Study of cast-in-place mortar compared to brick and mortar-block system for wall work of low cost housing construction in Indonesia

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ABSTRACT: Along with recovering condition from monetary crisis since 1998, Indonesian construction works start to rise up particularly at the housing sector. Moreover when Indonesian government announced the one million houses program in 2003, housing business seems not possible to be dam up. Many developers and contractors have taken the competition to provide houses. However, this condition affects hazard to environment since most of the houses were built using brick masonry wall. As brick is made from clay which is generally taken from rice field, its production becomes threat to the rice field existence. Unfortunately brick constitutes one of the major materials needed for house construction. Based on those problems and also with respect to find a feasible method for building houses, three wall construction techniques are studied. The study is aimed to distinguish the cost and man power effects of the brick wall plus plaster (BWP), mortar-block plus plaster (CBP) and cast in place wall system (CIP). Data of the BWP and CBP systems are taken from the Indonesian National Standard (SNI) while that of CIP are collected from a house reconstruction pilot project post-the May 2006 Yogyakarta's earthquake disaster. In addition, two basic wall systems: brick wall (BW) and concrete block (CB) without plaster finishing, are also presented. The effects of applying those wall systems at different total wall's area toward their total cost and man power are analyzed. Therefore, their environmental impacts, advantages and drawbacks are discussed.

KEYWORDS: cast in place, brick wall, concrete block, wall system, low cost housing.

1 INTRODUCTION

Along with recovering condition from monetary crisis since 1998, Indonesian construction works start to rise up particularly at the housing sector. Moreover when Indonesian government announced the one million houses program in 2003, housing business seems not possible to be dam up. Many developers and contractors have taken the competition to provide houses. However, this condition affects hazard to environment since most of the houses were built using brick masonry wall. As brick is made from clay which is generally taken from rice field, its production becomes threat to the rice field existence (Satyarno 2004; Satyarno 2005). Unfortunately brick constitutes one of the major materials needed for house construction.

Based on those problems and also with respect to find a feasible method for building houses, three wall construction techniques are studied.

2 LITERATURE REVIEW

Wall construction techniques have developed rapidly along with the development of new methods and researches. They not only brought new promises for efficiency, effectiveness, and strength of wall construction but also reduced their negative environmental impacts.

An interlocking load hollow block system is one of the techniques developed in Malaysia to alternate the traditional bonded masonry system (Thanoon, et al, 2004). It offers fast work and wall cost reduction. The interlocking keys provide integration between the blocks to form a sturdy wall and substitute the use of mortar layer which is commonly used in conventional system (Jaafar, et al, 2004). However, their difficult fabrications and transportation processes often become resistance in their development. Nonetheless, experiences shows that confined masonry, which behaved much better during the earthquake (Alcorer et al., 2001), also give additional resistance.

Concerning the environmental impact, study of utilizing Styrofoam as the substitution material for wall and lightweight concrete has been done (Satyarno 2004; Satyarno 2005). Since bricks are usually made of clay exploited from rice field, thus Styrofoam is expected to be able to reduce the brick dependency (Satyarno 2005). Research examining the possibilities of recycling brick masonry wall rubble has also been conducted to reduce the environmental impact caused by huge destruction problems of the May Yogyakarta earthquake (Satyarno 2006).

Unfortunately, there are no research has studied explicitly the feasibility of any wall systems particularly for low cost housing. Depart from problems emerged, hence, this research which mainly studies brick, concrete block and cast in place wall system is conducted.

3 RESEARCH METHODOLOGY

The objective of the research is to distinguish the cost and man power effects of three different wall systems, brick wall plus plaster (BWP), mortar-block plus plaster (CBP) and cast in place wall (CIP). Analysis of BWP and CBP is calculated based on construction work price analysis of the Indonesia National Standard (SNI, 2002) issued by the Indonesia Council for Standardizing (ICS), whereas CIP is analyzed based on the survey. In addition, a case study of a simple healthy house recommended by the Ministry of Public Work of Indonesia is taken and analyzed to provide clearer view of those effects in the real construction.

3.1 Brick and concrete block system

Both brick and concrete blocks constitute a popular materials used for wall of low cost housing construction in Indonesia. Bricks are usually made traditionally by local people. Its fabrication is placed at the rice field where its main material, clay, is exploited. Different from bricks, however, concrete blocks are made a bit more professional by local construction material suppliers. Materials are bought and brought to the warehouse where concrete blocks are fabricated. Nevertheless, compared to bricks, concrete blocks are less preferable. Table 1 provides the properties of brick and concrete blocks.

Table 1. The properties of brick and concrete block

	Length	Width	Height
Concrete block	400	100	200
Brick block	210	110	55

As wall, either brick wall (BW) or concrete block (CB) system is usually finished by applying plaster work to obtain better and flatter wall's surface. Thus, as the whole work, the process of each system comprises bricks wall plus plaster (BWP) or concrete block plus plaster (CBP), respectively.

As it is mentioned earlier, the analysis of BW, BWP, CB and CBP systems are calculated based on construction work price analysis of the Indonesia National Standard (SNI, 2004). The coefficients of materials and workers in this manual are measured from surveys in many construction projects in several areas in Indonesia by the Residential Research and Development Center of Indonesia. The worker's effective working time is considered as long as 5 hours of 8 hours working time per day. Therefore, according to the SNI, working rate of BW and CB system are the same. The detail of each resource's coefficient is given in Table 2 and Table 3.

3.2 Cast in place system

Observation was conducted at a pilot project of a simple house reconstruction. It was a part of disaster relief project for the victims of the May 2006 Yogyakarta great earthquake which has destroyed more than hundred-thousand houses in Bantul district, Yogyakarta province. Stimulated by the limited supply of wall materials, bricks and concrete block, which did not meet its great demand due to the reconstructing houses urgent need for the homelessness, this project was established. The cast in place wall system using recycled ruble was applied as the alternative solution.

As the objective of the project is to provide a sample of simple house with proper earthquake resistance strength, all applications are objected to be easily imitated by local people. The formworks were made as simple and cheap as possible with little necessary guidance.

The house sizes 6 x 6 m^2 and constructed using a common structural system, confined masonry, which is reinforced concrete frame confining masonry wall. The section property of its columns and lintel beams is 15 x 15 cm^2, while that of tie-beams is 15 x 20 cm^2. Three workers: one skilful labor and two helpers are employed. However, because CIP constituted a quite new wall system for the workers, thus some guidance was conducted during its construction.

4 DATA COLLECTION

Observation was conducted to collect the data of the CIP system. Two surveyors are assigned to record the workers' daily activity, particularly during the wall construction period. In order to get a clear view of each resource's contribution toward the construction cost and time of the CIP system as well as corresponding to the SNI system coefficient, the data is divided into two categories: material coefficient, and worker's effective working time. Further, CIP's stages are also classified into four different kind activities: 1) preparing formwork, 2) formwork assembling, 3) mortar pouring and 4) formwork dismantling. Time counting was started and stopped as soon as activity changed.

4.1 Preparing formwork

Preparing formworks is the first activity in CIP system taken before other following activities can be accomplished. The formworks were made from plywood having dimension of 1200 x 2400 mm^2 and 9 mm thickness. In order to be able to resist wet-mortar load, each plywood sheet was stiffed using timber frame for every 400 x 600 mm^2 area in which each frame member sized 40 x 60 mm^2. The frame was nailed on the plywood using 70 mm long nails.

In addition, there are also some materials need to be considered as formwork's material component, which are bout, pipe and bamboo. Bouts were used to join a pair of formworks to be more rigid when resisting wet-mortar's load during pouring process until it was cured for about a day. As the result, wall's surface becomes smooth and flat after formworks were dismantled

Twelve bouts were utilized to join every a pair of formwork. Four bouts were evenly distributed at upper edges, four at the middle and other four at the bottom. However, considering that the formwork must be easily assembled and dismantled, a technique which generated formwork repetitive use and reduced wall initial cost was applied. Twelve centimeters long pipes were applied to cover the bouts from the bounding mortar. It used also to keep

Table 2. Quantity of material per 1m^2 of wall in each work

Material	Unit	Brick[1)]	Conc.block[1)]	Plaster[1)]	Formwork[2)]	Mortar[2)]
Bout	kg				0.895	
Nail	kg				0.351	
Timber	m3				0.028	
Plywood	sheet				0.672	
Bamboo	bar				1.478	
Pipe	m				0.532	
Sand	m3	0.049	0.027	0.023		0.132
Portland cement	kg	8.320	7.500	3.680		19.800
Concrete block	piece		12.500			
Brick	Piece	70.000				

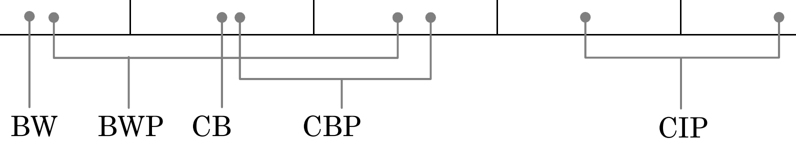
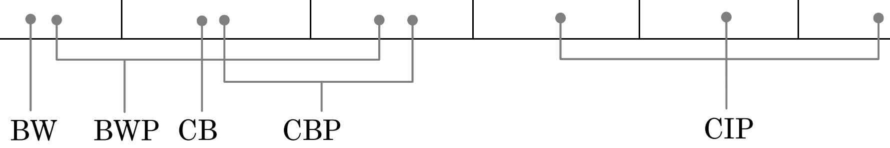


Table 3. Coefficient of man-power per 1 m2/day of wall on each work

Man-power	Brick[1)]	Conc.block[1)]	Plaster[1)]	Formwork[2)]	Casting[2)]	Mortar[2)]
skilful labor	0.100	0.100	0.150	0.104	0.053	0.075
Helper	0.320	0.320	0.200	0.104	0.243	0.207



1) Manual (SNI, 2002)

2) Measured in the survey

the space between the pairs of formworks remained fix and stable. Finally, bamboo was used to keep the formwork alignment vertically.

In the preparation stage, all three workers were employed. Time was recorded to measure formwork manufacturing duration.

4.2 Formwork assembling

Soon after formworks were ready, assembling stage were conducted. Pairs of formworks were placed onto tie-beam where the wall would be constructed. One of the most important steps has to be concerned is that the surface of the tie-beam must be made as smooth as possible so that the formworks could be placed on easily. This was crucial as once tie-beam had uneven surface, difficulties of placing formworks in correct order would be faced. This condition affected in prolonging assembling duration.

The same as preparation stage, all three workers were employed. Assembling time was measured as the workers sifted a formwork from storage onto particular tie-beam until it was completely assembled.

4.3 Mortar pouring

Mortar pouring starts when assembling activity was completely finished. A simple technique to make mortar mixture, using hoe and carried out by a helper, was applied. The mortar was composed of cement and sand in 1 : 6 volume ratio. Water was added until the mortar mixture reached enough workability.

While the first helper was preparing the mixture, the second helper was supplying its raw materials: sand, cement and water. The second helper was also assigned to deliver the ready mixture using two plastic buckets to the skilful labor who was employed to pour the mixture to the assembled formwork. Therefore, in order to reduce the casting time, the mixing place was chosen as closed as possible to the wall being constructed.

4.4 Formwork dismantling

Formwork was dismantled after mortar had been cured. This activity was usually conducted on the next day since mortar pouring was done. It was started from loosening twelve bouts from the formwork and continued by removing formwork from the wall. Then, any dirt remaining stick on the surface of the formworks was removed and scrubbed. Finally, the left pipes bonded in the wall were also pushed out. Only two helpers were assigned to accomplish this activity.

Based on the data survey, all resources coefficient of CIP system consisting of preparing formwork, formwork assembling, mortar pouring and formwork dismantling were calculated. Corresponding to the SNI system, it must be known that the calculation also considers 5 hours worker's effective working time. The coefficients are provided in Table 2 and Table 3 together with those of BW, CB and Plaster work which based on SNI-2002.

5 ANALYSIS

First, it must be acknowledged that except wall, techniques, which used to construct other house's component such as foundation, tie-beam, ring beam, and roof, are the same. Therefore, the effects of performing those works will not be discussed and analyzed any further.

According to the coefficients in Table 2 and Table 3, the effect of each system in varied wall's area toward the cost and man power per meter square of wall can be estimated. Total man-power needed by CIP is the total man power used for preparing a certain necessary square area of formwork plus that for casting (formwork assembling and dismantling) and added by that for making and pouring mortar mixture to form the wall. Whereas, considering that each wall system must have the same result so that only BWP and CBP can be fairly compared to CIP system. However, BW and CB are still presented to give comprehensive view of the plaster-work's influence toward total man power and cost of BWP and CBP systems.

Overall, total man power used to carry out the whole processes of CIP system is 0.786 man-days. Meanwhile, based on manual, both CBP and BWP have the same man power coefficient. Hence, the total man power used by both systems is the same which is equal to .077 man-days.

In term of effective man power, in fact, the formwork area must be adjusted corresponding to the number of workers employed. However, the more number of formworks must be provided the more material and labor cost must be expensed.

Figure 1 shows the relationship between total costs of wall construction versus wall's area of the systems compared. Three different conditions of CIP system: with total formwork area of 5.76 m2, 8.64 m2 and 11.52 m2 are simulated. It is admitted that at a small total wall's area, CIP system seems very expensive to be implemented as it needs high initial cost for obtaining formwork. But, along with increasing wall's area, CIP cost decreases as the result of formwork repetitive usage.

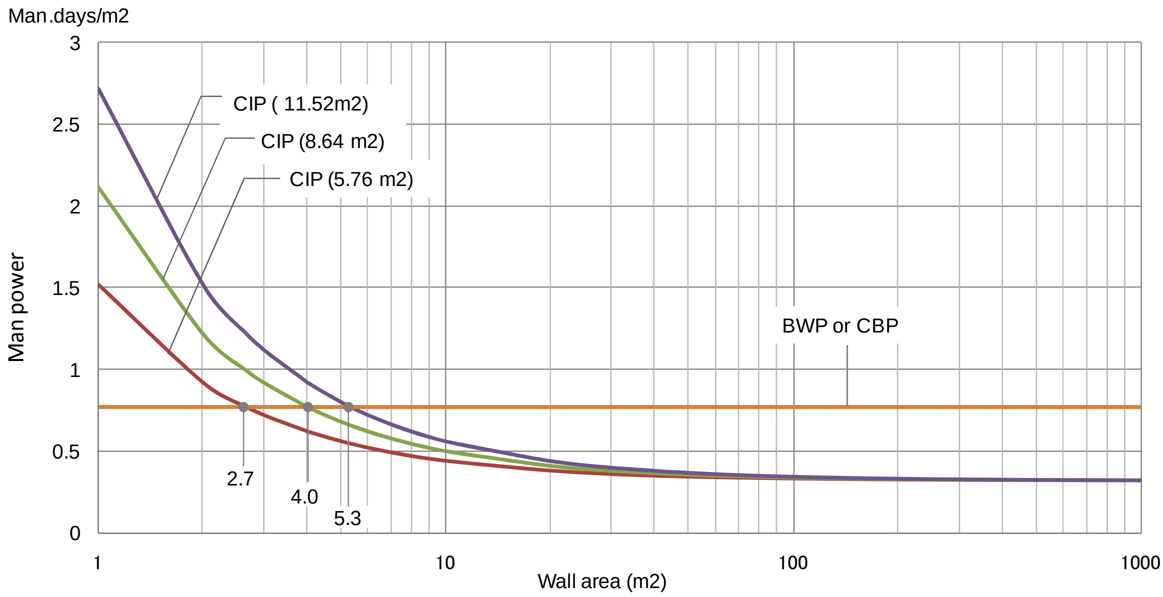


Fig. 1. Man-power effect at different total area of wall

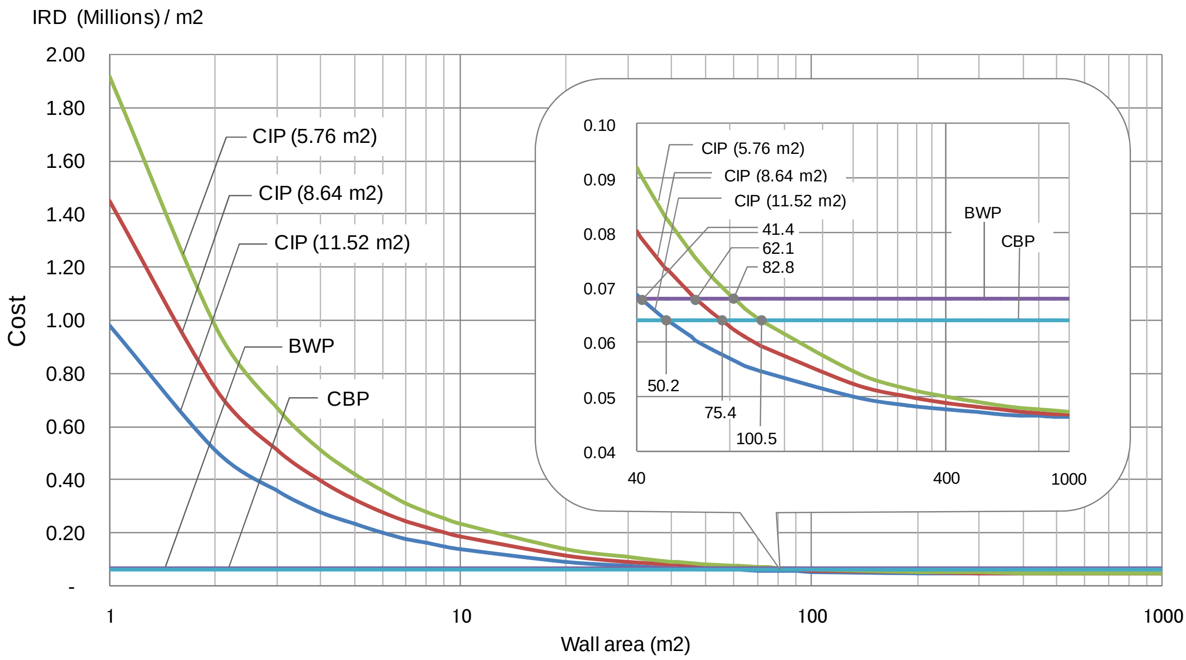


Fig. 2. Cost effect at different total area of wall

It also exhibits that at a small total wall's area needed to be constructed, those three different condition of CIP systems require very significant different of total wall construction cost. On the other hand at relatively big wall's area, approximately 60m2 or above, the different construction cost is not significant. Therefore the CIP with 5.76m2 of formwork, BWP and CBP have the same cost when the wall's area is 2.7 m2, while that with 8.64 m2 is 4.0 m2 and that with 11.52 m2 is 5.3 m2.

6 CASE STUDY

The standard of simple healthy house recommended by Ministry of Public Work of Indonesia (PU, 2006) is taken as a case study. Its design, originally, considers a possibility of its future development which is usually caused by the need of more number of rooms along with increasing number of family members such as having new children and the better welfare of the dweller. As a result, it is expected that the development, if any, can be conducted easily with only little renovation and low cost. The layout of the house is shown in Figure 3.

The house sizes 6.0 x 6.0 m^2 with 0.6 x 3.0 m^2 cut at the front face which consequently affects the total area of the main house becomes 34.2 m2. It has two bed rooms and one common room. The height of the wall is 2.4 m. There are 3 types of doors; D1, D2 and D3, and 2 types of windows; W1 and W2. The shower room is placed separately from the main house. However, to lessen the calculation, the shower room facility is not taken into account in the analysis.

Analysis is done to give clear view of the effect of applying the systems compared for a specified house design toward the total cost and man power of the wall work. First, calculation of wall's area is done to recognize the scope of wall work. One to be highlighted is that gross and net area of wall is needed to be calculated. The total gross area of wall including windows and doors is used to analyze the casting cost of the CIP system, whereas, the net area is used to analyze the actual volume of wall work. The gross area of wall is 77.76 m2 while the net area is 63.79 m2.Wall's thickness of CIP is considered as thick as 12 cm, same as the thickness of the doors and windows frame. The detail calculation of the gross and net wall's area together with the data of each door and window are given in Table 4.

It is assumed that the three systems compared use the same number of workers, one skilful labor and two helpers. Based on this, two sets of formwork are considered to be provided in order to reach the effective man power for one day working time. A set formwork consists of two pieces, each sizes 3 x 1.2 m^2.

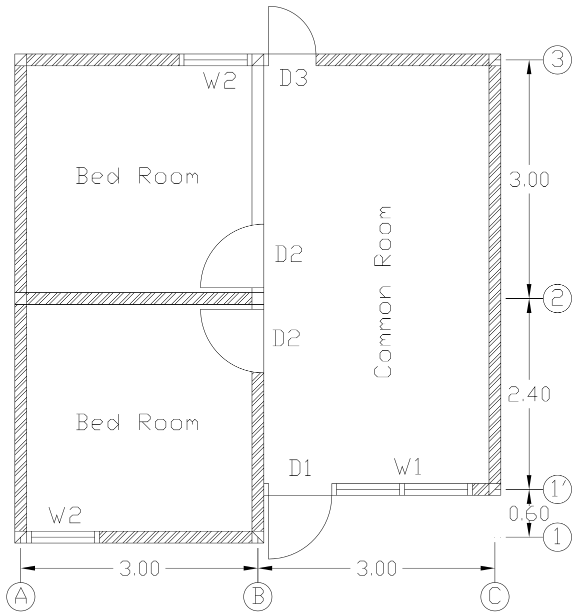


Fig. 3. Layout of a simple healthy house (PU, 2006)

Table 4. Wall's area

	No	Length	Height	Area
Gross wall's area				
Row 3, A, B	3	6.00	2.40	43.20
Row C	1	5.40	2.40	12.96
Row 1, 1' & 2	3	3.00	2.40	21.60
	Total gross (A)			77.76
Area of windows and doors				
D1	1	0.92	2.40	2.21
D2	2	0.92	2.40	4.42
D3	1	0.72	2.00	1.44
W1	1	1.72	1.66	2.86
W2	2	0.92	1.66	3.05
		Total opened area (B)		13.97
		Total net area of wall (A)-(B)		63.79

7 RESULT AND DISSCUSSION

Figure 4 and Figure 5 show the result of the wall construction cost and man power, respectively, of the simple healthy house for each system compared. To identify the effect of plaster work for CBP and BWP the basic wall system, CB and BW are also given. Meanwhile, the effect of providing formwork as the initial cost in CIP is also presented.

From the Bar chart in Figure 4, it is recognized that, among systems compared, CBP promises the cheapest price for constructing one simple house. The finishing plaster contributes about 28.43% of its total cost. Meanwhile, BWP constitutes the most expensive one.

In term of man power demand, Figure 5 shows that CIP offers the lowest total man power. Based on the few man power required for formwork, it is known that providing formwork in any cases does not significantly affect the total man power of the CIP system.

When it is looked at the high cost of formwork at CIP system, about 27.8% of its total cost, this system seems to promise better offer when the number of houses needed to be constructed increases. Table 5 shows the status of CIP compared to BWP and CBP in some taken condition. Some cases of constructing 1, 2, 3, 6, 10, 50 and 1000 number of the same simple houses were taken as the reference.

From Table 5, it is recognized that along with the increase number of the house, the total cost and man power of CIP system reduce significantly. Even when there is only two simple houses needed to be constructed, which the number of formwork repetitive usage reaches 22 times, CIP offers the lowest cost and man power. However, the cost and man power reduction is not significant when the total number of houses needed to be constructed is more than 6.

Considering the environmental impact, in general, CBP may offer the most environmental friendly technique because it does not trigger clay exploitation not or formwork negative impact. In contrast, BWP may harm environment since it requires about 5.67 m^3 clay for constructing every single simple house like one that analyzed in this research. Meanwhile, negative environmental effect caused by formwork waste in CIP system need to be considered through applying lean construction technique.

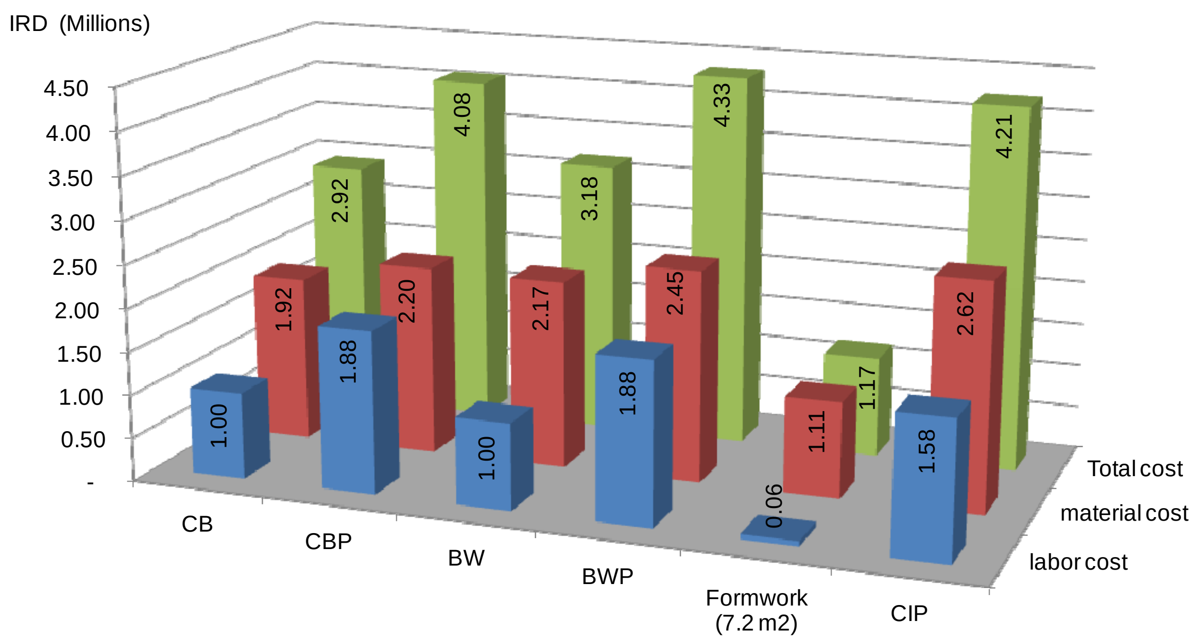


Fig. 4. Cost of each system

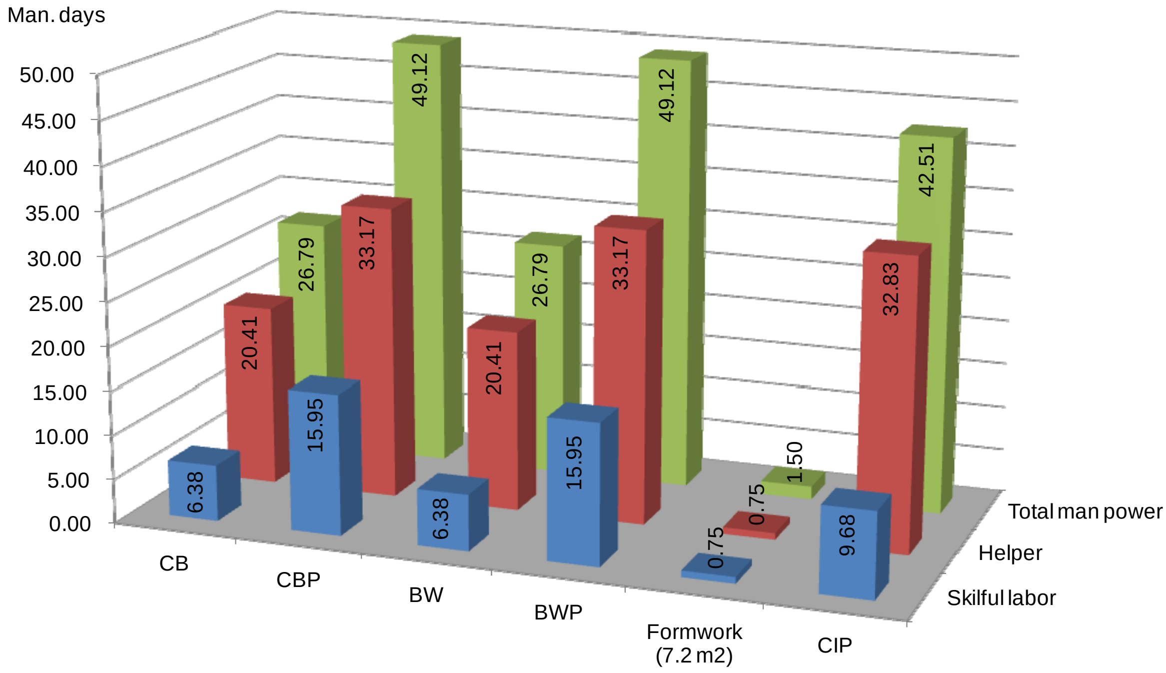


Fig. 5. Man power of each system

Table 5. Cost and man power effect at different number of house

No. of house	Number of repetition of formwork Usage	Total cost			Total man power		Percentage reduction of CIP toward		
		CBP (million)	BWP (million)	CIP (million)	CBP or BWP (man days)	CIP (man days)	CBP (cost)	BWP (cost)	CBP or BWP (man power)
1	11	4.08	4.33	4.21	49.12	42.51	-3.29%	2.76%	13.44%
2	22	8.15	8.66	7.25	98.23	83.53	11.05%	16.27%	14.97%
3	32	12.23	12.99	10.29	147.35	124.54	15.84%	20.77%	15.48%
6	65	24.45	25.98	19.41	294.69	247.59	20.62%	25.27%	15.98%
10	108	40.76	43.29	31.57	491.16	411.65	22.53%	27.07%	16.19%
50	540	203.78	216.46	153.19	2455.78	2052.27	24.83%	29.23%	16.43%
100	1080	407.56	432.92	305.21	4911.55	4103.05	25.11%	29.50%	16.46%

8 ADVANTAGES AND DRAWBACKS

According to the analysis has been discussed earlier, it seems that cast in place system (CIP) may offer some superiorities compared to brick wall with plaster (BWP) and concrete block with plaster (CBP) system particularly when there is very large wall's area need to be constructed. The superiorities of CIP compared to BWP and CBP can be described as following:

- Offer relatively faster work with fewer numbers of workers.
- Require lower labor cost and reduce the total wall's construction cost.

Nevertheless, compared to BW and CB which constitute the basic wall without plaster finishing, CIP seems not so effective and efficient as it requires much higher cost and man power. Further, CIP also has some drawbacks which are:

- As it requires formwork as one of the tools for forming the wall, the initial cost may need to be considered especially when the total wall's area is not wide enough.

- The more complex the shape of the house the more number of formworks must be prepared which may cause higher initial cost and man power.
- It may require more detail design and more precise work to avoid some difficulties particularly at formwork assembling stage.
- It also needs a good plan in order to reduce the negative environmental impact caused by providing formwork.

9 CONCLUSION

The application of CIP system in a pilot project in Indonesia was described. Its required resources were measured and the material and worker coefficient of each stage is analyzed and compared to the common wall systems, BW, CB, BWP and CBP.

The analysis shows that in special condition where there are a big number of houses needed to be built or the total constructed wall's area are large enough with a few variety of shape and or size, CIP may offers better result than BWP or CBP. Conversely, when total wall's area is not wide enough or too much variation of walls' shape and or size, CBP may become a good solution.

Finally, considering the environmental impact, although CIP may offer some attractions to the lay people, due to its low cost and man power, but the negative impact caused by the waste existence of formwork is needed to be minimized.

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