Development of A Method for Casting Formworks Using Small Size Precast Concrete Panels for Resource Saving And Durability

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SUMMARY:
Mamoru Nakamura(1890-1933) was an architect who was active in the early 1900s in Japan. He devised a new construction method which is known as "Nakamura's system for reinforced concrete block construction (hereafter, referred to as NRC)."

His method has shown excellent seismic performance. In Japan, many great earthquakes have occurred in the past 100 years. But no buildings built based on his method have suffered any damages. It is also worth noting its high seismic performance.

We report on our development of the method for casting formworks using small size precast concrete panels (hereafter, referred to as PCa panels) achieving resource saving and durability.

Keywords: Buildings, Concrete, Casting Formwork, Resource Saving, Durability

1. INTRODUCTION

NRC is a type of masonry construction which is used as an L-shaped concrete block formwork devised by Mamoru Nakamura. He is an architect who was active in the 1920s which were the dawn of the reinforced concrete method in Japan. **Figure 1.** shows units of NRC and a wall structural drawing. The most distinctive feature of the method is its economic efficiency. This method constructs simplify by using L-shaped concrete block formworks. A reason for this is that wood formworks are hardly used and use of material such as concrete is reduced. He realized the total construction costs of about 2/3 of the reinforced concrete total construction cost of those days by the method.

In addition to this, the method has excellent seismic performance, durability and functionality. When Hyogoken-Nanbu Earthquake (M7.3), Fukuoka-ken Seiho-oki Earthquake (M7.0) and the Pacific coast of Tohoku Earthquake (M9.0) happened, the NRC buildings suffered very slight damage but other buildings in the area suffered serious damage. In this way, the NRC buildings

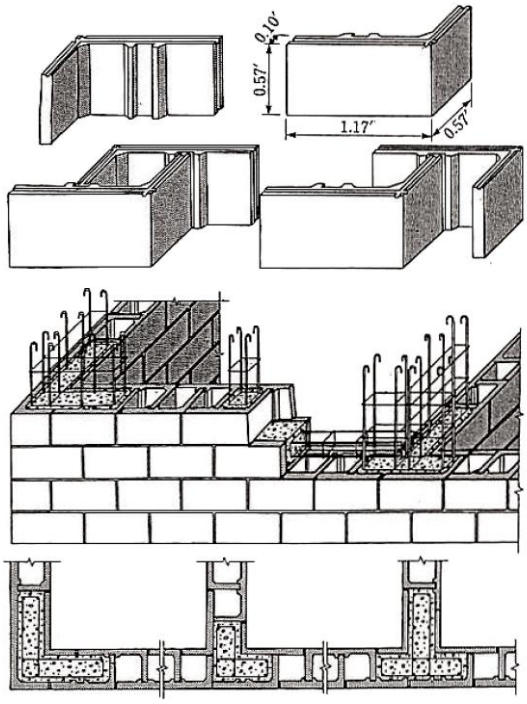


Figure 1. The unit form and a wall construction drawing of NRC

overcame many disasters and they exist currently throughout Japan. Nakamura's idea of the construction material manufacturing technique aimed at supply with low cost and the city construction with functionality and durability, and it should be inherited to the present. These days, a rising concern over global environmental problems and efficient formation of the sustainable social system without futility with limited resources are called on. In addition to improvement in durability, the technology which enables effective use and energy saving of industrial by-products is also needed for the concrete building. Therefore, in order to form a future superior housing stock, development of the method which makes possible resource saving and a "long-lived" building is desired. And for the spread of the method, it must excel in productivity and economy.

In this paper, additional advantages of NRC are also developed and PCa panels are also developed aiming at resource saving and "long-lived" building.

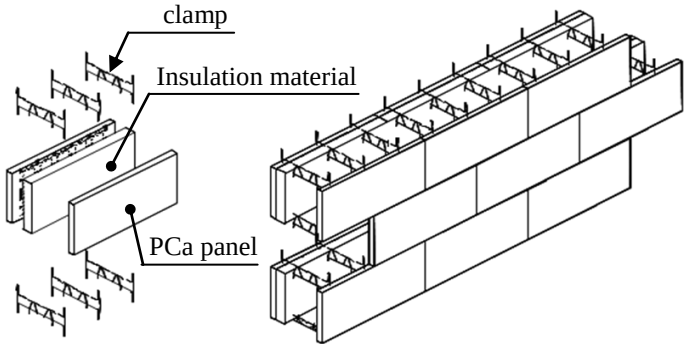
2. OUTLINE OF A METHOD

PCa panels are used as a formwork material of the foundation, the wall, and floor slab. (Form of a PCa panel: 598mm in length, 298mm in height, 33mm in thickness, and about 10kg in weight)
It is possible for PCa panels to become a structure member and to also become finished material. In addition, this method handles reinforced concrete boxed wall-buildings structure and not masonry structure.

2.1. Wall

A wall is constituted using PCa panels, insulation and clamps, as shown in **Photograph 1.** An outdoors which is an outer wall consists of PCa panels and insulation, an indoors consists of only PCa panels, and vented air space is formed between insulation of the outdoors PCa panels. The wall assembled to the state before concrete placement is shown in **Figure 2.** and **Photograph 2.** After placing reinforcement, an assembly procedure paste up the PCa panels by joint mixture, and to fix a steel rod with clamps hardware. Thermal insulation is then installed in the PCa panels of the outer wall. When concrete is placed in the formwork, the external heat insulation thermal storage construction method with an aeration layer of the outer wall of a building will become possible at the time of building frame construction.

Photograph 1. Composition member



(a)Composition member (b)Assembly situation

Figure 2. Composition of a wall

Photograph 2. Composition of a wall

2.2. Floor slab

We state that the variability of interior space is easy in addition to the durability of structure to use a long-lived building. Moreover, the charge of a flooring material which can realize space without a beam is desirable. The construction performance of a structure also improves that way. The assembly of a panel is shown in **Figure 3.** The composition of floor slab is shown in **Figure 4.** PCa panels is first unified by steel strand. And concrete is placed, after attaching reinforcing bar and fixing. The large interior which serves as T-shaped slab in which the section of floor slab continued, and does not have a beam becomes possible.

One of the manufacture methods is setting to laminated panels by a factory or construction site, as shown in **Figure 5.** Another method does not unify, and assembles joist material at a 60cm interval at the time of temporary construction, it constructs one PCa panel at a time, and this is the method of fixing reinforcing bar and void material in a spacer for exclusive use. Therefore, there is an advantage of choosing the method of assembling fitting construction conditions.

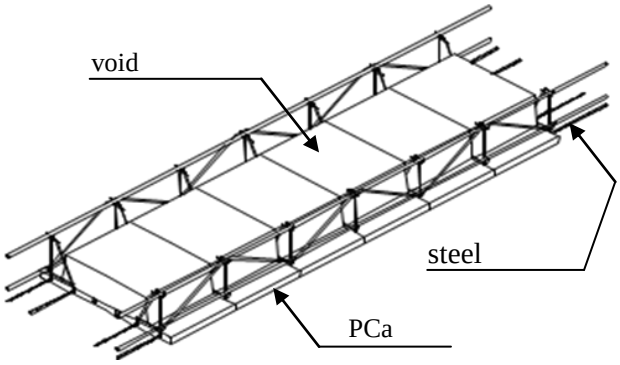


Figure 3. Assembly of a panel

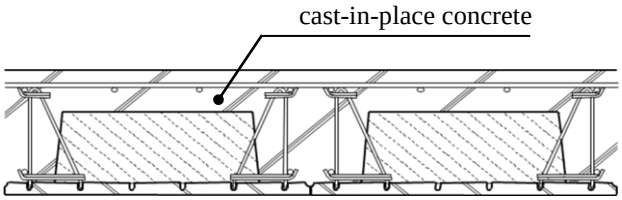


Figure 4. composition of floor slab

assembly method		site	assembly image
1	setting to laminated panels	factory	pressure shaping of PCa panels; setting to laminated panels
2		construction site	stock; setting to laminated panels by construction site
3	non setting to laminated panels		temporary work; Laying of PCa panels; Installation of void material

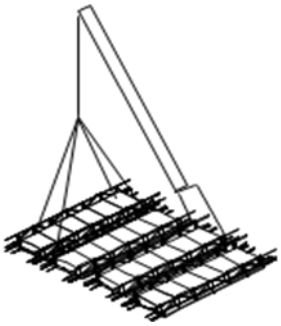


Figure 5. The manufacture image of laminated PCa panel

2.3. Roof slab

We aim at the roof gardening method which uses effectively as greening base material. Therefore, in a general waterproofing layer, maintenance, repair become difficult. Thus, we thought and the concrete itself was watertight and what is necessary was just to be able to have a waterproofing function. Roof slab is prepared with the concrete which controls a crack using super plasticizer (non air-entranining type) and steel fibers without preparing an organic matter waterproof layer as shown in **Figure 6.** Furthermore, silicicolous waterproofing admixture is applied after carrying out concrete placing. The material is excellent in durability with minerals, and it can be constructed simultaneously with concrete placing, and we can expect a self-repair function of a crack also at the time of structure crack generating after placing.

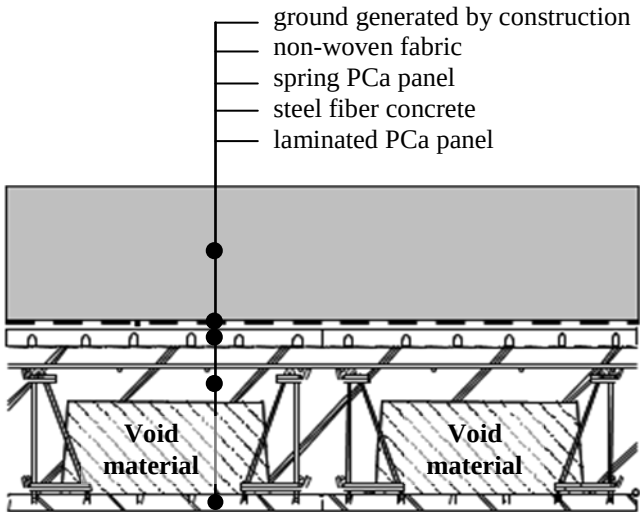


Figure 6. Green roof method

3. CHARACTERISTICS ON MATERIALS

3.1. PCa panels

PCa panels is a concrete product which uses blast furnace slag which is industrial by-product with planned densification. Polyvinyl fiber is mixed in order to improve its flexural rigidity. The molding method is pressure shaping by a compacting machine of 2000kN. The manufacture situation of PCa panels by compacting machine is shown in **Photograph 3.** PCa panels become precise concrete whose water-cement ratio is about 30%, when it pressure shaping is carried out. It becomes a high charge of exterior material of weatherability which controls neutralization and does not receive water with minerals. Moreover, since PCa panels have very little temperature changes, cracks which occur from thermal expansion and drying shrinkage by solar radiation do not show up easily. In addition, PCa panels are modularized and easy to systematize. It is effective also in the member order, production, and supply by computer aid, and is excellent in productivity.

Photograph 3. The manufacture situation of PCa panels by compacting machine

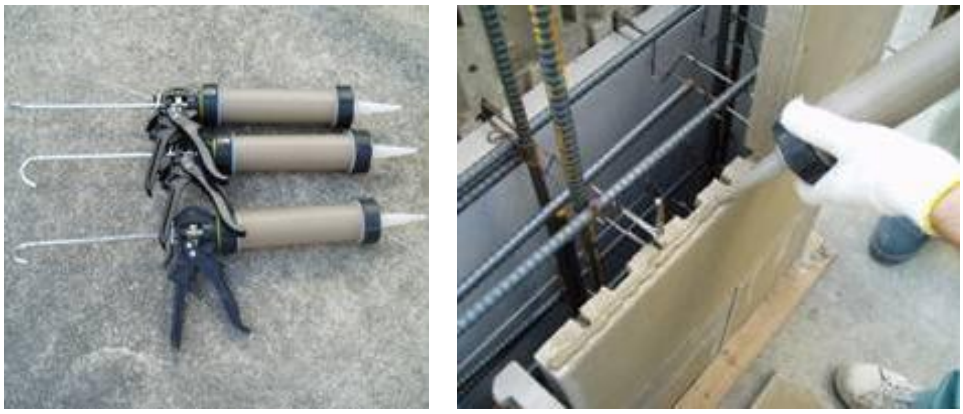
3.2. Clamps

This method uses clamps shown in **Photograph 4.** as form tie for making PCa panels unified. The functions required for this clamp are maintenance of the form over side pressure when placing concrete, and fixation of PCa panels. Then, the material is made into the product from stainless steel excellent in anticorrosion. The production method is made into a unified one, where the manufacture apparatus is used to process it at once by the rod of press processing and the central part bending the plate of both ends. The production according to the required size between an outside panel and an inner side panel is possible with this method.

Photograph 4. Automatic processing machine and clamps

3.3. Joint mixture

For adhesion of an upper part panel and a bottom panel, we use joint mixture for exclusive use and the tool which are shown in **Photograph 5.** We use granulated blast furnace slag aggregate which has improved form of aggregate for this joint mixture. We added waterproofing agent and water retention agent to slaked lime and blast furnace slag fine powder, which lessens the amount of addition of cement as much as possible by intensity revelation by latent hydraulicity of blast furnace slag fine powder. As a result, the work of time to knead and place joint mixture is attained in 3 hours. And since all aggregate is granulated blast furnace slag, there are very few worries about alkali-aggregate reaction.



Photograph 5. Dedicated tool and conducting

3.4. Placing concrete

The kind of cement of the concrete to place uses Portland blast furnace slag cement or fly-ash. The strong revelation of normal Portland cement is slower than Portland blast furnace slag cement, and especially early curing of winter is serious. And in a wet condition, the surface of concrete colors blue under the influence of trace sulfides contained in blast furnace slag, and it spoils aesthetic. Since concrete is placed between the PCa panels which embedded thermal insulating material outside, the problems are solvable by not exposing outside and curing performance. The concrete to place serves as low alkali by use of Portland blast furnace slag cement which utilized industrial by-product. Furthermore, the aggregate which produces alkali-aggregate reaction can also be used as concrete resources because there is no invasion of rain water and the exterior insulation finish system with vented air space maintains a dry state at the times of good aggregate resources exhausted.

4. THE HEAT INSULATING PERFORMANCE TEST

4.1. Test outline

In order to check the effect of heat storage performance of this method, the temperature change was measured using the experiment building. The experiment building was constructed in 2005. The measurement of temperature change is made during three days of each of summer (August 7-10, 2006) and winter (December 4-7, 2006). The temperature measurement positions are shown in **Figure 7.** They are on the wall of the experiment building on the south (GL+1200mm), and the number of the points of measurement is five. (①: surface of external walls, ②: between PCa panel and insulation material, ③: between insulation material and concrete, ④: center of concrete, ⑤: surface of inside walls)

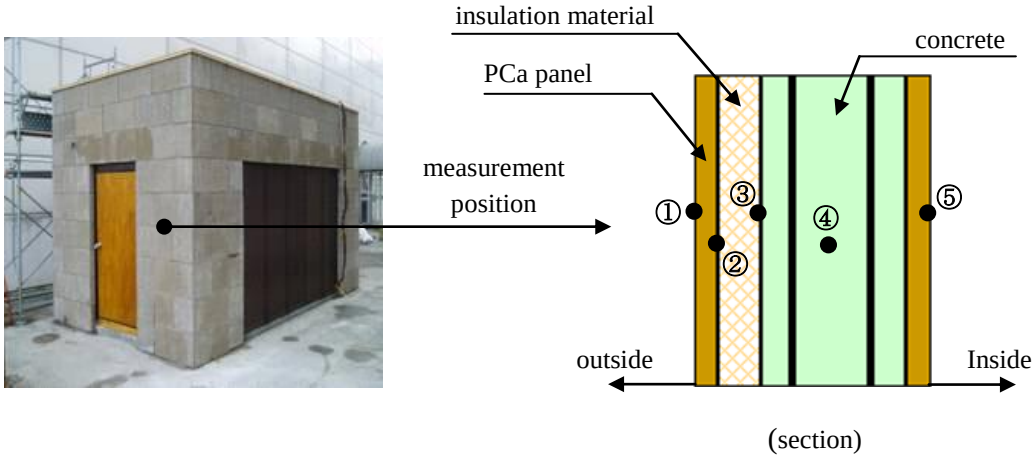


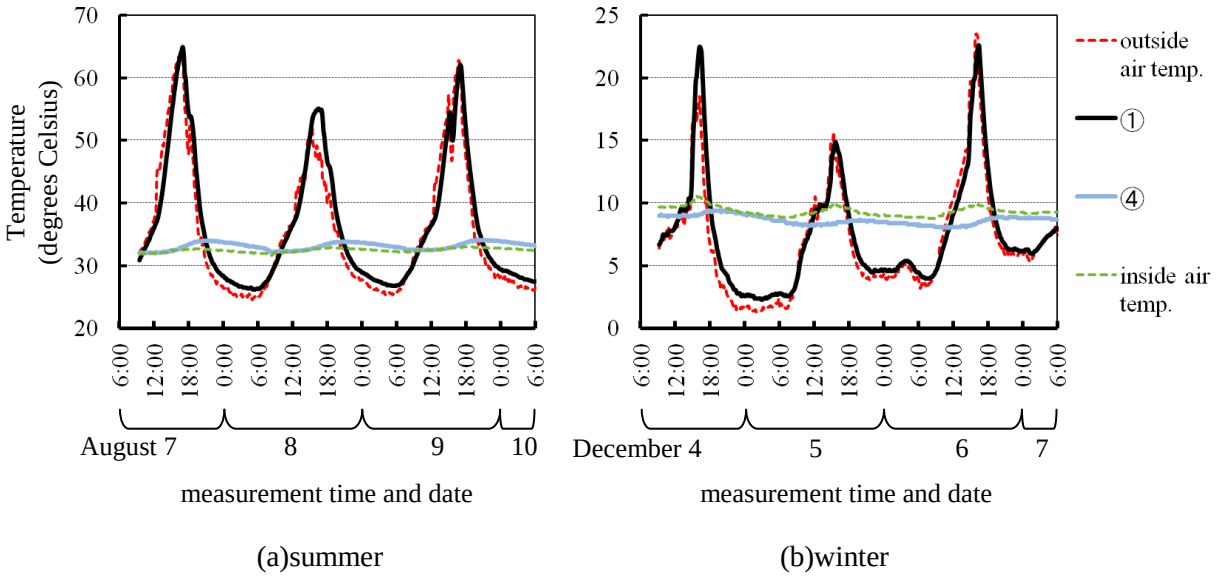
Figure 7. Temperature measurement positions

4.2. Test results

Each highest temperature and lowest temperature are shown in **Table 1.** The temperature change of four points in each summer and winter is shown in **Figure 8.** Although the temperature difference was 38.7 degrees in summer on surface of external walls, the inside the room the difference was 1.3 degrees. On the other hand, although the temperature difference was 20.3 degrees in winter on surface of external walls, the difference inside the room was 1.8 degrees. This shows that the temperature change inside the room by this method of structure are very moderate in both summer and winter.

Table 1. Highest temperature and lowest temperature (in degrees Celsius)

Measurement position	summer			winter		
	maximum	minimum	difference	maximum	minimum	difference
outside air temp.	63.6	24.6	39.0	23.5	1.3	22.2
①	64.9	26.2	38.7	22.6	2.3	20.3
④	34.0	32.1	1.9	9.4	8.0	1.4
inside air temp.	33.0	31.7	1.3	10.6	8.8	1.8



(a)summer (b)winter

Figure 8. The temperature change of four points in summer and winter

5. EXPECTED EFFECTS THIS METHOD

Substantial improvements expected with this method are described below.

5.1. "Long-lived" of the building

- Extension of "long-lived" of the building by improvement in the durability of the concrete protected by exterior insulation and PCa panels.
- Realization of high durability by control of alkali-aggregate reaction and the concrete densification by practical use of portland blast furnace slag cement.
- Realization of the changeability of the interior member by realization of interior space with no beam.

5.2. Reducing the effects on the environment

- Protection of the tropical rain forests by replacing plywood panel for concrete form and using PCa panels, and realization of resource saving.
- Activation of healthy indoor environment and domestic forestry is realized by making positive use of timber from forest thinning for interior member.
- The exterior insulation finish system serves as a heat reservoir and carries out drastic reduction of cooling and heating loads.
- Insulation performance is improved by the green roof.

5.3. Cost reduction

- It is a simple method which is modularized and is easy to systematize, and construction by a small number of people is possible.
- Since formwork supporting is reducible to a limit, low cost is realizable.
- Improvement in productivity is easy by training specialized builders.

5.4. Running-cost reduction

- It is maintenance-free by using PCa panels with high weatherability.
- The maintenance-free roof slab method constituted of mineral materials.

6. CONCLUSION

PCa panels method has seismic performance, durability, and resource saving, and can be used simply. However, for wide spread use of this method we need collective specialized builder training programs.

A residence using this method of structure was built in Tokyo, and there was no damage caused by Pacific coast of Tohoku Earthquake on March 11, 2011.

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