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Durability Quality Research of Concrete Containing Solar PV Cells

Sao-Jeng Chao [1], An Cheng [1], Hui-Mi Hsu [1, a], Jia-Ruey Chang [2], Li-Wei Teng [3], Sung-Ching Chen [3]

[1] Dept. of Civil Engineering, National Ilan University, Yilan 260, Taiwan
[2] Center for Sustainable Development, National Ilan University, Yilan 260, Taiwan
[3] Dept. of Harbor and River Engineering, National Taiwan Ocean University, Keelung 202, Taiwan

Abstract. In this article we demonstrated the study results of durability quality of concrete containing waste solar PV cells. The study used alkali activator to improve the activity of alkali-activated materials in solar PV cells so as to replace Portland cement as binder in concrete. By using sodium hydroxide as an alkali-activator, a high-pH environment is generated to excite the binding characteristics of alkali-activated materials in solar PV cells, and thus develops better durability of the mixes. The conclusions were made on effect of this cement replacement. As a result, we identified the durability for those of 16 concrete specimens predefined and made to consider various possible control factors. The conclusions also depicted that all experiments but the drying shrinkage may be helpful with the suitable use of control factors as far as concerning the recycled solar PV cells for mixing in concrete. In other words, the durability quality of concrete may be partially unacceptable of containing solar PV cells.

1 Introduction

Due to environmental and chemical factors, concrete structures undergo a number of degradation processes during their life cycles [1-3]. Hence, how to reduce the degradation of concrete has become a key issue to ensure effective concrete durability. Alkali-activation of slag, fly ash and other alumino-silicate materials have been intensively investigated during the last decades [4-6]. In comparison with conventional Portland cement-based composites these materials offer excellent durability in chemically aggressive environment, high compressive strength, lower basic creep, or environmental benefits. The objective of this paper aims at the properties of alkali-activated materials in solar PV cells. For a standard solar PV panel, the core components are all recyclable: silicon, aluminum, silver and glass. These materials comprise over 90% of the weight of a standard solar PV panel. It was the major interest of solar cells, not those extruded aluminum frames and glass. Therefore, the solar recycling process has been focused on the solar cells, comprised primarily of silicon, aluminum and silver.

In previous studies [7, 8], we had demonstrated the study results of durability quality of cement mortars blended with waste solar PV cells. The use of ground solar cells on the mechanical properties and durability of cement mortar has been investigated. The mortar mix with two different values of w/c ratio had been obtained and reported. In order to consider w/c effect, both w/c ratio values had been used respectively in all experiments for the previous case of cement mortar. A large w/c ratio of 0.55 had been set for high permeability and on the other side, low-permeability cement mortar with a lower w/c ratio, 0.35. As shown in the result, for both concerns of strength and durability, the performance caused by the two different w/c values had been observed as expected. In next step as indicated in this study, a large w/c ratio of 0.55 was set for the concrete stage of experiments since high permeability or more capillary pores may take a better observation on the experimental results.

2 The PV components

For a standard solar PV cell, chemically analyzing the ground powder on its components, it revealed those of compounds, in which the maximum one is silicon dioxide (silica), 75.9%. Meanwhile, toxicity characteristic leaching procedure (TCLP) employed as an analytical method to find toxic chemicals in the powder indicated no most commonly used heavy metals.

3 Test specimens

16 test specimens were made in a lab. Each specimen, except for the control specimen OPC, was denoted by a series of characters and numbers in a row, in which the first two characters NA represent Sodium Hydroxide (NaOH); the following number (0, 1, 3, 5) represents concentration (0, 3, 9, 15 % weight) of NaOH; character B represents a water-cement ratio of 0.55; the next character A (B) represents a No. 200 (325) sieve, the last number represents amount of replaced cement in terms of weight, either 10% or 20%. Taking NA5BB20 as an example, it represents a test specimen made as 20% of

[a] Corresponding author: hmhsu@niu.edu.tw

the cement which is replaced with sieve# 325 ground PV powders in 15 % weight of NaOH solution.

4 Drying shrinkage

Drying shrinkage is dependent upon several factors, including the properties of the components, proportions of the components, mixing manner, amount of moisture while curing, dry environment, and member size. Concrete cured will undergo some volumetric change and it happens mostly because of the reduction of capillary water by evaporation and the water in the cement paste.

As shown in Table 1, the shrinkage potential of OPC specimen is the lowest one comparing to all 16 test specimens. Since the water-cement ratio of 0.55 was fixed in the tests, the amounts of replaced cement and admixtures used during mixing suppose to have indirect effects on drying shrinkage of concrete. In other words, the severity of this shrinkage directly depends on the physical properties of concrete containing ground solar PV cells. It could be concluded that the use of concrete containing solar PV cells should not be helpful as far as the drying shrinkage of concrete is concerned.

Table 1. The drying shrinkage.

Mix No.	Drying Shrinkage(%)			
	alkali 0%	alkali 3%	alkali 9%	alkali 15%
OPC	0.00057	0.00057	0.00057	0.00057
NAxBA10	0.00074	0.00081	0.00073	0.00055
NAxBB10	0.00072	0.00071	0.00060	0.00100
NAxBA20	0.00084	0.00072	0.00063	0.00055
NAxBA20	0.00077	0.00076	0.00085	0.00059

5 The water absorption

The amount of water absorption is determined by the gain in weight of a dry specimen on immersion in water under specified conditions, test results obtained as tabulated in Table 2 depending on the values of alkali content. Water absorption obviously increases as the amount of porosity increases there must be voids (pores) for the water to be absorbed in or enter into the body of the specimen. The results revealed that all specimens compared with the control specimen exhibited lower water absorption or less porosity, in which 3% of alkali content was relatively effective. However, the specimen NA5BA10, the test specimen made as 10% of the cement was replaced with sieve# 200 ground PV powders in 15 % weight of NaOH solution, was the lowest case of water absorption. Besides, the water absorption was sensitive to cement replacement rather than the sieve size as indicated in most cases of these tables.

Table 2. The water absorption.

Mix No.	Absorption (%)	
	7days	28days
OPC	0.058	0.057
NA0BA10	0.051	0.048
NA0BB10	0.052	0.051
NA0BA20	0.049	0.036
NA0BB20	0.048	0.037
NA1BA10	0.052	*0.038*
NA1BB10	0.051	*0.042*
NA1BA20	0.052	*0.036*
NA1BB20	0.051	*0.037*
NA3BA10	0.049	0.046
NA3BB10	0.043	0.042
NA3BA20	0.052	0.046
NA3BB20	0.043	0.044
NA5BA10	0.042	0.030
NA5BB10	0.052	0.043
NA5BA20	0.045	0.041
NA5BB20	0.045	0.045

6 The sulphate resistance

The anti-sulphate ability was investigated by examining the performance of all specimens in sulfate environment, which experienced dry-wet cycles in sodium sulfate solution. The parameter in terms of the durability performance of specimens was loss ratio of weight. Thru 5 cycles of repeating tests, results were obtained and tabulated in Table 3 depending on the alkali content.

Table 3. The sulphate resistance in terms of weight loss.

Mix No.	alkali 0%	alkali 3%	alkali 9%	alkali 15%
OPC	0.0806	0.0807	0.0806	0.0806
NAxBA10	0.0276	0.0179	0.0064	0.0339
NAxBB10	0.0251	0.0126	0.0094	0.0151
NAxBA20	0.0695	0.0503	0.0428	0.0914
NAxBB20	*0.0873*	0.0518	0.1673	*0.1432*

It can be found out in these tables, the sulphate resistance in terms of weight loss for 9% alkali content is the best case. In other words, the optimum amount of alkali content with repect to the sulphate resistance is about 9%. On the contrary, NAxBB20, namely the test specimen made as 20% of the cement was replaced with sieve# 325 ground PV powders in 0-15 % weight of NaOH solution always show the worst performance. It also shows that both the sieve# 325 and 20% cement replacement together give a negative effect on the sulphate resistance. In other word, both conditions of high fineness and large replacement are no suitable for the sulphate resistance. Therefore, the case of 9% alkali content needs to discard the condition of high fineness as well as large replacement to result in a better performance of sulphate resistance.

7 The 4-point probe resistivity measurement

The 4-point probe station is equipped with manual prober or 4 point prober, Ohm-meter, and software to realize the resistance and conductivity measurement. Concrete surface resistivity meter provides information about the state of concrete structure. It is directly linked to the likelihood of corrosion and the corrosion rate. A direct correlation between resistivity and chloride diffusion rate has been indicated. Knowledge of the concrete resistivity, and how this varies with durability parameters of concrete, provides a valuable insight into how the desired concrete resistance value can be achieved. Electrical resistivity is an important physical property of concrete which is directly related to chloride induced corrosion process [9].

This study examined the electrical surface resistivity of 16 concrete cylinders at 28 days. Results as listed in Table 4 depicted that most values of resistance were larger than the OPC value and it may mean the better resistance of chloride induced corrosion with the admixture of ground solar PV cells. In addition, the case of 9% alkali content performed the best among these four different alkaline contents.

Table 4. The 4-point probe resistivity measurement.

Mix No.	4-point probe resistance (KΩ-cm)			
	alkali 0%	**alkali 3%**	**alkali 9%**	**alkali 15%**
OPC	10.2	10.2	10.2	10.2
NAxBA10	8.4	12.3	16.3	18.0
NAxBB10	9.4	11.0	18.3	14.0
NAxBA20	12.3	16.7	23.3	21.3
NAxBB20	12.7	17.3	25.7	22.0

8 Conclusions

In previous studies, we had demonstrated the study results of durability quality of cement mortars blended with waste solar PV cells. The use of ground solar cells on the mechanical properties and durability of cement mortar has been investigated. Following those experimental results, in this article we studied the durability quality of concrete containing waste solar PV cells. By using sodium hydroxide as an alkali-activator, a high-pH environment is generated to excite the binding characteristics of alkali-activated materials in solar PV cells, and thus develops better durability of the mixes. The conclusions were observed on effect of this cement replacement. The observations were fourfold as follows.

Firstly, as indicated from the tests of drying shrinkage, it could be concluded that the use of concrete containing solar PV cells should not be helpful as far as the drying shrinkage of concrete is concerned.

Secondly, the results of water absorption revealed that all specimens compared with the control specimen exhibited lower water absorption or less porosity, in which 3% of alkali content was relatively effective. However, the specimen NA5BA10, the test specimen made as 10% of the cement was replaced with sieve# 325 ground PV powders in 15 % weight of NaOH solution, was the lowest case of water absorption. Besides, the water absorption was sensitive to cement replacement rather than the sieve size as indicated in most cases of these tables.

Thirdly, as far as the anti-sulphate ability is concerned, the optimum amount of alkali content with respect to the sulphate resistance was about 9%. On the contrary, both conditions of high fineness and large replacement together were no suitable for the sulphate resistance. Therefore, the case of 9% alkali content needs to discard the condition of high fineness as well as large replacement to result in a better performance of sulphate resistance.

Finally, results depicted that it existed the better concrete surface resistance of chloride induced corrosion with the admixture of ground solar PV cells. In addition, the case of 9% alkali content was the best performance of concrete surface resistivity among these four different alkaline contents.

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