields; strut and tie (STM) modeling is widely recommended for design and detailing checks. Open access theses and journal articles describe STM's improved reliability over sectional methods for shear or punching behaviors in pile caps and provide step by step procedures that can be translated into algorithmic checks (i.e nodal zones, strut efficiency factors). In this context, STM informed rules help parameterize minimum bar lengths, anchorage or hook requirements and bar layout constrains that an automation routine must honor [17] [18].

Spreadsheets remain ubiquitous in construction engineering due to transparency, portability, and rapid iteration. VBA macros allow encapsulating design rules, lookup tables and validation logic to automate QTO and rebar scheduling. Engineering studies have implemented Excel-VBA for STM related components (e.g bridge bent caps), demonstrating feasibility for RC substructures with complex detailing. Microsoft's official documentation provides the programmable object model and best practice entry points to structure robust, maintainable macros [19]. Rebar cutting waste (RCW) directly amplifies embodied CO_2 in RC works. Optimization studies show that combining stock length assignment, special length ordering, and lap splices adjustments can push RCW toward <1% (near zero) while also lowering total rebar tonnage and costs, indicating that waste aware computation should be integrated at bar list generation [20–22].

Recent work proposes two stage heuristics, integer and metaheuristic cutting stock formulations, and BIM coupled genetic approaches for large, mixed rebar sets. These can be implemented as greedy/heuristic solvers in VBA or interfaced with external solvers, producing cutting patterns, splice layouts and waste reports programmable within spreadsheet environments [23–25]. These strategies can be embedded into Excel via VBA either natively or by calling compiled solvers so that the macro computes both required quantities and minimum waste cutting plans from pile cap reinforcement layouts [24].

A pragmatic pathway emerges from the literature comprising (a) encode detailing constraints (hook, bends, lap limits) and base data (mass per length, stock lengths) from standards/tables; (b) generate bar schedule from pile cap geometry consistent with STM design checks; (c) run a waste aware optimizer to assign reinforcing bar requirements to stock or special lengths; (d) report total mass, cutting patterns, waste, and optionally CO_2 proxy metrics. This mirrors BIM based aims while leveraging Excel's ubiquity for fast adoption on small and medium-sized projects or in settings with limited BIM maturity. The approach aligns to diverse project teams [26, 27].

Construction quantity take-off has increasingly adopted BIM and automated workflows [11], [15], [26], [27]. However, spreadsheet-based workflows remain useful where project documentation is primarily issued as conventional drawings. Previous research has developed spreadsheet estimation tools [10] and specialized reinforcement optimization methods [20]-[25]. Reinforcement scheduling depends on approved geometries, bend allowances, bar diameters, quantities, anchorage and development requirements. The theoretical mass of each bar-mark entry is obtained from its cut length, piece count and mass per metre, using consistent units and full-precision source values. Pile caps transfer column actions to piles through three-dimensional stress fields; strut-and tie models can inform structural verification [17]-[19], [28]. In the present paper, structural sizing and safety are treated as external design constraints taken from the approved drawings, not outcomes independently designed or validated by the Excel macro.

The literature converges on three actionable ideas (encode reinforcement detailing and mass/length tables as machine readable rules, optimize cutting patterns to pursue near zero cutting waste and operationalize these within everyday tools) while BIM studies validate automated QTO and waste reduction, there is a practical gap in Excel based, standards compliants macros tailored to pile cap reinforcement that both compute quantities and output optimized cutting plants or waste for procurement. The industry lacks a validated, auditable and easily adoptable excel macro solution that unfies BBS (Bar Bending Schedule) generation, automated rebar quantity calculation, and explicit, optimization informed estimation of cutting waste for pile cap structures, while enforcing detailing rules and aligning with applicable standards. In this study, the proposed integration directly addresses this adoption gap by combining STM informed rules, robust lookup data and lightweight optimization within a widely available platform Excel/VBA thus bridging advanced methods with field practicality.

Prior work on cutting-stock optimization, special-length procurement and coupler-based strategies addresses the minimization of unusable offcuts [20]-[25], [29], [30], [32]-[33]. This study does not demonstrate that such algorithms were implemented in the supplied Excel macro; its contribution is limited to documented quantity computation and procurement-balance reporting. This retrospective quantitative case study examines pile-cap groups P1, P2, and P3 in one apartment project (May-July 2025). Inputs described in the source manuscript include approved working drawings, reinforcement bar marks, diameters, cutting lengths, number of piece counts, theoretical unit masses and reported 12-m stock-bar purchasing quantities. The unit of

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descriptive comparison is a pile-cap group or nominal bar diameter, not an independently randomized project sample.

For each BBS line, the macro reads the nominal diameter, prescribed bar shaped, calculated cutting length and required quantity. It multiplies the cutting length (cm), the piece count and the applicable theoretical mass per metre (kg/m), then sums the resulting masses by nominal diameter and pile-cap group. For purchased bars, the reported surplus is the difference between the two mass totals, and the surplus percentage is normalized by purchased mass. The data were analyzed using an Excel macro to calculate the steel requirements, waste material, and total steel usage recapitulation, and to compare the theoretical steel requirements with the estimated procurement surplus using the Bar Bending Schedule model using Excel macros.

Pile caps are structurally designed members; reinforcement quantities and shapes should be taken from engineer-approved drawings after verifying the applicable design basis. SNI 2847:2019 (structural concrete requirements) is an applicable Indonesian reference for reinforced concrete and must be checked against project approvals. The relevant reinforcing-steel material edition must likewise be identified from procurement specifications; SNI 2052:2024 is a published Indonesian reinforcing-steel standard. This investigation performs quantity accounting from drawings and does not establish compliance with axial, shear, punching, strut-and-tie, anchorage or seismic load combinations. The table 1 shows the variables and operational definitions.

Table 1. Variables and operational definitions

Role	Variables	Definition/unit
Independent/input	Pile cap group (P1/P2/P3)	Categorical drawing based geometry/detailing group
Independent/input	Nominal diameter (13/16/19 mm)	Bar-size category recorded in source schedule
Independent/input	Scheduled cut length and bar count	Metres per piece and dimensionless pieces, respectively
Independent/input	Purchased bars by diameter	Count of 12-m stock bars
Dependent/output	Calculated reinforcement demand	Sum of scheduled bar lengths x theoretical unit mass (kg)
Dependent/output	Procurement surplus	Purchased mass minus calculated demand (kg)
Dependent/output	Surplus ratio	Procurement surplus divided by purchased mass x 100%
Not yet observed	Physical scrap and reusabel offcuts	Actual weighed unusable cut-offs and reusable inventory, unavailable in supplied dataset.

*The independent and dependent variable listed above specify computational inputs and outputs, not causal variables in an experimental model. No intervention or control treatment was implemented, so causal claims about the effect of macro use are not justified.

Descriptive analyses report group-level totals, composition shares and procurement surplus. As only aggregated outcomes are provided, no valid inferential test of "macro versus manual" accuracy, runtime or waste reduction can be conducted. Such tests would require matched independent manual and VBA calculations on identical bar marks, plus a specified reference measurement; possible metrics include absolute error, mean absolute percentage error (where meaningful), calculation time and paired differences with confidence intervals. The research workflow is shown in Figure 1.

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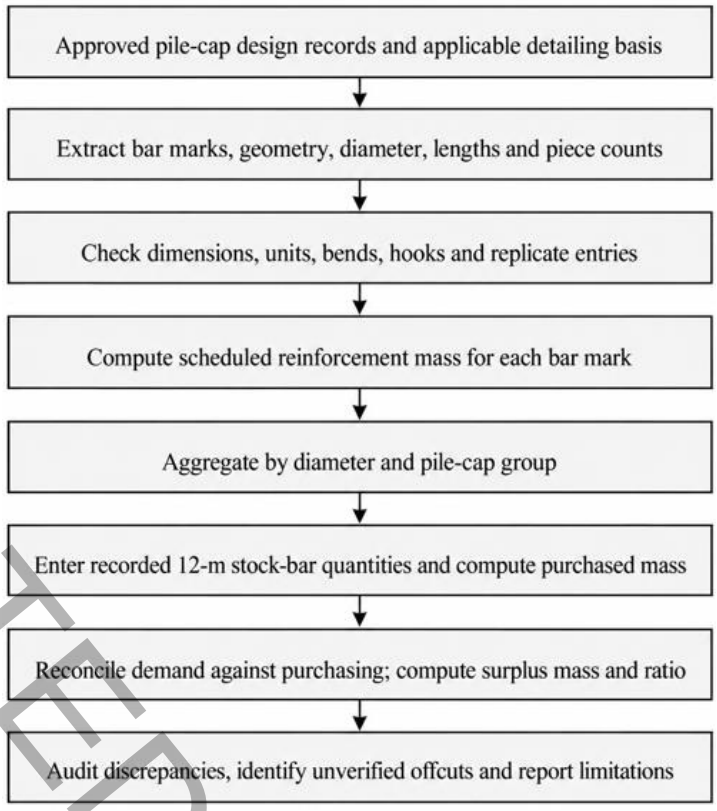


Fig 1. Research Workflow

3. Results and Discussion

Identification of Working Drawings

The creation of a bar bending schedule requires data in the form of shapes or patterns, sizes including the length and diameter of the steel, and the number of reinforcing bars to be used in the reinforcement work. This data can be obtained by identifying the shop drawings used in the project's implementation. The source project documents show three reinforcement detail types (P1, P2, and P3), including top and bottom bar mats and bent anchorage details (Figures 2-5). These are the geometric sources for scheduling rather than proof of independent structural checking. The resolution of the original drawing is insufficient to verify all documentations, spacing and annotations, and reproducing them as redrawn engineering designs without CAD evidence would introduce a risk of inaccurate detailing.

Figure 2 illustrates typical reinforced concrete pile cap detailing in which column loads are transferred to a group of piles through a disturbed region (D region); accordingly, the strut and tie method (STM) provides the appropriate design idealization: bottle shaped concrete struts extend from the pedestal/column toward the pile heads, while the bottom reinforcement mat acts as the principal ties. These meet within nodal zones whose stresses and confinement must satisfy STM capacity checks.

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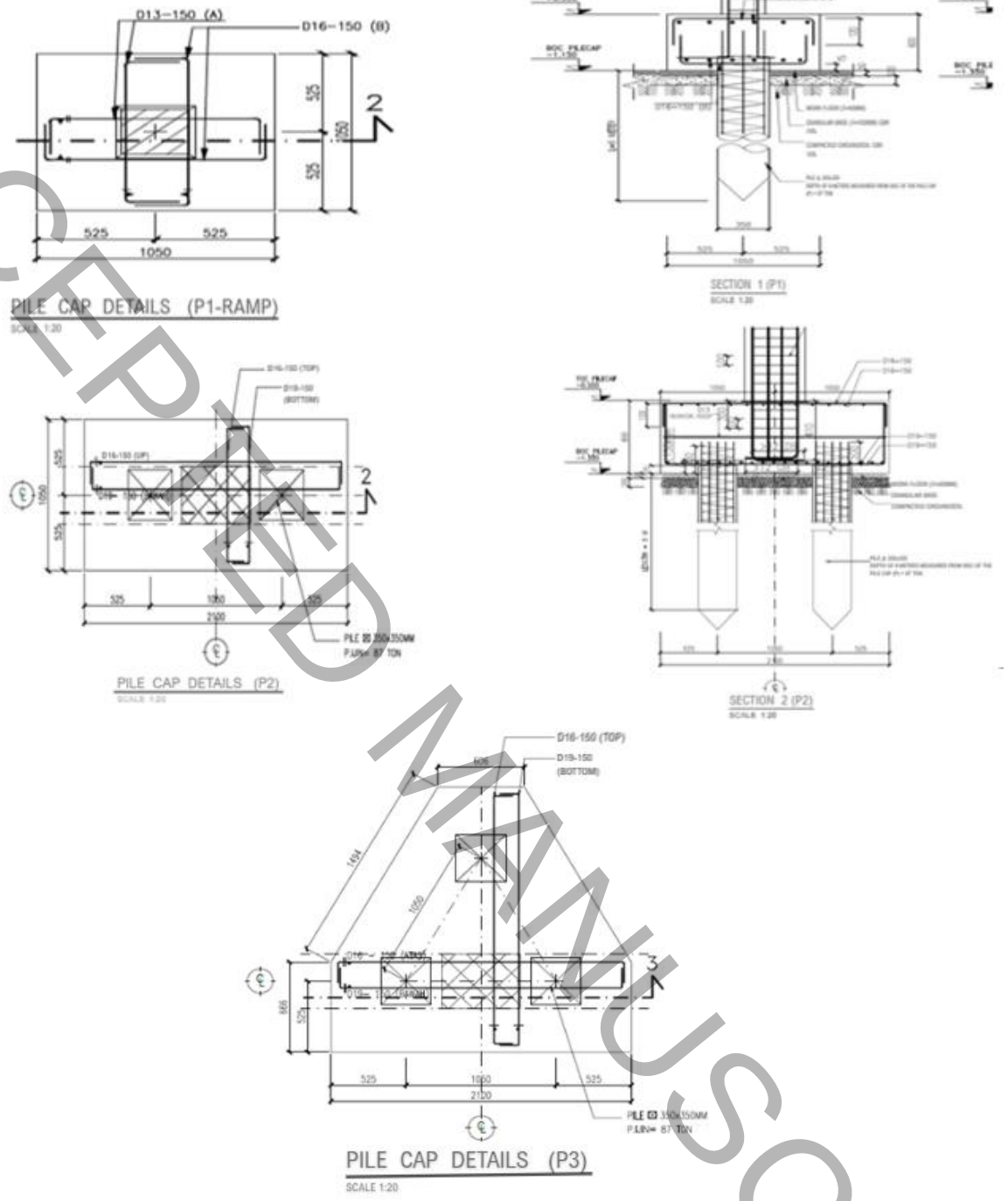


Fig 2. Detail Pile Cap

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An explanation of each reinforcement pattern for Pile Cap 1 can be seen in Figure 2.

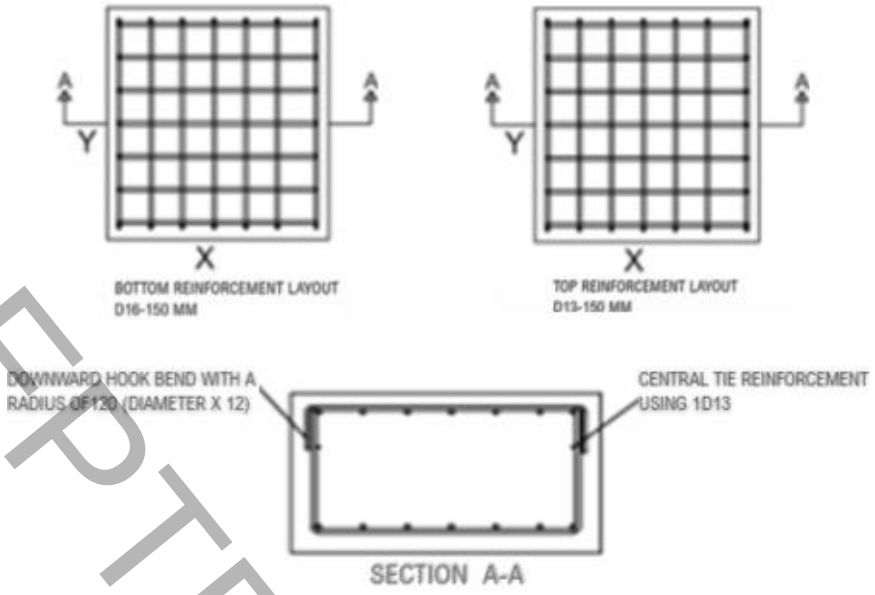


Fig 3. Reinforcement Pattern P 1

Figures 3-5 show project reinforcement arrangements for P1-P3. These drawings are scheduling inputs and do not establish independent compliance with the structural design code. Original approved CAD/vector exports are needed to make bar marks and dimension legible. Figure 3 depicts a typical pile cap reinforcement arrangement in plan and section. In a strut-and-tie idealization, the column load is carried by bottle shaped concrete struts toward the piles, while the bottom mat acts as the primary ties spanning between reaction points.

The reinforcement pattern for Pile Cap 2 can be seen in Figure 4.

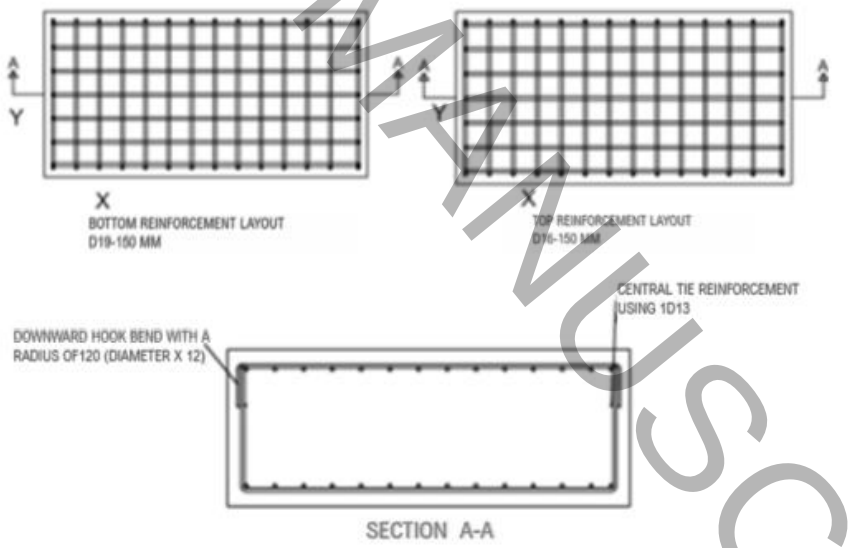


Fig 4. Reinforcement Pattern P 2

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The reinforcement pattern for Pile Cap 3 can be seen in Figure 5.

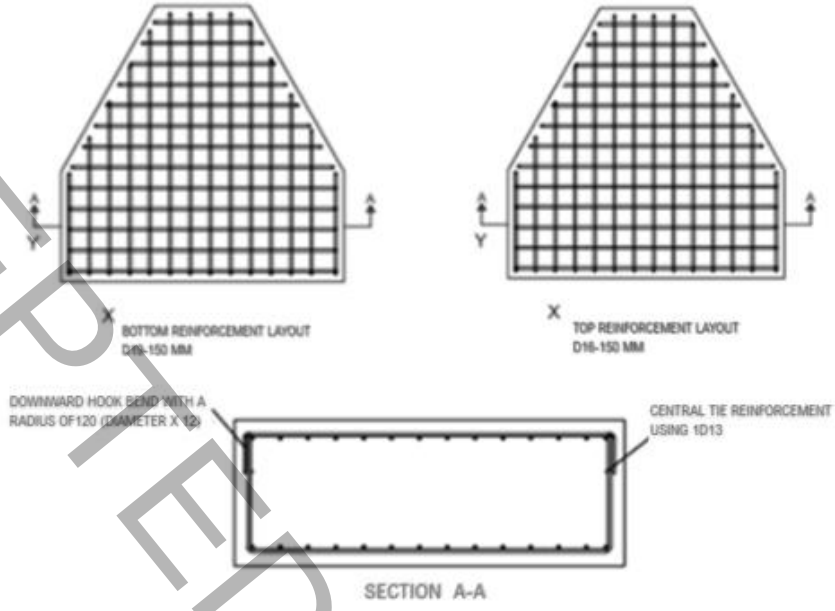


Fig 5. Reinforcement Pattern P 3

Calculation Results for Reinforcing Steel Requirements

The original project drawings were translated into bar marks, shape descriptions, cut lengths, diameters and quantities. The macro-based worksheet extract is preserved as an example of the reported bar schedule; its editable transcription is presented in Table 2. Based on the working drawings of the pile cap structure for the apartment project, the calculation of concrete reinforcement requirements was modeled using a previously designed Excel Macro, as shown in Table 2.

Table 2. Excel Macro Based Modeling Of Reinforcing Steel Quantity Calculation

Code Number	SHAPE (Size in cm)	Length (cm)	Amount	Diameter	Total Weight (Kg)
	For Foundation Reinforcement PC-1				-
PC1-1001	45 — 45 / 68	158	24	13	39,513
					-
					-
					-
	For the upper reinforcement of the foundation PC-1				-
PC1-1002	40 — 40 / 70	150	24	13	37,512
					-
					-
					-
	Reinforcing Steel				-
PC1-1003	66 / 7,5 / 66	279	2	13	5,814
					-
					-
					-
					-
			Total Iron Weight		82,84

From Table 2, the final results of the Excel macro can be seen in Table 3, which presents the calculation results for the length and weight of the reinforcement for each reinforcement element:

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Table 3. Weight of reinforcement for each pile cap

Pile-cap group	Steel Bar (mm)	Total Length (m)	Mass Per meter	Total Weight (kg)
PC1	13	282,90	1,04	294,22
	16	336,27	1,58	531,31
PC2	13	36,31	1,04	37,76
	16	213,93	1,58	338,01
	19	327,01	2,23	729,24
PC3	13	259,66	1,04	270,05
	16	1.948,45	1,58	3.078,55
	19	2.869,17	2,23	6.398,24
Total Reinforcement Requirements for Pile Caps				**11.677,38**

The Table 3 shows the original macro-derived group and diameter masses. The displayed results should be checked against the workbook before final submission, especially the unit masses and displayed rounding. The results in Table 3 are direct outputs from the Excel Macro worksheet, which has been programmed to read cutting lengths, number of bars, and mass conversion based on the theoretical mass of steel per meter.

Table 4. Steel weight requirements

Pile-cap group	Weight (kg)	Total Weight (kg)
P1	294,22	825,53
	531,31	
P2	37,76	1.105,01
	338,01	
	729,24	
P3	270,05	9,746,84
	3.078,55	
	6.398,24	
Total Reinforcement Requirements for Pile Caps		**11.677,38**

Across P1-P3, the source table reports a total of 11,677.38 kg, whereas the displayed individual subgroup values sum to 11,677.38 kg (Table 4). Full precision worksheet formulas must be consulted to resolve the final reported total.

Estimated Procurement Surplus (Not Verified Cutting Scraps)

Table 5. Steel to be ordered

Steel Bar (mm)	Number of bars	Length (m)	Mass Per meter	Total Weight (kg)
13	53	12	1,04	662,85
16	219	12	1,58	4148,96
19	275	12	2,23	7346,75
Total reinforcing steel ordered				**12.158,56**

The original source reports procurement of 12,158.56 kg in 12 m steel bars. Using the displayed aggregate demand of 11,677.38 kg, the difference is 481.18 kg or approximately 3.958% of reported procurement. This percentage is a calculated procurement surplus, not verified onsite cutting waste (Table 5).
This estimated procurement surplus may reflect several operational factors, including:

a. Cutting and joining steel bars, which may generate offcuts that cannot be reused.
b. Length and shape tolerances of reinforcement bars that are adjusted to field conditions and implementation methods.
c. The need for material reserves to anticipate design changes or unexpected conditions during implementation.

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However, this surplus figure is also an important indicator in evaluating the effectiveness of material planning and procurement. A lower procurement surplus may indicate more precise quantity planning, althoug it does not establish a reduction in physical waste. Therefore, a more systematic approach is needed in preparing the BBS through the implementation of a digital-based material management system for real-time tracking of stock and material leftovers.

Discussion

The principal case-study finding is the auditable relationship between detailed pile-cap reinforcement demand and reported stock procurement, with a nominal 3.958% surplus. By contrast, previous studies have described explicit cutting-plan/stock length optimization strategies [20], [24], [25]. The present study does not provide a stock-assignment objective function, solved cutting patterns or a pre/post-optimization baseline. Therefore, its contribution is transparent spreadsheet integration for quantity and procurement reporting, not evidence of mathematical optimization or superiority to existing algorithms. The amount of reinforcement and its fabrication losses are design-dependent. Pile-cap geometry, number and arrangement of piles, load combinations, shear and punching demands, concrete grade, bar grade, anchorage, cover and constructability jointly constrain feasible detailing. A procurement balance from three groups on one apartment site should not be generalized to other pile configurations, seismic classifications or structural elements. An external validation should repeat the procedure across projects and code-approved designs and stratify outcomes by reinforcement diameter, pile-cap size, cutting-length distribution and stock-length availability [17]-[19], [28].

State of the art reviews and pile cap studies confirm STM's suitability for deep transfer elements and clarify nodal requirements and tie anchorage around the coloumn block [17, 19]. In four pile configurations like those suggested, a three dimensional STM with diagonal ties captures the true load path and tension fields better than 2D or sectional approaches, improving capacity prediction and detailing rationale [28]. Pile cap thickness and local reinforcement near the column are governed by one way shear and punching. Experiments on three pile caps show punching strength and failure mode are strongly influenced by the shear span to depth ratio and the presence of secondary or top reinforcement for crack control around the column region [18]. Moreover, recent work demonstrates that column or pile geometry and spacing can alter shear performance and cracking patterns, underscoring the need to coordinate layout decisions with reinforcement detailing shown in Figure 2. Every bar mark and bend in the drawing must translate consistently into a Bar Bending Schedule (BBS) and cutting plan from a production standpoint, systematic and algorithmic studies show that adopting special length priority, optimized cutting patterns and where appropriate mechanical couplers can markedly reduce rebar consumption and cutting waste, advancing cost and carbon goals [20, 29, 30]. Collectively, these findings explain the detailing choices visible in Figure 1 and frame the motivation for automating BBS based quantity and waste calculations in this study. Figure 3 is a Bar bending Schedule (BBS) extract that converts each bar mark and its shape into a cut length (cm), quantity, diameter, and total weight (kg), then aggregates a total iron weight (82.83 kg). In a BBS, weight is obtained from length x quantity x mass per meter, for reinforcing steel the unit mass can be computed from density (ρ = 7,850 kg/m^3, giving the well known theoretical relation $\omega = 0.006165\ d^2$ (kg/m, d in mm). For reinforcing bars with a nominal diameter of 13 mm, the theoretical unit mass of reinforcing steel was calculated based on the nominal bar diameter, yielding a value of approximately $1.042\ \mathrm{kg/m}$. The reinforcement weight for each bar group was then determined by multiplying the cutting length by the number of bars and the theoretical unit mass. Accordingly, the calculated reinforcement weights for the first, second, and third rows are 39.51 kg (1.58 m × 24 bars); 37.51 kg (1.50 × 24 bars) and 5.81 kg (2.79 m × 2 bars), respectively matching the worksheet totals explaining the 82.83 kg, consistent with the results reported in the Excel based bar bending schedule.

According to Santos et al. [17], the top mat near the column controls cracking and distributes nodal stresses from the converging struts; experiments on pile caps confirm that punching/one way shear behavior and failure mode are sensitive to a/d and the presence of top/secondary reinforcement around the column block, which suports the use of closely spaced top reinforcement in the detail. The hooks oriented downward provide positive anchorage in the compression zone and mitigate bar slip or splitting at edges. Tests on standard hooked bars report the roles of bend radius, tail length, side cover, and confinement on anchorage strength consistent with adopting a bend radius on the order of 12 db in practice [18]. The perimeter contributes confinement of the nodal zones and continuity of tension fields across the section, a requirement highlighted in STM based design for deep transfer elements like pile caps. Finally, every bar mark and hook in this detail translate into a BBS, waste aware cutting plans are recommended to reduce off cuts and embodied carbon from rebar, aligning reinforcement detailing with production efficiency [20, 29].

The shape sketches in the BBS encode bend allowances (e.g U bars with legs 45-40 cm), hooks and laps that determine the cutting length. Anchorage provided by standard hooked bars depends on bend radius, tail length, and confinement. Hence, the explicit hook depiction and dimension are structurally meaningful not merely drafting details [31]. From a production and sustainability perspectives, a BBS provides inputs for waste

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aware cutting plans: contemporary journal studies show that prioritizing special length procurement, optimizing cutting patterns and tuning lap splice positions can push rebar cutting waste toward near zero (<1%), while also reducing purchased tonnage, cost, and embodied CO_2 benefits that a spreadsheet macro can leverage once each bar's length/quantity standardized as in Figure 5 [24, 29, 30, 32].

Contemporary literature shows that, once BBS quantities are standardized, cutting stock optimization becomes the main lever to reduce waste and even rebar tonnage itself. For example, special length priority (SLP) and two stage algorithms cut waste to near zero (<1%) while lowering total steel usage by reducing unnecessary splices, meta analyses and case studies further confirm that planned waste driven by discrete stock lengths can be systematically suppressed by combining special length procurement with optimized cutting patterns [20, 29].

The explicit cutting stock formulations (integer programming and metaheuristics, GA) and BIM coupled approaches can materially address the cutting-stock problem; paired with SLP and lap splice adjustments (or selective use of mechanical couplers), projects consistently report large reductions in both cutting waste and embodied carbon from rebar [23, 33].

For an individual building, the workflow can operate on one approved pile-cap schedule: imports its bar marks and geometry, review code-constrained cutting lengths, calculate theoretical demand, compare against available stock lengths, and retain a documented surplus register. Batch purchasing may be less flexible than in mass haousing projects, making stock sharing, supplier returns and reuse of code-permitted offcuts important procurement decisions. Reusable pieces must not be reassigned to structural reinforcement without checking the engineer-approved detailing, splice and anchorage requirements.

Contractors should (i) freeze approved bar schedules before purchase, (ii) validate the full-precision mass-per-length database, (iii) keep traceable bar-mark-to-stock assignments and actual cutting logs, (iv) segregate reusable remnants from unusable scraps and (v) compare calculated results with independent take-offs and actual weighbridge or inventory records. Studies claiming time savings or waste reduction must document both baseline and intervention datasets, the calculation code, matched items and uncertainty of the observed differences. A direct comparison with published optimized rebar-cutting results [20], [24], [25] is informative at the level of method and outcome definitions, but does not constitute controlled benchmarking: element types, stock constraints, splice riles and field data differ. Statistical claims of superior accuracy, time savings or reduced physical waste require independent matched observations, which are not available in this study.

4. Conclusion

The study documents an Excel macro assisted BBS quantity reporting workflow for three pile-cap reinforcement groups in one apartment construction project. From the displayed group level results, P1 requires 825.53 kg, P2 requires 1,105.01 kg and P3 requires 9,746.84 kg, a combined 11,677.38 kg. Against reported procurement of 12,158.56 kg, the estimated surplus is 481.18 kg, or approximately 3.958% of purchased mass. This value is not a verified field-waste rate and does not demonstrate a statistically significant reduction relative to manual scheduling. The practically transferable output is a traceable schedule-to-purchasing audit process that may support more disciplined procurement at both individual-building and repeated housing scale. Generalization, code compliance and optimization claims require project-approved structural information, validated VBA logic, independent benchmark calculations and actual cutting and remnant records.

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