Evaluating Productivity Reinforced Cast in Place Concrete Construction Project in Puerto Rico: From Case Study to Framework

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Abstract – *This research project focuses on the evaluation of the production of reinforced Cast in Place (CIP) Concrete building in a project located in the southern region of Puerto Rico. The projects analyzed consist of several similar buildings constructed within identical site limits, safety requirements, and federal specifications. While the construction processes were nearly identical, the two buildings studied were built by different workforces and managed under different leadership. This documentation serves as a benchmark for small construction firms in Puerto Rico. By comparing self-performed work against subcontracted specialized labor, firms can better decide whether to build internal capacity or leverage external expertise to balance between cost efficiency and schedule performance.*

Keywords **–** *Efficiency, Productivity, Schedule Performance, Subcontractor.*

INTRODUCTION

Reinforced CIP concrete construction is one of the most widely used methods for building houses, buildings, roads, and other infrastructure because it is capable of withstanding the island's seismic activity and hurricane risks at a moderate cost. Since the 1960's Post-War Urbanization, concrete placement became synonymous with urban growth; cities like San Juan and Ponce were the epicenters of infrastructure for public housing, highways, and schools made of Reinforced CIP Concrete. During the 1980s, the construction and concrete industry in Puerto Rico was also characterized by significant infrastructure growth and modernization, heavily supported by local industrialization strategies and tax incentives. The economic changes prompted the construction of the reinforced CIP concrete construction of residential areas, apartments, and industries. For residential areas and apartments, the widespread use of concrete blocks mixed with the structural CIP concrete added value to the residential construction and for the infrastructure, there was also an increase of the use of the reinforced CIP concrete for marine and offshore, which also highlighted the need for improved maintenance and repair.

Recently, the construction concrete industry has experienced a significant reconstruction-driven boom in the mid-2010s, characterized by soaring cement production and high employment levels. However, the sector is heavily pressured by rising material costs, labor shortages and high inflation. Today, there are many types of reinforced CIP concrete that focus on enhanced durability, sustainability and accelerated construction cycles. Key trends include the integration of Fiber Reinforced Concrete (FRC) for improved tensile strength, the use of Ultra High Performance Concrete (UHPC) for joints and advanced on-site one-of-a-kind structural applications. While precast offers speed and other CIP technologies provide some specific savings, the reinforced CIP remains dominant in unique, large-scale, and complex projects utilizing specialized formwork for small and high rise buildings and infrastructure projects.

RESEARCH DESCRIPTION

This research provides a direct comparison of documentation—including daily logs, shop drawings, actual schedule data, and material reports—from two reinforced cast-in-place concrete buildings (two stories) within the same project in Puerto Rico. Productivity was evaluated in the following areas: materials, personnel, equipment, and execution of the work. The goal is to identify areas for improvement to increase productivity in future projects, thereby boosting profit margins, keeping safety standards, and maintaining good quality control practices. Other construction disciplines were involved in the building. However, the research will be limited to the reinforced CIP concrete activities.

RESEARCH OBJECTIVES

This article highlights the importance of rigorous planning and monitoring during the construction of two-story reinforced CIP concrete structures in Puerto Rico. It outlines the advantages of collaborative teamwork among key roles (Foreman, Project Manager, Superintendent, Inspectors, etc.) and identifies other factors that impact field productivity.

RESEARCH CONTRIBUTIONS

This article's framework is used to analyze all phases of the productivity of reinforced CIP concrete structures and outlines some advantageous collaborative roles that the project's key personnel may follow during the pre-during-post construction phases. A few small construction companies that work in Puerto Rico lack a structured analysis of productivity. This article will also assist in documenting, comparing, and finding efficiencies in production.

LITERATURE REVIEW

Reinforced CIP Concrete

Concrete is the most widely used construction material worldwide. Well-made concrete has been the subject of innumerable technical documents and provides long-lasting, useful, and aesthetically pleasing structures for good economic value [1]. In order to achieve the Long-Term Performance of the Reinforced CIP Concrete, the construction contractor must build it so that concrete strength meets the design requirements, the assessment performance or serviceability of the structure, and it needs to be durable (see Figure 1).

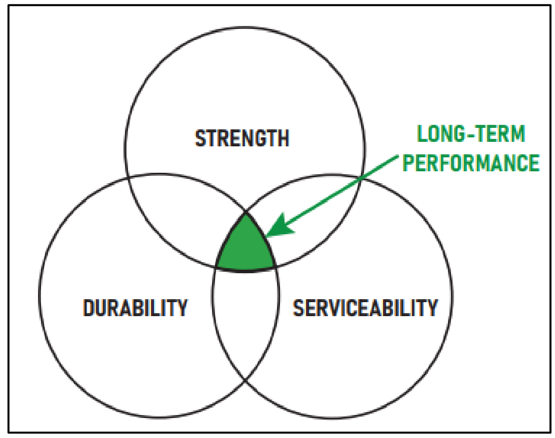

Figure 1
Harmonization Permits Long-Term Performance

The designed service life for these buildings is 50 years [2].

Construction Requirements

This project has several contractual documents that the construction contractor followed to construct these two-story buildings. These documents include the specification, the construction drawings, and the contract.

- Specification — the specifications [3] were developed by the Designer of Record (DOR) and are part of the requirements that the construction contractor needed to follow in order to meet the specified Quality Standard [4]. This document is divided into General Information and references, Products, and Execution. Section 03 30 00 was used for the analysis of this project.
- Drawings — the drawings were developed by the DOR for this specific two-story reinforced CIP concrete project. The designed considerations were the Unified Facility Criteria (UFC) and the ACI 301 2010.
- Contract — this document includes the Federal Acquisition Regulation (FAR) [5] that the contractor signed and followed during the construction of the project.

Scheduling Concept Review

The project schedule is necessary for tracking the progress of the development and identifying problems early, while there is time to correct them. The schedule tracks the project's progress using the same task breakdown as the WBS. By tracking work as it is completed and accounting for expenditures, the project can use the schedule to closely monitor its financial status [6]. The definition of project success often includes completing the project on time. The development and management of a project schedule [7] that will complete the project on time is a primary responsibility of the project manager, and completing the project on time requires developing a realistic plan and effectively managing the plan.

METHODOLOGY

This article compared two (2) reinforced CIP construction processes of the buildings. However, the two buildings analyzed were within the same construction limits, safety requirements, and federal construction specifications, but were built using different manpower and leadership.

The first project is B470, subcontracted to a third-party company. The second project is B304, and it was built by the main contractor or self-performed. For this research, the following four (4) steps were completed for the analysis.

Step I. Establish a Baseline and Scope Definition

Define the scope of work for both buildings, ensuring a common basis for comparison. Identify variables like structural systems (e.g., footings, columns, slabs), materials, and site constraints. Detail the critical path and task sequencing to obtain a better understanding of the scope of work and identify specific improvement areas.

Step II. Production Data Collection (Time Study)

Perform a study and collect actual data on key activities, such as labor (hours, rate, manpower, etc.), equipment (own, rented rates, etc.), materials (concrete, rebar, etc.), and miscellaneous (temporary facilities, storage areas, insurances, inspections, etc.). The information will gather three important groups: the initial estimated cost and the initial estimated PoP, the actual costs and actual time of performance for B470 and B304. Develop a new independent estimate and independent schedule for the construction of a similar building.

Step III. Cost and Time Comparative Analysis

Utilize the data obtained from B470 and B304 and compare it with the initial estimate. This information will provide a comparative of the costs that were to be incurred prior work and what were the actual costs for the construction of each building. This result can lead us to determine if the resources that were originally intended for the project were sufficient or not. In addition, both buildings will be compared to each other, this will help us understand what areas were more efficient than the others.

Step IV. Document Results for Future Reference

The final phase of the methodology focuses on the Root Cause Analysis (RCA) and the formal documentation of lessons learned. Compared to information already gathered from the initial estimate, actual building construction information, and the independent estimate to document the efficiencies during the process. Calculate and compare total costs (labor, material, equipment, etc.) and duration for similar tasks to pinpoint variance. Identify patterns and performance drivers, then document findings in a final report, highlighting differences in productivity.

RESULTS AND DISCUSSION

This section discusses the research results at each step.

Step I. Establish a Baseline and Scope Definition

The scheduling department provided the Baseline Schedule where the initial construction approach was defined, and the Scheduler provided the schedule fragment for each structure, isolating the reinforced CIP concrete activity. Note that the submittal process for the concrete mix, rebar, and scaffolding shop drawing process, and other relevant information/actions took approximately six months to be approved by the Designer of Record (DOR), for the procurement or rental of the equipment and the materials, and the delivery and installation of the rebar, molds, and the implementation of the safety considerations required under the contract. B470 and B304 had the same initial baseline, which consisted of the construction of the Footings, Slab on Ground (SOG), 1st floor Concrete Columns, Structural slab and Beams, 2nd floor Concrete Columns and Roof beams, slab, and parapets. Figure 1 is a representation of the original baseline of B304. There are no sire constraints on the area that the building is to be constructed.

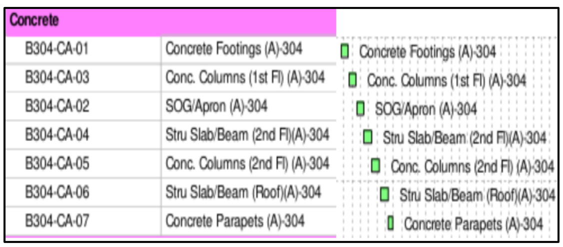

Figure 1
Actual Representation of the Project Baseline

Step II. Production Data Collection

First, the data were collected from the initial breakdown of payments. This would provide initial estimated costs and their respective profits for the buildings under discussion. The Period of Performance (PoP) is described on the Base Line schedule for B470 and the PoP for B304. This information was summarized in Table 1.

Table 1
Costs Summary

	B470	B304
Estimated Cost ($)	$2,872,864.00	$4,683,815.00
Estimated PoP (days)	243	297

Second, for the actual costs, the information was separated into the following components: labor, equipment, materials, and overall miscellaneous for each project.

Man-power analysis: The research was conducted on the project's daily logs for the period during which the reinforced CIP concrete activities occurred. It was noted that several days were impacted by severe weather events, limited access due to specific base requirements, and a few standdowns due to safety situations encountered during the progress of both projects.

Equipment analysis: The research was conducted on the safety inspection reports and the project's daily logs for the period during which the reinforced CIP concrete activities occurred. It was noted that several days were impacted by severe weather events, equipment cannot be used while there is lightning, delays in the delivery of rented equipment, several equipment breakdowns, and oil spills encountered during the progress of both projects.

Material analysis: The research was conducted on the project submittals, documentation, suppliers, and the industry for the period during which the reinforced CIP concrete activities occurred. It was noted that there were some delays in the approval process of the submittals; several Request for Information (RFIs) were made because the way the shop drawings were designed was very difficult to implement, and there were some variations of the design due to requirements established in the contract that could not be achieved in Puerto Rico.

Table 2
Costs Summary

	B470	B304
Actual Payroll Costs	$1,247,232.00	$1,351,168.00
Actual Equipment Costs	$395,200.00	$412,773.70
Actual Material Costs	$559,000.00	$607,500.00
Miscelaneous Costs	$220,143.20	$237,144.17
Total Cost	$2,421,575.20	$2,608,585.87
PoP	287	333

Miscellaneous analysis: The research was conducted on the contract requirements (Specifications, drawings, etc.) for the period during which reinforced CIP concrete activities occurred. There were special inspection requirements, quality control phases, and additional safety requirements that were considered for this project; however, the anticipated time originally established for this activity was significantly exceeded. The manpower, equipment, material, and the PoP are summarized in Table 2.

Third, Table 3 shows the independent analysis performed (B445) on the activities associated with the reinforced CIP concrete buildings and will describe the most efficient way to build a two-story barrack.

Table 3
Costs Summary

	B445
Estimated Cost ($)	$2,470,775.00
Estimated PoP (days)	299

Step III. Cost and Time Comparative Analysis

Figure 2 shows the comparison between the original intended effort and the actual work for buildings B470 and B304.

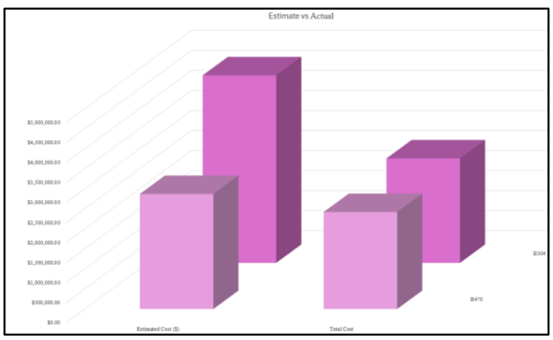

Figure 2
Comparative Estimate vs Actual

According to this comparison, B470 was built at a lower cost than the initial estimate. This represented additional earnings of 18.64%, and B304 was also constructed at a lower cost than initially expected, resulting in earnings of 79.56%. Related to the PoP, B470 was built in an additional 44 days than the initial estimate, and B304 was built in 36 additional days.

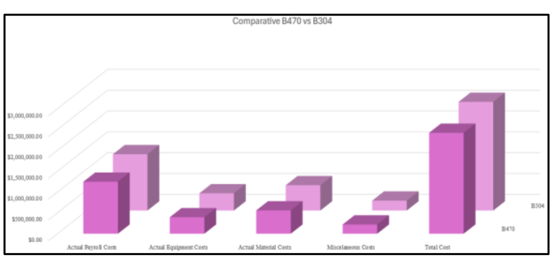

Figure 3
Comparative B470 vs B304

Figure 3 shows a comparison between the actual work for buildings B470 and B304.

According to this comparison, B304 resulted in an increase of 8.33% in labor, 4.45% in equipment, 8.68 in materials, and 7.72% in miscellaneous. Related to the PoP, the construction time increased by 16.03 %.

Step IV. Document Results for Future Reference

The final stage of this research involves a Root Cause Analysis (RCA) and the formal documentation of performance drivers to bridge the gap between theoretical estimates and field reality. By synthesizing the data from the initial baseline, the actual performance of B470 and B304, and the independent B445 estimate, several critical conclusions regarding productivity in Puerto Rico's reinforced CIP concrete sector are identified.

While both projects yielded higher profit margins than initially estimated, both significantly exceeded their original Period of Performance (PoP). The analysis identifies the following primary factors for these variances:

- Labor & Leadership Impact: B304 (self-performed) showed higher costs across all categories compared to B470 (subcontracted). The 8.33% increase in labor costs and 16.03% increase in duration for B304 suggest that the third-party subcontractor (B470) likely utilized more specialized crews or optimized sequencing for CIP activities.
- Environmental & Logistical Constraints: Both projects were hampered by "force majeure" and site-specific delays, including severe weather (lightning stand-downs) and stringent base access requirements. These factors are often underestimated in baseline schedules but are critical in the Puerto Rican maritime climate.
- Technical Bottlenecks: The material analysis revealed that the "one-of-a-kind" structural designs led to complex shop drawings that were difficult to implement. This resulted in a high volume of Requests for Information (RFIs) and submittal delays (averaging six months), which stalled the momentum of the construction cycle.

Conclusion

The study demonstrates a clear performance gap between subcontracted and self-performed work. Despite the higher profit margins observed in self-performance (B304) due to the absence of subcontractor markups, the subcontracted project (B470) proved more operationally efficient, utilizing 8.33% less labor and completing the scope 16.03% faster. This suggests that specialized third-party expertise often yields better technical execution and resource optimization.

Productivity was primarily hindered by "soft" delays rather than physical construction limitations. The six-month submittal approval cycle and the high frequency of RFIs due to complex structural designs indicate that pre-construction coordination is the most critical area for improvement. Baseline schedules must incorporate realistic buffers for "unexpected" events, such as severe weather and lightning stand-downs, which are characteristic of the region.

Strengthening the synergy between the Project Manager, Superintendent, and Foreman during the shop-drawing phase can reduce implementation errors in the field.

The following are strategic steps to determine whether to self-perform or to subcontract reinforced CIP concrete construction:

- Assess specialized technical proficiency - evaluate crew specialization, analyze operational speed and technical execution.
- Conduct a comprehensive Cost-Benefit Analysis - look for the past absence of markups, factor in resource optimization.
- Evaluate risk management and delay buffers - climate and site risks and administrative capacity.
- Implement a data-driven decision framework - establish a baseline, document, and benchmark
- Prioritize pre-construction synergy - analyze field office collaboration and strategic capacity buildings.

Ultimately, this research serves as a vital benchmark for small and medium-sized construction firms in Puerto Rico. It proves that documenting and comparing productivity data is not merely an administrative exercise but a strategic necessity for finding efficiencies, managing labor shortages, and ensuring the long-term performance of the island's critical infrastructure.

"This work used Google for brainstorming, editing, and data support. All interpretations, arguments, and conclusions are the author's own and have been verified for accuracy".

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