Hindawi Publishing Corporation
Advances in Civil Engineering
Volume 2014, Article ID 652362, 6 pages
http://dx.doi.org/10.1155/2014/652362

Research Article

Self-Compacting Concrete Incorporating Micro-SiO_2 and Acrylic Polymer

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Received 31 December 2013; Accepted 8 March 2014; Published 3 April 2014

Academic Editor: Okan Karahan

This study examined the effects of using acrylic polymer and micro-SiO_2 in self-compacting concrete (SCC). Using these materials in SCC improves the characteristics of the concrete. Self-compacting samples with 1-2% of a polymer and 10% micro-SiO_2 were made. In all cases, compressive strength, water absorption, and self-compacting tests were done. The results show that adding acrylic polymer and micro-SiO_2 does not have a significant negative effect on the mechanical properties of self-compacting concrete. In addition using these materials leads to improving them.

1. Introduction

Concrete is the world's widely used construction material because of its properties. By increasing the use of engineers, SCC [1–6] was developed in Japan. One of the biggest differences between SCC and usual concrete is their incorporation of materials [7, 8]. SCC is considered to be a concrete that can be placed and compacted with no vibration and segregation [9–12]. Because cement, the most important part of the concrete, is very expensive, using SCC is very economical.

Polymer concrete (PC) is a composite material which is formed by combining mineral aggregates or monomers [13]. Because of its high strength properties, rapid setting, and ability to resist a corrosive environment, PC is increasingly being used as an alternate to cement concrete in construction, highway pavements, waste water pipes, and other places. Polymers are mostly incorporated in the concrete mixed as emulsions of polymer in water (latexes), but dry polymer powders or liquid monomers or resins may be used [14]. The nature of microstructural modification and void filling and bridging of cracks that occurs when polymer formulations are incorporated in cement systems is such that polymers change the pore structure [15].

The polymer used in this paper is the polymerization product of acrylic acid. This polymer is based on acrylic resins. It has the ability to mix easily at any mortar and is consistent with a variety of acrylic paints.

Micro-SiO_2 had been used as an addition to SCC for 10 percent by weight of cement, although the normal proportion is 5 to 15 percent. With an addition of 10 percent, the potential exists for very strong, brittle concrete. High replacement rates will require the use of a high range water reducer. When it is used in concrete, it acts as a filler and as a cementitious material. The small microsilica particles fill spaces between cement particles and between the cement past matrix and aggregate particles. Microsilica also combines with calcium hydroxide to form additional calcium hydrate through the pozzolanic reaction. Both of these actions result in a denser, stronger, and less permeable material. This study aimed to investigate the effect of acrylic and micro-SiO_2 on the fresh and hardened properties of SCC. Fresh concrete tests such as slump-flow and L-box and hardened concrete tests such as compressive strength, water absorption test, and split tensile strength were investigated.

2. Experimental Investigation

2.1. Materials. The Portland cement Type II used in this study was produced in Shahrekord cement factory in Iran. It was

Table 1: Physical and mechanical properties of the aggregates.

Property	Fine aggregate	Coarse aggregate
Specific gravity	2.6	2.55
Fineness modulus	2.9	—
Maximum size (mm)	4.75	12.5
Bulk density (kg/m^3)	1520	1575
Water absorption	1.8	0.5

used because it was the best type of cement in Shahrekord. In addition, micro-$SiO_2$was used as admixtures.

2.2. Aggregates. The sand and the coarse aggregate used in the concrete were crushed limestone aggregates. All of them were used in dry form. Some properties of aggregates used in test are shown in Table 1. Grading curves of sand and coarse aggregates that are in the range of ASTM are plotted in Figures 1 and 2.

2.3. Water. The water utilized in SCC was taken from the city of Shahrekord in Iran. The pH, sulfate, and chloride content of the water utilized in this experimental study were 7.8, 29, and 40 mg/L, respectively.

2.4. Super Plasticizer. In this study, resin was used to increase the flow capability of the concrete and improve the viscosity. The resin used in this study decreased the ratio of water on cement. It made the concrete versatile, so polishing the concrete could be better.

2.5. Acrylic Polymer. Polymer used in this study is based on acrylic. Until now, all of the people used this material to make the concrete waterproof by using it on the surface of the concrete but in this research it was used as a self-concrete component. Some properties of the polymer that is used are given in Table 2.

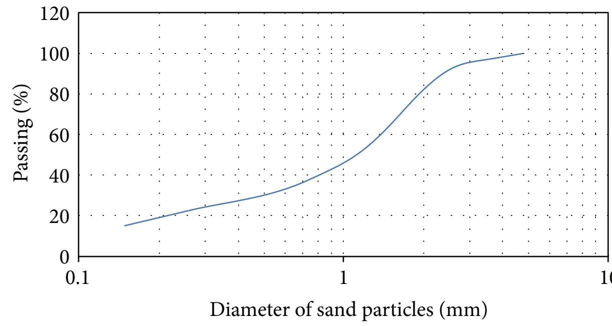

Figure 1: Grading curve of sand.

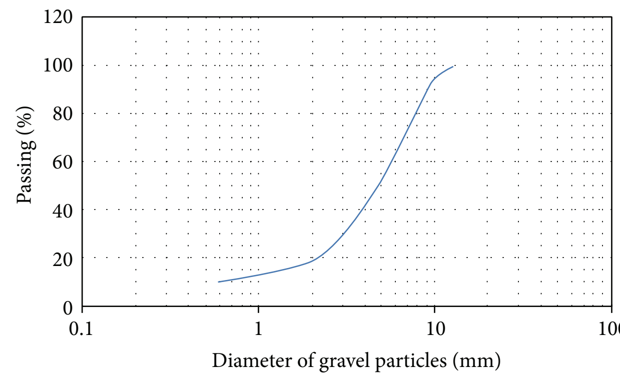

Figure 2: Grading curve of coarse aggregate.

Table 2: Some properties of acrylic polymer.

Mechanical stability	Excellent
Hardness	20 mm
The ultimate stability	12 days
Protection against freezing	Excellent
Viscosity	700–1400
PH	7-8
Water proof	100%
Density	40 + 1
Solvent	Aqueous

3. Mix Design Proportions

In the laboratory of the Shahrekord University in Iran, experimental researches have been carried out by investigating, in parallel, the properties and technology of SCC.

Regarding concrete mix design, the mixture was designed according to ACI-211-89. The proportions of the produced mixtures are given in Table 3. Materials were mixed with aggregates, water, and super plasticizer in accordance with ASTM C 192 in a 120-litter drum mixer.

The amount of coarse aggregates in the SCC mixtures is much more than in the traditional cement concrete. After preparing the concrete, they were taken to 100 mm × 100 mm × 100 mm cubic moulds. They were used for the determination of compressive strength and water absorption and other tests. The testing of fresh concrete was conducted to characterize the workability of it. After testing and filling the cubes moulds, the samples were taken out after one day, and being in water pool for curing.

Table 3: SCC mixture properties.

Properties	Mixture name				
	CA0	CA0.5	CA1	CA1.5	CA2
Coarse aggregate (kg/m^3)	600	600	600	600	600
Sand (kg/m^3)	1100	1100	1100	1100	1100
Water (kg/m^3)	156	156	156	156	156
Cement (kg/m^3)	410	410	410	410	410
W/C	0.38	0.38	0.38	0.38	0.38
Acrylic polymer (%)	—	0.5	1	1.5	2
Super plasticizer (%)	1	1	1	1	1
Micro-SiO_2 (%)	10	10	10	10	10

4. Test of Fresh SCC

To evaluate the ability of SCC in flow ability and viscosity, the slump-slow test and L-box test were carried on the fresh SCC.

Table 4: Typical acceptance criteria for SCC [16].

Test method	Unit	Typical range of values	
		Min	Max
Slump-flow	mm	650	800
The spread diameter (T_{50})	sec.	2	10
L-box	h_2/h_1	0.8	1

The typical acceptance criteria for slump-flow test for SCC are shown in Table 4. The results for SCC tests are listed in Tables 5 and 6. Figures 3 and 4 illustrate the flow ability of the SCC produced with acrylic polymer and micro-SiO_2.

As shown in Table 5, the slump-flow test, by increasing polymer and micro-SiO_2, flow ability increased. It can be seen from Table 6 that, by using additives, the time required flowing to T_{20} and T_{40} decreased. This means that the time required to reach L_{20} and L_{40} of L-box for the SCC in which acrylic polymer and micro-SiO_2 were used was somewhat faster than that for the SCC without them. Figure 5 presents the L-box test. Figure 3 shows that by adding additives in concrete the parameter (h_2/h_1) became more than concrete without them. All of the results obtained from these tests indicated that SCC mixes had good passing ability as well as the time recorded for 500 mm diameter of concrete; the final concrete diameter increased but the time in slump test decreased with the increase in percentage of acrylic polymer and micro-SiO_2 in SCC.

5. Test Results and Discussion

5.1. SCC Compressive Strength. The obtained values of SCC compressive strength according to different used percentages of acrylic polymer and micro-SiO_2 are plotted in Figure 6. These figures indicate that by using them as an additive the compressive strength decreased.

It can be seen that the highest value of compressive strength for all test cases was gained in water for 90 days. In each sample the compressive strength increased from 7 to 90 days but by using additives in SCC it decreased in comparison to the control sample. For example, the compressive strength of the specimen CA0.5 in 90 days increased 23.76% higher than 28 days. Decrease percentages in compressive strength are drawn in Table 7, which shows that CA0.5 decreased less in each period. It means that each sample compared with its control sample. As shown in Figure 6 the compressive of the sample of CA0.5 for 7 days is 36.6 while its compressive strength of control sample is 39.2, so by decreasing of these two numbers and dividing on 39.2 the answer will be 0.066 (6.62%). It means that by using 0.5% of acrylic and 10% of micro the compressive strength of 6.62% decreased.

The results of the SCC split cylinder tensile test are shown in Figure 8. It can be understood that, by using polymer and microsilica, the compressive tensile strength increased but by increasing the percent of additives it decreased. Figure 7 shows that no segregation occurred in tested cubic samples because of good design mixes and materials so it is very good to use in construction.

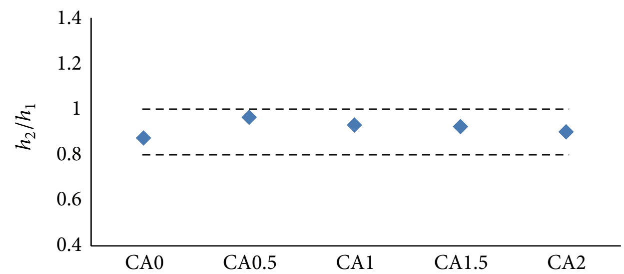

Figure 3: Ratio of h_2/h_1 in L-box test.

Table 5: Results of slump-flow test.

Specimen	Slump-flow (mm)	The spread diameter (T_{50}) (s)
CA0	63	7.5
CA0.5	69	5
CA1	69.7	4.1
CA1.5	70	4.5
CA2	71	3.9

Table 6: Results of L-box test.

Specimen	T_{20} (s)	T_{40} (s)
CA0	1.4	2.33
CA0.5	0.98	2.05
CA1	0.85	1.9
CA1.5	0.63	1.75
CA2	0.58	1.25

Table 7: Decrease in compressive strength.

Curing day	Decrease of compressive strength of samples compared with control sample in %			
	CA0.5	CA1	CA1.5	CA2
7 days	6.62	4.33	33.37	33.76
28 days	19.34	41.66	53.83	84.37
56 days	23.93	24.21	24.77	25.77
90 days	17.6	30.67	35.17	35.39

5.2. Weight of Specimens. Figure 9 displays the unit weight of specimens. It shows that by increasing acrylic polymer and micro-SiO_2 in SCC the weight of samples decreased.

5.3. Water Absorption. The water absorption test was performed on all mixtures. Their results on the 90th day of curing are shown in Figure 10. It can be noticed that, by increasing additives, the water absorption percent increased and this issue is not good in construction.

6. Conclusion

Based on the results and discussions of this investigation the following conclusions are drawn.

(i) Incorporation of acrylic polymer and micro-SiO_2 reduced the cost per unit compressive strength of

Figure 4: Slump test.

Figure 5: L-box test.

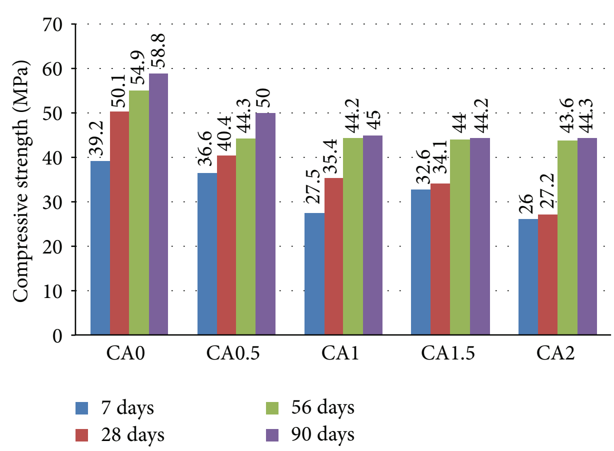

Figure 6: Compressive strength.

these SCC mixtures. Therefore, by less expense we can reach good quality.

(ii) All the mixtures had partial SCC properties in fresh and hard state.

(iii) By using additives in SCC, its workability increased and there was no segregation in the combination of concrete.

(iv) Based on split cylinder tensile test results, using additives in concrete increased in comparison with

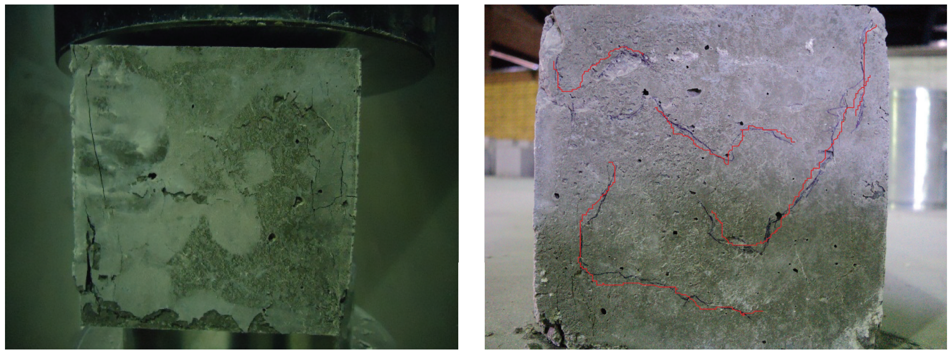

Figure 7: Breaking cubic samples.

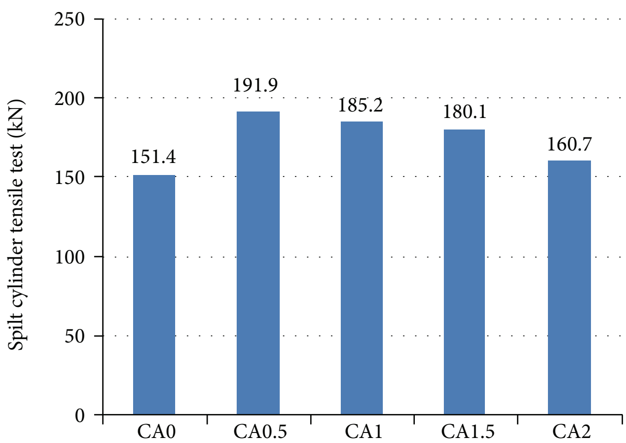

Figure 8: Split cylinder tensile test.

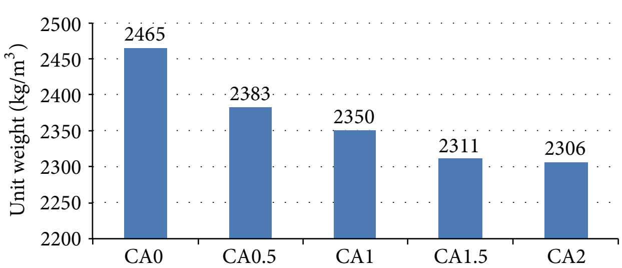

Figure 9: Comparison of average unit weight in specimens.

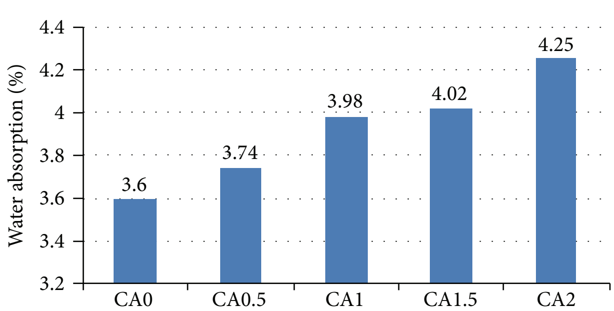

Figure 10: Comparison of water absorption in samples.

the sample with no additives, but by increasing the percent of polymer and micro-SiO_2 the split cylinder tensile decreased.

(v) In all specimens, AC0.5 had the highest compressive strength and it had the lowest difference with the control sample.

(vi) In general, because of improving the qualities of the SCC, using acrylic polymer and micro-SiO_2 is a good way to reach high quality.

Conflict of Interests

The authors declare that they have no conflict of interests.

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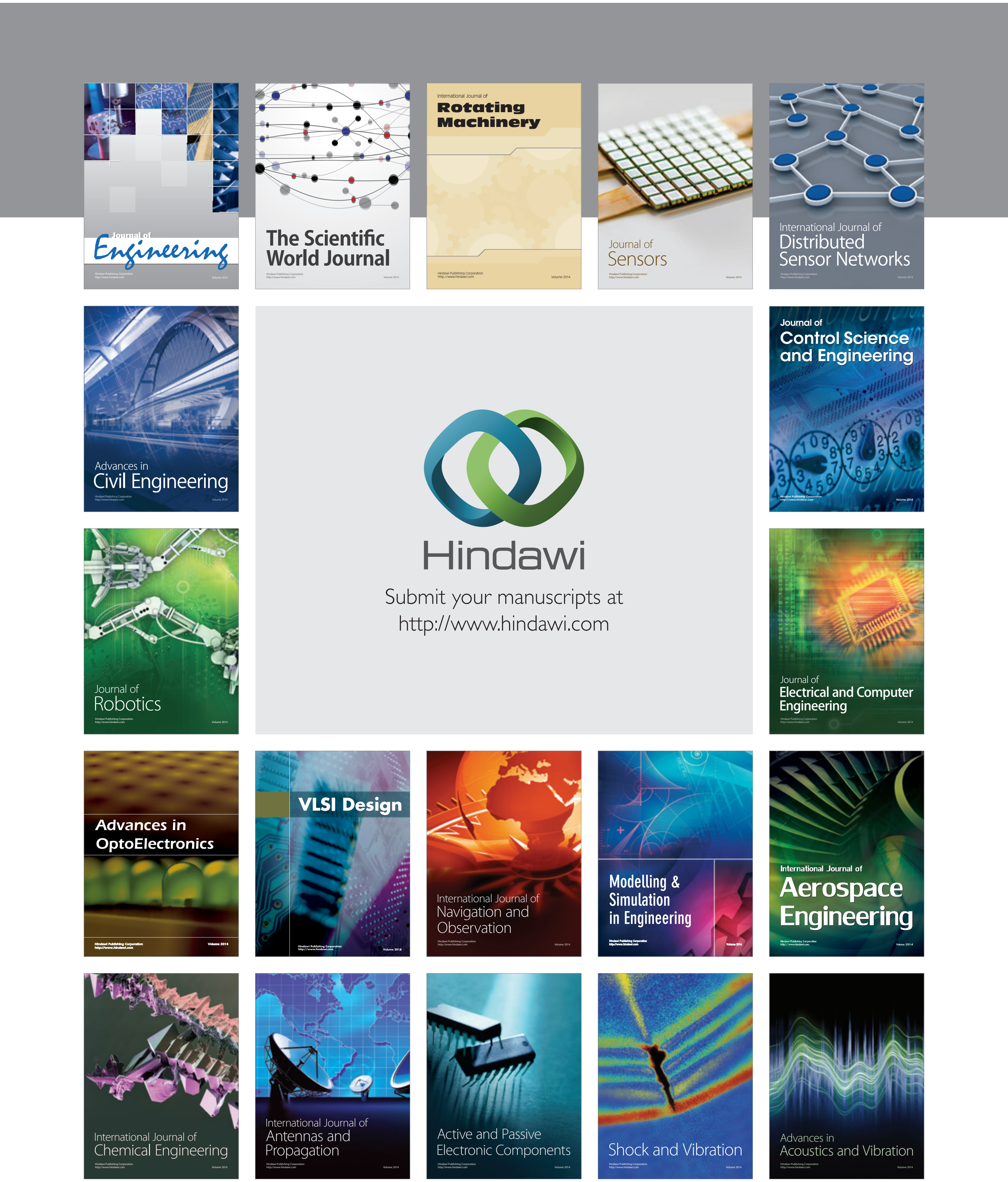
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