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Precast Design Flaws: A Case Study on Coordination Issues in Saudi Arabia Residential Villa Project

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Abstract

This case study investigates a precast concrete residential villa project in Saudi Arabia that faced significant setbacks due to coordination failures. Although precast systems offer advantages such as faster construction timelines and enhanced quality control, the project encountered substantial delays, design inconsistencies, and cost overruns. Major issues identified included incomplete Issued-for-Construction (IFC) drawings, limited use of Building Information Modeling (BIM), inadequate communication among project teams, and the assignment of inexperienced personnel to critical design tasks.

Survey results revealed that design-related coordination issues were responsible for over 90% of the observed rework, with 48.4% of respondents estimating that more than 6% - 8% of the total project cost was lost due to rework activities. Furthermore, 80.6% of participants reported productivity losses exceeding 50%, with some cases reaching up to 300% impact on schedule. These findings were supported by document reviews and stakeholder interviews, which highlighted misaligned precast elements and uncoordinated revisions as recurring challenges.

This study reinforces the importance of clear communication, rigorous design verification, and digital integration in precast construction. It advocates for the full implementation of BIM tools, structured workflows, and proper staff training to reduce the risk of costly errors. The insights drawn from this case offer valuable guidance for future projects, stressing the need for proactive coordination and digital collaboration to ensure the success of prefabricated systems.

Keywords: Coordination Challenges, Design Flaws, Precast Construction, Residential Villa Project, Saudi Arabia.

I. INTRODUCTION

Precast construction has become a popular choice in today’s construction industry, especially for projects that demand speed, cost-efficiency, and high-quality outcomes. By allowing components to be manufactured off-site in controlled environments, precast systems can significantly shorten construction timelines and improve workmanship consistency. In line with Saudi Arabia's Vision 2030, an ambitious plan to accelerate infrastructure development a two-story residential villa was designed using a full precast concrete system, including beams, columns, wall panels, and prestressed hollow-core slabs (Al-Mutairi & Al-Saleh, 2021).

However, despite the inherent advantages of precast construction, this project encountered a series of serious coordination challenges. The root causes included incomplete Issued-for-Construction (IFC) drawings, unverified site measurements, reliance on junior design staff, and poor communication between project stakeholders (Othman & Muhammad, 2020; Chen & Zhao, 2023). These issues led to significant design flaws, misalignments between precast elements, and numerous on-site modifications, which negatively impacted both project cost and schedule.

Quantitative data reveals that design errors and coordination lapses commonly result in rework costs amounting to 5–11% of the total project value. In this case, rework was estimated to reach nearly 9.9%, with some productivity losses spiking up to 300% on tasks affected by redesign and reinstallation (Love et al., 2000; PCI, 2020; Ebekozien & Ezeokoli, 2015). These figures highlight the scale of impact that inadequate coordination can have in industrialized construction settings.

The lessons from this project clearly point to the need for strong design management, detailed documentation, and early-stage interdisciplinary collaboration, especially in fast-track projects. Precast systems require precise planning, as even minor mismatches between components can trigger a chain of costly and time-consuming problems (Patel & Singh, 2021). The urgency to meet Vision 2030 timelines only intensified the existing coordination weaknesses, proving that experienced personnel and reliable digital tools are essential to manage such complex undertakings effectively (Zhang & Wang, 2020; Aalto University, 2021).

This case study investigates the coordination breakdowns in this precast villa project, examines the underlying causes, and offers practical solutions for future improvement. Special emphasis is placed on digital tools like Building Information Modeling (BIM), improved communication workflows, and the strategic upskilling of engineering teams, all of which are essential to ensure that precast construction lives up to its full potential (Nguyen & Tran, 2020; Kumar & Gupta, 2022).

Despite these advantages, the success of precast construction heavily depends on meticulous coordination among design disciplines, timely issuance of construction documents, and accurate site verification. Inadequate coordination often leads to design inconsistencies, on-site modifications, and compromised structural performance. This is especially evident in projects where design and execution are fast-tracked or delegated to teams lacking comprehensive project oversight.

In the context of Saudi Arabia, residential projects utilizing full precast systems are susceptible to coordination lapses due to the complexity of integrating architectural, structural, and MEP (Mechanical, Electrical & Plumbing) components in a modular construction environment. These issues are further compounded when IFC (Issued-for-Construction) drawings are incomplete, outdated, or misaligned with actual site conditions, and when junior engineers or third-party subcontractors are involved without effective oversight.

II. METHODOLOGY

To understand the root causes of design and coordination issues in this precast villa project, a mixed-method research strategy was employed. This included gathering both quantitative metrics and qualitative insights from project stakeholders. While the study focused on a specific villa case, appendices A through D present to support the real-world precast project. These were used to illustrate typical workflows, coordination documents, and digital modeling practices relevant to the observed challenges.

Primary Data Collection

Structured interviews and surveys were conducted with project engineers, contractors, and fabricators. These firsthand insights revealed common frustrations with incomplete design details, late revisions, and unclear communication.

Document Review

While some documentation was reviewed from the project reflects how precast projects handle coordination:

Visual Model Demonstration

Though BIM was not implemented in the case project includes sample 3D models created from actual shop drawings of a similar precast villa. These models help illustrate the benefits of digital coordination:

Quantitative Benchmarks

To quantify project impacts:

- Rework was estimated at 8–10% of the total contract value.
- Productivity losses of up to 300% were reported on reworked elements.
- Schedule delays extended the timeline by an estimated 15–20%.

Root Cause and Workflow Analysis

The study used the “5 Whys” method and Ishikawa diagrams to trace surface-level issues, such as panel misalignments, back to root causes like poor drawing verification and inadequate staff training. A SWOT analysis was also conducted to evaluate strengths and weaknesses in the project’s design and coordination workflow.

To deeply understand why coordination issues occurred in the precast villa project, the study utilized a combination of practical diagnostic tools: the 5 Whys method, the Ishikawa (Fishbone) diagram, and a SWOT analysis. These tools made it possible to move beyond surface-level problems and reveal systemic root causes affecting project performance.

One recurring problem on-site was the misalignment of precast wall panels. Using the 5 Whys technique, this issue was traced step-by-step:

1. Why were the panels misaligned on site?
   Because they did not match the foundation layout.

2. Why didn’t they match the layout?
   Because the shop drawings used different dimensions than those used for the footing.

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3. Why were the dimensions inconsistent?
   Because updated revisions to the footing drawings were not coordinated with the precast team.

4. Why weren't the revisions communicated?
   Because there was no version tracking or controlled distribution of updated drawings.

5. Why wasn't version tracking in place?
   Because the project lacked a digital document control system and relied on manual coordination processes.

This simple yet structured questioning revealed that the visible site issue was actually the result of missing version control protocols and lack of digital coordination tools, a theme that was echoed in multiple rework scenarios throughout the project.

To visualize the broader set of causes behind the project's challenges, a simplified Ishikawa (Fishbone) diagram was developed. It categorized the contributing factors under five major groups:

- People: Inexperienced detailing staff, lack of supervision.
- Design: Incomplete or inaccurate IFC drawings, late-stage changes.
- Process: Absence of review checkpoints rushed approvals.
- Tools: No BIM for clash detection, no version control platform.
- Communication: Fragmented handovers, unclear revision tracking.

This diagram helped clarify how various technical and organizational weaknesses combined to create avoidable errors during design, fabrication, and installation.

To assess the strategic context of the project, a SWOT analysis was conducted. This offered a broader view of internal capabilities and external pressures affecting project success:

- Strengths: Off-site precast production, experienced contractors
- Weaknesses: Incomplete drawings, no digital coordination tools
- Opportunities: Implementing BIM, document management systems
- Threats : Tight Vision 2030 deadlines, dependency on junior staff

This analysis reinforced the idea that while the construction method was modern and efficient, the lack of supporting digital infrastructure and experienced detailing led to cascading problems on-site. Tools enabled the study to move beyond identifying what went wrong, to exploring why it happened, and most importantly, how it can be prevented in future precast developments.

III. CASE FINDINGS

Project Background

This case study focuses on a two-story residential villa project in Saudi Arabia that adopted a full precast system. During its execution, the project encountered multiple coordination challenges that exposed critical design flaws. These included misaligned elements, inadequate embedment provisions, and non-conformance to approved shop drawings—ultimately requiring costly rework and delays. By examining these flaws, the study aims to highlight the root causes of coordination failures and offer practical

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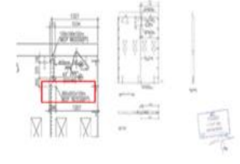
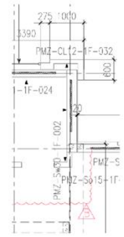
recommendations to improve integration and communication among stakeholders in future precast projects.

No.	Panel ID	Comments		Response
1	PMZ-So15-GF-019		Panel # PMZ-SO15-GF -019 MEP comments in the concern Panel (AC box on wrong elevation instead of NF it is at FF)	The initial approved MEP drawing, the recess is in the FF. Drawing is not yet updated. Please refer to DE-NCR-0435.  Status: Sent for rectification Date: 11/19/2023

15	PMZ-SW-30-1F-002		PMZ-SW-30-1F-002 Missing opining that supposed to be on 1F Continuing with GF	The approved GA layout the opening is not shown. Please refer to NCR-DE-23-0458.  Status: Sent for rectification Date: 11/19/2023

The villa was a two-story residential building constructed entirely with precast concrete components. While this approach offered speed and controlled quality, it also demanded exact design coordination, something the project struggled to maintain.

Key Coordination Issues

Several major issues were uncovered:

- Incomplete or inaccurate dimensions in IFC drawings.
- No use of 3D or BIM tools to identify conflicts between elements.
- Uncontrolled design changes without version tracking.
- Junior staff preparing critical shop drawings with minimal oversight.

While the study did not include BIM-based coordination, Appendices C and D offer examples of SketchUp and Revit models based on actual shop drawings from a similar villa. These illustrate how such tools can help visualize conflicts and improve the precision of precast detailing.

Project Impacts

The impacts of these coordination failures were significant:

- Misaligned and mismatched components led to fabrication errors and site improvisations.

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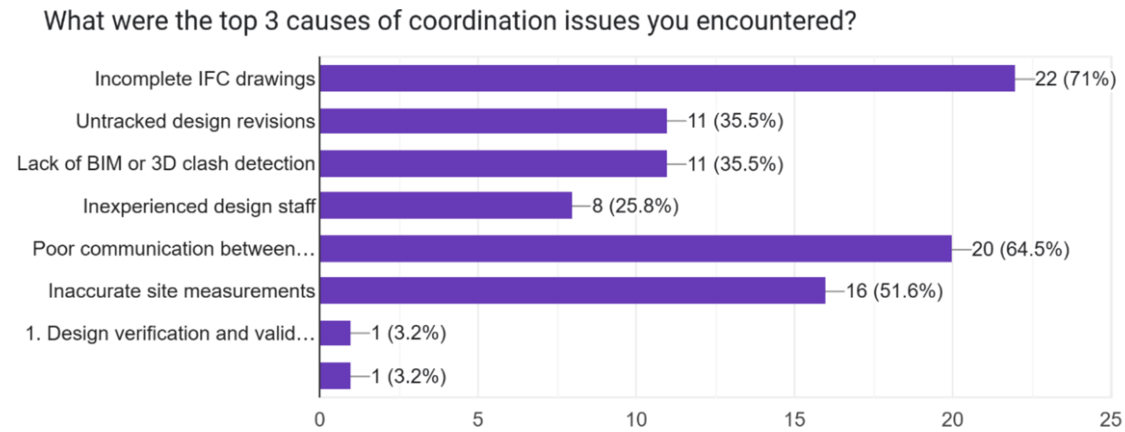
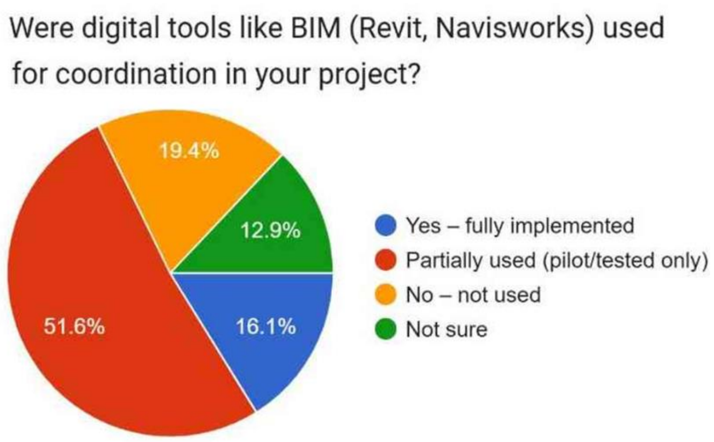
- Rework costs were estimated at 8–10% of the project's total value.
- Productivity on rework tasks dropped dramatically, by as much as 300%.
- The construction timeline extended by roughly 15–20%.

The extent of incomplete IFC drawings leads to design flaws and misaligned precast components, which seventy-one percent (71%) identified incomplete or inconsistent IFC drawings as a major cause of rework and element misalignment. These drawings often lacked coordination between structural, architectural, mechanical, electrical, and plumbing elements.



The limited or lack of BIM/3D model coordination contributes to unresolved clashes and site issues, which fifty-one point six (51.60%) reported no use of BIM on their project; only sixteen-point one percent (16,10%) has full BIM implementation. The lack of model coordination led to unresolved design clashes and missed conflicts during planning as shown in the graph:



Furthermore, the graph shown below shows that the communication gaps among architects, engineers, and contractors impact the project timeline and quality, wherein sixty-four point five (64.50%) cited poor communication between disciplines as a major issue. Many noted that revisions were not tracked properly, leading to delays, incorrect fabrication, and onsite improvisation.

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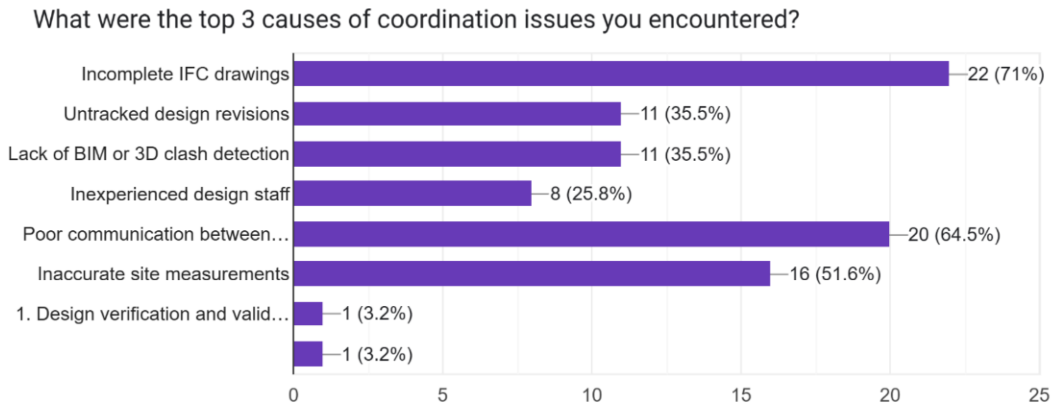
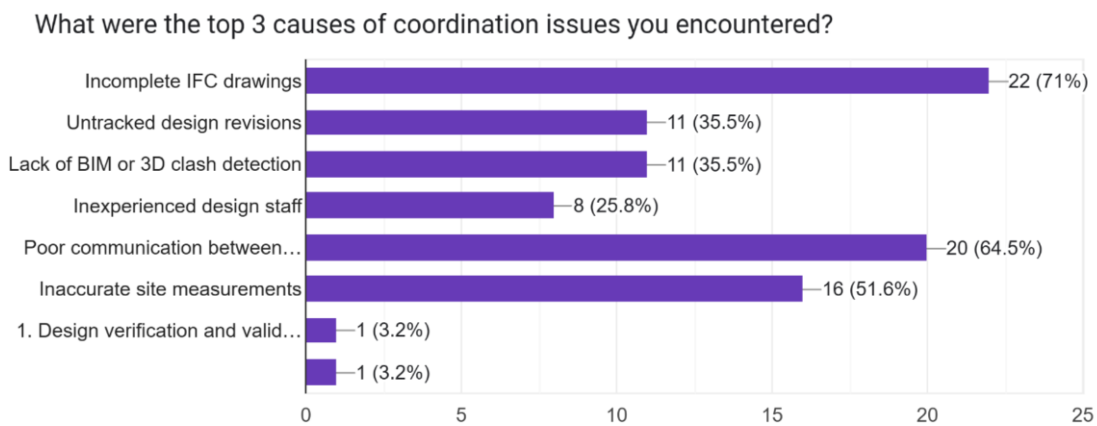
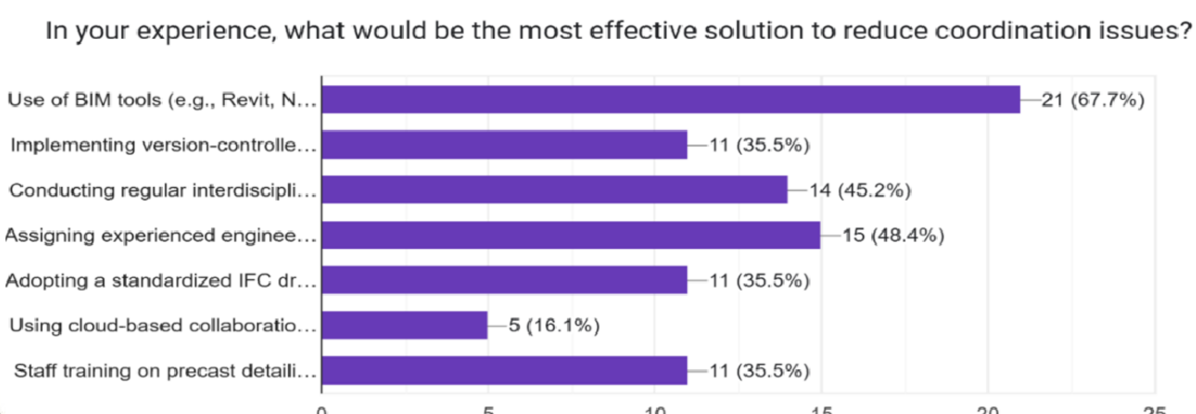


The inexperience of engineering staff influences errors during design and execution, which twenty-five point eight percent (25.8%) attributed to design flaws to inexperienced junior staff handling critical tasks without proper oversight, particularly during shop drawing preparation, as shown on the graph below:



Moreover, the role could digital tools and integrated workflows have played in preventing theses coordination issues as shown in the graph that the respondents suggested solutions that full BIM adoption with sixty-seven point seven percent (67.70%), regular coordination meetings and assigning senior staff to lead design check of fourty-five point two percent (45.20%), and version-controlled document systems with thirty five point five percent (35.50%), respectively.



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IV. DISCUSSION

Root Causes and Analysis

The root causes behind the project's difficulties were clear and interrelated:

- Inadequate dimensional checks in IFC drawings.
- No clash detection or BIM validation during the design stage.
- Informal handling of late-stage design revisions.
- Design tasks assigned to unqualified or unsupervised junior engineers.

Revit and SketchUp are both examples of BIM software. As shown in Appendices C and D, if these tools had been used during the design phase, many of the issues documented in this study such as component clashes and dimensional mismatches could have been identified and resolved digitally, well before fabrication started.

Best Practice Comparison

Compared to industry's best practices, the project had clear gaps:

- No BIM-based review for precast interfacing.
- No structured communication protocol for version control.
- No formal verification of IFC drawings for dimensional accuracy.
- Critical tasks handled by underqualified staff.

Lessons Learned

Key lessons for future precast projects include:

- IFC drawings must be complete and verified early.
- BIM modeling should be standard for design coordination.
- Design changes must be formally managed with clear version tracking.
- Experienced professionals must oversee detailing work, with junior engineers actively mentored.

Impact Summary

The tangible impacts are summarized in **Figure 1**, which shows:

- Design errors: 9.9%
- Schedule delays: 6.0%
- Productivity loss: 3.0%
- Material waste: 2.5%

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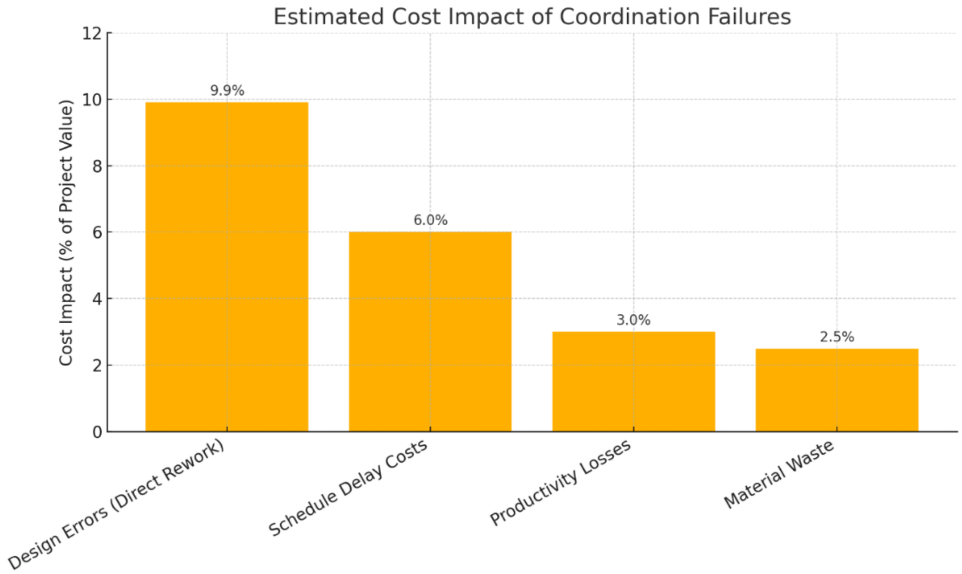

Figure 1: Estimated cost impact due to coordination failures: Design errors (9.9%), schedule delays (6.0%), productivity losses (3.0%), and material waste (2.5%), based on quantitative case findings.

These figures reflect broader industry trends, confirming that poor coordination can consume over 10% of total project cost and extend schedules by up to 50%.

V. CONCLUSION

Based on the results and findings of the study, the following conclusions were drawn: This study confirmed that coordination failures remain a significant barrier to achieving the full benefits of precast concrete construction. While the use of off-site prefabrication and experienced contractors offers clear advantages in terms of speed and quality, these were overshadowed by persistent issues in design integration and communication.

The findings revealed that incomplete and inconsistent Issued-for-Construction (IFC) drawings, limited or nonexistent use of Building Information Modeling (BIM) tools, and a lack of structured communication among stakeholders were the primary contributors to rework, misalignments, and site improvisations.

Moreover, the delegation of critical design and supervision tasks to inexperienced engineering staff further compounded the challenges. As a result, the project experienced frequent revisions, costly rework, and notable delays—impacting both productivity and overall performance. These outcomes underscore that success in precast projects is not solely dependent on technology or construction materials, but also on the strength of coordination processes, digital integration, and the competence of the project team.

VI. RECOMMENDATIONS

Based on the salient findings of this case, the project team initiated several corrective actions, including the use of BIM pilot studies for precast coordination, targeted training for design staff, and

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formalized design review sessions. Mandate the full implementation of BIM tools (e.g., Revit, Navisworks) in precast projects to improve clash detection, interdisciplinary coordination, and real-time design integration.

For further development of the study, the following recommendations may be considered:

1. Standardize communication protocols across all stakeholders by conducting regular coordination meetings and using centralized platforms for document control.
2. Conduct thorough design verification of IFC drawings before fabrication to prevent field misalignments and reduce costly on-site rework.
3. Assign experienced engineers to lead critical design stages and provide structured training for junior staff in digital tools and coordination workflows.
4. Further research is recommended to evaluate the cost-benefit impact of full BIM integration in precast residential projects across various regions in Saudi Arabia, using comparative analysis between BIM-enabled and traditionally managed projects.

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- Engr. Marry Jane M. Cepeda, Technical Engineer, Solid M Construction
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- College of Engineering and Graduate Studies Faculty, University of Eastern Philippines
- Respondents of the study

VII. COMPETING INTERESTS

The author declares no competing interests.

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APPENDICES

Appendix A: RFI logs and resolution sheets

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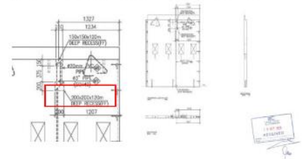
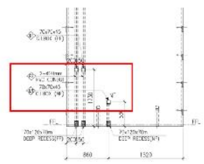
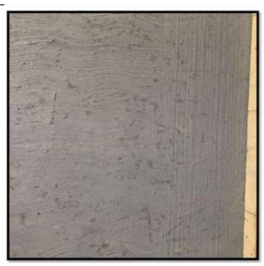
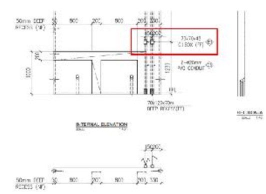
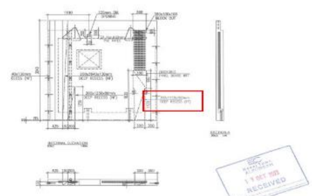
No.	Panel ID	Comments	Response
1	PMZ-So15-GF-019	 Panel # PMZ-SO15-GF -019 MEP comments in the concern Panel (AC box on wrong elevation Instead of NF it is at FF)	The initial approved MEP drawing, the recess is in the FF. Drawing is not yet updated. Please refer to DE-NCR-0435.  Status: Sent for rectification Date: 11/19/2023
2	PMZ-So15-GF-020A	 Panel # PMZ-SO15-GF-020A MEP comments in the concern Panel (AC box on wrong elevation Instead of NF it is at FF	The initial approved MEP drawing, the recess should be in the NF. Please refer to DE-NCR-0390.  Status: Sent for rectification Date: 01-Nov-23
3	PMZ-So15-GF-006 (not PMZ-So15-GF-006A)	 Panel # PMZ-SO15-GF-006A Light Switches for stair case are provided on FF which supposed to be on NF	Recess for the switch is in the FF as per the client comment and the shop drawing. Please refer to NCR-DE-23-0388.  Status: Sent for rectification Date: 01-Nov-23
4	PMZ-Sw21-1F-36	 Panel # PMZ-SW21-1F-36 Recess for Electric conduits is provided on FF which supposed to be on NF	The initial approved MEP drawing, the recess is in the FF. Please refer to NCR-DE-23-0418.  Status: Sent for rectification Date: 06-Nov-23
5	PMZ-So15-GF-006 & PMZ-So15-GF-006A	 PMZ-SO15-GF-006 And PMZ-SO15-GF-006A Recess for bathroom oioes are provided on external elevation which suppose to be at internal face.	Please refer to NCR-DE-23-0388. Status: Sent for rectification Date: 01-Nov-23

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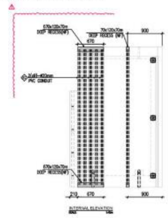
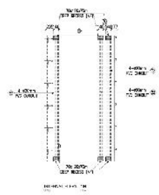
6	PMZ-So15-GF-005 & PMZ-Sw21-GF-004	 PMZ-SO15-GF-005 & PMZ-SW21-GF-004 Recess for bathroom oloes are provided on external elevation which suppose to be at internal face.	For panel PMZ-So15-GF-005, please refer to NCR-DE-23-0416. **Status: Sent for rectification** **Date: 06-Nov-23** For panel PMZ-Sw21-GF-004, the drawing is not yet updated. Please refer to DE-NCR-0436. **Status: Sent for rectification** **Date: 11/19/2023**
7	PMZ-Sw21-GF-020	 PMZ-SW21-GF-020 The highlighted AC sleave is not provided in the upper panel which suppose to be till roof	For panel PMZ-SW21-GF-020, please refer to NCR-DE-23-0389. **Status: Sent for rectification** **Date: 01-Nov-23** For panel PMZ-SW21-1F-023 (above panel of PMZ-SW21-GF-020), drawing is not yet updated. Please refer to DE-NCR-0437. **Status: Sent for rectification** **Date: 11/19/2023**
8	PMZ-Sw30-1F-001	 PMZ-SW30-1F-001 The highlighted AC sleave is not provided in the upper panel which suppose to be till roof	Please refer to NCR-DE-23-0414.  **Status: Sent for rectification** **Date: 01-Nov-23**
9	PMZ-So15-1F-005	 PMZ-SO15-1F-005 The highlighted AC sleave is not provided in the upper panel which suppose to be till roof	Please refer to NCR-DE-23-0416.  **Status: Sent for rectification** **Date: 06-Nov-23**
10	PMZ-Sw21-GF-037A & PMZ-Sw21-GF-038 (not PMZ-Sw21-GF-037)	 PMZ-SW21-GF-037 and 038 Provided Window level is different then the other window	For panel PMZ-SW21-GF-037 previously and divided into to 2 panels (037 & 037A), please refer to NCR-DE-23-0391. **Status: Sent for rectification** **Date: 01-Nov-23** For panel PMZ-SW21-1F-038, please refer to NCR-DE-23-0392 **Status: Sent for rectification** **Date: 01-Nov-23**
11	PMZ-Sw30-GF-003 & PMZ-Sw30-GF-006	 PMZ-SW30-GF-003 And PMZ-SW30-GF-006 PVL loop provided at door opening	These are not panels, these are columns PMZ-Pc00-GF-001 & PMZ-Pc00-GF-02. For panel PMZ-Pc00-GF-001, the drawing is not yet updated. Please refer to DE-NCR-0438. **Status: Sent for rectification** **Date: 11/19/2023** For panel PMZ-Pc00-GF-02, the drawing is not yet updated. Please refer to DE-NCR-0439. **Status: Sent for rectification** **Date: 11/19/2023**

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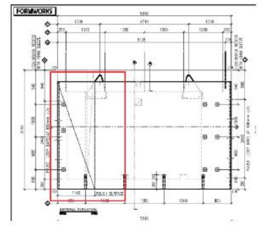
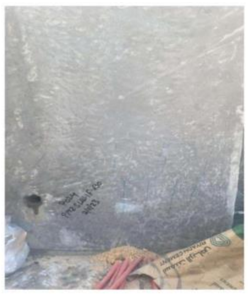
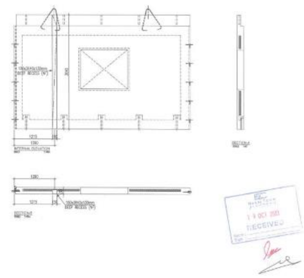
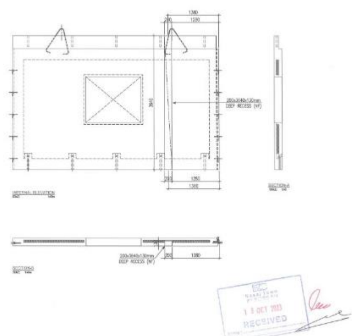
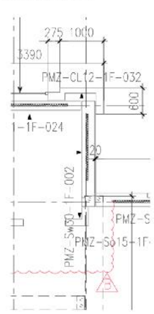
12	PMZ-Sw21-1F-009	 PMZ-SW21-1F-009 Surface finishing is provided smooth instead of rough as this is bathroom area	The initial approved MEP drawing, the location of the rough surface is correct. Please refer to DE-NCR-0440.  **Status: Sent for rectification** **Date: 11/19/2023**
13	PMZ-SW21-1F-030	 PMZ-SW21-1F-030 Missing MEP box in NF	As per the approved MEP drawing, there's no MEP box in the NF. Please refer to NCR-DE-23-0456.  **Status: Sent for rectification** **Date: 11/19/2023**
14	PMZ-SW21-1F-007	 PMZ-SW21-1F-007 Missing MEP box in NF	As per the approved MEP drawing, there's no MEP box in the NF. Please refer to NCR-DE-23-0457.  **Status: Sent for rectification** **Date: 11/19/2023**
15	PMZ-SW-30-1F-002	 PMZ-SW-30-1F-002 Missing opining that supposed to be on 1F Continuing with GF	The approved GA layout the opening is not shown. Please refer to NCR-DE-23-0458.  **Status: Sent for rectification** **Date: 11/19/2023**