EXPERIMENTAL STUDY ON THE DURABILITY OF CONCRETE BY ADDITION OF WATERPROOFING ADMIXTURES

Dr. K. Chandrasekhar Reddy[1] and Y. Likesh Reddy[2]

[1]Professor & Principal, [2]PG student
Department of Civil Engineering
Siddharth Institute of Engineering & Technology, Puttur, Andhra Pradesh, India
[1]kamasani.kcr@gmail.com, [2]likesh.likki@gmail.com

Abstract

The study aims to assess the changes in the durability of concrete when admixtures are added and also to suggest appropriate dosages. In this study, two types of waterproofing admixtures, one in the liquid form and others in the powder form, were selected. M25 grade of concrete design mix was chosen for the study. Concrete cube/cylinder specimens were cast by adding liquid-type waterproofing admixture at proportions of 1, 2, and 3% by weight of cement. Similarly, the specimens were cast by adding powder-type at 1, 2, and 3% by weight of cement. All the cast concrete specimens, including nominal mix specimens after curing for 28 days in normal water, were soaked for 90 days in the chemical water solution made with 5% of NaCl. The chloride resistance and compressive strength tests were conducted on the specimens to assess the concrete's durability. The test results were compared with the nominal mix. It was observed that liquid-type and powder-type at 2% showed better durability than the nominal mix.

Keywords: Waterproofing admixtures, Durability, Seepage of water, Damped environment.

1. INTRODUCTION

One major cause of the deterioration of concrete structures is the seepage of water through hardened concrete. Particularly, when constructed underwater or continuously exposed to the damped environment. There are several practices to solve this issue. One such method is adding waterproofing admixtures while mixing concrete or coating the surface of hardened concrete. Waterproofing admixtures help to minimize the seepage of water by reducing the permeability of concrete. These admixtures may be available in powder, paste, or liquid form.

In this study, we assessed the durability in terms of percentage of loss of weight and compressive strength of the concrete by using two types of waterproofing admixtures in liquid form and solid form. The admixtures are added while mixing of the concrete (integral waterproofing).

2. LITERATURE REVIEW

Pejman et al. (2020): Studied the effect on microstructural features and durability properties of cementitious composites by adding K, P, and X crystalline waterproofing admixtures (CWA). The composites were tested by image analysis technique on backscattered mode Scanning Electron Microscopy (SEM) images and the Energy Dispersive X-ray Spectroscopy (EDS) technique. Sulphur peak (a sign of ettringite) has been observed in the composites added with P and X crystalline waterproofing admixtures. But the composite added with K crystalline waterproofing admixtures does not show sulphur peak (no sign of ettringite) on the EDS spectrum.

Yupeng et al. (2019): They studied the influence of Silicon Resin (SR) on the durability of concrete while integral mixing of concrete (water-repellent concrete) and surface coating on hardened concrete (water-repellent concrete surface). Water-repellent concrete specimens were prepared by adding SR at 0%, 1%, 2%, 3%, and 4% by the weight of cement, and the water-repellent concrete surface was uniformly coated with SR at dosages of 100, 200, 300, 400, and 600 g/m^2. Finally, it concluded the effect of different dosages on the durability of the concrete.

Adelia and Joshua (2018): studied the effect on compressive strength and permeability of concrete specimens by the addition of the Xypex C-1000 waterproofing agent. The specimens were prepared by adding the waterproofing agent at the dosages of 0.2%, 0.4%, 0.6%, 0.8%, 1%, and 1.2% by weight of cement. The specimens were tested after 7 and 28 days curing and compared with control concrete. Variations in compressive strength and permeability of concrete were analyzed from the test results.

Silva et al. (2017): They have done a case study on 30 cm thick and 750 m^3 volume of an anti-flotation reinforced concrete slab used in a building located in the Northwest Sector, Brasilia, Brazil. A permeability-reducing admixture was used to seal the cracks up to 0.4 mm by self-healing phenomenon to ensure the water-tightness of the slab. It was concluded that both permeability-reducing admixture and setting suitable constructive strategies were vital to safeguard the whole structure to be watertight.

Jiri and Eva (2016): They studied the effect on water vapor permeability and compressive strength of concrete by adding Penetron Admix and Xypex Admix C-1000 waterproofing crystalline admixtures at a dosage of 2% by weight of cement. Tests conducted and compared the results with concrete made without admixtures. It was observed that admixtures reduced the water vapor permeability of concrete by 16-20 % compared to concrete made without admixtures. But, the compressive strength of concrete after 28 days is almost identical in concrete made with or without admixtures.

Nasiru et al. (2015): The study establishes the taxonomy and hypothesis of research in waterproofing concrete research. They reviewed the various studies conducted on waterproofing efficiency of concrete using various agents and tests. It is observed that most of the researchers experimented on the surface coating of hardened concrete and most common test the researchers preferred, as the water absorption test. The study concluded to establish three classifications of waterproofing agents based on its structure, method of application, and functions.

3. MATERIALS AND METHODS

3.1 Cement:

Ordinary Portland Cement of 53 Grade (Ultra tech brand) satisfies the requirements as per IS 12269: 2013 was used in the present investigations. The cement's various physical properties were tested following IS 4031, and the results were tabulated in table1..

Table 1: Physical properties of the cement

S.No.	Property	Test value	Standard value (IS 12269: 2013)	Method of the test, Ref. to
1	Specific gravity	3.13	---	IS 4031 (Part 11) : 1988
2	Fineness, m^2/kg	370	Min. 225	IS 4031 (Part 2) : 1999
3	Soundness, mm (By Le-Chatelier method)	6	Max. 10	IS 4031 (Part 3) : 1988
4	Normal consistency	33%	---	IS 4031 (Part 4) : 1988
5	Initial setting time, min	42	Min. 30	IS 4031 (Part 5) : 1988
	Final setting time, min	350	Max. 600	
6	Compressive strength, MPa (After 28 days curing)	53	Min. 53	IS 4031 (Part 6) : 1988

3.2 Fine Aggregate:

Manufactured sand (M-sand) produced by crushing hard stone was used as fine aggregate in the present investigations. River sand poses severe problems concerning its availability, cost, and environmental impact. Hence, M-sand instead of river sand was used. Another reason for the usage of M-sand is it locally available at the proximate places, reducing the cost of transportation river sand from distant places. M-sand fulfills the requirements as per IS 383: 2016 was used in the current investigations. The various physical properties of the M-sand were tested following IS 2386: 1963, and corresponding test results were shown in Table 2.

Table 2: Physical properties of M-Sand

S.No.	Property	Test value	Standard value (IS 383: 2016)	Method of the test, Ref. to
1	Specific gravity	2.61	Max. 3.2	IS: 2386 (Part III) - 1963
2	Water absorption, %	0.72	Max. 5	IS: 2386 (Part III) - 1963
3	Bulk density, kg/m^3	1659	---	IS: 2386 (Part III) - 1963
4	Grading Zone	Zone II	Zone I to IV	IS: 2386 (Part I) - 1963

3.3 Coarse Aggregate:

Locally available crushed stone was used as coarse aggregate in the present work. The coarse aggregates are granite origin, and it is free from clayey matter, silt, and organic impurities, etc. Coarse aggregate is tested for their properties' following IS: 2386-1963 and compared its requirements as per IS 383: 2016. The maximum size used as a coarse aggregate in concrete is 20 mm.

Table 3: Physical properties of coarse aggregate

S.No.	Property	Test value	Standard value (IS 383: 2016)	Method of the test, Ref. to
1	Specific gravity	2.64	Max. 3.2	IS 2386 (Part III): 1963
2	Water absorption, %	0.45	Max. 5	IS 2386 (Part III): 1963
3	Unit weight, kg/m^3	1593	---	IS 2386 (Part III): 1963

3.4 Integral Waterproofing Admixtures (Confining to IS: 2645-2003)

3.4.1 Properties liquid (Conplast) type admixture:

Name	Conplast
Form type	Liquid
Brand	Fosroc
Grade standard	SP500
Colour	Dark brown
Specific gravity	1.26

3.4.2 Properties of powder (Crystalline) type admixture:

Name	Crystalline
Form type	Solid (Powder)
Brand	Supreme
Grade standard	EN 934-2
Colour	Grey
Specific Gravity	2.9

3.5 Specimen preparation:

The cube specimen of 150 mm x 150 mm x 150 mm size cubes were cast to assess the durability in terms of percentage of loss of weight and compressive strength of the concrete by using two types of waterproofing admixtures.

Concrete cubes were cast by adding liquid-type waterproofing admixture at proportions of 1, 2, and 3% by weight of cement. Similarly, concrete cubes were cast by adding powder-type at 1, 2, and 3% by weight of cement.

Three cube specimens were cast for each proportion of waterproofing admixture and each type. The average values were taken for the study. And also, the nominal mix at 0% of waterproofing admixture three cube specimens was cast, and the average value was taken.

3.6 Durability of hardened concrete

3.6.1 Chloride resistance test:

The cube specimens were used for chloride resistance test by following IS 456-2000. The specimens were soaked in normal water for 28 days. After the curing period, the specimens were weighed (W_1) and soaked for 90 days in the chemical water solution made with 5% of NaCl. After 90 days, the specimens were taken outside and once again weighed (W_2). Then, the percentage of losses in weight of specimens was calculated.

Percentage (%) of loss = $(W_1 – W_2)/W_1$ x100

Where,

W1 - Weight of cube specimens before soaking in the chemical water solution.

W2 - Weight of cube specimens after soaking in the chemical water solution.

3.6.2 Compressive strength of concrete test:

The compressive strength test was carried out on cube specimens, after 90 days soaking in the chemical water solution made with 5% of NaCl, using a compression testing machine of capacity 2000 kN following IS 516:1959 specifications.

4. RESULTS AND DISCUSSIONS

4.1 Loss of weight (Chloride resistance):

The results of the Chloride resistance test of M25 grade of concrete after 90 days soaking in the chemical water solution made with 5% of NaCl. Various combinations of liquid-type waterproofing admixture (1, 2, and 3%) are obtained along with a nominal mix tabulated in table 4 and corresponding graphical representation shown in figure 1. Similarly, various combinations of powder-type waterproofing admixture (1, 2, and 3%) are obtained along with a nominal mix tabulated in table 5 and the corresponding graphical representation shown in figure 2.

Table 4: Results of Chloride test on concrete specimens for various proportions of liquid-type (Conplast) waterproofing admixtures after 90 days soaking in the chemical water solution.

S.No.	Type of mix	Weight of the specimens before soaking in the chemical water solution (W_1) (kg)	Weight of the specimens after soaking in the chemical water solution (W_2) (kg)	% of loss in weight of the specimens
1	Nominal mix	8.312	8.159	1.84
2	1 % liquid-type admixture	8.331	8.189	1.71
3	2 % liquid-type admixture	8.349	8.212	**1.64**
4	3 % liquid-type admixture	8.368	8.221	1.76

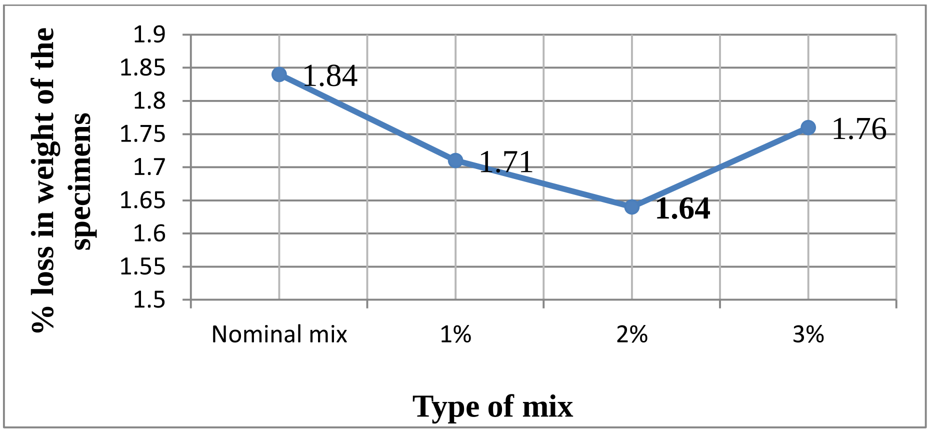

Figure 1: Results of Chloride test on concrete specimens for various proportions of liquid-type (Conplast) waterproofing admixtures after 90 days soaking in the chemical water solution

Table 5: Results of Chloride test on concrete specimens for various proportions of powder (Crystalline) type waterproofing admixtures after 90 days soaking in the chemical water solution.

S.No.	Type of mix	Weight of the specimens before soaking in the chemical water solution (W_1) (kg)	Weight of the specimens after soaking in the chemical water solution (W_2) (kg)	% of loss in weight of the specimens
1	Nominal mix	8.312	8.159	1.84
2	1 % powder-type admixture	8.331	8.187	1.73
3	2 % powder-type admixture	8.349	8.210	**1.66**
4	3 % powder-type admixture	8.368	8.218	1.79

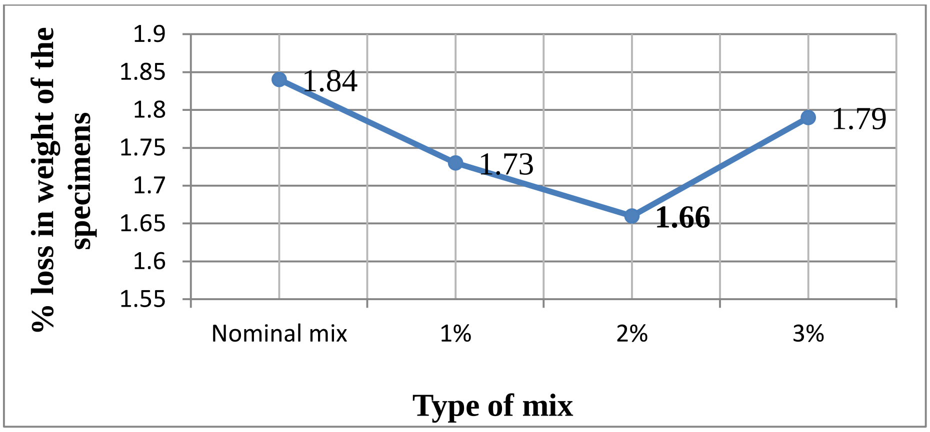

Figure 1: Results of Chloride test on concrete specimens for various proportions of powder (Crystalline) type waterproofing admixtures after 90 days soaking in the chemical water solution.

4.2 Compressive strength of concrete:

the compressive strength of M25 grade of concrete after 90 days soaking in the chemical water solution made with 5% of NaCl, for various combinations of liquid-type waterproofing admixture (1, 2, and 3%) are obtained along with the nominal mix were tabulated in table 6 and corresponding graphical representation shown in figure 3. Similarly, various combinations of powder-type waterproofing admixture (1, 2, and 3%) are obtained along with a nominal mix tabulated in table 7 and the corresponding graphical representation shown in figure 4.

Table 6: Compressive strength of concrete specimens for various proportions of liquid type (Conplast) waterproofing admixtures after 90 days soaking in the chemical water solution.

S.No.	Type of mix	Compressive strength before soaking in the chemical water solution (N/mm^2)	Compressive strength after soaking in the chemical water solution (N/mm^2)	% of loss in Compressive strength
1	Nominal mix	30.09	28.31	5.92
2	1 % liquid-type admixture	32.52	30.74	5.47
3	2 % liquid-type admixture	34.92	33.08	**5.27**
4	3 % liquid-type admixture	31.47	29.70	5.62

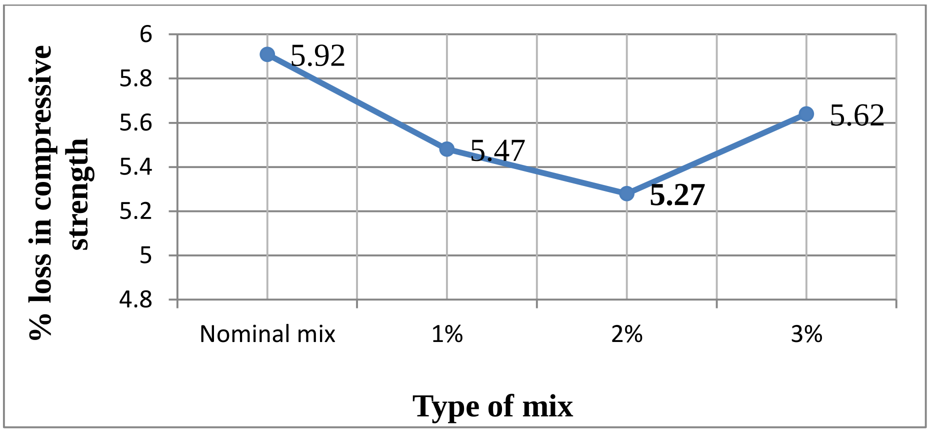

Figure 3: Compressive strength of concrete specimens for various proportions of liquid type (Conplast) waterproofing admixtures after 90 days soaking in the chemical water solution.

Table 7: Compressive strength of concrete specimens for various proportions of powder (Crystalline) type waterproofing admixtures after 90 days soaking in the chemical water solution.

S.No.	Type of mix	Compressive strength before soaking in the chemical water solution (N/mm^2)	Compressive strength after soaking in the chemical water solution (N/mm^2)	% of loss in Compressive strength
1	Nominal mix	30.09	28.31	5.92
2	1 % powder-type admixture	31.86	30.09	5.56
3	2 % powder-type admixture	33.37	31.59	**5.33**
4	3 % powder-type admixture	30.73	28.95	5.79

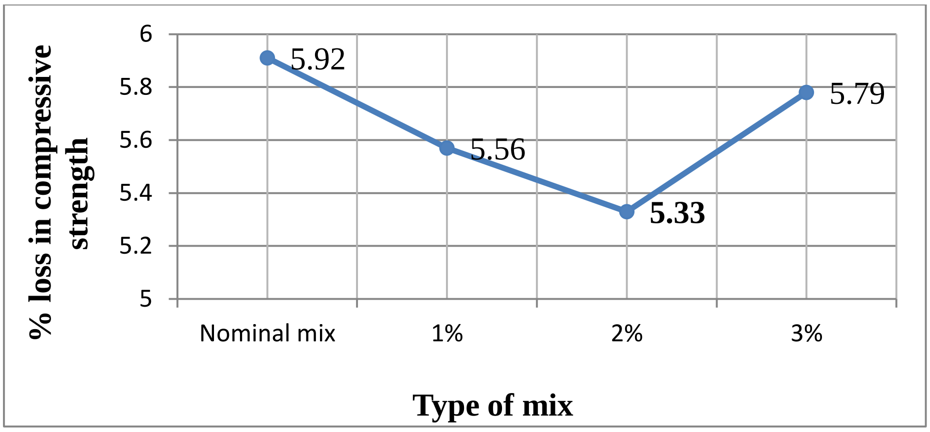

Figure 3: Compressive strength of concrete specimens for various proportions of powder (Crystalline) type waterproofing admixtures after 90 days soaking in the chemical water solution.

5. CONCLUSIONS

From the experimental investigation, the following findings are made to be valid:

It could be concluded that the addition of waterproofing admixtures increases the durability of concrete. It is due to an increase in bonding between the aggregates and matrix by reducing porous nature in the concrete.

- The % loss of weight for the M25 design mix concrete without adding waterproofing admixture (nominal mix) after 90 days soaking in the chemical water solution made with 5% of NaCl is observed as 1.84%. Whereas the lower % loss of weight observed at 2 % adding of liquid-type and powder-type waterproofing admixtures to the nominal mix as 1.64% and 1.66%, respectively. That means loss of weight due to the addition of liquid-type and powder type, which is 11% and 10% less than the nominal mix.
- The % loss in compressive strength for the M25 design mix concrete without adding waterproofing admixture (nominal mix) after 90 days soaking in the chemical water solution made with 5% of NaCl is observed as 5.92%. Whereas the lower % loss of weight observed at 2% adding of liquid-type and powder-type waterproofing admixtures to the nominal mix as 5.27% and 5.33%, respectively. That means the loss in compressive strength due to the addition of liquid-type and powder type, which is 11% and 10% less than the nominal mix.
- Finally, it can be concluded that at 2% adding, liquid-type and powder-type waterproofing admixtures gives better durability than the nominal mix. Also, liquid-type provides slightly better durability than the powder-type admixture, and it is recommended for use in M25 grade concrete.

References:

1. Adelia Dwidarma Nataadmadja and Joshua Adam Picasso Runtuwene (2018): Analysis of concrete permeability with additional waterproofing admixture, IOP Conf. Series: Earth and Environmental Science. December 2018, Volume 195. https://doi:10.1088/1755-1315/195/1/012002
2. IS 516-1959: Method of Tests for Strength of Concrete, BUREAU OF INDIAN STANDARDS, New Delhi, India. http://www.iitk.ac.in/ce/test/IS-codes/is.516.1959.pdf
3. IS 2386 (Part I)-1963: Methods of Test for Aggregates for Concrete, Particle Size, and Shape. BUREAU OF INDIAN STANDARDS, New Delhi, India. http://www.iitk.ac.in/ce/test/IS-codes/is.2386.1.1963.pdf
4. IS 2386 (Part III)-1963: Methods of test for aggregates for concrete, Specific gravity, density, voids, absorption and bulking, BUREAU OF INDIAN STANDARDS, New Delhi, India. http://www.iitk.ac.in/ce/test/IS-codes/is.2386.3.1963.pdf
5. IS 2645-2003: Integral Waterproofing Compounds for Cement Mortar and Concrete – Specification, BUREAU OF INDIAN STANDARDS, New Delhi, India. http://www.iitk.ac.in/ce/test/IS-codes/is.2645.2003.pdf
6. IS 4031 (Part 2)-1999: Methods of physical tests for hydraulic cement, Determination of fineness by specific surface by Blaine air permeability method, BUREAU OF INDIAN STANDARDS, New Delhi, India. https://law.resource.org/pub/in/bis/S03/is.4031.2.1999.pdf
7. IS 4031 (Part 3)-1988: Methods of physical tests for hydraulic cement, Determination of soundness, BUREAU OF INDIAN STANDARDS, New Delhi, India. https://law.resource.org/pub/in/bis/S03/is.4031.3.1988.pdf
8. IS 4031 (Part 4)-1988: Methods of physical tests for hydraulic cement, Determination of consistency of standard cement paste, BUREAU OF INDIAN STANDARDS, New Delhi, India. http://www.iitk.ac.in/ce/test/IS-codes/is.4031.4.1988.pdf
9. IS 4031 (Part 5)-1988: Methods of physical tests for hydraulic cement, Determination of initial and final setting times, BUREAU OF INDIAN STANDARDS, New Delhi, India. http://www.iitk.ac.in/ce/test/IS-codes/is.4031.5.1988.pdf
10. IS 4031 (Part 6)-1988: Methods of physical tests for hydraulic cement, Determination of compressive strength of hydraulic cement (other than masonry cement), BUREAU OF INDIAN STANDARDS, New Delhi, India. http://www.iitk.ac.in/ce/test/IS-codes/is.4031.6.1988.pdf

11. IS 4031 (Part 11)-1988: Methods of physical tests for hydraulic cement, Determination of density, BUREAU OF INDIAN STANDARDS, New Delhi, India. https://law.resource.org/pub/in/bis/S03/is.4031.11.1988.pdf
12. IS 5816-1999: Splitting Tensile Strength of Concrete - Method of Test (First revision), BUREAU OF INDIAN STANDARDS, New Delhi, India. http://www.iitk.ac.in/ce/test/IS-codes/is.5816.1999.pdf
13. IS 12269-2013: Ordinary Portland Cement, 53 Grade - Specification (First Revision), BUREAU OF INDIAN STANDARDS, New Delhi, India. http://www.iitk.ac.in/ce/test/IS-codes/is.12269.2013.pdf
14. Jiri Pazderka and Eva Hajkov (2016): Crystalline Admixtures and their effect on Selected Properties of Concrete, Acta Polytechnica Journal of Advanced Engineering, 2016, Volume 56, Issue 4, pp. 306–311. https://doi.org/10.14311/AP.2016.56.0306
15. Nasiru Zakari Muhammad, Ali Keyvanfar, Muhd Zaimi Abd. Majid, Arezou Shafaghat, and Jahangir Mirza (2016): Waterproof performance of concrete: A critical review on implemented approaches, Construction and Building Materials Journal, Elsevier, December 2015, Volume 101, Part 1, pp. 80-90. https://doi.org/10.1016/j.conbuildmat.2015.10.048
16. Pejman Azarsa, Rishi Gupta, and Alireza Biparva (2020): Inventive Microstructural and Durability Investigation of Cementitious Composites Involving Crystalline Waterproofing Admixtures and Portland Limestone Cement, Materials journal, MDPI, March 2020, Volume 13, Issue 6, pp.1-19. https://doi:10.3390/ma13061425
17. Silva, E. F., Moreira, M., Manzano, M. A. R., and Blanco, R. (2017): Case study of permeability-reducing admixture use in anti-flotation slabs: building in Brasilia, Brazil, Journal of Building Pathology and Rehabilitation, Springer, December 2017, Volume 2, Issue 1, Article No.1. https://doi.org/10.1007/s41024-016-0014-5
18. Yupeng Tian, Penggang Wang, Tiejun Zhao, Zhiming Ma, Zuquan Jin, and Haitao Zhao (2019): Influence of Water-Repellent Treatment with Silicon Resin on Properties of Concrete, Advances in Materials Science and Engineering, Hindawi, Volume 2019, Article ID 5743636, 12 pages. https://doi.org/10.1155/2019/5743636