Breakeven Analysis for Selecting Construction Methods: Precast vs. Cast in Place Concrete

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Abstract

In Saudi Arabia, it is common practice that most of the structures of individual housing and small building is erected by Cast in Place (CIP) concrete while most of the structures of mass houses and large building and malls are one of Precast concrete (PC). The reason for the previous characterization is dictated by the economics, shortening of construction period, knowledge of the contractor, and aesthetics. Gradually but slowly, PC is taking more territory for the traditional CIP. The aim of this paper is to devise criteria for selecting either of the above methods from an economic perspective. The criteria will help the owner/contractor/designer to decide the favor ability of either construction method based on the size of the project.

Keywords: Precast Concrete, cast in place concrete, and construction method, Saudi Arabia

1. Background

Many structural systems have been used in the housing and building industry of Saudi Arabia which is predominated by the two systems, Cast-in-Place concrete structures, short named CIP; and that is of Precast concrete structure, short named PC. This practice has been dictated by cost competitiveness, contractors experience, aesthetics, flexibility and lower cost of change orders and other factors. It is common to have individual family detached dwellings of two stories built with CIP concrete because it is more economical and flexible whereas mass housing and large commercial and office buildings are built with PC concrete for their modular design, repetition of standard structural members, and economics of scale.

The choice between the two structural systems by owners/designers/contractors, based on their areas or space volumes and thus costs, are comparable in some cases of construction projects.

2. Problem Formulation

Designers and Engineers are frequently requested by the owners to advise them more accurately on the most economical structural system when their estimates are based on previous projects, quotations and rules of thumb. Hence, in the case of evaluating a CIP concrete structure versus PC concrete structure for a given project, a quantitative method of comparing the two alternatives in terms of their construction costs, is desirable in the early stages of architectural and structural design. The total costs for the contractor in a construction projects equal to the

total direct costs and total indirect costs. For simplicity, this relation can be expressed as cost function as follows [1]:

$$\sum RC\_Cost = \sum DC \times Qi + \sum IC \times Ti \qquad \textbf{Eq.1}$$

Whereas the following symbols represent the stated variables:

RC_Cost (in SR):	Total concrete cost in Saudi Riyals for either CIP or PC.
DC (in SR/Cu Meter):	Direct costs of proportional erected concrete (i.e. dependant on the quantity of erected CIP or PC concrete).
***Qi (in Cu Meter)*:**	Quantity of concrete in cubic meter for either CIP or PC.
IC (in SR/day):	Indirect costs for concrete works that is proportional to the duration of concrete erection.
Ti (in Days):	Duration of Concrete Erection (including Manufacturing for PC Concrete)

The relationship between the cumulative cost of concrete works (including pouring/erection) and quantity of concrete measured in cubic meters can be simply expressed by the following equations.

3. Example Project Real Data

To examine the formula for selecting either of the two structural systems of CIP or PC, relevant input data is drawn from two compatible projects utilizing both structures. Table 1. presents unit prices and quantities of concrete for major structural members for CIP and PC systems, which are drawn from two colleges building projects in King Saud University located at Riyadh, Saudi Arabia [2], [3]. The two projects have similar project definitions and are presumably equivalent in price, size and quality. The CIP concrete activity duration, per schedule of the contractor when reviewed by the author, is 320 days while the PC concrete activity duration (design and manufacturing and erection) is 240 days.

Table 1: Quantities of Concrete Works by Structural Members [2], [3]

	College of Architecture and Planning Project			College of Computer Science Project		
Type of Structure	**Cast-In-Place Concrete**			**Precast Concrete**		
Structural Member	**Quantity of Concrete (In Cu Meter)**	**Unit Cost (In SR/Cu Meter)**	**Total Cost for Individual Structural Element (In SR)***	**Quantity of Concrete (In Cu Meter)**	**Unit Cost (In SR/Cu Meter)**	**Total Cost for Individual Structural Element (In SR)**
Foundations	2675	700	1872500	2174**	650	1413100
Columns	772	800	617600	564	1520	857280
Beams	4702	800	3761600	4100	1700	6970000
Slabs	6295	800	5036000	2678***	700	2574600
Stairs	161	900	144900	161	2800	450800
	Cumulative Costs		11432600	Cumulative Costs		9691180

* SR, Saudi Riyal, is Saudi Arabia currency which is equivalent to US $ 0.27
*CIP Concrete is used for foundations and slab on earth for PC structure
** Volume of the PC slab is much smaller than the CIP slab since it is a hollow slab with 0.3 meter of thickness

4. Formula Derivation

4.1 Cast-in-Place Concrete (CIP) Structure Costs

From Table 1., total Quantity of CIP concrete is 11,769 cubic meter is to be erected in 320 days (from project schedule) at average price of 800 SR/M³ for all structural members excluding foundation and stairs (which are common for both alternatives); therefore

Total cost = 11769 * 800 = 9,415,200 SR.
Assuming an inverse linear relationship between concrete cost and duration of its erection and that all concrete works fall on the critical path, then

Cost of 1000 m³ CIP concrete = 8,000,000 SR Eq 2.
And if the Time for erecting 11769 m³ of concrete is 320 days; then
Time to finish 10,000 m³ of concrete is 272 days.

Assuming indirect cost & profit margin is 25% (of 8 millions) of total costs which is 2,000,000 SR; and then
The indirect cost & profit margin / day = 2,000,000 /272 = 7353 SR /Day Eq. 3
Thus, the direct cost for 10,000 M3 of CIP concrete is 6,000,000 SR, i.e.
Direct Cost = 600 SR/ m³ Eq. 4

For simplification, the findings of equations 2-4 are represented by the following variables:

DC1: Direct cost = 600 SR/m³
T1: Time for finish 10,000 m³ = 272 days
IC1: Indirect cost & profit margin = 7353 SR

Substituting the above variables in Eq.1, then it can be written as follows:
Total Costs (in SR) of CIP concrete = DC1*Qi + IC1*Ti
= 600 * Qi + 7353*272
= 2000016 + 600 * Qi Eq. 5

4.2 Precast concrete (PC) Structure Costs

From Table 1., total Quantity of PC concrete is 12699 cubic meter is to be erected in 240 days (from project schedule) at average price of 1060 SR/M³ for all structural members excluding the foundations and stairs; therefore,
Total cost of PC concrete = 12699 * 1060 = 13,460,940 SR.
And by extrapolation between concrete cost and duration of its erection given all concrete works fall on the critical path, then

Cost of 10,000 m³ PC concrete = 10,600,000 SR Eq 21.
And if the Time for erecting 12699 m³ of concrete is 240 days; then
Time to finish 10,000 m³ of concrete is 189 days.

For the sake of simplicity, assume that the indirect cost & profit margin for the PC contractor is similar to contractor of the CIP, then
IC2 = IC1 = 7353 SR/Day Eq. 31
Total Indirect Cost for PC concrete = 7353 SR/Day * 189 Days
= 1,398,717 SR

Thus, the direct cost for 10000 M^3 of PC concrete = 10,600,000 SR – 1,389,717 SR
= 9,210,283 SR, or
= 921 SR/ M^3 Eq. 41

For simplification, the findings of equations 21,31 and 41are represented by the following variables:

DC2: Direct cost = 921 SR/m³
T2: Time for erecting 10,000 m³ of PC concrete = 272 days
IC2: indirect cost & profit margin = 7353 SR

Substituting the above variables in Eq.1, then it can be written as follows:
Total Costs (in SR) of CIP concrete = DC2*Qi + IC2*Ti
= 921 * Qi + 7353*189

$$= 1389717 + 921 * Qi \qquad \text{Eq. 51}$$

4.3 Finding the Breakeven Point

Having developed Eq. 5 and Eq.51 for the relationship between both CIP and PC quantity of concrete versus total costs of erection, then a breakeven point whereby both linear equations are equal in total costs and equal in quantity of concrete can be found by equating Eq. 5 and Eq.51 as follows:

TC1 = TC2, i.e., 2000016 + 600 * Qi = 1389717 + 921 * Qi, and thus

Qi = (2000016 - 1389717) / (921 – 600) = 1901.24 Cubic Meter of concrete.

Table 2. Presents the values of CIP concrete and PC concrete costs in SR/Cu Meter for ascending quantities of concrete in Cu Meter. When the two previous variables plotted in X-Y plane as in figure 1, which it shows the breakeven occurs at Qi = 1901.24 Cubic Meter at a total cost of 3,200,016 SR. From the figure, we can see if the total quantity of the used concrete is less than 1901 cubic meter then it is cheaper and favorable to use the PC concrete while if the required quantity of concrete is more than 1901 cubic meter, then it is cheaper and favorable to use CIP concrete for the structure of the building.

Table 2 : Data of the Concrete Quantities vs. CIP/PC Costs

Data No.	Quantity of Concrete (Cu Meter)	Cost of CIP Concrete (SR/Cu Meter)	Cost of PC Concrete (SR/Cu Meter)
1	500	2300016	1850217
2	1000	2600016	2310717
3	1500	2900016	2771217
4	2000	3200016	3231717
5	2500	3500016	3692217
6	3000	3800016	4152717
7	3500	4100016	4613217
8	4000	4400016	5073717

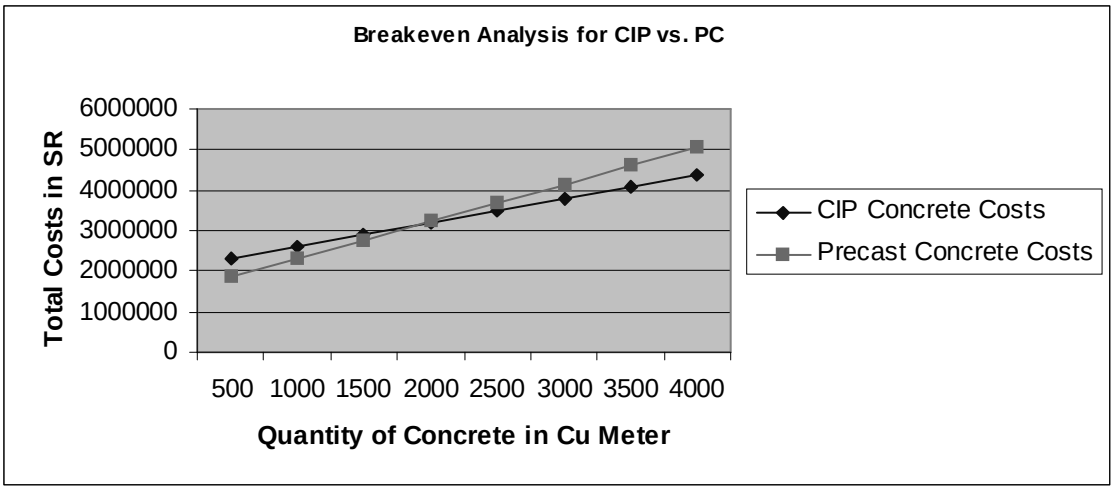

Figure 1: Plot of Concrete Quantities vs. CIP/PC Costs

5. Conclusions

Breakeven formula is derived to preliminarily evaluating and selecting best alternative between two competing construction methods offered by two different contractors for the structural members, those of Cast-in-Place concrete vis-à-vis Precast concrete. The criterion for selection is based on the most economic solution. The quantities of works, i.e., concrete, are treated as independent variable while the component of contractor overhead is held constant and equal for both contractors. The outcome of this research assist decision makers and engineers to compare both concrete construction methods early in the construction planning phase of a project. The approach developed herein can be also applied for similar construction methods for other project activities.

The author intends to further treat the validations of the findings in upcoming paper.

References

[1] S.W. Nunnally (2004). Construction Methods and Management, Publisher: Pearson Education, NY, USA.

[2] Bid Documents for the College of Architecture and Urban Planning (2002). King Saud University, Riyadh, Saudi Arabia

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