Improvement of surface quality of concrete structures by unique formwork

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Meilleure qualité de surface du béton avec une nouvelle méthode de coffrage

Verbesserung der Oberflächenbeschaffenheit von Betonbauteilen mit einer neuartigen Schalung

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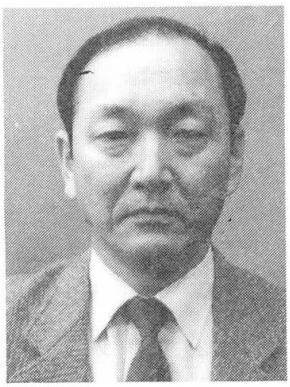

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SUMMARY

This paper outlines a unique method of permeable formwork developed for the purpose of improving surface quality of concrete structures. The major contents of the paper relate to the materials used for the permeable form, the composition of the form, the mechanism of bleeding excess water from the form, the test data of improvement of surface quality and durability, the economy of the method and several construction examples.

RÉSUMÉ

Cette contribution présente une nouvelle méthode de coffrage permettant d'améliorer la qualité des surfaces des ouvrages de béton. Elle traite des matériaux utilisés pour la réalisation des coffrages, de la composition des coffrages, du mécanisme de drainage de l'excès d'eau à partir du coffrage, des données d'essai concer nant l'amélioration grâce à l'utilisation des coffrages perméables pour les surfaces des ouvrages en béton et pour leur résistance . Elle présente aussi l'économie que cette méthode de réalisation apporte ainsi que quelques exemples de construction.

ZUSAMMENFASSUNG

Der Beitrag behandelt in grossen Zügen einen neuen Schalungtyp, welcher hinsichtlich eine Verbesserung der Betonoberfläche entwickelt wurde. Es werden vor allem die verwendeten Materialien, welche für diesen durchlässigen Schalungstyp verwendet werden, behandelt, wie auch der Schalungsaufbau und das Entwässerungssystem in der Schalung für die Ableitung des überschüssigen Wassers. Einige Versuchsergebnisse, die Wirtschaftlichkeit dieser Schalungsart und einige Ausführungsbeispiele werden besprochen.

1. INTRODUCTION

In Japan, four years ago, major mass communication reported the fact that many kinds of reinforced concrete structures began to deteriorate beyond expectations. Since then the general public take a growing interest in durability of concrete.

Now that the authors and others notice the feature that many of deterioration phenomena of reinforced concrete structures are prone to happen on the surfaces of the structures, we could conduct researches in improving surface quality of concrete structures, resulting in developing new form method entitled "Textile Form Method".

The principle of the method is that using a unique permeable form, immediately after fresh concrete is placed in the form, excess water is bled naturally out of it, thereby producing concrete having higher density toward the surface with smooth and beautiful one.

The conception which eliminates excess water from fresh concrete on purpose to improve the quality of concrete is not novel. Considerably previous to the development of this method, three following systems have been developed with similar view.

a) Using the form on which the sheet having considerable absorption has stuck;
b) Using airtight mat with vacuum pump;
c) Adding mechanical pressure to fresh concrete in a form;

Though the Textile Form Method is not above the said methods b) and c) in drainage performance, the Textile Form Method gains the following advantages being as good as the aforesaid methods a), b) and c) :-

(1) the effect of improving the quality of concrete surface is practically too much;
(2) this method is simply applicable to in-situ concrete work due to no need of any supplementary equipments, which are used for forcing a drainage.
(3) this method is not influenced by weather like a); and
(4) permeable form developed is economical because of the possibility of use from five to ten times.

Therefore, putting the Textile Form Method to practical use in 1985, it is adopted to a wide range of concrete form works.

2. MATERIALS AND COMPOSITION OF PERMEABLE FORM

2.1 Basal conditions on permeable form

The permeable form used for improving the quality of concrete surface needs to meet the following basal conditions :-

(1) the form has high aeration efficiency and permeability;
(2) the form scarcely allows cement particles to pass through;
(3) there gains smooth and beautiful concrete surface.

Moreover, for the purpose of practical use, the following economical conditions are added :-

(4) material cost and manufacturing cost to compose the form are reasonably low;
(5) the form can be used repeatedly and frequently.

2.2 Materials to compose permeable form

2.2.1 Double woven cloth for filtration and drainage

The authors and others developed the newly conceptual double woven cloth

Fiber material	Polyester & Polypropylene
Textile	Double woven cloth
Thickness	0.74 mm
Weight	440 g/m^2
Coefficient of permeability	9.5×10^{-3} cm/sec
Tensile strength	Lengthwise : 303 kg/3cm width Breadthwise: 335 kg/3cm width

Table 1 Character of double woven cloth

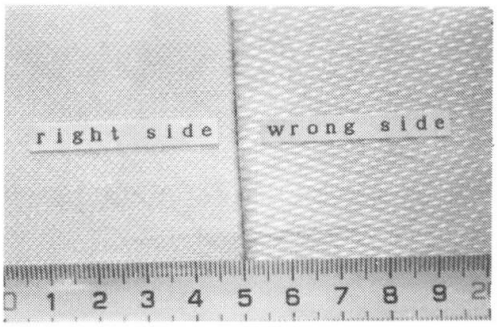

Fig. 1 Texture of double woven cloth

suitable for the permeable form as a filter material.

The character of developed cloth is shown in Table 1 and the textures of the cloth is shown in Fig.1. There is the difference between the texture of the right side and that of the wrong side of the cloth, and the right side of the cloth is used to be the concrete placing side, and the wrong side the side of form panel. The difference of both sides of the cloth implies that each of requested function also differs. Namely as for the right side, firstly the function of the filter which is pervious to water and air, but hardly to cement particles is requested, and secondly the cloth has simply to be removed from settled concrete surface. For these two reasons the closed weave is adopted to the right side of the cloth. But as for the wrong side, the open weave is adopted since fine space is maintained between panels, in order to allow water and air to be passed through.

Besides, as fiber used for this cloth, synthetic fiber such as polyester and polypropylene, which have strong chemical resistances, high strength, modulus of elasticity, small suction and which is low cost, are suitable.

2.2.2 Form panel with numerous tiny holes

To maintain air and water passed through laid cloth in the space between the cloth and the form panel is undesirable for two reasons. One reason is that in order to maintain a sufficient space in which such excess water and air are being kept after passing through the laid cloth, either much thicker cloth may be necessary, probably more than 3 mm in thickness, or some porous and flat material are required to be put into the space between the cloth and the form panel, and this results reasonably in the raise of form cost. Another reason is that internal water pressure is requested as low as possible as to the form side in order to move excess water in fresh concrete to form side.

In the developed permeable form, therefore, the form panel has many fine drilled holes or punched holes as the treatment of bleeding the air and water out of the form smoothly after passing through the cloth.
According to numerous concrete placing test results, the following values concerning these hole diameters and intervals are recommended :-

a) hole diameter is more than 3mm
b) hole interval is less than 100mm

2.3 Composition of permeable form

Appearance and sectional detail of an example of developed permeable forms are shown in Figures 2 and 3. This is that a plywood is used as a form panel, but in actual work the panel such as steel,

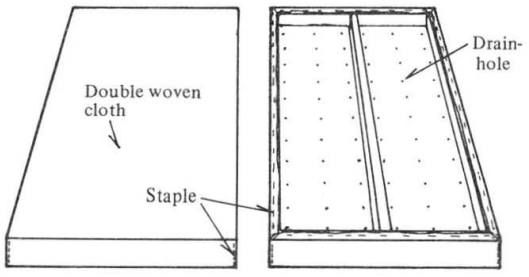

Fig. 2 Permeable form

aluminum and plastic is used instead of it.

Main considerations of production of permeable form are listed as follows :-

(1) heat cutter is used to cut the cloth on a plate of glass
(2) where the cloth is fixed on form panel with numerous tiny holes, the work is done while giving tension to the cloth to some extent so as not to wrinkle.
(3) Fixating the cloth to the panel on the portion that the cloth is folded back in the surroundings of the panel. In the case of wooden panel, stapler is used, and in case of metal panel, adhesive agent is used to set it. And besides, attention should be paid to the fact that if adhesive agent is applied to the cloth of the portion adjacent to placed concrete, the permeability becomes remarkably low.

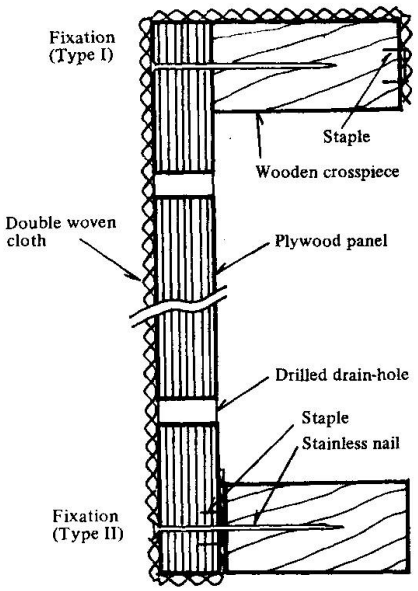

Fig. 3 Cross section of permeable form

3. MECHANISM OF BLEEDING EXCESS WATER OUT FROM PERMEABLE FORM

When concrete is placed in fabricated forms, high pore water pressure comes about in the concrete in proportion to its depth. When conventional watertight form is used, pore water pressure in a horizontal plane having a voluntary depth is fixed in any parts, thereby the lateral movement of pore water does not occur. But when the permeable form is used, the more the pore water pressure comes near the form, the more the pressure lowers due to the natural drainage from the form. As a result, pore water in the concrete moves from the high pressure inside, which is far off from the form, to a low pressure form side. Movable water in the concrete in the latter case may be thought an unnecessary excess water against long-term hydration.

The movement and drainage of the very excess water do play the most important role in improving the quality of concrete surface using permeable form.

4. FUNCTION OF PERMEABLE FORM

4.1 Permeability

The relation between water volume, which is bled from the same kind of permeable form used for form work of five different types of concrete structures, and the time elapsed is shown in Fig.4. Depending on the type of structures, the difference in drainage speed is recognized, but the difference in final water displacement per unit area lessens.

Ordinary Portland cement is used for all of these structures, while it is reported that a water displacement became more than 5l/m2 in massive concrete structures when later setting time cement was used [1].

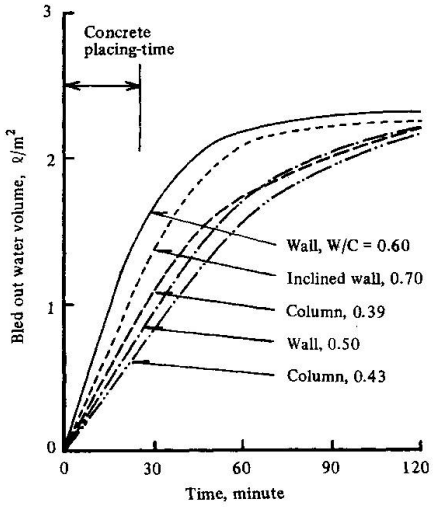

Fig. 4 Water volume bled out from permeable form

4.2 Improvement of surface quality of concrete structures

4.2.1 Appearance of concrete surfaces

Compared with concrete surface used conventional plywood form, where permeable form was used, the happenings of air bubbles and blow holes have remarkably been reduced and the concrete surface becomes smooth, evenly colored and beautiful due to natural bleeding of excess water and entrapped air in fresh concrete from the form. Especially in the surface of inclined concrete structures, such effect is highly noticeable (Fig.5).

4.2.2 Concrete surface strength

Schmidt hammer test result of wall and column, which are constructed by both permeable form and plywood form using the same concrete, is shown in Fig.6. Surface strength of concrete improves remarkably by using permeable form. And it is proven that the surface concrete from which excess water has been bled clearly high strength development as potential.

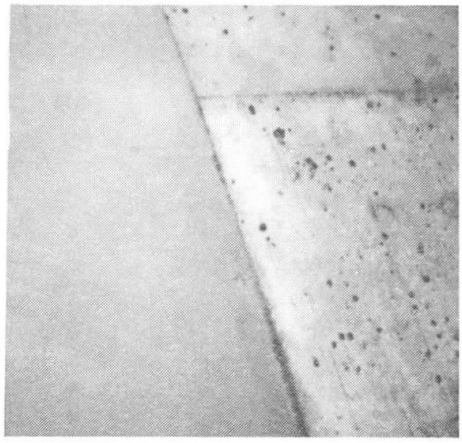

Fig. 5 Slope concrete surface of a dome constructed by permeable form (left) and plywood form (right)

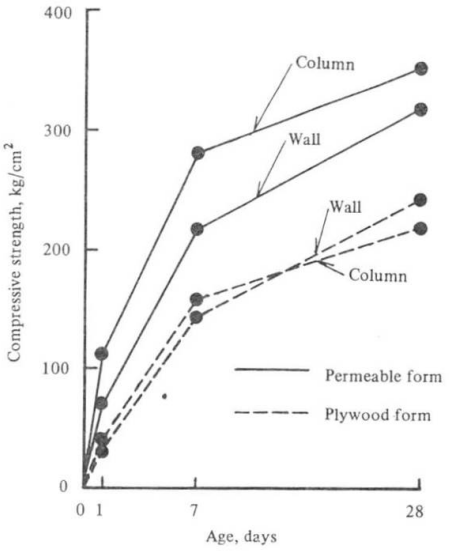

Fig. 6 Comparison of is Schmidt hammer test results

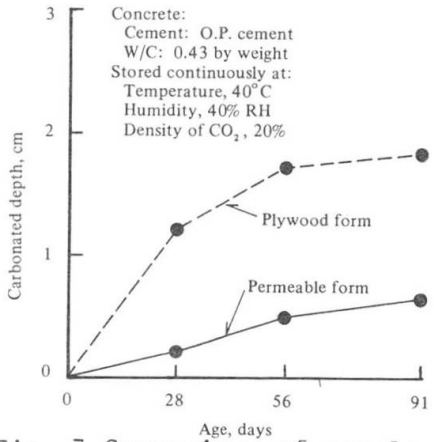

Fig. 7 Comparison of accelerated carbonation test results

4.3 Improvement of durable quality of concrete structure

Generally it is difficult for the peculiar durability of concrete structure to be valued absolutely, since it is influenced by concrete-making materials, construction accuracy, use conditions of structure, environmental conditions and so forth.

The authors and others announced the comparative durability test result of concrete cores, which are taken from simulated members of two massive walls using the developed permeable form and conventional plywood form at Annual Meeting of AIJ last year[1]. According to it, test items consist of accelerated carbonation test, freezing and thawing resistance test, salt penetration test and permeability test and so on. Putting all of these test results together, it confirmed that in case of concrete using permeable form the durable quality improves more than 50 percent as to the valuation of durable quality, as compared with that of conventional plywood form.

Apart from these tests, comparative accelerated carbonation test result of concrete cores, which are taken from simulated members of column is shown in Fig.7. Even in this test result the effect of high improvement of concrete quality was also demonstrated.

5. VALUATION ON THE ECONOMICAL ASPECTS

Initial cost of the developed permeable form is about 4.5 times conventional plywood form in Japan. The breakdown of initial cost is that laying cloth is about 45 percent, panel 25

percent, drilling cost 11 percent and installation cost of cloth approximately 22 percent. Advancing the standardization and mass production in the future, there is a prospect of cutting the cost by about 3.5 times that of plywood form.

But comparison in itself of conventional form with this one having essentially special function in an aspect of initial cost is a problem.

Reasonable valuation of economic value of permeable form differs in that its usage, namely to what extent the function peculiar to this form which can improve many kinds of the qualities of concrete is able to make the most of as to an actual structure.

6. APPLICATION OF PERMEABLE FORM METHOD

6.1 Construction examples

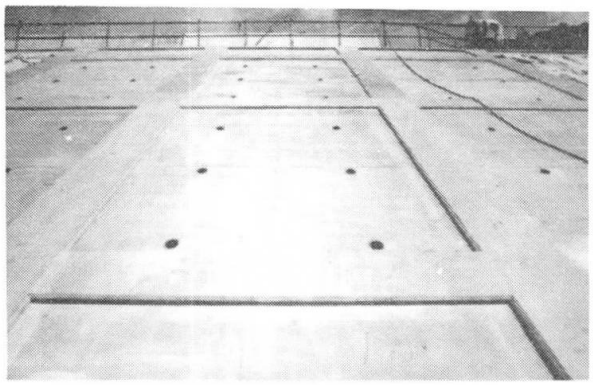

Fig. 8 Inclined retaining wall of Aseishigawa dam (Aomori pref.) [2]

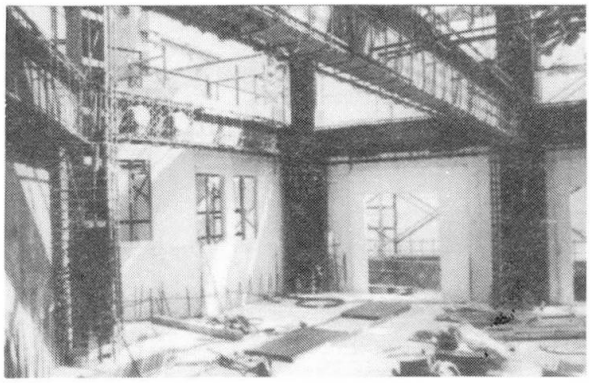

Fig. 9 External wall formwork of Ichikawa Heights bldg. (Chiba pref.)

6.2 Range of application

There are 135 construction works to which the permeable form method has been applied during the past two years.

This method has an easy application to an extensive concrete works because of its very simplicity. But the method is thought advantageous in particular to the following concrete structures considering the said performances of works:-

a) structures having slopes such as dam, retaining wall, pier, roof, and the like;
b) structure requiring high durabilities such as nuclear power plant building facilities, military facilities, huge buildings, and the like;
c) marine structures such as breakwater, sea wall, bridge, waterway, marine facilities and the like;
d) precasted concrete members having complicated shapes such as blocks used for weakening wave strength, tetrapods and the like.

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