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ASSESSMENT OF LIFE CYCLE COST (LCC) OF PRE-CAST AND CAST-IN SITU RESIDENTIAL BUILDINGS

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Abstract

Pre-cast concrete offers many more benefits to all the stake holders associated with the pre-cast concrete construction industry. Unlike the Cast in situ, which requires additional on-site labour, mixing equipment's and various other formwork systems for production and installation, pre-cast construction technology offers a faster and better way to eliminate several variables such as mixing, placing, and curing of concrete on-site and lot of time consumption. This research paper employed a quantitative research method and Life Cycle Cost Analysis (LCCA) approach. To understand the different aspects of the Cast-in-situ and Pre-cast building construction, the real life buildings of both types were analyzed. The scope of research was to compare life cycle costs impacts associated with building constructed with pre-cast construction and cast-in-place construction. The study established that the use of precast concrete is increasing due to life cycle cost.

I. Introduction

India has been trying for decades to transform from agricultural society to industrial society. For the development of the people, India has invested a lot in the education sector that helps in transforming agricultural to industrial. Due to this, the labour cost rises, and now India facing the issue of rising labour costs and a lack of unskilled and skilled workers. Construction industry presently facing several problems like shortage of manpower and increment of the cost of the construction materials also the labour cost and

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availability is problematic. This increases the pressure on the developers as they are the customers and they want on-time delivery of their project with excellent quality of construction works. This problem is solved with the use of pre-cast technology. Most of the new construction uses more prefabrication. Prefabrication becomes the most important part of building construction. With rising urbanization in India, there is a shortage of housing of around 18.78 million houses. The shortage is more in Lower Income Group (LIG)/Middle Income Group (MIG)/Economically Weaker Section (EWS) which contains 95.62% of housing shortage after analyzing both the cast-in-situ and pre-cast construction we got to know that the initial cost is more in pre-cast construction than the Cast-in-situ construction as cost of pre-cast labour is more than the cost in place labour [1].

When it comes to mass housing construction the conventional construction methods are not able to give much satisfaction and advantage as the new construction technology which is much faster minimum use of labour and zero wastage of materials. This construction provides more safety with a reduction in the completion time of the construction project.

Cast-in-place concrete is widely used in India for many decades and pre-cast concrete building construction is a new technology in the construction industry of India. Pre-cast concrete buildings have more advantages over cast-in-place buildings in terms of quality, time, reliability, long life of the structure, less pollution, less wastage of material and resources, and many more but in terms of cost, cast-in-place building construction needs less investment cost and pre-cast building construction needs a huge investment at the beginning stages. This raises a question is that pre-cast concrete building construction is more expensive or less expensive than cast-in-place building construction in their whole life cycle. This is being identified with the Life Cycle Cost (LCC). But there are different methods for evaluating the Life Cycle cost for the building. From all the methods which method is more suitable for the LCC analysis? The aim of this research is to compare and analyse the Life Cycle Cost (LCC) of both pre-cast concrete and Cast-in-place buildings construction. It provides greater control over quality in a controlled environment condition unlike open weather conditions like in cast-in-place construction. A life cycle cost analysis (LCCA) is an analysis that enables engineers, architects, and urban planners to better understand the economic

impacts of infrastructure decisions over time along with the opportunities that exist to reduce impacts [2] [3]. Finally, it promotes cost reduction and increases in profits with a sustainable environment by using various alternate construction materials as well as construction technologies that have lesser economic and environmental impacts.

II. Description of Prefab Construction

The total Prefabricated construction technology is mostly based on plant mass manufactured structural Prefab Components which are conforming the provisions of Indian Standards.

A. Prefabricated Sandwich Panel System

"Prefabricated Sandwich Panel System is a form of sandwich panel system that incorporates insulation, predominantly used for residential and light commercial construction. They are high-strength, high□performance, and can be fabricated to fit nearly any building design" [4]. There are two types of sandwich insulated panel (1) Expanded Polystyrene Core Panel System (EPS), (2) the other panels made of inner and outer boards (cement/fibre/MGO) with infill core of lightweight concrete/ patented/ proprietary materials etc. [4]. EPS cement panels can be used as partition walls in place of conventional brick and mortar wall construction and can be used as non-load bearing and load-bearing wall systems for residential and commercial buildings. For the buildings which are higher than single storey, system can be used either with RCC or steel framed structure [5].

B. Monolithic Concrete Construction using Tunnel Formwork

In 'Tunnel Formwork' technology, concrete slabs and walls are casted in one go at site giving a monolithic structure with the use of high-precision, room-sized, re-usable steel forms or moulds called "Tunnel Form". The system use customised steel formwork consists of two half shells which are place together and then concreting is done to make a room size module and several such modules make an apartment [4].

C. Pre-cast Concrete Construction System

"This is an already established technology for construction of building; Pre-cast construction is a type of system where individual Pre-cast

components such as slabs, walls, stairs, beam, column, etc, of the buildings are manufactured in plant in controlled conditions. After that the finished components are then transported to site, erected and installed [4].

D. Pre-cast Concrete Construction – 3D Volumetric

This 3D volumetric construction is a revolutionary method of building construction, which allows large-sized modules to be constructed comprehensively in a factory. It saves time and significantly reduces the cost. The modules can be transported, erected and installed using cranes and push-pull jacks and are integrated together in the form of complete building unit". Pre stressed slabs are then installed as flooring elements [6].

E. Light Gauge Steel System

Light Gauge Steel (LGS) frame construction is an innovative and reliable construction method that is broadly used in the world and has surpassed wood frame construction in many design and construction aspects. There are various components of Light Gauge Steel Frame, (1) Wall system (2) Flooring System (3) Roof System (4) Light Gauge Steel Coating (5) Shapes of Light Gauge Steel Frame Members (6) Accessories (7) Connections. The System uses factory made galvanized light gauge steel components. The sequence of construction comprises of foundation laying, fixing of Pre-Engineered Steel Structural System, fixing of tracks, fixing of wall panels with bracings as required, fixing of floor panels, decking sheet, fixing of electrical and plumbing services and finally fixing of concrete walling panels with light weight concrete as infill" [4].

F. PVC Stay in Place Formwork

Stay-in-Place (SIP) formwork is a more practical alternative to traditional steel or wood formworks due to its improved constructability and durability. PVC Wall Forms have been developed in various cross□sectional sizes as per project requirement. It was found that the PVC encasement enhanced the thermal insulation property, one of the fire resistance performance criteria [4].

III. Methodology

Life Cycle Cost Analysis provides an approach for computing the cost of building made up of pre-cast and cast-in-situ construction technology. It is used to compare the cost of the two different construction technologies, one is pre-cast building construction technology, and the second is Cast-in-situ building method over its life, considering all the parameters of cost and benefits. For the infrastructure, the major total cost over the lifetime of the buildings includes the construction stage and maintenance stage of the building. To achieve the mentioned objectives, this research employed a quantitative research method. This research study use Life Cycle Cost Analysis (LCCA) approaches. For this, the research study needs to cover the processes which include analysis of documents and historical records after that this research study analyses the mail questionnaire which is distributed during the conduction of research which includes the question on comparison of the cost incurred in pre-cast and Cast-in-situ building technology and collects data of raw materials extraction, its manufacturing, on-site construction of plant and installation and the demolition phase. At last, this research study includes the comparison of the different case studies of Pre-cast and Cast-in-situ building construction for the conclusion that whether pre-cast construction is more expensive or Cast-in-situ construction is more expensive during its construction stage and maintenance stage. The scope of research was to compare life cycle costs impacts associated with building constructed with pre-cast construction and cast-in-place construction.

IV. Life Cycle Costing Method

There are various methods for Life cycle costing. It can calculate and analyze by eight methods namely Simple payback method, Discounted payback method, Net present value, Equivalent annual cost, Internal rate of return, Net saving , Breakeven analysis and Life cycle cost analysis model. The life cycle cost can be calculated at different stages of the building, form an early planning phase of the projects to the execution of the projects. The description, benefits and applications, problems of the different methods of the LCC are discussed in Table

Table 1. Description, benefits and application of different LCC Methods.

Methods	Description	Benefits and Application	Problems	Method Formulae
Simple Payback Method (SPM)	The time required for the return of the starting investment is calculated. The most profitable investment is which has the shortest payback time [7].	Easy and quick for the interpretation of the result. Best for the Rough estimate.	It does not take inflation, cash, and interest.	Payback Period = $\frac{\text{Initial Investment}}{\text{Net Cash Flow per Period}}$
Discounted payback method (DPM)	This method only takes the time value into account.	Time value is considered Used as a screening method, not as a piece of decision making tool.	It ignores all cash flow that is outside the period of payback.	i = Discount Rate n = Time Period
Net Present Value (NPV)	NPV is not anything but a discount factor which depends on the rate of the return per year.	NPV generates equal return which is equal to the market rate. Most of the Life Cycle Cost models utilize the Net Present Value method.	It is not suitable when comparing the two alternatives and it is not easy to interpret [8].	$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+i)t}$ Where: R_t = Net cash inflow-outflows i = Discount rate t = Time Period
Equivalent annual cost (ECA)	ECA method uses the one-time Net Present Value to show uniform annual cost including the annuity into it.	Different alternatives can be compared. Different life lengths of different alternatives are compared.	It does not give the actual cost of LCC, only shows the approximate value [9].	$EAC = \frac{\text{Asset Price} \times \text{Discount Rate}}{1-(1+\text{Discount Rate})}$ N = Time Period
Internal rate of return (IRR)	IRR determines the rate of return to the value reduced to the zero at the start point of the time.	Results are presented in percentages that are more represent able form. IRR can only be used investment will create income only in case of the	Calculations need trial as they can produce an error.	$0 = NPV = \sum_{t=1}^{T} \frac{C_t}{(1+IRR)t} - C_0$ Where: C_t = Net cash inflow C_0 = Total initial investment T = Time Period

		construction industry.		
Net Saving (NS)	The difference between Present worth and the amount invested is known as Net Worth.	This technique is easily understood. It is useful to compare investments.	It is when the investment is generated by the amount.	NS = PW-AI Where, PW = Present worth AI = Amount invested
Breakeven Analysis	The breakeven analysis measures safety margins by comparing the units that are sold to cover the sales.	It helps to measure the profit and loss at different stages and analyze the relationship between a variable and fixed cost. It is used for highlighting an area of economic strength, identify firm weakness, and increase in profit.	It assumes sales prices are constant and sales and production are the same.	$\Sigma TC = \Sigma DC \times Qi + \Sigma IC \times Ti$ Where: TC (Rs) = Total cost DC (Rs/Cum) = Direct costs Qi (Cum) = Quantity of concrete IC (Rs/day) = Indirect costs Ti (Days) = Time Duration
Life cycle cost analysis model	LCC is method used for the estimating the cost of the building over its life which includes its maintenance cost, salvage value and the construction cost.	This helps to remove the traditional making process which is based on capital cost. Its use for the evaluation of total cost project rather than just capital cost.	Various category of information need to be collected which is very difficult.	LCC = 1 + Repl - Res +L(OM & R) I = Initial cost Repl = The Replacement cost Res = Any remaining value L = Time Period OM&R = Operating, Maintenance, and Repair costs

V. Data Analysis

The data on the Pre-cast and Cast-in-situ construction are compared based on Life cycle cost (LCC). The sample of one Pre-cast building and one Cast-in-situ building is taken here to compare the cost of construction in both cases respectively. As both, the building is in their construction phase so

maintenance cost is not available here and is not considered in this research. Salvage value is 10% of the construction cost for the time period of 100 years of a building. As in this study 20 year time period is taken so no salvage value is included in these methods. Replacement cost like Water Pumps, pipes, elevators, Generator is not taken in this study because both Pre-cast and Cast-in-situ buildings have almost same replacement of services. There are different methods of Life cycle cost analysis as shown in table 1. Three methods are considered for Life Cycle Cost analysis of two types of building (Precast and Cast in situ) that are as follows:

- Life Cycle Cost Analysis Model
- Discount Rate Selection Method
- Equivalent Annual Cost Method

Table 2. Comparison of different aspects of pre-cast and cast-in-situ Construction.

Particular	Pre-Cast	Cast-in-Situ
Speed of Construction	The construction speed of Pre-cast construction is very fast and quick because panels need to be jointed on site.	Speed of construction is slow because on-site casting is a time-consuming process.
Control of Quality	Very good quality control because the panels of Pre-cast construction are made in ideal environmental conditions.	Quality is not up to mark as open weather conditions are not the ideal conditions for the best quality of concrete.
Requirements of Labour	Very minimal labour is required only for the panels fixing which are lifted by the cranes. (Lianke and Venkateswarlu, 2016)	All works are on the shoulders of labour from footing shuttering to topmost slab casting.
Durability	More durable because the panels are made in the ideal conditions.	Cast-in-situ is sufficiently durable also but it requires proper quality control.
Size & Shape	The size and shape are not very identical as they are cast on the site.	The size of panels is identical to each other as they are made up of the same blocks and shuttering.
Cost	Cost is more in Pre-cast construction but	The cost of construction is

	the scale is more important. On large scale construction, Pre-cast is cost-effective.	less in Cast-in-situ construction.

Table 3. Project Description (Pre-Cast Construction and Cast-In-Situ Construction).

Project: Delhi Development Authority			
Pre-cast construction Project		Cast-in-situ construction Project	
Name of Work	Construction of 3BHK, 2BHK, and EWS housing using Prefab technology for DDA at Pocket-9, Sector A-1, A-4, Narela Delhi	Name Of Work	Construction of EWS, MIG, And HIG Houses In Pkt-1c At Sector A-1 To A-4 Narela, Delhi
Delivery System	Design & build model	Delivery System	Design & Built
Agency	BG Shirke Construction Pvt Ltd	Agency	M/S Ahluwalia Contracts (India) Ltd
Estimated Cost	Rs. 202,59,65,256	Estimated Cost	Rs. 238,08,00,000 /-
Revised Estimated Cost	Rs. 290,80,51,946	Revised Estimated Cost	Rs. 403,62,76,241 /-
Tender Amount	Rs. 232,71,68,405	Tender Amount	Rs. 338,95,59,600 /-
Stipulated Date of Start	12-4-2017	Stipulated Date of Start	03-06-2014
Stipulated Date of Completion	24-5-2020	Stipulated Date of Completion	02-2-2017

VI. Life Cycle Cost Analysis Model Source

Life cycle cost (LCC) includes construction cost, maintenance cost, demolition cost, and the salvage value which is recovered at the end of life of the building structure. Here we use the LCC to compare the Cast-in-situ building construction and Pre-cast building construction by use of the data collected on-site which is represented above. Different periods can be used to compare both construction techniques. The life cycle costing model is used for the LCC comparison here.

$$LCC = I + Repl - Res + L\,(OM\&R)$$

I = Initial cost or Construction cost, Reply = Replacement cost for any system

Res = Salvage Value, L = Time period

OM&R = The yearly average operating, maintenance, and repair costs.

Table 4: Summary of life cycle cost analysis of pre-cast and cast-in-situ construction.

BUILDING NO.	PRECAST CONSTRUCTION		CAST IN SITU CONSTRUCTION	
	CONSTRUCTION COST	MAINTENANCE COST	CONSTRUCTION COST	MAINTENANCE COST
1	43,62,85,978	28,70,400	50,90,23,603	35,77,600
2	48,41,94,870	33,12,000	56,43,04,243	36,96,000
3	50,79,54,793	26,49,600	59,30,87,275	33,02,400
4	26,15,50,250	24,00,000	30,29,13,145	26,78,400
5	27,30,18,238	22,25,600	31,34,65,130	26,52,000
TOTAL	**1,96,30,04,129**	**1,34,57,600**	**2,28,27,93,396**	**1,59,06,400**
LCC 1 YEAR	1,97,64,61,729		2,29,86,99,796	
LCC DIFFERENCE	**32,22,38,067**			
LCC 20 YEARS	2,23,21,56,129		2,60,09,21,396	
LCC DIFFERENCE	**36,87,65,267**			
INCREMENT	25,56,94,400		30,22,21,600	

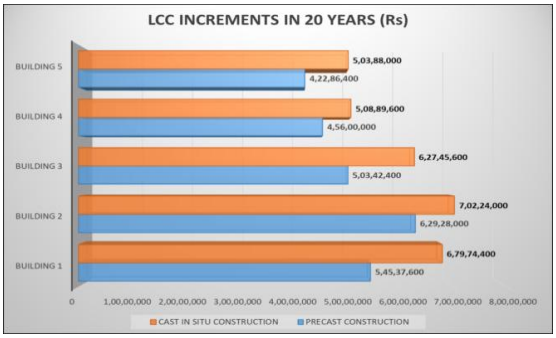

Figure 1. Comparison of Life Cycle Cost (LCC) increments of Pre-cast and Cast-in-situ building construction in 20 years.

VII. Discount Rate Method

The Discount Rate method reflects the time value of the money, which is further used to evaluate the future cost in the relation with present cost, accounting the prevailing inflation rate. It is also defined in terms of

opportunity cost.

$$F = P(1+r)^n$$

F = Future Value, P = Present Value, r = Discount Rate, n = Number of Discount Period

Table 5. Discount Rate Analysis.

BUILDING NO.	PRECAST CONSTRUCTION		CAST IN SITU CONSTRUCTION	
	CONSTRUCTION COST	MAINTENANCE COST	CONSTRUCTION COST	MAINTENANCE COST
1	43,62,85,978	28,70,400	50,90,23,603	35,77,600
2	48,41,94,870	33,12,000	56,43,04,243	36,96,000
3	50,79,54,793	26,49,600	59,30,87,275	33,02,400
4	26,15,50,250	24,00,000	30,29,13,145	26,78,400
5	27,30,18,238	22,25,600	31,34,65,130	26,52,000
TOTAL	**1,96,30,04,129**	**1,34,57,600**	**2,28,27,93,396**	**1,59,06,400**
PRESENT VALUE	1,97,64,61,729		2,29,86,99,796	
PV DIFFERENCE	**32,22,38,067**			
DISCOUNT VALUE	3.25%			
TIME PERIOD	20 YEARS			
FUTURE VALUE	3,74,70,51,100		4,35,79,62,249	
FV DIFFERENCE	**61,09,11,149**			
FV-PV	1,77,05,89,372		2,05,92,62,453	
FV COMPARISON	28,86,73,081			

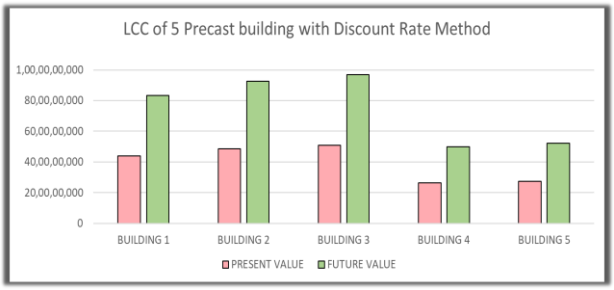

Figure 2. Comparison of the FV and PV of Pre-cast Construction of 5 buildings.

Table 6. Discount Rate Analysis of Pre-cast Building Construction.

BUILDING NO.	PRECAST CONSTRUCTION		DISCOUNT RATE METHOD		
	CONSTRUCTION COST	MAINTENANCE COST	PRESENT VALUE	FUTURE VALUE	INCREMENT
1	43,62,85,978	28,70,400	43,91,56,378	83,25,69,316	39,34,12,938
2	48,41,94,870	33,12,000	48,75,06,870	92,42,34,012	43,67,27,142
3	50,79,54,793	26,49,600	51,06,04,393	96,80,23,172	45,74,18,779
4	26,15,50,250	24,00,000	26,39,50,250	50,04,06,894	23,64,56,644
5	27,30,18,238	22,25,600	27,52,43,838	52,18,17,706	24,65,73,868
TOTAL	**1,96,30,04,129**	**1,34,57,600**	**1,97,64,61,729**	**3,74,70,51,100**	**1,77,05,89,372**

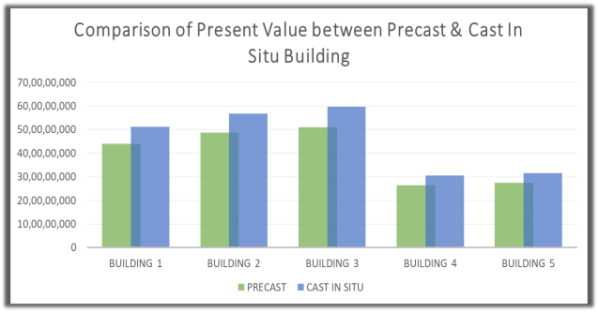

Figure 3. Comparison of Present Value of both Pre-cast and Cast-in-situ Construction.

Table 7. Discount Rate Analysis of Cast-in-situ Building Construction.

BUILDING NO.	CAST IN SITU		EQUIVALENT ANNUAL COST METHOD	
	CONSTRUCTION COST	MAINTENANCE COST	TOTAL ASSET COST	EQUIVALENT ANNUAL COST
1	50,90,23,603	35,77,600	51,26,01,203	3,54,45,828
2	56,43,04,243	36,96,000	56,80,00,243	3,92,76,613
3	59,30,87,275	33,02,400	59,63,89,675	4,12,39,712
4	30,29,13,145	26,78,400	30,55,91,545	2,11,31,330
5	31,34,65,130	26,52,000	31,61,17,130	2,18,59,163
TOTAL	**2,28,27,93,396**	**1,59,06,400**	**2,29,86,99,796**	**15,89,52,645**

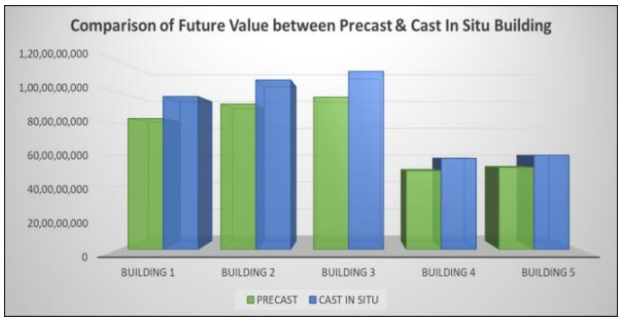

Figure 4. Comparison of Future Value of both Pre-cast and Cast-in-situ Construction.

VIII. Equivalent Annual Cost Method

Equivalent Annual Cost (EAC) is the annual cost of maintenance and owning of an asset or building. This method is used for the Life Cycle Cost of the building for particular period of time.

$$EAC = \frac{\text{Asset Price} \times \text{Discount Rate}}{1 - (1 + \text{Discount Rate})^{-n}}$$

Where, n = Time Period The result indicates that present value (construction cost + maintenance cost) of the precast buildings are 16% cheaper than the cast-in-situ.

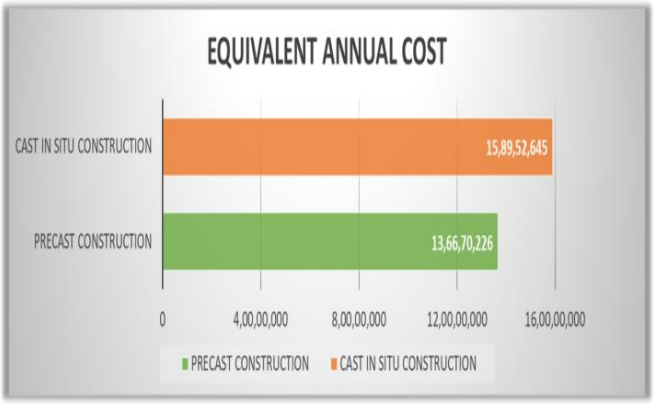

Figure 5. Comparison of the EAC of both Pre-cast and Cast-in-situ Construction.

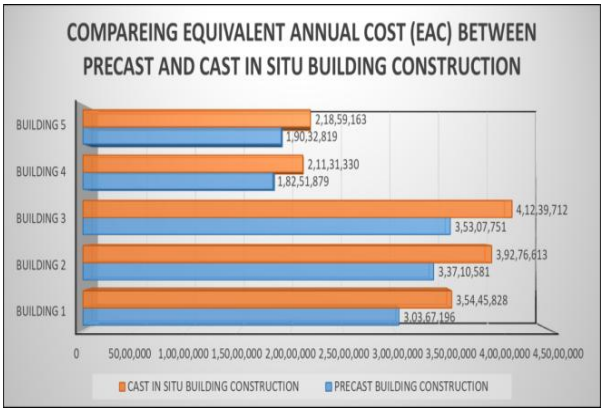

Figure 6. Comparison of the EAC of both Pre-cast and Cast-in-situ Construction.

IX. Discussion and Concluding Remarks

In case of cost overall cost required for constructing the building using

precast concrete method is reduced by 20% when compared to conventional method. Compared to cast in situ, the following savings can be expected:

1. Formwork 75% less

2. Scaffolding 75% to 90% less

3. Wet concrete 90% less.

Compared with cast in situ structures, site labour is reduced by between 50% and 80% using precast. Construction professionals prefer the use of precast concrete construction mainly because of low life cycle cost, reduction of on-site waste, speed of construction, and quality of work done. The Life Cycle Cost Analysis Model summaries the result in of five buildings of the cases in table 5 to 15, indicates that the construction cost of cast-in situ buildings is 16.29% higher, whereas the maintenance cost is 18.20% higher than the pre-cast construction of buildings.

The Discount Rate Selection Method reflected in table 16 to 18 indicates that the construction cost and maintenance cost as per present value and future value of cast-in situ buildings is 16.30% higher than the pre-cast construction of buildings. This helps in evaluation of future cost in relation to present cost. Equivalent Annual Cost Method summaries in figure 7 and 8 indicates that the pre-cast construction costs less than Cast-in-situ construction over the life cycle of 20 years using Equivalent Annual Cost Method. The lifetime quality and the cost effectiveness of buildings would improve by using LCC in the early stage design. The construction client, and the end-user, could save much money in the long run, if LCC is adopted as a decision making tool. When LCC is used more frequently, the construction client could judge LCC in the same manner as they do with estimated capital costs today.

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