An Experimental Study on Compressive Strength of Various Cement Concrete Under Sea Water

Swati Maniyal, Ashutosh Patil

Abstract— Potable water is becoming a scarce commodity on this planet Earth with time. Hence, we need to find alternatives for potable water as billons of liters of water is used in construction industry. This research work seeks to investigate the use of sea water as mixing and curing of concrete as 97% of the water on Earth surface is sea water. For this concrete cubes were cast for a design mix of M-20, 1:1.777:2.826 by weight and 0.47 water cement ratio and M-25, 1:1.432:2.472 by weight and 0.414 water cement ratio using OPC 43 grade, OPC 53 grade and PPC cement as per guidelines for concrete mix proportioning with a slump of 75 mm to 100 mm. Half of the cubes were cast and cured with potable water and half with sea water. The cubes were cast and cured for 7, 14, 21, 28 days and was tested for compressive strength. From the results it was found that compressive strength increases during initial days of curing when cubes are cast and cured in sea water but finally characteristic strength decreases by about 5% as compared to cubes cast and cured with potable water.

Keywords—Compressive strength, concrete cubes, curing, design mix, mixing, potable water, sea water.

1 Introduction

Concrete is one of the most common and widely used construction materials due to its strength and durability properties. It is all most impossible to find an alternative for concrete. It is an artificial material made from the mixture of cement, aggregate, sand, admixtures and water to form a uniform plastic material which sets gradually and gains strength with time.

The strength of concrete depends on the concrete mix, method of curing, water cement ratio, aggregates and cement types. Water is an important ingredient of concrete as it participates in the chemical reaction with cement. According to the literatures available, it is said that in 2025, the half of the world will not have water even for daily necessities. Globally, billon of tons of water is used for concreting. In order to save water we are trying to investigate the usage of sea water as mixing and curing for concrete. It is important to investigate the possibility of usage of sea water in construction industry as 97% of the total water on Earth is sea water. Also, United Nations (UN) and World Metrological Organization (WHO) have predicted that 5 billion people will be in short of even drinking water. So, there is a need to explore alternative for potable water in construction industry. A large number of structures are exposed to seawater either directly or indirectly. Thus, possibility of usage of sea water in concrete is studied.

In the present study, concrete with various types of cement viz; Ordinary Portland Cement (OPC) 43 Grade, Ordinary Portland Cement (OPC) 53 Grade, Pollozona Portland cement (PPC), is adopted. Concrete grades of M-20 and M-25 design mix with a slump in between 75 to 100 mm were considered in the study. The exposure conditions of "Concrete mixing and curing with potable water" and "Concrete mixing and curing with sea water" are adopted.

- *Swati Maniyal is currently pursuing Master's Degree program in Structural Engineering in N.B.N.S.C.O.E; Solapur University, India, PH-9890323027. E-mail: swati.maniyal@gmail.com*
- *Ashutosh Patil is currently working as an Assistant Professor in in N.B.N.S.C.O.E; Solapur University, India, PH-9403688721. E-mail: er.ashutoshpatil@gmail.com*

2 Necessity of Project

Predications say that in near future there will be shortage of drinking water. Hence, fresh water will not be available for concreting purpose. We use bore water for mixing as well as curing of concrete instead of fresh water. The bore water available is neither free from impurities nor is considered as soft water. There are number of salts presents in bore water which results in hardness. Here in this research work we are working on the effect of sea water as mixing and curing on concrete. We test the concrete for extreme case i.e. sea water case.

3 Literature Review

According to **Water Encyclopaedia (2012)**, great bodies of water covers about five seventh of the earths' surface about 71 percent in some places to depth more than ten kilometres. **Adebakin, H. I. (2003)** describes fresh water as purified water which is free from impurities. **Akinkurolere O.O et.al (2007)** said sea water is a complex solution of many salts containing living matter, suspended silt, dissolved gases and decaying organic material. The average salt concentration of sea water is about 3.5% depending upon its location. The primary chemical constituents of seawater are the ions of chloride, sodium, magnesium, calcium and potassium. The concentration of major salt constituents of seawater we are given in weight % of salt as 78%NaCl, 10.5% $MgCl_2$, 5% $MgsSO_4$, 3.9% $CaSO_4$, 2.3% $K2SO_4$ and 0.3% KBr.

Studies were conducted during past on effect of mixing and curing of sea water in concrete. **Falah M. Wegian (2010)** investigated the effects of mixing and curing concrete with sea water on the compressive, tensile, flexural and bond strengths and reported that there are increases of strengths of concrete mixed and cured in sea water at early ages and a definite decrease for ages more than 28 days and up to 90 days. **Donald F. Griffin et.al (1964)** concluded that a small amount of sea-water salts may be to concrete if rigid controls are exercised. Maximum compressive strength occurs between salinities of 18 and 36 gm/kg for concrete incorporating NaCl

in the mixing water. Depending upon the age of concrete, relatively high salinities of NaCl can occur before strengths become less than those for zero salinity. Natural sea water does not deteriorate plain concrete; strength is generally increased with salinities up to nearly three times that of natural sea water. **Nobuaki Otsuki et.al (2011)** concluded from the test results and discussions and are confident to safely use sea water as mixing water. **P. Krishnam Raju et.al (2014)** concluded that there is no reduction in compressive strength due to mixing and curing of sea water, whereas the average compressive strength arrived for designated concretes are more than the target strength. **O.O. Akinkurolere et.al (2007)** concluded that concrete cast with sea water and cured with sea water increases the 28 days compressive strength dramatically and linearly beyond that obtained when cast in fresh water and cured in fresh water. **Preeti Tiwari et.al (2014)** performed series of experiments on M-30 grade and said that there is marginal increase in the strength of cubes cast and cured in salt water as compared to those of cast and cured in fresh water at all ages of curing and concluded that there is no reduction in the strength if we use salt water casting and curing the concrete. **K. J. Kucche et.al (2015)** quoted that from stream, river and even sea is also suitable, if it not contain brackish matter. **Tarek Uddin Mohammed et.al** said that seawater-mixed concrete shows earlier strength gain compared to the tap water-mixed concrete. However, after a long-term of exposure, no significant difference in compressive strength is observed.

4 Materials and Methodology

4.1 Materials

The detail of various materials used in the experimental investigation will be:

- Coarse Aggregate:-Crushed granite stone aggregate of maximum size 20 mm confirming to IS 383-1970 was used. The specific gravity was found to be 2.925.
- Sand (Fine Aggregate):- The fine aggregate used was sand passing through 4.75 mm sieve. The specific gravity was found to be 2.83. The grading zone of fine aggregate was zone I as per IS specification.
- Cement:- OPC 43 grade, OPC 53 grade, PPC (Ultratech Cement) was used.
- Water:- Ordinary clean potable water free from suspended particles and chemicals was used for mixing and curing of concrete.
- Sea water:-Seawater is water from a sea or ocean. Here sea water from Arabian Sea was used.

4.2 Methodology

Experimental Procedure: To investigate the effect of sea water on compressive strength of concrete, half of the concrete cubes were cast and cured with potable water and half of the concrete cubes were cast and cured with sea water.
The concrete cube size measuring 150×150×150 mm in dimension will be used. The batching of the concrete was carried out by weight. The mix proportion was calculated for characteristic compressive strength of 20 N/mm^2 and M-25 N/mm^2. The concrete was properly mixed using the sea water and potable water respectively, the concrete cubes mould were filled in three layers. In each of the layer, the concrete cubes will be compacted 25 times respectively. The concrete cubes were cast and cured for 7, 14, 21 and 28 days and will be tested for compressive strength.

Workability: Workability of cubes mixed with sea water and potable water are measured separately before casting of cubes. The workability maintained was medium i.e. slump was maintained between 75 mm to 100 mm for mass concrete.

Compressive Strength: The compressive strength is taken as maximum compressive load resisted by per unit area. The test specimens for the determination of compressive strength of concrete were prepared using the standard metallic cube mould. The concrete cube mould were lubricated with oil before the mixed concrete was placed inside it, in order to reduce friction between the concrete and the cubes.
The cubes are demoulded after 24 hour of casting, and cured in water having similar quality as used in the preparation of mix. For each of the curing period of 7, 14, 21 and 28 days, cubes were tested and the average compressive strength recorded.

***Test Results*:** After casting and demoulding, the sea water concrete cubes has a darker surface than the reference concrete cubes, when cured in sea water a deposit of salt formed on a specimens. The concrete cubes were tested in "Compression Testing Machine of Technical and Scientific Sales Instruments" which has a capacity 200 tones. The tests were carried out at "Vidya Vikas Pratishthan (VVP) Polytechnic, Solapur".
Results indicate that, that compressive strength increases during initial days of curing when cubes are cast and cured in sea water but finally characteristic strength decreases by about 5% as compared to cubes cast and cured with potable water.

TABLE 1
QUANTITIES FOR 12 CUBES, M-20

Grade	M-20
Proportions	1 : 1.777 : 2.825
W/C Ratio (Potable/Sea)	0.47
Cement	24 kg
Fine Aggregate	42.648 kg
Coarse Aggregate	67.642 kg
Water (Potable/Sea)	11.28 kg

TABLE 2
QUANTITIES FOR 12 CUBES, M-25

Grade	M-25
Proportions	1 : 1.432 : 2.472
W/C Ratio (Potable/Sea)	0.414
Cement	24 kg
Fine Aggregate	34.368 kg
Coarse Aggregate	59.328 kg
Water (Potable/Sea)	9.936 kg

TABLE 3
TEST RESULTS FOR M-20 (OPC 43 GRADE)
(Laboratory: VVP Polytechnic, Solapur)

Age of Concrete	Avg. Compressive Strength (N/mm^2)		Increase	% Increase
	Potable Water	Sea Water		
7 Days	20.351	21.198	0.847	4.162
14 Days	27.759	30.296	2.537	9.139
21 Days	30.338	31.895	1.557	5.132
28 Days	32.055	31.104	-0.951	-2.967

TABLE 4
TEST RESULTS FOR M-20 (OPC 53 GRADE)

Age of Concrete	Avg. Compressive Strength (N/mm^2)		Increase	% Increase
	Potable Water	Sea Water		
7 Days	20.979	22.266	1.287	6.1347
14 Days	28.191	31.297	3.106	11.0177
21 Days	30.939	33.357	2.418	7.8154
28 Days	32.811	33.175	0.364	1.1094

(Laboratory: VVP Polytechnic, Solapur)

TABLE 5
TEST RESULTS FOR M-20 (PPC)

Age of Concrete	Avg. Compressive Strength (N/mm^2)		Increase	% Increase
	Potable Water	Sea Water		
7 Days	20.772	21.83	1.058	5.093
14 Days	28.121	30.877	2.756	9.801
21 Days	30.911	32.602	1.691	5.471
28 Days	32.062	31.769	-0.293	-0.914

(Laboratory: VVP Polytechnic, Solapur)

TABLE 6
TEST RESULTS FOR M-25 (OPC 43 GRADE)

Age of Concrete	Avg. Compressive Strength (N/mm^2)		Increase	% Increase
	Potable Water	Sea Water		
7 Days	24.045	25.422	1.377	5.727
14 Days	32.242	35.685	3.443	10.679
21 Days	35.804	36.625	0.821	2.293
28 Days	37.572	35.672	-1.9	-5.057

(Laboratory: VVP Polytechnic, Solapur)

TABLE 7
TEST RESULTS FOR M-25 (OPC 53 GRADE)

Age of Concrete	Avg. Compressive Strength (N/mm^2)		Increase	% Increase
	Potable Water	Sea Water		
7 Days	24.502	26.257	1.755	7.163
14 Days	32.734	36.792	4.058	12.397
21 Days	36.418	37.884	1.466	4.025
28 Days	37.884	37.632	-0.252	-0.665

(Laboratory: VVP Polytechnic, Solapur)

TABLE 8
TEST RESULTS FOR M-25 (PPC)

Age of Concrete	Avg. Compressive Strength (N/mm^2)		Increase	% Increase
	Potable Water	Sea Water		
7 Days	24.303	25.804	1.501	6.1762
14 Days	32.675	35.954	3.279	10.0352
21 Days	36.239	37.398	1.159	3.1982
28 Days	37.8	36.533	-1.267	-3.3519

(Laboratory: VVP Polytechnic, Solapur)

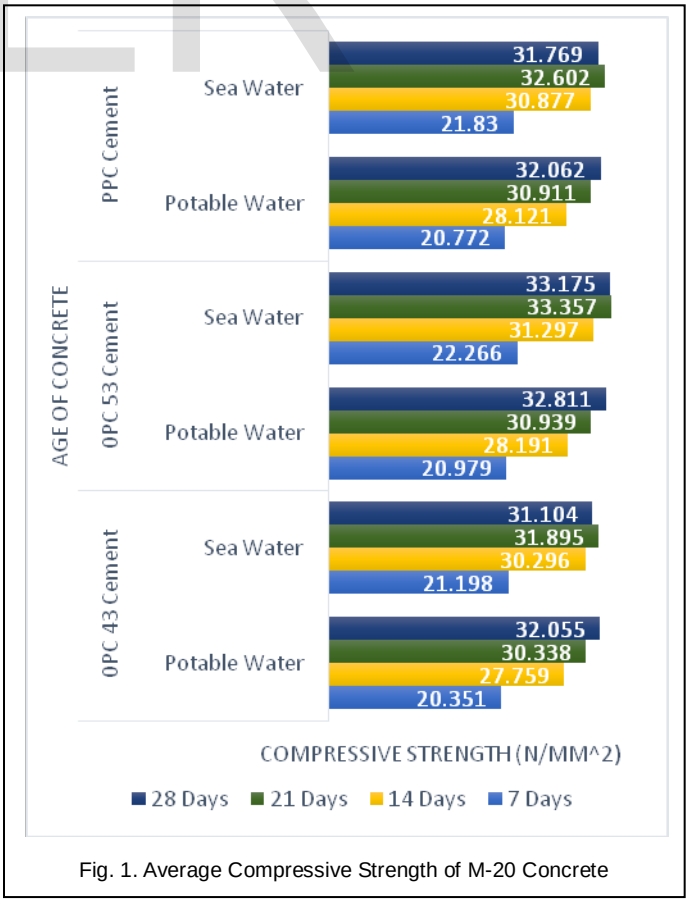

Fig. 1. Average Compressive Strength of M-20 Concrete

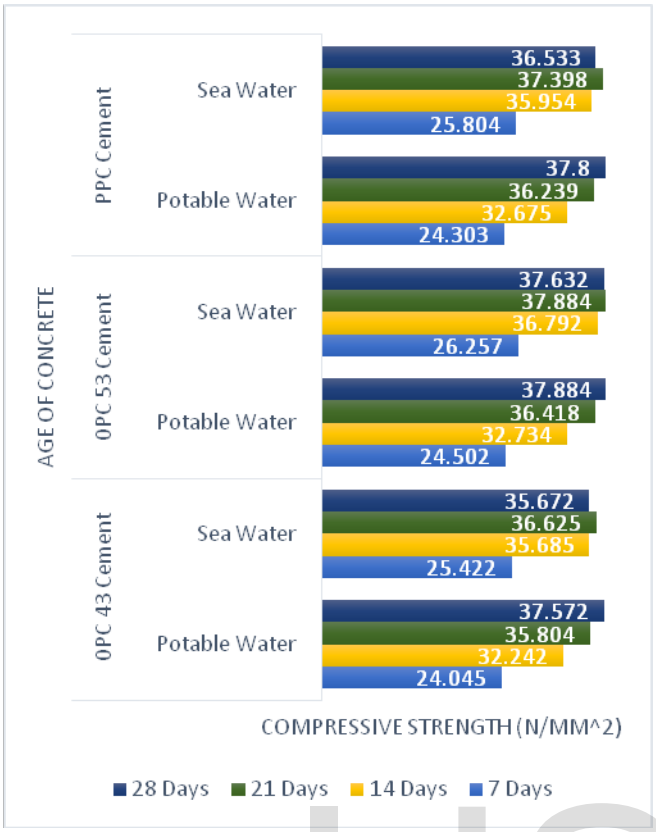

Fig. 2. Average Compressive Strength of M-25 Concrete

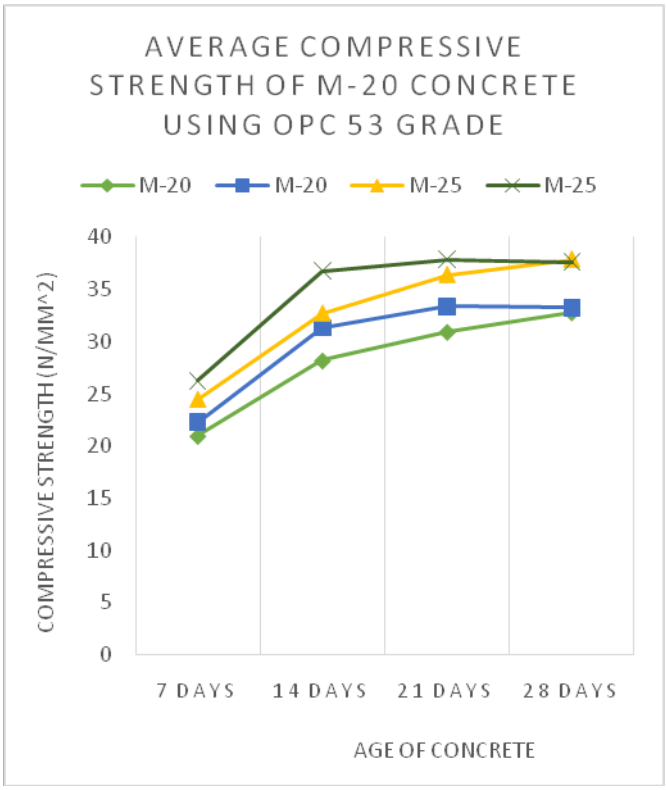

Fig. 4. Graphical Representation of Average Compressive Strength of M-20 and M-25 Concrete Using OPC 53 Grade

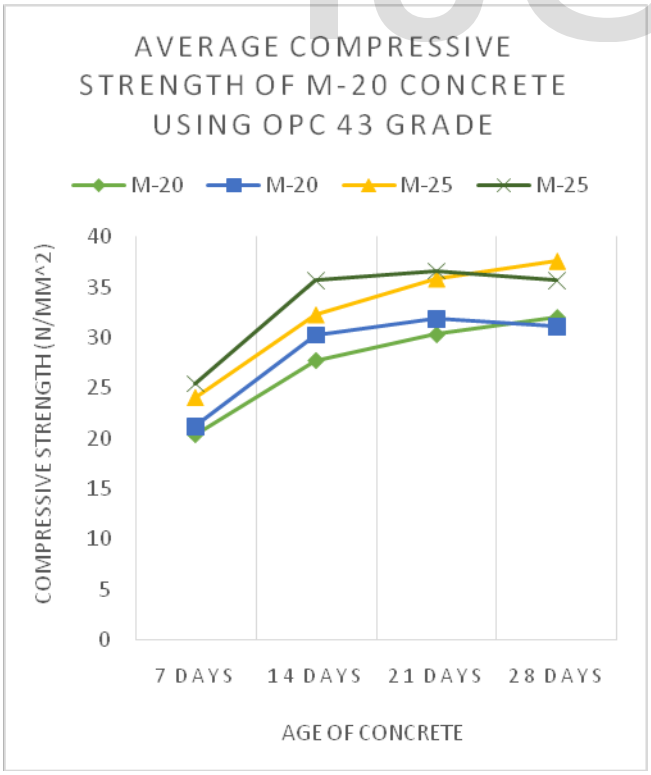

Fig. 3. Graphical Representation of Average Compressive Strength of M-20 and M-25 Concrete Using OPC 43 Grade

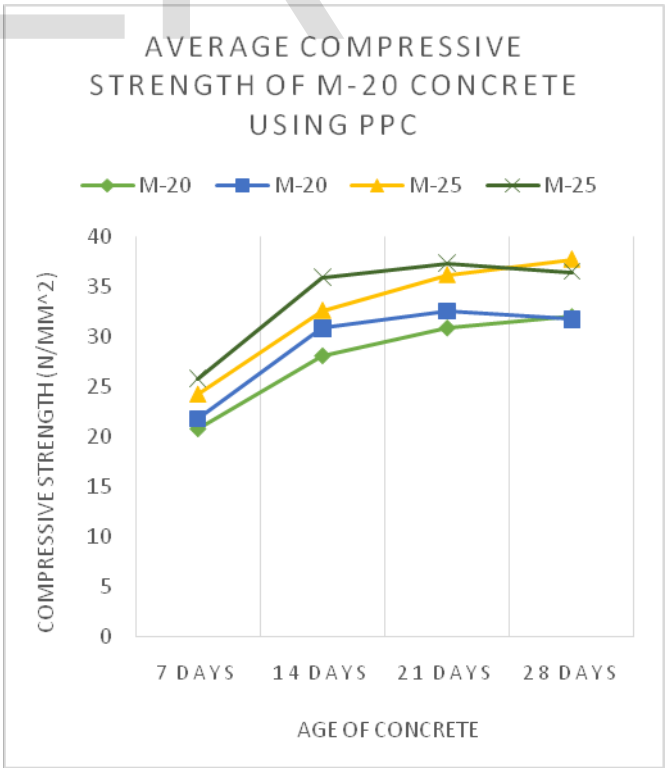

Fig. 5. Graphical Representation of Average Compressive Strength of M-20 and M-25 Concrete Using PPC

5 CONCLUSIONS

1. Series of experiments were conducted on M-20 and M-25 grade of concrete using OPC 43 grade, OPC 53 grade and PPC. From the results it can be said that, there is an increase in the of compressive strength of concrete cubes at early ages which were cast and cured with sea water as compared with the concrete cubes cast and cured with potable water. The strength increases by 4-8% at 7 days and 9-13% at 14 days.
2. There is no remarkable reduction in compressive strength due to mixing and curing of sea water, the strength decreases by about 1-5% at 28 days when concrete is mixed and cured with sea water as compared to characteristic target strength when concrete mixed and cured with potable water.
3. The reduction of strength percentage is most for PPC and least for OPC 53 grade for both M-20 and M-25 grade of concrete.
4. Studies may be carried out for higher grades of concrete i.e. M-30 and above and other types of cements, other types of admixtures and ground granulated blast furnace slag cements etc.

From the above finding we can conclude that there is no remarkable variation in the compressive strength if sea water is used for casting and curing the concrete. This concrete can be safely used for mass concreting without any alteration in strength properties.

6 REFERENCES

[1] Swati Maniyal, Ashutosh Patil, "An Experimental Review of Effect of Sea Water on Compressive Strength of Concrete", International Journal of Emerging Technology and Advance Engineering (IJETAE), Vol. 5, Issue 3, pp 155-159.

[2] IS 10262-2009, "IS 10262-2009, "Concrete Mix Proportioning"

[3] P. Kumar Mehta & Paulo J.M. Monteiro. "Concrete in Sea Water", Concrete Microstructure, Properties and Materials.

[4] Building research Station (1956). "Analysis of water encountered in construction", Digest No. 90, London, H.M.S.O.

[5] Donald F. Griffin and Robert L. Henry (1964). "The Effect of Salt in Concrete on Compressive Strength, Water Vapour Transmission and Corrosion of Reinforcing Steel", U.S. Civil Engineering Laboratory, California,

[6] Osei, Y. A. (2000). "Neutralization, New School Chemistry", African First Publisher Onitsha Nigeria.

[7] Adebakin, H. I. (2003). "Effect of Salinity on Compressive Strength on Concrete."

[8] Akinkurolere O.O. et.al. (2007). "The Influence of Salt Water on Compressive Strength of Concrete", Journal of Engineering and Applied Sciences 2(2). Medwell Journals, pp 412-415.

[9] Water Encyclopaedia (2012). "Earth: The water Planet", (Ed). Earth Sylvia. Retrieved fromwww.watercyclopedia.com/ Da-En/ Earth- The water-planet.html # b.

[10] Falah M. Wegian (2010). "Effects of sea water for mixing and curing on structural concrete Studies", The IES Journal Part A: Civil & Structural Engineering, Vol. 3, No. 4, and November 2010, pp 112-115.

[11] P. Krishnam Raju, V. Ravindra and M. Bhanusingh (2014). "A Study on Strengths of Ordinary Portland Cement Concrete Under Marine Water", International Journal of Engineering Science and Technology (IJEST), Vol. 6 No.3 Mar 2014, pp 6-11.

[12] Preeti Tiwari, Rajiv Chandak, R.K. Yadav (2014), "Effect Of Salt Water On Compressive Strength Of Concrete", Int. Journal of Engineering and Application, Volume 4, Issue 4, April 2014, pp 38-42.

[13] Takahiro Nishida1, Nobuaki Otsuki, Hiroki Ohara, Zoulkanel Moussa Garba and Tomohiro Nagata, "Some Considerations for the Applicability of Seawater as Mixing Water in Concrete", Third International Conference of Sustainable Environment.