Development of Precast Concrete Forms Two Storey Concrete Structure

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Abstract

The country is beset by natural calamities such as floods, typhoons and drought among others. Observers of the dynamics of the environment point to the wanton cutting of trees as one of the causes of flash floods that contribute to destroy lives and property both in the countryside and in the cities. Illegal logging has contributed to an increase in lumber production but this has also inflicted harm to the environment. To minimize this problem, this study introduced to the local construction industry the application of concrete as forms instead of plywood and plank forms to minimize the use of wood products in concrete formworks as well as for faster and economical construction. The concrete forms were studied for use in columns and beams for two- storey structures.

This innovation was based on the site observation of construction activities of the conventional method of erecting a two storey building in order to modify and introduce the method of precast concrete for forms of columns and beams.

The result of the study showed that because of the versatility of concrete, its forms can be created for columns and beams of different structural sizes for different locations. The concrete forms also increased the compressive strength of the ferroconcrete. The application of this construction system without the conventional wooden form significantly minimized expenses in the construction formworks of a two-storey structure.

Keyword Index: *development, precast, concrete forms, concrete structure*

INTRODUCTION

Due to the flourishing construction activity in the country, buildings and structures continue to be erected everyday, everywhere. The cutting of trees for logging and lumber production is partly intended for the construction industry as building fonns and scaffoldings. An observed effect of this activity are floods caused by massive and irresponsible cutting of trees without reforestation.

To minimize the use of wood products and lessen its demand for construction, This study is intended to find a solution to reduce the use of wooden fonns. Concrete pre-casts as concrete fonns can be used instead of the conventional wooden forms in the construction of beams and columns for two storey buildings. A precast concrete form when cured becomes an artificial stone as a result of mixing cement, fine aggregate, chalker and water. The rough surface of the concrete precast form has a compatible bonding with ferroconcrete or fresh concrete with reinforcement that is filled inside and creates an extra compressive strength and integrates with it well.

The U-block precast concrete was an earlier research of the author in 2005 published at the UNP Research Journal, involving a six inches (6") width block used as form for minimally- spanned columns and roof beams for one storey structure. It was found out that this system could reduce the activities of labor and material costs. It also made possible for a faster construction time.

Because of the benefits and advantages discovered from this system, the author wanted to look for more innovations for the construction of beams and columns for two storey structure based on the U- block precast concrete but with different sizes and shapes for greater flexibility in application.

The comparative estimated cost of the conventional method of constructing column and beam structure against the precast concrete form is shown separately **in** Table I (A & B) and Table 2 **(A** & B).

Table 1-A. Average Estimated Cost of Formworks for One (1) Column Using the Conventional Method of Construction

Description	Q'ty	Unit	Unit Price	Total
2' Thk. Marine Plywood	I	Pc.	380	380.00.00
2"x2"x8' Tanuile Phil. Wood	11	Pcs.	120	1,320.00
2"x3"x IO' Coco Lumber	20	Pcs.	140	2,800.00
CWN (Asstd)	0.246	Kg.	65	16.00
Cost of Material				4,516.00
Cost of Labor Form fabrication+ Installation)				645.00
Cost of Labor and Materials oer I-Column				5,161.00
(plus) Formwork Stripping Cost after Erection of Column				75.00
Total Exoenses for One (1) Column Formworks				**PhD 5.236.00**

Table 1-B. Estimated Cost of Materials in the Installation of One (1) Column using the Precast Concrete Form Method and Using only a Wooden Guide

Description	O'ty	Unit	Unit Price	Total
2"x2"x12' Tanguile Phil. Wood	2	Pcs.	180	360.00
2"x3"x8' Coco Lumber	4	Pcs.	112	448.00
CWN (Asstd)	0.092	Kg.	65	6.00
			Cost of Material	814.00
			Cost of Labor	40.00
			Removal of Guides & Braces	5.00
			Total Expenses for One (1) Column Formworks	**PhD 859.00**

Table 2-A. Estimated Cost of Formworks for One (1) Beam at 3.00 meters length Using the Conventional Method of Construction

Description	O'ty	Unit	Unit Price	Total
¼" Thk. Marine Plywood	0.80	Pc.	380	304.00
22x2° Tanguile Phil. Wood	20	Bd.ft.	45	90.00
2"x3" Coco Lumber	144	Bd.ft.	**28**	4,032.00
CWN (Asstd)	1.20	Kg.	65	78.00
			Cost of Material	4,504.00
			Cost of Labor (Form fabrication+ Installation)	990.00
			Formwork Stripping Cost after Erection of Beam	80.00
			Total Expenses for One (1) Beam Formworks	**PhD 5,574.00**

Table 2-B. Estimated Cost of Formworks for One (1) Beam at 3.00 meters length Using the Precast Concrete Form Method

Description	Qty	Unit	Unit Price	Total
2"x2" Tanguile Phil. Wood	10	Bd.ft.	45	450.00
2"x3" Coco Lumber	116	Bd.ft.	**28**	3,248.00
CWN (Asstd)	0.86	Kg.	65	56.00
			Cost of Material	3,754.00
			Cost of Labor	790.00
			Formwork Stripping Cost after Erection of Beam	60.00
			Total Expenses for One (1) Beam Formworks	**PhD** 4,604.00

Objectives of the Study

The main objective of the study was to develop precast concrete forms two story concrete structure.

The specific objectives include the following:

I. To design other shapes and sizes of concrete forms for beams and columns for a two storey structure;
2. To design the moulder of the proposed concrete forms;
3. To detennine the weight of the concrete form for the worker's capability to lift during fabrication and installation; and
4. To detennine the effect and location of crack when the concrete forms are subjected to compression

Review of Related Literature

When cement, aggregates and water are mixed, a chemical reaction is started that is independent of drying. Concrete does not need air to cure and can set under water with water starting the reaction. Concrete sets or becomes firm within hours after it has been mixed, but curing, the process of attaining strength, takes considerably longer. Proper curing of concrete is essential if the design strength of the concrete mix is to be obtained. Hydration is a chemical reaction between the water and the cement when concrete is in curing. The longer the water is present in the concrete, the longer the reaction takes place, hence, the stronger it becomes.

After exposed surfaces of concrete have hardened sufficiently to resist marring, they should be cured by sprinkling (covering) with water or by using moisture-retaining materials such as waterproof paper, plastic sheets, wet burlap, or sand, or left in forms for a longer period. In hot weather, it should be kept moist for at least three days (Encarta Encyclopedia, 2001).

Under normal conditions, concrete grows stronger as it grows older. The chemical reactions between cement and water that cause the paste to harden and bind the aggregates together require time. The reactions take place very rapidly at first and then more slowly over a period of time. In the presence of moisture, concrete continues to gain strength for years.

Fajardo Jr. (1993) gave the following concrete duration of compressive strength: three days for 50 percent, seven days for 70 percent, 28 days for 100 percent, and for slower rate, 21 days for 30 percent. He further indicated that the compressive strength of concrete may continue to increase beyond the designed strength, depending on its curing.

There are many ways and techniques in concrete construction. Concrete is poured into places in a number of ways. For the footing of small buildings, the wet concrete is poured directly into trenches dug into the earth. Concrete for columns and beams is placed between supporting wood or metal forms which are removed after the concrete has hardened.

A formwork system is defined as "the total system of support for freshly placed concrete including the mould or sheathing which contacts the concrete as well as supporting members, hardware, and necessary bracing." Formwork cost accounts for 40 to 60 percent of the cost of the concrete frame and for approximately 10 percent of the total building cost. Formwork costs are not the only significant component of the formwork life cycle. Other important aspects of the framework operation include speed, safety and quality. Wood products are the most widely used materials for forrnwork (Awad).

The use of concrete forms like the 6" U-block precast concrete was found to reduce the expenses of labor and materials such as wood, and eliminate entirely the use of plywood for forms. Labor activities for fonnworks have been eliminated except for the checking of plumb and the levelling of columns. This system makes possible faster construction time compared to the conventional system.

In this research, it was concluded that the U-block concrete form has only a limited use in a structure, but different sizes of reinforced concrete columns can be adopted and the precast form must be designed for more flexible and complex uses like the construction of floor and roof beams for a two-storey structure (Queypo, 2005).

The average concrete column size for a conventional two storey concrete structure is 8"x 12" in a module of 3.00 meters x 3.60 meters, having a floor to floor height of 3.00 meters. The maximum length of column shall not be greater than 20x the smaller width. An 8"x 12" cross sectional floor beam can be used for a concrete suspended slab for a residential structure at a given module size above.

Concrete used in most construction work is reinforced with steel. When concrete structural materials must resist extreme tensile stresses, steel supplies the necessary strength. Steel is embedded in the concrete in the form of the mesh or deformed bars. A bond forms between the steel and the concrete, and stresses can be transferred between both components (Encarta Encyclopedia, 2001).

Reinforcing steel, manufactured as round rods with raised deformations **for** adhesion and resistance to slip in the concrete, is available in several grades (yield strengths). Commonly used reinforcing rods have yield strengths of 40,000 and 60,000 psi available in sizes from #3 (10mm diameter) to any bigger size.

Fajardo Jr. (1993) gives the following proportions of structural elements:

Column
Area of Steel (As) = is the cross sectional area of steel
=3 to 6% of cross-sectional area of column is the common range
=8% of cross-sectional area of column is the maximum

An important component of concrete construction is concrete masonry. Concrete masonry is block building units moulded of concrete and used in all types of masonry construction. Concrete masonry is used for load bearing and non-load-bearing walls; partitions; fire walls; back-up for walls of brick, stone, and stucco facing materials; fireproofing over steel structural members; fire safe walls around stairwells, elevators, and other enclosures; retaining walls and garden walls; chimneys and fireplaces; concrete floors; and many other purposes.

In the Philippines, the size of the concrete hollow block (CHB) is 4" x **8" x** 16" for interior walls, and 5" x **8" x** 16" and 6" **x 8" x** 16" for exterior walls. CHB units are laid every 3 layers with horizontal steel reinforcement and laid every 2 blocks vertical reinforcement, being attached at each end of walls to concrete columns with a continuous reinforcement or a reinforced dowel. On the top end of the wall, the CHB steel reinforcement is continuously attached to the concrete beams soffit by a reinforced dowel.

Definition of Terms

Admixture. This refers to a material other than water, aggregate, or hydraulic cement, used as an ingredient of concrete and added to concrete before or during its mixing to modify its properties.

Aggregate. This is an invert granular material such as natural or manufactured sand, gravel, crushed stone, vermiculate, perlite, and air-cooled blast-furnace slag, which when bound together into a conglomerate mass by a matrix forms concrete or mortar.

Bar. This refers to a length of metal or other solid material used as part of a structure.

Cast-in Place Concrete. This is same as in-situ concrete

CHB. This is a Concrete Hollow Block madder from a mixture of cement, fine aggregates, and water formed from a steel mold.

Chalker. A fine aggregate or a mixed sand and fine gravel used to mix with cement and water to mold a concrete block.

Concrete. This refers to a mixture of cement, sand, aggregate, and water in specific proportions that hardens to a strong stony consistency over varying length of time.

Conventional concrete construction. This refers to a system of construction using plywood, board, and wood used as forms and scaffoldings of the concrete poured at job site.

In-situ concrete. This is a term given to any concrete that is poured in place at a job site. It is also referred to as cast-in-place concrete.

Ferroconcrete. This is also known as Reinforced Concrete, is a concrete made with metal wire or rods embedded in it to increase its strength.

Fine Aggregate. This is any aggregate that passes a no. 4 sieve (which has wires spaced i n. on centers in each direction).

Fly ash. This refers to a finely divided residue resulting from the combustion of ground or powdered coal, used as an admixture for concrete fortifier.

Formwork. This is a temporary construction to contain wet concrete in the required shape while it is casting and setting.

JB9. It is a concrete J-form shape having a width of 9 inches measured in the base of a block with the same length of a standard CHB, the height at smaller side is eight inches and at the bigger side is 12 inches.

Precast. This refers to pouring concrete into a cast of the required shape and allowed to harden before taken out and put into position.

Reinforce. This refers to making something stronger, adding a tensile strength of the concrete.

Steel. This **is a** strong alloy of iron containing up to 1.5 percent carbon along with small amount of other elements such as manganese, chromium, and nickel.

U-block. This is a large solid piece of a hard substance, usually flat sides and in "U" shape used to enclose steel reinforcement to become a reinforced concrete structure.

UB6. This refers to a concrete U-form shape having a width of 6 inches measured in the base of a block with the same height and length of a standard CHB.

UB9. This is a concrete U-form shape having a width of 9 inches measured in the base of a block with the same height and length of a standard CHB.

Scope and Delimitation of the Study

The study is based on the conventional concrete construction method and technique and delimited to the creation of the precast concrete forms for columns and beams of a two storey structure.

METHODOLOGY

The fabrication of the precast concrete forms is the same as in the fabrication of the CHB, using cement. fine aggregates and small amount of water mixed thoroughly before its insertion to steel molder. Tamping of fresh concrete takes place before piling the forms under a shed. Curing of the created forms is done by spraying with water for at least three days after the fabrication.

Technical Description of the Process

1. **Observation.** Actual construction visits to two storey buildings and one storey structure of conventional system using plywood and wood for forms were done to observe the use of the first introduced U-block precast concrete.

2. **Weighing and Computation.** The weighing of the first introduced U-block precast concrete and computation of its volume were undertaken to detennine the basic data for the weight of the proposed concrete forms for beams and columns for a two storey structure.

3. **Design.** The concrete forms to be used for columns and beams for two storey structure were designed taking into consideration their size, location and application. The size of the concrete fonns for column and beam was based on the cross-sectional 200mm x 300mm conventional reinforced concrete beam size for a two storey residential structure, and on the frame thickness of the conventional CHB.

4. Fabrication. Based on the proposed design of the fonns, fabrication of steel molders was done.

5. Concrete Mixture Testing. Cement, fine aggregates and water with the experimental fly ash were mixed to create three precast concrete fonns, UB6, UB9 and JB9, for the columns and beams for a two storey structure. UB6 is for tie beam, UB9 and JB9 are for columns and beams. The concrete mix is 40 kilograms cement, 5 cubic feet fine aggregates and water to create a sticky mix and stronger output. 5 kilograms of fly ash was added to JB9 fonn to let it stand finn during molding.

6. **Production.** The concrete fonns were made from the concrete mix using the fabricated steel molders. Concrete curing was done for three to five days by spraying UB6, UB9 and JB9 with water daily after being removed from the molder. The finished products are the precast UB6, UB9 and JB9 fonns.

7, Compressive Testing. The cured precast concrete forms UB6, UB9 and JB9 were subjected to compressive material testing to determine the maximum load of each specimen from unfilled precast concrete forms to the forms with the ferroconcrete, and to determine the effect of bonding between the precast and the in-situ concrete.

RESULTS AND DISCUSSION

The design of the concrete forms was based on a regular two-storey building columns and beams. These precast concrete forms are moulded with a hole in the centre as shown in Figures 1 and 2, so as to allow the dowel or horizontal reinforcing bars of the wall to be attached to the reinforced concrete column. The hole will also serve as a key-lock of the precast form block to the ferroconcrete.

Figure I
Full **View** of the Created Precast Concrete Forms

Figure 2
Back View of the Created Precast Concrete Fonns

Multiple sizes and different column locations such as comer, mid and end columns were derived from composite forms of J and U as shown in Figure 3, and their application to floor beams to support the suspended slab (See Figure 4). Individual sizes and measurements are shown in Table 3 below.

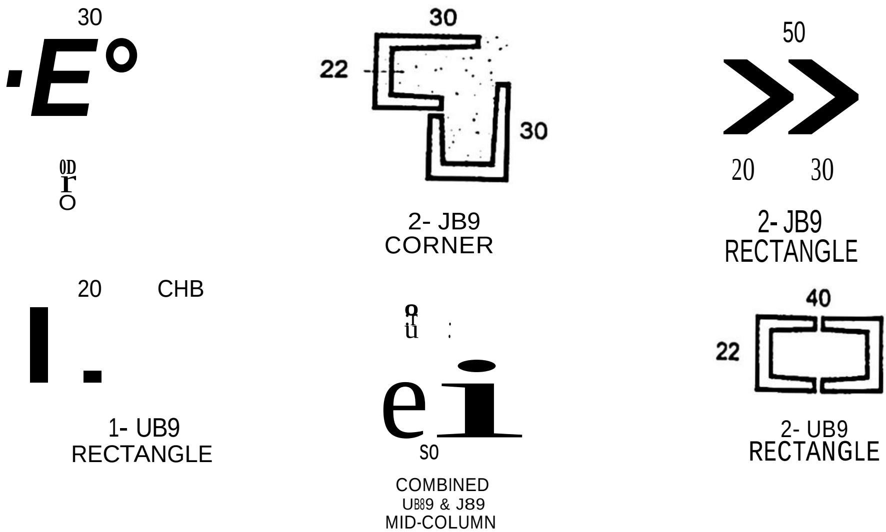

Figure 3
Derivation of the Different Sizes of Columns from the Designed Concrete Forms

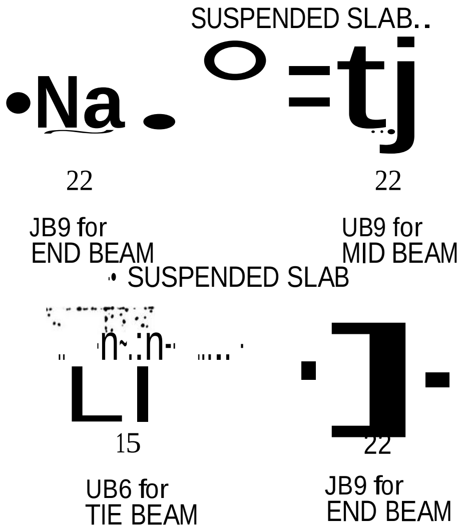

Figure 4

Pre-cast Concrete Forms for **Suspended Slab**

Table 3. Compressive Test Results Taken From BIP Geotechnical and Materials Testing Engineers-Baguio City

ONC. FORMS	WT (kgs)	PRE-CAST FORMS MIXTURE CONTENT	Age before Comp. Testing (Days)	·COMPRESSIVE STRESS (MPa) w/Conc. Filler @Average Net Area(sq.mm)	MEASUREMENTS OF PRE-CAST FORMS (Centimeter)	FEATURE
UB6	10.25	1- Bag P.Cement 5-Cu.FL Chalker, (Without Fly ash)	12	s.nMpa @60,900 mm2	g 15 10 9	
JB9	16.6	1-Bag P.Cement 5-Cu. FL Chalker, (5-Kgs. Fly ash)	12	7.42 Mpa @91,027 mm2	22 16 29 5 10 19 14	
UB9	15.95	1- Bag P.Cement 5-Cu. FL Chalker, (Without Fly ash)	12	10.11Ma @89,910 mm2	g 22 15 LJ 5 14	

Concrete forms UB6 and UB9 formed well with wet concrete mix of plain cement, fine aggregates and water but the JB9 could not be formed properly with wet concrete. To stabilize it during moulding, 5 kilograms of fly ash were mixed in a 40 kilograms of cement, 5 cubic feet of fine aggregates and water to create a sticky mix and stronger output

The weight of UB6, UB9 and JB9 were lighter as expected because of the effect of small amount of water and the use of chalker/fine aggregates. The weight at 1,870 kilograms per cubic meter or equivalent to 22 percent reduction from the well compacted concrete was observed. The weight result of the concrete fonns is shown in Table 3.

The precast fonns were taken to BIP Geotechnical Services in Baguio City for testing to determine their compressive strengths as shown in Table 3. The specimens were the UB6, UB9 and JB9, which were all filled with concrete. When the specimens were subjected to maximum load during the compressive test, the cracks appeared on the inserted concrete but not along the joints. Minimal cracks also appeared on the joints between the precast fonns and the ferroconcrete. The textured surface of the block due to the nature of the aggregates was an advantage which gave a firmer and greater bonding between the precast forms and the concrete filling. The result is shown in Figure 3 below.

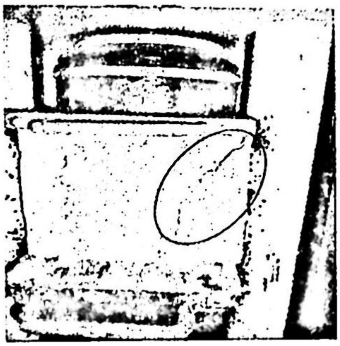

Figure3
A Material Testing Result Showing the Direction of Crack Created at Maximum Compressive Load

CONCLUSIONS

The cured precast fonns had a textured surface that made it ideal to bond with the inserted concrete *(in-situ* concrete) forming a composite structure with the reinforcement inside and at the same time acting as additional concrete cover of the column and beam reinforcements.

The reinforcing bar assembled in-place for column is to be enclosed by these precast concrete forms with continuous pouring of concrete in order to become a monolithic structure. The concrete fonn already served as concrete cover of the rebar.

RECOMMENDATIONS

The structural engineer will design the reinforcement for the two-storey structure to integrate with the strength and thickness of the precast concrete form and investigate the safety of the application. The maximum height of columns and length of beams will be analyzed to design the correct number and sizes of the reinforcing bars.

The mixtures of concrete for the precast forms used in this study should be further studied to provide other solutions to increase the strength of the bare block forms. The use of admixtures as fortifier for the concrete mix to create the precast forms is also recommended.

A further study can also be made to determine the number of blocks produced per one bag of cement each for UB6, UB9 and JB9 from an approved concrete mix.

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