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STUDY OF NEW CAST-IN-PLACE MORTAR WALL FOR HOUSE CONSTRUCTION COMPARED TO BRICK AND MORTAR-BLOCK SYSTEM (A SIMULATION IN DIFFERENT AREAS)

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ABSTRACT: Study from Yogyakarta earthquake reconstruction program, cast-in-place wall using fix-size formwork system (Old-CIP) has offered a good alternative for house construction. A simulation has also confirmed that this system using mortar as the main material can provide cheapest cost and lowest total man power compared to conventional wall construction technique: brick or mortar-block wall. This paper presents the new wall construction technique: full size cast-in-place wall (New-CIP). The detail of how this new technique implemented is described. In addition, considering that material and labor cost in one area is different to others, cost analysis for different resources prices and wages of three cities are taken into a simulation. The analysis is aimed to distinguish the implementation feasibility of New-CIP system compared to the four common wall systems. Finally, its implementation resistance is also discussed.

Keywords: Wall construction technique; Cast-in-place wall; Cost simulation.

1. INTRODUCTION

Infill wall is an important part in house construction. Having larger size compared to its confining reinforcement element such as beams and columns, infill wall can behave as shear-wall and contributes to add the load resistance capacity of the wall panel as a unity structure [1,2].

There are two common walls used in housing construction in Indonesia: brick and mortar-block wall, but brick wall is the majority [3]. Both systems are grouped as non-engineered structures since no engineer involves during its design or construction [4]. However, these systems are often applied in improper implementation and resulting rude quality of house structures [4,5]. Thus, in a case of earthquake, not few houses constructed using common systems are damage or even collapsed [4].

When earthquake occurs and destroys many buildings including residential, house reconstruction stage for victims is urgent to be conducted. Unfortunately, for the victims, particularly poor and uneducated people, who do not know how to construct proper earthquake resist building; cost often becomes the first consideration before the strength [6]. Hence, a technique offering cheap construction cost but providing proper strength is then required [3]. Study from Yogyakarta earthquake reconstruction program, cast-in-place wall (CIP) using fix-size formwork system has offered a good alternative [7].

A simulation of CIP system using mortar as wall infill based on prices and wages of Yogyakarta city in 2006 has also confirmed that this system can ask the cheapest cost compared to brick wall with plaster (BWP) and mortar-block wall with plaster (MBP) [3]. The plaster work is compulsory as most of bricks and mortar-blocks used in Indonesia are not good in quality; they do not have smooth surface and good appearance. Plaster is applied to cover the brick or mortar-block so that the wall surface become flat and finishing cement paste and painting can be applied. Unfortunately the requirement of the plaster work caused brick (BW) and mortar-block (MB) wall system force additional cost.

Different from the common system, CIP produces wall surface the same as plaster. Then, plaster work is not needed [3]. However, improper plan may cause unexpected waste and loss due to formwork utilization. This research concerns the new technique of cast in place wall system (New-CIP) which offers cost reduction through eliminating timber necessity and flexible implementation for house with various wall sizes.

2. RESEARCH METHODOLOGY

This research aims to distinguish the betterment of new cast in place mortar wall (New-CIP) toward the previous cast-in-place mortar wall (Old-CIP) and four common wall systems: brick wall (BW), mortar-block wall (MB), brick wall with plaster (BWP) and mortar-block with plaster (MBP). The data of resources coefficients of both New- and Old-CIP system was taken from the second and first pilot project, respectively. The first pilot project was done during earthquake disaster relief action in 2006 while the second was conducted due to the CIP system improvement. Therefore, the resources coefficient of the common wall systems consisting of brick, mortar-block, plaster, reinforcement, concreting,

and column/beam molding work are taken from the Indonesia National Standard (SNI-2002) [8].

To recognize the improvement of the new-CIP system, cost simulation is carried out. However, construction cost is strongly influenced by prices and wages of resources. Resources prices or wages are different between one to other places where the construction is conducted. Thus, different resources prices and wages of three different cities in Indonesia: Yogyakarta, Semarang and Jakarta, are taken in the simulation. These three cities are relatively big cities. Yogyakarta is the cities where the first and second pilot project was conducted. It has population about 500,000 inhabitants, while Semarang is a capital city of Central Java which has 1.5 million populations, and Jakarta is the capital city of Indonesia with population of 10 million inhabitants.

There is a unique correlation particularly related to the resources which their prices or wages are not controlled by government such as sand and workers. Sand and workers are two main house construction resources which their involvement greatly affect the total construction cost. Sand is used as the fine aggregate for brick and mortar plaster, while workers constitute man power which is always needed in any construction.

Sand supply for Yogyakarta and Semarang is brought from the same quarry, Merapi mountain. Nevertheless, its price is influenced by the distance from the quarry to the construction field. Because the distance from the Merapi mountain to Yogyakarta (25 km) and to Semarang (100km) are obviously different, sand prices of these two cities are also clearly diverse. Sand supply for Jakarta is taken from a place which also causes its price very high. Different from sand, the labor wages are more influenced by different living cost in the different cities.

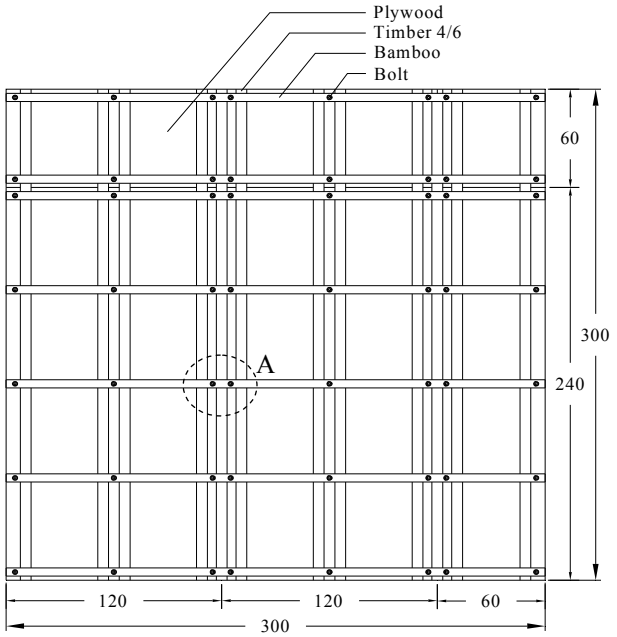
3. NEW-CIP SYSTEM

The cast-in-place wall system (Old-CIP) for house construction is initially introduced in Yogyakarta since the Yogyakarta earthquake relief action in late of year 2006. Previously, the technique is only popular for casting reinforced concrete structure for retaining wall or shear-wall of high rise building. However, the New-CIP constitutes betterment of the Old-CIP.

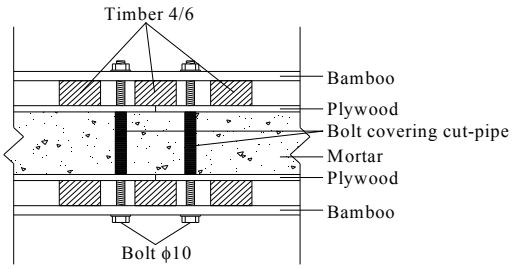
The design is specifically made so that easy implementation without additional sophisticated tools or heavy equipment can be carried out. The main improvement is on the casting technique. Instead of casting wall partially every certain high, in New-CIP system, wall is constructed in wanted size. Formwork is prepared so that it can be used for molding wall in any wide size. The formwork is made knock-down and can be dismantled in pieces. No formwork manufacturing stages is required. The preparation activity is demanded due to the preparation for making hole for bolt on the plywood and preparing timber clamping bamboo.

Four primary materials are required: Plywood sheet, timber, bamboo, bolt and cut-pipes. Plywood is used as sheet layer which resist the mortar when it is poured to form the wall. To prevent from deformation during the mortar curing period, some bolts are assigned at certain distances. Two edges of each bolt hold bamboo as clamping bar. To avoid bolts stick to the mortar after the curing period, in the inner part of the formwork, bolts are covering by cut-pipes. Next, to make the formwork more rigid to against the wet mortar lateral load, timbers are placed between the bamboo and the plywood. As the timbers are only clamped, no defect is remained to the timbers. Although, timber is considered as the main material in the new-CIP system but its existence is only borrowed timber. This technique is one of the advantages of the new-CIP to reduce the formwork cost. Except for clamping the timber, bamboo is also used as the support for the assembled formwork from inclination or collapsed during the mortar pouring and curing time.

The formwork arrangement of new-CIP for constructing 3x3 m^2 of mortar wall is depicted in Figure 1. Two sets of 1.2x2.4 m^2 plus 0.6x2.4 m^2 of plywood sheet



Front view



Detail

Figure 1. The New-CIP System

are used as the bottom part, whereas a set of 2.4x0.6 m^2 and 0.6x0.6 m^2 of the plywood are used as the upper part. Figure 2 (d), (e) and (f) depict the application of new-CIP system in a pilot project.

4. OLD AND NEW CIP COMPARISON

The main different between Old- and New-CIP is on the formwork design and the wall molding technique. Old-CIP formwork is manufactured in advanced before it is used to mold the mortar wall. Plywood is prepared on timber framework using nail; some holes are made at some points so that formwork uniting bolt can pass it through when the assembling stage is conducted.

Because the size of plywood in the market is 1.2 times 2.4 m^2, Old-CIP formwork is prepared and manufactured so that its wide is the same as the wide of the wanted wall panel to be constructed. Commonly the high of the formwork is made as same as the wide of the plywood, while the wide follows the wide of the wall panel to be constructed. For instance, for constructing 3x3 m^2 wall panel, the formwork is manufactured as the size of 1.2m times 3m. The length of the formwork is made by composing 2.4 m plus 0.6 m plywood. Figure 2 (a), (b) and (c) show model of Old-CIP application in the first pilot project.

Due to the different technique used by both Old- and New-CIP system, their resources necessity and total construction cost are also different. Hence, to distinguish how good the betterment of the New-CIP take effect toward the old-CIP, resources coefficient and cost comparison of both techniques are presented.

4.1 Resources Coefficient

The resources coefficients of Old- and New-CIP system per m^2 of constructed mortar-wall are given in Table 1. To deeply recognize the volume or amount change of each necessary resource of the New-CIP toward Old-CIP, resources are differentiated into material and man power. The man power is, again, divided into manufacturing, assembling and dismantling, and mortaring work.

Regarding to the different technique of formwork system, the Old- and New-CIP also requires different number of resources. The old-CIP requires eight kinds of resource consisting of two man powers: skillful labor and helper, and six materials: bolt, nail, timber, plywood, bamboo and PVC-pipe. While the New-CIP, only six kinds of total resources are really needed. Although timbers are used in New-CIP, but because they are borrowed material from the roof supporting structure, then their existence is not counted in the New-CIP system cost calculation.

In term of material, both Old- and New- CIP requires the same amount of plywood per m^2 of wall. However, in term of bolts, New-CIP uses more bolts. Bolts in of New-CIP are needed to unite all plywood composing formwork in every necessary space so that formwork unity is obtained. While, the amount of cut-pipes is the same as the bolts since their number is directly related. In term on nail and timber usage, different from the Old-CIP in which nails are used to attach the plywood on the timber frame, in the New-CIP nail are not used and timber frame are applied only as the borrowed material to increase the rigidity of the formwork.

In term of man power, the negative reduction of the New-CIP system is only on the assembling and dismantling activity. The New-CIP requires more man

Figure 2. Old-CIP: (a) The Assembled Formwork, (b) The Dismantled Formwork, (c) The Constructed Wall; and New-CIP: (d) The Assembled Formwork, (e) The Dismantled Formwork, and (f) The Constructed Wall

power since it needs longer time to arrange the formwork unity from pieces. However, other activities, manufacturing and mortaring demand less man power.

4.2 Construction Cost

The cost of both old- and new-CIP is equal to the multiplication of the amount of each resource (Table 1) with its prices or wages (Table 2). Among all resources required by Old- and New-CIP system, man power is the resources which have clearly different value. The wage of skillful labor in Semarang and Jakarta are about 1.3 and 1.7 times of that in Yogyakarta, respectively, while that of helper are 1.1 and 1.6 times respectively. Meanwhile, the price of the material used by both system are remain similar or the same. Regarding to the resources coefficient comparison, it is known that the different technique of utilizing timber take much effect to the total cost.

Table 1. Resources Coefficient of Old- and New-CIP system per m^2 of Wall

	Unit	Old	New	Reduction
MATERIAL				
Bolt	kg	0.089	0.133	-48.8%
Nail	kg	0.035	-	100.0%
Timber	m3	0.003	-	100.0%
Plywood	sheet	0.069	0.069	0.0%
Bamboo	unit	0.148	0.098	33.8%
PVC-pipe	unit	0.053	0.033	-48.8%
MAN POWER				
Manufacturing				
Skillful labor	man.day	0.010	0.009	14.5%
Helper	man.day	0.010	0.009	14.5%
Assembling and dismantling				
Skillful labor	man.day	0.053	0.089	-9.8%
Helper	man.day	0.243	0.267	-66.3%
Mortaring				
Skillful labor	man.day	0.062	0.056	3.4%
Helper	man.day	0.172	0.167	10.9%

Table 2. Prices and Wages of Resources

	Unit	Yogyakarta	Semarang	Jakarta
Skillful labor	man.day	35.00	45.00	60.00
Helper	man.day	25.00	27.50	40.00
Bamboo	unit	6.00	8.50	10.00
Brick	unit	0.30	0.34	0.35
Bolt	kg	15.00	15.00	15.00
Mortar block	unit	1.50	1.75	1.85
Timber	m3	2250.00	2250.00	2250.00
Nail	kg	15.00	15.00	15.00
Sand	m3	60.00	120.00	175.00
Plywood	sheet	147.00	147.50	140.00
PVC	unit	4.00	4.00	4.00
Cement	kg	1.00	1.00	1.00
Rebar	kg	12.00	12.00	12.00
Coarse agg.	m3	175.00	175.00	175.00
Timber sheet	sheet	6.00	6.50	7.00
Steel wire	kg	16.00	16.00	16.00

* All values are in thousand IDR.

Table 3. Cost Comparison of Old- and New-Formwork per m^2 of Wall.

	Old-CIP	New-CIP	Reduction
Yogyakarta	34111.03	29014.85	14.9%
Semarang	36806.99	31898.18	13.3%
Jakarta	43773.17	39402.32	10.0%

Table 3 shows the cost simulation result between the Old- and New-CIP in three studied cities, Yogyakarta, Semarang and Jakarta. The New-CIP system needs lower cost compared to the Old-CIP in all reference cities. As the different of all resources prices and wages of the three cities have no linear relationship, hence the cost reductions offered by New-CIP are also different. In Yogyakarta, new CIP-formwork offer 14.9% cost reduction, while in Semarang is 13.3% cost reduction and Jakarta is 10.0% cost reduction. This reductions seem to show that the higher the wages of the man power, the lower the cost reduction achieved, and vice versa.

5. SIMULATION FOR DIFFERENT CITIES

To distinguish the feasibility of New-CIP toward four common wall systems: BW, MB, BWP and MBP, simulation for the same three different cities are carried out. The Simulation is calculated based on a standard wall panel which is 3x3 m^2. The size includes two columns on the right and left, one tie-beam at the bottom and one ring-beam on the top of the infill wall. They act as the infill wall confining structures. The columns, tie-beam and ring-beam have the same section properties, 10x10 cm^2, and rebar specification, 4ϕ8 longitudinal rebar and ϕ6-150 lateral rebar. Except the longitudinal and lateral rebar of the confining structure, the New-CIP also requires some additional rebar for wall reinforcement. The rebar is ϕ6-60 arranged in vertical. However, the infill material and construction technique of the confining structure for the New-CIP and other systems are different. In the new-CIP, columns, tie-beam and ring-beams are molded simultaneously with the wall using the same formwork and the same mortar, whereas, in the four common wall systems, concrete is used as the infill for the confining structure. The concrete is molded using simple formwork separately after the brick or mortar block arrangement. The resources amount of each system per unit of wall panel 3x3 m^2 is provided in Table 4 and the total volume of the composing work of each system is given in Table 5.

Figure 3 shows the result of the simulation of five studied systems. The patterns of the total cost comparison in the three cities seem to be similar. When finishing-work (Plaster) of the common system (BWP and MBP) is considered, New-CIP promises the lowest cost. However,

if the finishing work is not taken into account in which plaster work for BM and MB are not applied, New-CIP is still require higher construction cost.

6. DISSCUSSION

Although cast-in-place mortar wall for house construction is relatively new, but its lower cost compared to the common system (MBP and BMP) is expected to bring new promise for implementation. Its possibility of casting wall in different wall size without reduced maximally will become a good point of its popular implementation.

Regarding to the experiment from the Yogyakarta earthquake relief action in which new cast in place wall system with recycled rubble is introduced; implementation resistance may come from two parties:

1. The construction workers.
   The construction workers are needed to be trained so that they become familiar with the system. However, assigning workers to use this New-CIP system without proper supervision will cause low quality wall or even

Table 4. Resources Amount of Each System per Unit of Wall Panel, 3x3 m^2

	Unit	BW	MB	BWP	MBP	Old-CIP	New-CIP
Wall							
Brick	unit	548.80		548.80			
Mortar block	unit		98.00		98.00		
Sand	m3	0.38	0.21	0.38	0.21	0.99	0.99
Cement	kg	65.23	58.80	65.23	58.80	148.50	148.50
Helper	man.day	2.51	2.51	2.51	2.51	1.55	1.50
Skillful labor	man.day	0.78	0.78	0.78	0.78	0.56	0.50
Plaster							
Sand	m3			0.41	0.41		
Cement	kg			66.24	66.24		
Helper	man.day			3.60	3.60		
Skillful labor	man.day			2.70	2.70		
Mold/Formwork							
New-CIP formwork	set						1.00
Old-CIP formwork	set					3.02	
Timber sheet	sheet	6.00	6.00	6.00	6.00		
Nail	kg	0.48	0.48	0.48	0.48		
Helper	man.day	0.72	0.72	0.72	0.72	2.28	2.53
Skillful labor	man.day	0.79	0.7				
Concrete							
Cement	kg	38.98	38.9				
Sand	m3	0.06	0.0				
Coarse aggregate	m3	0.09	0.0				
Helper	man.day	0.23	0.2				
Skillful labor	man.day	0.04	0.0				
Reinforcement							
Rebar	kg	26.41	26.4				
Steel wire	kg	0.38	0.3				
Helper	man.day	0.18	0.1				
Skillful labor	man.day	0.18	0.1				

Table 5. The Work Volume of a Unit of Wall Panel, 3x3m^2

	Unit	Volume
The infill	m2	7.840
Plaster	m2	18.00
Shear rebar f6	kg	6.21
Longitudinal rebar f8	kg	18.94
Additional rebar f6	kg	2.66
Beam/column mold	m2	2.40
Concrete	m3	0.116

requiring different advanced manufacturing work also bring its flexibility for constructing house with non-uniform wall sizes. Further, this also provides reduction to the manufacturing time and cost.

One of the resistances causing New-CIP difficult to be applied is the present of the formwork. Formwork is often considered causing higher cost. Other reason is related to environment which often claims that formwork utilization is not environment friendly [9]. However, managing the technique and improving the system so that waste can be

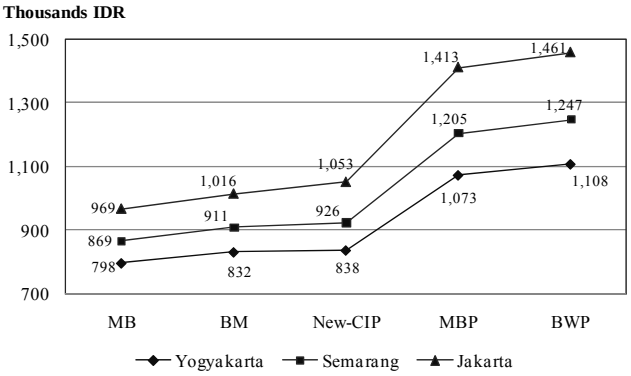


Figure 3. The Simulation Result

loss.

2. The users (house owners).
   The user's reluctance is usually caused by their unfamiliarity toward the New-system. Moreover, formwork utilization in the New-CIP can reduce construction cost is difficult to be believed by house owners. Nonetheless, more implementation and frequent dissemination are expected to change the people misperception.

Regardless the benefit, the new-CIP system still remain drawbacks for improvement, particularly related to the possibility of formwork repetitive use which is still limited only up to 10 times.

7. CONCLUSION

The New-CIP mortar wall system has been presented and discussed. Its improvement technique has brought additional attraction for CIP implementation. Reducing cost and time for manufacturing and utilizing borrowed timber from roof supporting truss constitute a good betterment which eliminating timber waste caused by formwork utilization is obtained.

Based on cost simulation in three big cities in Indonesia, implementation of the New-CIP seems to be feasible. When plaster work is counted, New-CIP offers 23.7% and 26.2% cost reduction, in average of three studied cities, compared to the MBP and BWP respectively. Therefore, when plaster as finishing work of both common wall systems is not taken into account, the CIP still requires quite higher cost. However, improvement and more application need to be carried out to make the system better and widely known.

REFERENCES

[1] Imansyah, R., "Karakteristik pasca elastik dinding pasangan bata beton pejal dengan tulangan horizontal akibat beban siklik", *Master Thesis*, Civil Eng. Dept. Gadjah Mada University, Yogyakarta, 2005.

[2] Raharjo, E. P., "Karakteristik pasca elastik dinding bata merah dengan tulangan horizontal akibat beban bolak-balik", *Master Thesis*, Civil Eng. Dept. Gadjah Mada University, Yogyakarta, 2005.

[3] Nugroho, A. S. B. and Takano, S., "Study of cast-in-place mortar compared to brick and concrete block system for wall work of low cost housing construction in Indonesia", *Proc. of Int. Symposium of Society for Social Management Systems-2008*, 2008.

[4] Suhendro, B., "Lessons learned from the May 27 Yogyakarta earthquake", *Proc. of Int. Sem. and Symp. on Earthquake Engineering and Infrastructure & Building Retrofitting*, CD-ROM, 2006.

[5] Nugroho, A.S.B., Takano, S., and Purba, P.M., "Survey of the implementation diversities of non-engineered buildings post-Yogyakarta earthquake 2006", *The AUN/SEED-Net Field Wise Seminar*, Bangkok, 2007.

[6] Sarwidi, "Lessons from the performance of non-engineered building in earthquake damaged area", *Proc. of Int. Sem. and Symp. on Earthquake Engineering and Infrastructure & Building Retrofitting*, CD-ROM, 2006.

[7] Nugroho, A.S.B. and Takano, S., Cost analysis of rubble recycling and cast-in-place wall system for house reconstruction schemes of the Yogyakarta earthquake aftermath, *Japan Society of Civil Engineers (JSCE)*, 2008.

[8] The Indonesia Ministry of Public Work, *Collection of construction cost analysis for buildings and houses*, SNI, 2002.

[9] Thanoon, W.A., Jaafar, M.S., Kadir, M.R.A., Ali, A.A.A., Trikha, D.N. and Najm, M.S., "Development of an innovative interlocking load bearing hollow block system in Malaysia", *Construction and Building Material*, Vol. 18, pp. 445-454, 2004