Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13744404

ANALYSIS OF POLYETHYLENE GLYCOL AS A SELF-CURING AGENT OF CONCRETE

SAEED AHMED
DHA SUFFA University, Department of Civil Engineering, Karachi, Sindh Pakistan.

Dr. GUL MUHAMMAD *
Ziauddin University, Department of Civil Engineering, Faculty of Engineering Science Technology & Management, Karachi, Sindh Pakistan. *Corresponding Author Email: gul.muhammad@zu.edu.pk

SAIFULLAH ABBASI
DHA SUFFA University, Department of Civil Engineering, Karachi, Sindh Pakistan.

NOOR AHMED FAREEDI
Department of Civil Engineering Technology, Faculty of Engineering, Science & Technology, Indus University Karachi.

IQRA ABID HUSSAIN
Department of Civil Engineering Technology, Faculty of Engineering, Science & Technology, Indus University Karachi.

Abstract

The current problem in the building sector is the excessive use of water in the curing process of concrete, leading to water scarcity issues and higher operational costs. The traditional methods of curing concrete such as water curing, are time-consuming and require extensive labor. Additionally, the production of cement for construction purposes makes a significant quantity of carbon dioxide released, contributing to environmental degradation. The Pakistan is facing potable water scarcity issues especially for the construction industry. To address these challenges, there is a need to explore alternative self-curing methods that can reduce water consumption. This method partially replaces cement with self-curing agents, reducing evaporation and moisture, thus preventing water scarcity and promoting future industry growth. This study has a restricted scope to the M20 Grade in which the research is focused on examining the efficacy of polyethylene Glycol (PEG) 400 and 6000 as a substance that cures itself use with varying percentage such as 1.5%, 2% and 2.4%. The timeframe for testing the efficacy of self-curing with PEG is set at 7 to 28 days. Finally, the research has revealed that with the addition of PEG 400 and PEG 6000 in the concrete mixing have significant effect on the compressive strength, split tensile strength and water absorption capacity of the mixed concrete.

Keywords: Concrete, Polyethylene Glycol, Curing, Compressive Strength, Split Tensile Strength.

1. INTRODUCTION

Civil engineers are highly sought-after professionals for their creativity, inventiveness, and technical expertise. They oversee initiatives including the rebuilding, upgrading, and repair of roads, levees, bridges, airports, buildings, and other infrastructure. They also plan, build, run, and maintain infrastructures while preserving the environment and public health and rehabilitating outdated systems and structures. In addition, civil engineers also play an important role in disastermanagement and emergency response, ensuring that structures are designed and constructed to resist calamities like storms, floods, and

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13744404

earthquakes. The work of civil engineers are essential to the safety and well-being of communities around the world [1].Concrete is a fundamental building material used in civil engineering constructions due to its affordability, permanence, and simplicity of manufacturing. It is also known for its versatility and can be molded into different shapes and sizes, making it a popular choice for architects and designers. Additionally, advancements in technology have allowed for the development of specialized types of concrete with unique properties and applications [2]. Concrete is one of the world's most prominent projection materials nowadays, to achieve good strength and durability, concrete is usually reinforced with steel bars or mesh to withstand tensile forces that it cannot resist on its own [3]. Concrete is a man-made substance created from cement, fine aggregates, coarse aggregates, and water. Its best quality is its ease of shaping into the appropriate form, and its most important component is aggregate. Concrete should be specified for its qualities and adaptability in light of the changing environment to promote resource conservation, save money, and ensure optimum energy use. By using sustainable materials and incorporating recycled content, concrete can be an environmentally friendly option. Additionally, its durability and low maintenance make it a long-lasting choice for construction projects [4]. The development of concrete technology has been accelerating recently. The different properties of concrete can enhance the sustainability of the structure's construction for increased durability and performance [5]. When cement continues to hydrate in the presence of enough water and heat, hydraulic cement concrete matures and takes on hardened qualities over time. This process is commonly referred to as curing. Concrete construction must be properly cured to fulfill demands for efficiency and long-term reliability. This is accomplished in traditional curing by external curing. After combining, setting up, and completing. External curing involves exposing the concrete to moist conditions for a specified period to ensure proper hydration and strength development, this process is crucial in achieving durable and long-lasting concrete structures [6, 7]. Since Cement concrete regulate the temperature and moisture content throughout the initial phases of concrete curing, they are crucial to preventing the expansion of the concrete's characteristics. The use of curing compounds can also help to reduce cracking and enhance the overall strength of the concrete and it is important to choose the appropriate curing compound for the specific type of concrete being used [8]. Since they regulate the temperature and moisture content throughout the initial phases of concrete curing, they are crucial to preventing the expansion of the concrete's characteristics. In order for concrete to obtain the necessary qualities, curing entails keeping the material at a suitable temperature and moisture level in the early stages of its development [9]. When the concrete to reach its full strength potential and resist cracking over time, ensuring the longevity of the structure it supports [10]. Self-curing agents are different from normal concrete in that they work to increase the concrete's water retention capacity by reducing the quantity of water that evaporates from the material. Water soluble polymers have been found to be effective in concrete as self-curingagents. This technology is particularly useful in hot and dry environments where conventional concrete may crack due to excessive water loss. Self-curing agents can also improve Concrete's toughness and longevity structures [11]. This method involves the

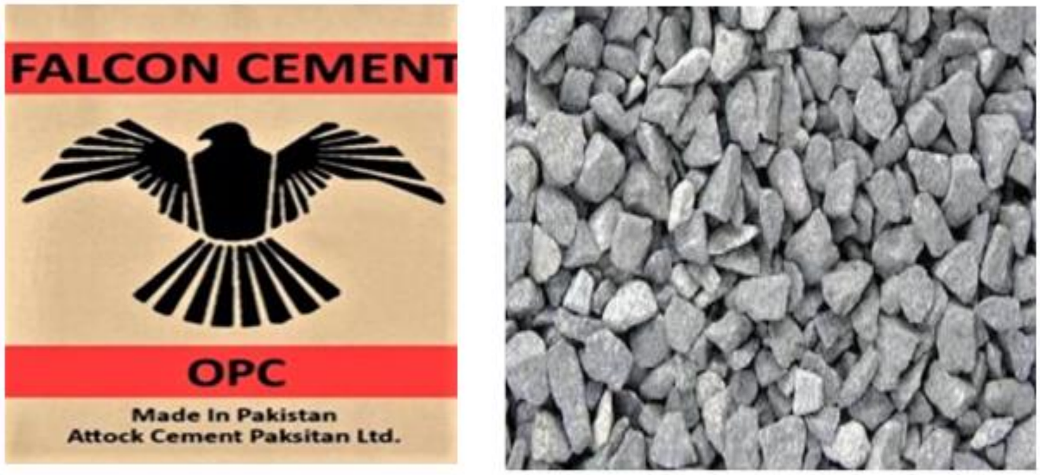
Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13744404

use of lightweight aggregates or pre-wetted fine aggregates that can provide moisture to the concrete. Concrete constructions can become stronger and more durable by self-curing [12]. Therefore, a number of researchers have looked at the possibility of self-curing concrete to decrease the need for external curing techniques, which may be expensive and time-consuming, including water spraying or covering with plastic sheets [13]. By using this technique, shrinkage cracking and heat cracking are reduced and firm, dense concrete is produced. Lightweight Aggregate (LWA), Super-absorbent Polymers (SAP), and Shrinkage-reducing admixtures (SRA) are some of the particular types of materials used in the internal curing process. Internal curing is a crucial step in ensuring the durability and longevity of concrete structures, especially in harsh weather conditions and by using these components, the moisture content of the concrete is maintained, Preventing it from drying out too quickly and becoming brittle [14,15]. The water soluble nature of PEG seems to be a common characteristic. Numerous medicinal products employ polyethylene glycol because it is environmentally friendly, odorless, neutral, lubricating, non-volatile, and non-irritating and It is a shrinkage-reducing admixture, the shrinkage-reducing properties of PEG make it a valuable additive in various industries, including construction and pharmaceuticals [16]. The ACI-8 Code defines "internal curing" as the process by which cement hydrates due to the presence of extra internal water that is distinct from the mixing water. Saturated, lightweight, super-absorbent polymer particles consisting of polyethylene glycol are often added to the concrete in very tiny amounts to supply the extra internal water. Polyethylene glycol is also known as polyethylene oxide (PEO) or polyoxyethylene. In this study the effects of polyethylene glycol (PEG) additives with different percentages on normal and self- curing concrete's workability, compressive strength, split tensile strength, and water absorption were examined.

2. MATERIALS AND METHODS

The ordinary Portland cement and polyethylene glycol (PEG 400 and PEG 6000), coarse aggregate, and fine aggregate and portable water are used in this study to create normal and self-curing concrete. Every substance is stored in sealed containers to protect its qualities from environmental factors. The Slump test (ASTM C143), Compressive Strength (ASTM C39), Split Tensile Strength (ASTM C496), Water Absorption (ASTM C1585) and Compaction factor (ACI 211.3-75) methods Figure 1 shows the port land cement and coarse aggregate used in concrete. Polyethylene glycol-6000 (PEG-6000) is a mixture of polyether. It is a white, waxy solid widely used in various industries for its unique properties. Polyethylene glycol-400 (PEG-400) is a versatile mixture with multiple applications across various industries. PEG-400 properties are solvent, humectant, emulsifier, and stabilizer both are shown in the Figure 2. The Chemical composition and the various physical properties of OPC are shown in Table 1 and Table 2 respectively. The physical properties of course and fine aggregate are shown in Table 3 and Table 4 respectively.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13744404



(a) Ordinary Portland cement (b) Size of coarse aggregate in M20

Figure 1: OPC cement and Coarse aggregate

(a) Polyethylene glycol-400 (PEG-400) (b) Polyethylene glycol-6000 (PEG-6000)

Figure 2: (PEG-400) and (PEG-6000)

Table 1: Chemical Composition of Ordinary Portland cement

Chemical Composition of OPC Cement	
Silicon dioxide, SiO_2	20.96
Aluminium Oxide, $Al2O_3$	5.24
Iron Oxide, Fe_2O_3	2.93
Cacium Oxide, CaO	63.94
Magnesium Oxide, MgO	2.03
Sodium Oxide, Na_2O	0.58
Potassium Oxide, K2O	0.22
Sulphur, SO_3	2.59
LOI	1.42

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13744404

Table 2: Physical Properties of Ordinary Portland Cement [17]

S.No	Properties	Result	Range	Standard
1	Fineness	94%	% Passing # 200 ≥90%	ASTM C-184-94
2	Consistency	30%	20%-33%	ASTM C187
3	Initial Setting Time	45 minutes	30-120 minutes	ASTM C-191
4	Final Setting Time	144 minutes	2-10 hours	ASTM C-191

Table 3: Physical Properties of coarse aggregate [18]

Properties	Values
Size	20mm
Specific gravity	2.6 to 2.9
Water Absorption	0.5 % to 2.0%

Table 4: Physical Properties of fine aggregate [18]

Properties	Values
Size	0.125 to 4.75mm
Specific gravity	2.5 to 2.9
Water Absorption	1% to 2%

3. EXPERIMENTAL SETUP

The following are the stages of the testing plan which outline the approach used to accomplish the goals and objectives of this research project.

Table 5: Experimental Details of concrete testing

Sample State	Test type	Standard	Type of measurement	Equipment	Testing age	Sample size	Number of Sample	Unit
Fresh State	Slump	ASTMC143	Workability	Slump cone	Freshstate	0.005 m^3	3	mm
	Compaction factor	ACI 211.3-75	Workability	Cylinder Hoppers	Freshstate	150x285mm 250x125x275mm	3	mm
Hardened State	Compressive Strength	ASTM C39	Crushing Strength	Compressive testing machine (CTM)	7 and 28 days	150x150x150mm cube	3	N/mm^2
	Split TensileStrength	ASTMC496	Tensile Strength	UTM Universal testing machine	7 and 28 days	150x300mm Cylinder	3	N/mm^2
	Water Absorption	ASTMC1585	Water Absorb	Oven	24 hours	150x150x150mm Cube	3	%

The slump test device is utilized to determine the workability of the concrete. Compaction Factor test of Normal Concrete and Self-curing Concrete is particularly useful for concrete mixes of very low workability and normally used when concrete is to be compacted by vibration. The equipment which are used for workability is shown in Figure 3.the compressive strength tests of modified concrete cubes and cylinders are tested with compression testing machine (CTM) and universal testing machine (UTM) respectively as shown in Figure 4.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13744404

(a) Slump test apparatus (b)Compaction Factor test apparatus

Figure 3: Apparatus used for workability of concrete

(a) compression testing machine(CTM) (b) sample under compressive strength testing (c) universal testing machine (UTM) (d) sample under split tensile testing

Figure 4: Apparatus used for compression test

4. PREPARATION OF SAMPLE

In this investigation fourty five (45) samples are constructed. At different percentages (1.5%, 2% and 2.4%) of polyethylene Glycol (PEG) 400 and 6000 mixed with cement concrete. The materials are selected and mixed thoroughly in a manually (hand) mix the mixing process should continue for at least two to three minutes, until a uniform consistency is achieved as shown in Figure 5. The materials are calculated and weighed as shown in Figure 6. Samples of concrete cubes and cylinders were made in the lab using ASTM C 192 as a guide. The concrete mixture is then cast into the Cylinder and cube shape mold, the constructed cubes and cylinders are shown in Figure 7. It is important that the mold is properly prepared and cleaned before casting the concrete.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13744404

Cleaned and oiling the mold then cast the concrete. The materials used to prepare the M20 concrete mix should be carefully selected, ensuring that they meet the required specifications and quality standards. This includes the cement, sand, coarse aggregate, water, and Polyethylene glycol admixture.

Figure 5: Mixing & Placing of Concrete

Figure 6: Weighing of materials

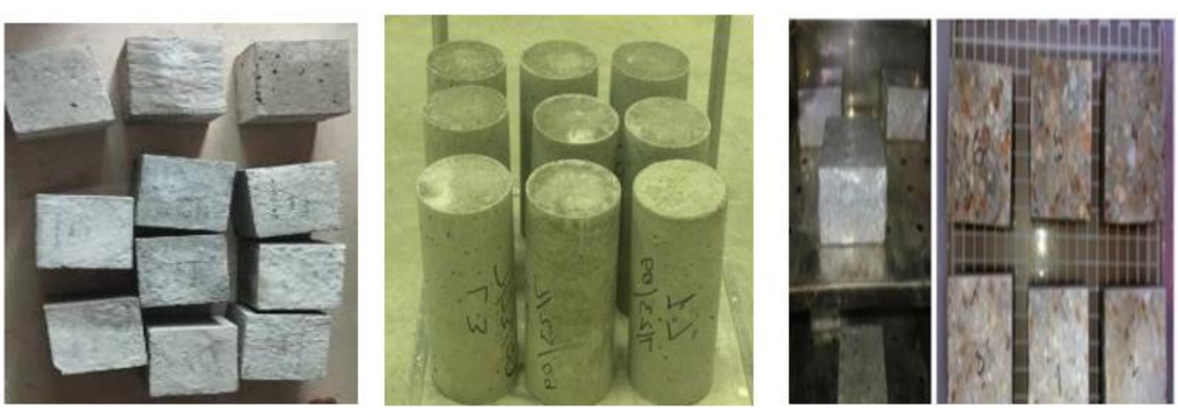


Figure 7: Concrete cubes and cylinders

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13744404

5. RESULTS AND DISCUSSION

5.1 Effect of polyethylene Glycol (PEG) 400 and 6000 on Slump test

The water-to-material ratio in slump test significantly affected the workability of both normal and self-curing concrete, making it average. Adding PEG-400 improved workability with the addition of amount, while PEG- 6000 is increasing the workability up to addition of 2% PEG- 6000 amount further addition of the amount is decreasing workability as shown in Table 6. PEG-Mix also increased workability with the addition of polyethylene Glycol. PEG- 400 and PEG-Mix appear to be good options for improving workability, as it has been revealed in **Error! Reference source not found.**.

Table 6: Result of Slump test

Concrete Type	PEG Percentage (%)	Slump (mm)
M20 Normal concrete	0	53
PEG-400	1.5	85
PEG-400	2	90
PEG-400	2.40	100
PEG-6000	1.50	75
PEG-6000	2	80
PEG-6000	2.40	50
PEG-Mix (400-6000)	1.50	70
PEG-Mix (400-6000)	2	65
PEG-Mix (400-6000)	2.40	80

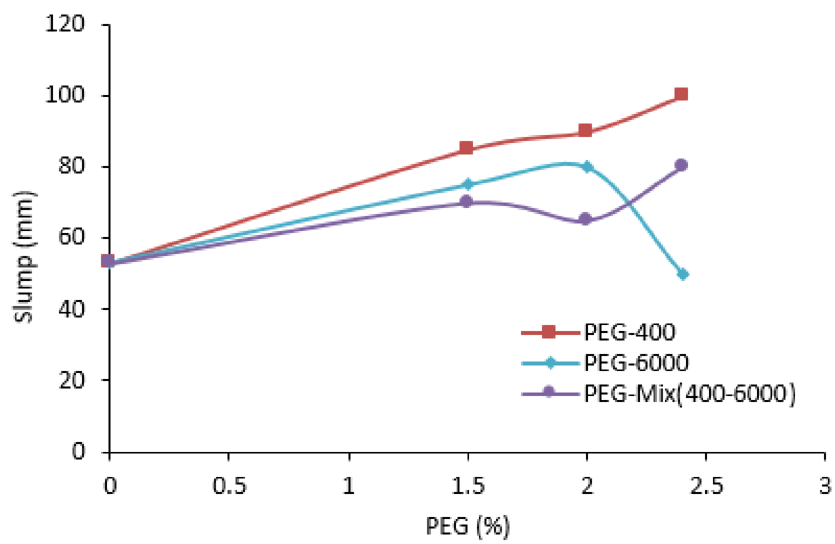


Figure 8: Slump test values with addition of PEG

5.2 Effect of polyethylene Glycol (PEG) 400 and 6000 on compaction factor test

The water-to-material ratio in your Compaction Factor test significantly affected the workability of both normal and self-curing concrete, making it average. As shown in Table 7 the adding PEG-400 improved workability at 1.5% after that with 2% of addition it has

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13744404

dropped and further addition improved the workability, while PEG-6000 only show the improvement up to 1.5% addition and with further addition workability is decreasing . As the Curve trend has revealed in Figure 9 that with the addition of PEG-Mix is going to improve. PEG-Mix has appear to be good options for improving workability.

Table 7: Result of Compaction Factor Test

Concrete Type	PEG Percentage (%)	Compacting Factor (mm)
M20 Normal concrete	0	0.87
PEG-400	1.5	0.92
PEG-400	2	0.88
PEG-400	2.40	0.90
PEG-6000	1.50	0.91
PEG-6000	2	0.89
PEG-6000	2.40	0.86
PEG-Mix (400-6000)	1.50	0.90
PEG-Mix (400-6000)	2	0.91
PEG-Mix (400-6000)	2.40	0.92

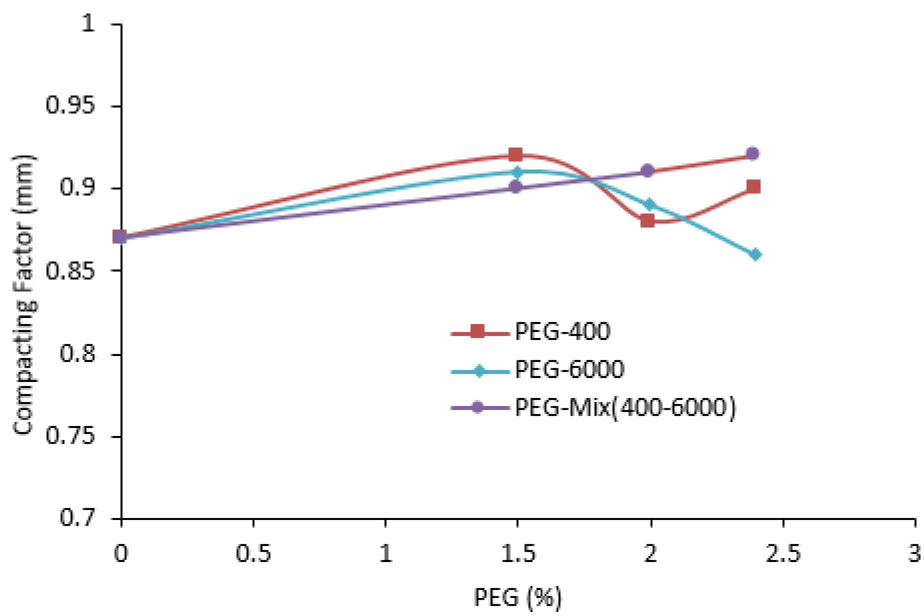


Figure 9: Compacting factor values with addition of PEG

5.3 Effect of polyethylene Glycol (PEG) 400 and 6000 on compressive strength

The results of testing on the compressive strength of normal concrete and self-curing concrete, incorporating different percentages of polyethylene glycol (PEG-400 in liquid form and PEG-6000 in powder form) as shown in Table 8, reveal distinct effects on compressive strength. An increase in the proportion of PEG-400 is associated with increase at seven days (7) curing but with the passage of time like twenty-eight (28) days curing compressive strength has decreased. Conversely, a rise in the amount of PEG-6000 correlates with an increase in compressive strength on both phase of curing. An increase in the proportion PEG-Mix (PEG- 400 and PEG-6000) correlates with an increase in compressive strength for 28-days. The graphical representation of all these findings are shown in Figure 10 and Figure 11.

Table 8: Results of Compressive Strength on cubes sample

Concrete Type	PEG Percentage (%)	Compressive Strength (N/mm2) @7days	Compressive Strength (N/mm2) @28days
M20 Normal concrete	0	13.98	19.73
PEG-400	1.5	19.92	18.2
PEG-400	2	19.54	19.16
PEG-400	2.4	17.05	19.16
PEG-6000	1.5	14.56	21.45
PEG-6000	2	14.37	17.82
PEG-6000	2.4	15.52	22.03
PEG-Mix (400-6000)	1.5	15.33	16.28
PEG-Mix (400-6000)	2	16.67	19.16
PEG-Mix (400-6000)	2.4	14.75	22.99

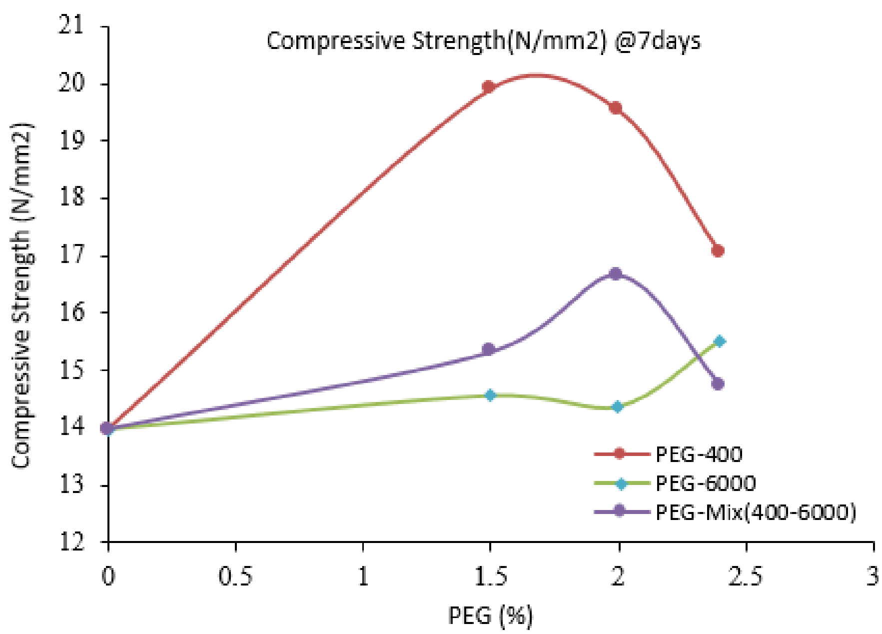


Figure 10: Compressive strength @ 7days curing with addition of PEG

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13744404

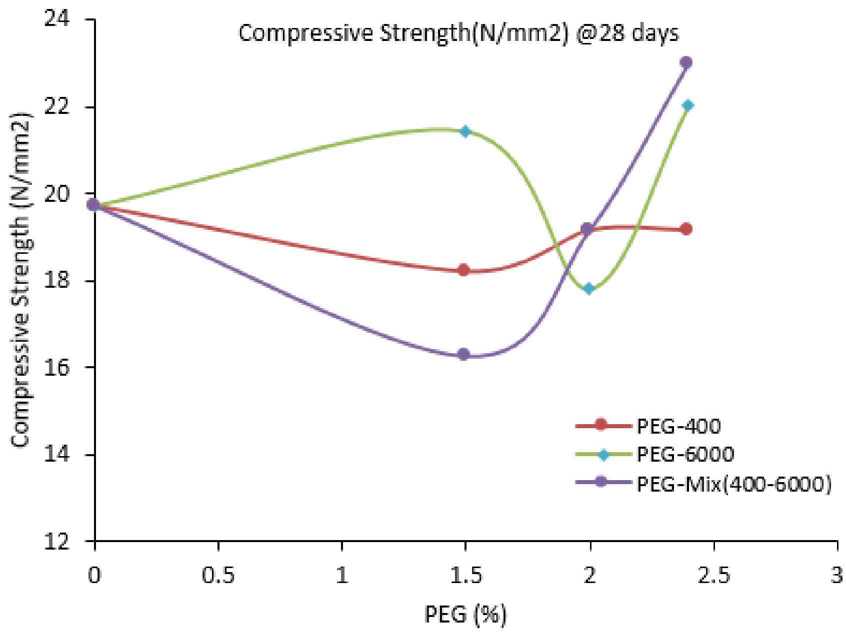


Figure 11: Compressive strength @ 28 days curing with addition of PEG

5.4 Effect of polyethylene Glycol (PEG) 400 and 6000 on Split Tensile Strength

The results of Split Tensile Strength test on cured cylinder specimens with the addition of different percentages of PEG-400 and PEG-6000 are shown in Table 9. The test results of split tensile strength of the concrete increased with the addition of PEG, up to a certain percentage. For example, the 28-day split tensile strength of the control normal concrete was 2.2 N/mm², while the 28-day split tensile strength of the concrete with 1.5% PEG-400 was 2.5 N/mm². However, the split tensile strength of the concrete increase with the addition of too much PEG-400. AS shown in Figure 12 and Figure 13 the difference is most noticeable at the highest PEG-6000 dosage (2.4%). Here, the split tensile strength is 21% lower compared to the normal concrete. This trend is the opposite of PEG-400, which shows an increasing split tensile strength with higher PEG-400 content. Overall, the results suggest that PEG-6000 is not a suitable additive for improving the split tensile strength of concrete.

Table 9: Results of Split Tensile Strength on cylinder sample

Concrete Type	PEG Percentage (%)	Split Tensile Strength (N/mm2) @7days	Split Tensile Strength (N/mm2) @28days
M20 Normal concrete	0	1.9	2.2
PEG-400	1.5	2.02	2.5
PEG-400	2	1.87	2.6
PEG-400	2.4	2.3	2.7
PEG-6000	1.5	2.2	2.4
PEG-6000	2	2.3	2.3
PEG-6000	2.4	2.4	2.1

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13744404

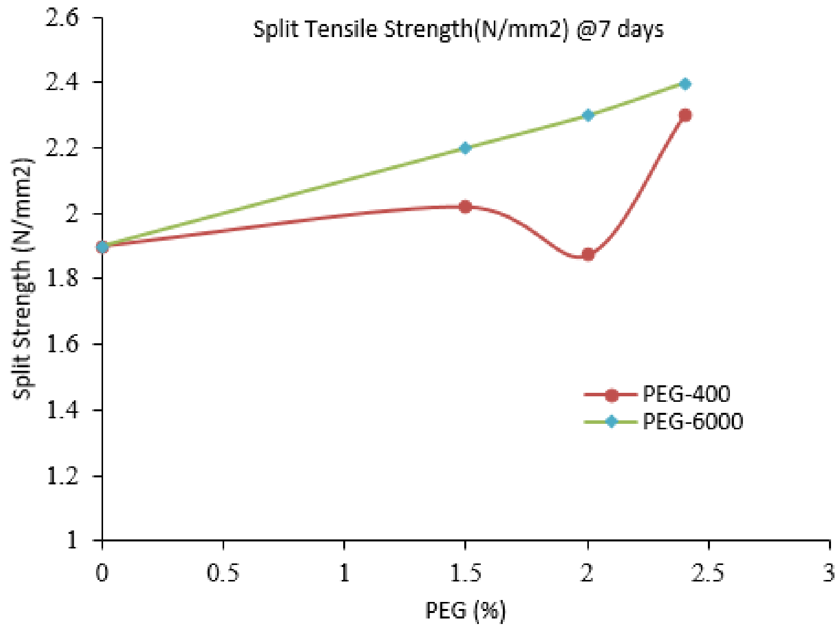


Figure 12: Split Tensile Strength @ 7 days curing with addition of PEG

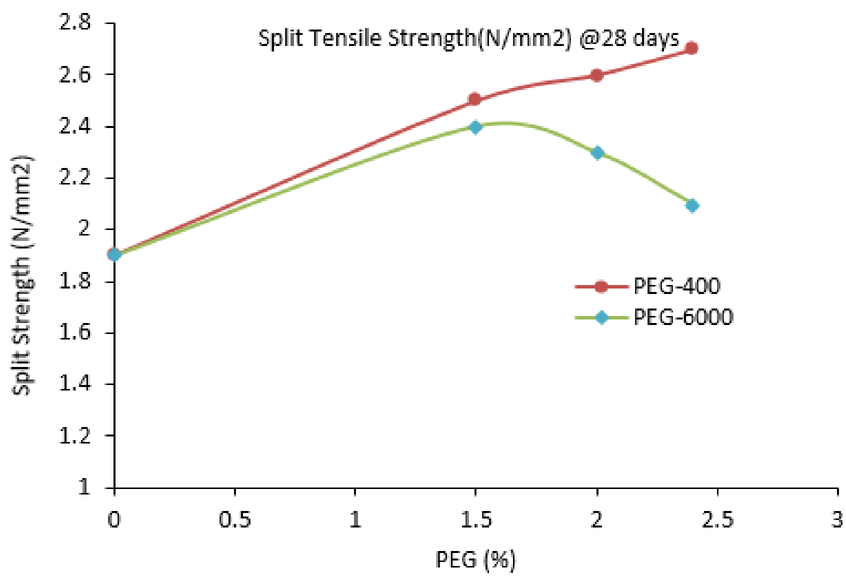


Figure 13: Split Tensile Strength @ 28 days curing with addition of PEG

5.5 Effect of polyethylene Glycol (PEG) 400 and 6000 on Water Absorption of Concrete

Based on the data as shown in Table 10: Effect of PEG on water absorption of **concrete**, PEG-6000(powder form) has the most significant impact on reducing water absorption in concrete. Across all three PEG percentages, PEG-6000(powder form) consistently

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13744404

resulted in the lowest absorption rates. As shown in Figure 14, at 1.5% PEG, PEG-6000(powder form) had an absorption rate of 0.163%, which is 23% lower than the absorption rate of control concrete (0.213%). At 2% PEG, the difference was even greater, with PEG-6000(powder form) having an absorption rate of 0.199%, which is 37% lower than the control concrete.PEG-400(liquid form) and PEG Mix also reduced water absorption, but their effects were less pronounced than PEG-6000 (powder form). For example, at 1.5% PEG, PEG-400 had an absorption rate of 0.242%, which is 11% lower than the control concrete. PEG Mix had an absorption rate of 0.236% at 1.5% PEG, which is 5% lower than the control concrete. Overall, the results suggest that PEG-6000 is the most effective PEG additive for reducing water absorption in concrete.

Table 10: Effect of PEG on water absorption of concrete

Concrete Type	PEG Percentage (%)	Water Absorption (%) @24 hours
M20 Normal concrete	0	0.213
PEG-400	1.5	0.242
PEG-400	2	0.257
PEG-400	2.4	0.298
PEG-6000	1.5	0.163
PEG-6000	2	0.199
PEG-6000	2.4	0.221
PEG-Mix (400-6000)	1.5	0.236
PEG-Mix (400-6000)	2	1.044
PEG-Mix (400-6000)	2.4	1.556

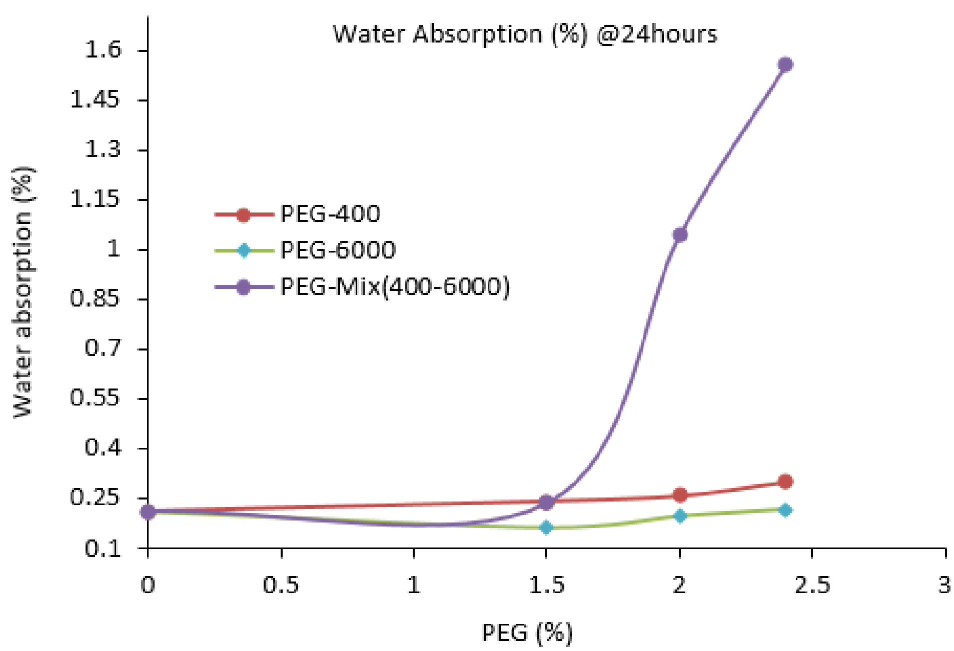


Figure 14: Effect of PEG on Water absorption

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13744404

6. CONCLUSION

From the results the following conclusion were drawn:

- Both normal and self-curing concrete exhibited average workability at the tested water-to- material ratios.
- Only PEG-400 and PEG-Mix, enhanced workability PEG-6000 had no significant impact.
- PEG-400 and PEG-Mix seem to be beneficial options for enhancing the workability of concrete.
- Adding PEG-400 (2.4%) resulted 17.05 N/mm^2 28 days curing in a decrease in compressive strength, while increasing PEG-6000 (2.4%) resulted 22.03 N/mm^2 28 days curing led to an increase in strength. while increasing PEG-Mix 2.4% resulted 22.99 N/mm^2
- PEG-400 reduced compressive strength, perhaps as a result of its capacity to lower the amount of water available for hydration.
- PEG-6000 improved microstructure and enhanced hydration, which is probably reason it boosted compressive strength.
- For 28 days, PEG-Mix improved compressive strength.
- Split tensile strength was improved by PEG-400 up to a 2.4% percentage.
- Split tensile strength was reduced by PEG-6000 at every tested dose.
- PEG-6000 is not a suitable additive for improving split tensile strength, while PEG-400 is good.
- The greatest notable effect in decreasing water absorption was observed with PEG-6000.
- PEG-400 and PEG-Mix also reduced water absorption, but to a lesser extent than PEG-6000.
- The best PEG addition for lowering water absorption is PEG-6000.

Acknowledgement

The Authors express gratitude to Department of Civil Engineering Technology Indus University, Department of Civil Engineering Ziauddin University, Department of Civil Engineering DHA SUFFA University, Karachi, for the support and assistance in experimental work at Laboratories.

Reference

1) K. Flaga, “Advances in materials applied in civil engineering,” *J. Mater. Process. Technol.*, vol. 106, no. 1–3, pp. 173–183, 2000, doi: 10.1016/S0924-0136(00)00611-7.

2) S. Satapathy, N. Patel, and P. G. Scholar, “An Experimental Investigation of Self Curing Concrete,” pp. 129–132, 2021, [Online].

3) G. Thrinath and P. Sundara Kuma, “Eco-friendly self-curing concrete incorporated with polyethylene glycol as self-curing agent,” *Int. J. Eng. Trans. A Basics*, vol. 30, no. 4, pp. 473–478, 2017, doi: 10.5829/idosi.ije.2017.30.04a.03.

4) D. S. Vijayan, S. Arvindan, D. Parthiban, R. Sanjay Kumar, B. Saravanan, and Y. Robert, “An experimental study on mechanical and durable properties of self-curing concrete by adding admixture,” *Mater. Today Proc.*, vol. 33, no. xxxx, pp. 496–501, 2020, doi: 10.1016/j.matpr.2020.05.071.

5) S. Aishwarya, M. S. Kavya, R. Reffin, S. Veena, and R. Vasudev, “Experimental Study on the Properties of Bendable Concrete,” *Lect. Notes Civ. Eng.*, vol. 46, no. November, pp. 111–121, 2020, doi: 10.1007/978-3-030-26365-2_11.

6) P. G. Scholar, C. Engineering, and G. College, “Experimental Investigation of Self Curing Concrete and Self Compacting Concrete,” vol. 05, no. 31, pp. 6548–6553, 2016.

7) E. Science, “Effect of self-curing agent on mechanical properties of concrete with GGBS replacement Effect of self-curing agent on mechanical properties of concrete with GGBS replacement,” 2021, doi: 10.1088/1755-1315/796/1/012062.

8) P. Mandiwal and S. Jamle, “Use of Polyethylene Glycol as Self Curing Agent in Self Curing Concrete - An Use of Polyethylene Glycol as Self Curing Agent in Self Curing Concrete - An Experimental Approach,” no. January, pp. 9–12, 2018.

9) G. V. Jasmine, M. P. Kumar, and P. Markandeya, “Study on early age and ultimate compressive strength of M30 grade self-curing concrete Study on early age and ultimate compressive strength of M30 grade self-curing concrete”, doi: 10.1088/1757-899X/1025/1/012018.

10) G. Sudharson, M. Kalpana, D. Anburaja, and M. G. Prathap, “PEG 400 Effect on Properties of Self Curing Concrete,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1026, no. 1, p. 012014, 2021, doi: 10.1088/1757-899x/1026/1/012014.

11) A. Titiksh and S. P. Wanjari, “Sustainable pavement quality concrete containing ultra-high volume fly ash in the presence of a novel superplasticizer,” *Case Stud. Constr. Mater.*, vol. 15, no. June, p. e00603, 2021, doi: 10.1016/j.cscm.2021.e00603.

12) P. Mandiwal and M. T. Scholar, “Tensile Strength & Durability Study on Self-Curing Concrete as a Partial Replacement of Cement by PEG-400,” *Int. J. Res. Eng. Appl. Manag.*, vol. 04, no. 10, pp. 2454–9150, 2019, [Online].

13) N. Mohamad, K. Muthusamy, R. Embong, A. Kusbiantoro, and M. H. Hashim, “Environmental impact of cement production and Solutions: A review,” *Mater. Today Proc.*, vol. 48, no. xxxx, pp. 741–746, 2021, doi: 10.1016/j.matpr.2021.02.212.

14) M. V. Jagannadha Kumar, K. Jagannadha Rao, B. Dean Kumar, and V. Srinivasa Reddy, “Development of self-curing concrete using polyethylene glycol as internal curing agent,” *Int. J. Civ. Eng. Technol.*, vol. 9, no. 7, pp. 1133–1141, 2018.

15) V. P. Chavan, “Self-Curing Concrete: - with Poly-Ethylene Glycol,” vol. 9, no. 09, pp. 195–197, 2020.

16) R. A. Khan and C. Gupta, “A review on the study of self-curing concrete,” vol. 11, no. 2, pp. 1–7, 2020.

17) A. A. Bashandy, N. N. Meleka, and M. M. Hamad, “Comparative study on the using of PEG and PAM as curing agents for self-curing concrete,” vol. 8, no. 1, pp. 1–10, 2017.

18) N. Dharani and J. G. Rajan, “Experimental Study On Strength Properties of Self Curing Concrete Using Polyethylene Glycol with Partial Replacement of River Sand by M Sand,” vol. 6, no. 3, pp. 446–453, 2021.