Journal of Civil Aspects and Structural Engineering

www.case.reapress.com

J. Civ. Asp. Struct. Eng. Vol. 1, No. 2 (2024) 220–234.

Paper Type: Original Article

Evaluation of Mechanical Behavior of Reinforced Concrete Containing Rock Wool Fibers Resistant to Cold and Frost

Kiarash Fozouni*

Department of Civil Engineering, Mulla Sadra Ramsar Vocational Technical University, Ramsar, Iran.

Citation:

Received: 14 Jully 2024 *Revised: 26 August 2024* *Accepted: 19 November 2024*	Fozouni, K. (2024). Evaluation of mechanical behavior of reinforced concrete containing rock wool fibers resistant to cold and frost. *Journal of civil aspects and structural engineering, 1(2), 220-234.*

Abstract

Concrete is one of the main materials in construction due to its unique properties, but it suffers from weaknesses due to its low tensile strength and brittleness. One of the methods for improving these weaknesses is the use of fibers in concrete. Rock wool is one of the fibers that can be effective in enhancing the mechanical performance of concrete. This research aims to analyze the effect of rock wool fibers with a diameter of 0.004 mm and lengths of 6 and 12 mm on the resistance of concrete to cold and frost. In this research, four mixtures with different amounts of rock wool fibers (0, 0.2, 0.4, 0.6 percent) were investigated. The results showed that concrete containing 0.4 percent rock wool fibers showed good resistance to cold, and its resistance increased compared to ordinary concrete. At the same time, adding more rock wool fibers reduced the resistance of concrete to cold. Due to the high water absorption of rock wool fibers, the water-to-cement ratio increased, which reduced the mechanical strength of concrete. For this reason, a lubricant was used to reduce the water-cement ratio to increase the resistance of concrete to cold.

Keywords: Mechanical behavior, Reinforced concrete, Rock wool fibers, Cold and frost, High-strength concrete, Fiber concrete.

1 | Introduction

In recent decades, advances in civil engineering sciences and the development of new technologies have led to significant changes in the design and construction of specific structures. Concrete, as one of the most widely used building materials, has had a special place in these developments due to its characteristics such as high compressive strength, long life, availability of raw materials, and economy. However, despite all the advantages of concrete, its poor performance against tensile forces continues to be a major challenge that affects the durability and stability of structures [1]. One of the effective solutions for improving the

Corresponding Author:

performance of concrete is the use of fibers in its structure. Adding fibers to concrete not only increases compressive and thermal strength but also improves the ductility of concrete and prevents the spread of microcracks to large cracks [2]. Fiber-reinforced concrete with high energy absorption capacity performs better in structures that need to withstand dynamic loads or harsh environmental conditions. Since the 1960s, the use of various fibers such as glass, steel, natural and synthetic fibers has begun to be widespread in advanced industrial countries, and much research has been conducted to improve the quality and performance of these fibers [3].

As one of the new materials in the construction industry, rock wool fibers have attracted great attention due to their unique properties. These fibers, which are obtained from igneous rocks such as basalt and diabase, as well as slag from iron smelting furnaces, are known as a completely inorganic and environmentally friendly material. The main components of these fibers include silica, alumina, calcium oxide and magnesium oxide, all of which increase the mechanical strength and durability of concrete. Rock wool can also help reduce environmental problems caused by waste disposal and play an effective role in the production of concrete with high performance and resistance [4].

Research has shown that the use of rock wool fibers in concrete improves mechanical properties such as compressive strength and reduces dry shrinkage. These fibers also have positive effects on reducing initial surface absorption and improving the thermal performance of concrete. However, excessive increases in fiber volume may reduce concrete efficiency, increase the volume of trapped air, and ultimately reduce the strength and durability of concrete [5]. Although numerous studies have been conducted on the effects of rock wool fibers on the compressive and thermal strength of concrete, limited research has investigated the resistance of these concretes to frost and freezing. This is of great importance, especially in cold regions where structures are exposed to successive cycles of freezing and thawing [6].

The present study, by focusing on the investigation of the mechanical behavior of fiber concrete containing rock wool fibers, especially in cold and freezing conditions, has taken a step towards providing new solutions to increase the durability and strength of this type of concrete. This study, by analyzing the effects of rock wool fibers on the mechanical and physical properties of concrete, seeks to develop practical applications of this material in the construction industry [7].

In 2012, Tang Lin et al. reported that the pozzolanic strength activity index for rock wool waste samples after 91 days was 103%. The inclusion of rock wool waste in cement-based composites reduced its dry shrinkage and initial surface absorption and increased its compressive strength. These improved properties are the result of the dense structure resulting from the filling effect and pozzolanic reactions of rock wool waste. The optimal amount of adding 30% and 10% rock wool waste to cement is 0.35 and 0.55 based on the results of the initial compressive strength and surface absorption, respectively. Therefore, rock wool waste can be used as a partial replacement for cement in cement-based composites [1].

In 2022, the results showed that the density of the sample combined with rock wool decreased sharply (up to a 73% reduction) when the incorporation of rock wool fibers reached 15%. The oven-drying density of the samples for fiber contents ranging from 2.5% to 10% was 800 kg/m3 to 2000 kg/m3, which can be classified as LWC. The permeable pores of the samples increased by 63% by volume with a 15% incorporation of rock wool fibers. Only a certain mixture ratio met the requirement for use as load-bearing interior walls.

The correlation between compressive strength and tensile strength of the crack was subsequently analyzed. Finally, the empirical models for all properties were generated using the response surface methodology with 0.90. As a result, the selection of different rock wool fiber mixing ratios and water-to-cement (W/C) ratios to achieve better physical or mechanical properties of LWC is presented [2].

The results showed that the moisture resistance, Marshall stability, flow and volumetric parameters of hot asphalt were improved due to the reinforcement with rock wool fibers, indicating a decrease in moisture sensitivity and an increase in tensile strength. In addition, hot asphalt mixtures with 1.5% rock wool fibers showed the highest tensile strength (11.37) and Marshall stability compared to the control mixtures. The observed improvement in moisture resistance and Marshall properties of hot asphalt with rock wool fibers resulted in the presence of an interconnected structure and stiffness in the asphalt concrete matrix and can be used for pavement construction [3]. Most of the previous research has been on the fibers used in concrete, and most of the rock wool fibers have been used as composites in concrete and few studies have been conducted on the use of rock wool fibers in high-temperature and frost-resistant concrete.

In addition to increasing the resistance of concrete to atmospheric factors, rock wool fibers create a special type of high-strength concrete that does not harm the environment and reduces the problems caused by the disposal of rock wool waste [8]. It is also considered a recycled concrete. It is expected that the optimal use of rock wool fibers will improve some of the mechanical characteristics of high-strength concrete, such as compressive strength, tensile strength, and strain at maximum load, and this type of concrete can be more economical [9].

2 | Research Method

In this study, library methods were first used to familiarize with the subject and references related to the testing of rock wool fiber concrete, and the necessary tests and investigations were also carried out in the laboratory.

2.1 | Laboratory Method

To achieve the appropriate results in this study, experiments have been conducted, and in these experiments, the specifications of the materials, the method of making the test samples, and the stages of conducting the tests need to be fully explained. In this chapter, the specifications of the materials used to make the samples, including sand, gravel, cement, fibers, etc., are introduced, and the tests performed on each of them are described separately, and the stages of preparing the tests, the mixing design, the curing method, and the water-cement ratio are also explained. The items discussed in this chapter help to create a better understanding of future chapters.

2.1.1 | Specifications of the materials used in the experiment

In this section, the materials and materials used to make the test samples are examined.

2.1.2 | Coarse aggregate (sand)

The sand used in this study is factory-made crushed stone. It has a water absorption rate of 0.01 percent and a specific gravity of 2650 kg/cubic meter. The sand used is crushed river rock from the Cheshmeh-e-Kileh River in Tonekabon, which is crushed by a stone crusher.

Table 1. Coarse sand grading.

Y	Sieve Hole Diameter (Mm)	Residual Weight on each Sieve (Grams)	Percentage Remaining on each Sieve	Cumulative Percentage Remaining on each Sieve	Cumulative Percentage Rejected from each Sieve
1	25.0	0	0	0	100
3.4	19.0	0	0	0	100
1.2	12.5	515.84	51.58	51.58	48.42
3.8	9.5	276.85	27.68	79.27	20.73
4	4.76	207.31	20.73	100	0
8	2.38	0	0	100	0

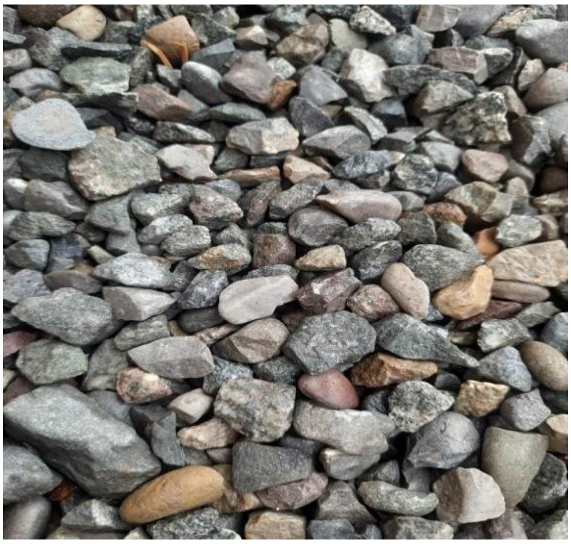

Fig. 1. Coarse aggregate (sand).

2.1.3 | Fine aggregate (sand)

The fine aggregate used in this research is natural mineral rocks with a specific gravity of 2600 kg/m3. The sand used in this project is from the Three Thousand Tonekabon Sand and Sand Mine, where natural mineral rocks are converted into sand by a crusher and are sedimented several times by water so that the sand is free of mud and silt.

Table 2. Fine-grained sand grading.

Sieve	Sieve Hole Diameter (Mm)	Residual Weight on each Sieve (Grams)	Percentage Remaining on Each Sieve	Cumulative ercentage Remaining on each Sieve	Cumulative Percentage Rejected from each Sieve
4	4.76	0	0	0	100
8	2.38	315.95	31.59	31.59	68.40
16	1.19	196.01	19.6	52.1	48.8
30	0.595	148.96	14.9	66.1	33.91
50	0.297	133.52	13.35	79.44	20.55
100	0.149	130.44	13.04	92.49	7.51
The last dish	-	75.1	7.51	100	0

The softness model is the sum of the cumulative percentages remaining on the standard sieves divided by one hundred. The softness modulus determines the fineness or coarseness of the grains, and the coarser the stone grains, the higher their softness modulus. Also, fine grains have a lower softness modulus.

2.2 | Cement

The cement used in all concrete samples is Portland cement type 2 of Golestan Peyvand Company with a specific gravity of 15.3, which is one of the best cement produced in the country according to the ISIRI 389 standard. The main features of this cement are its compressive strength, resistance to chlor-alkali reactions, and high concrete temperature, especially in adverse weather conditions, which is very important in this test.

Table 3. Specifications of Golestan bonded Portland cement.

Specifications	Factory Test	Standard (ISIRI 389)	GOST 10178	Unit
Primary setting time	170	Minimum 45	Min 45	Minute
Secondary setting time	3.5	Maximum 6:00	Max 10:00	Hour
Expansion	0.1	Maximum 8/0	Max 8/0	Percent

Fig. 2. Cement consumption.

2.2.1|Water

The best option for mixing concrete is drinking water. This water has the lowest hardness and undesirable elements. In addition, the lowest pollutants, such as mud, can be seen in the drinking water transmission system. In this project, drinking water from Tonekabon City was used, which is problem-free for making concrete.

Water suitable for making concrete must have the following properties:

I. Not acidic or alkaline (PH between 6 and 8).

II. Its carbonate percentage is less than 0.1%.

III. Its solids (suspended particles) percentage (such as silicate) is less than 0.1%.

IV. Its chloride percentage is less than 0.05%.

V. Its sulfate percentage is less than 0.1%.

2.2.2|Concrete lubricant

In this project, Kimix Company's fast-setting concrete superplasticizer was used. In addition to accelerating the setting of concrete, this lubricant reduces the water-to-cement ratio, increases the fluidity of the concrete mixture, and produces homogeneous concrete. It allows the completion of the concrete hydration reaction and achieving high final strength despite concreting in cold weather. Therefore, some disadvantages of concreting in cold weather are neutralized.

KX-FLOW A 300 lubricant is produced according to ASTM C494, ASTM C1017, and ISIRI 2930 standards.

This lubricant can be used for concrete in cold weather, for making reinforced and unreinforced concrete in cold regions, for the ability to execute concrete in situ using a pump, and for making prefabricated concrete parts.

This lubricant is used by adding the lubricant product to the concrete and continuing mixing for 2 minutes, after which the concrete is used. It can also be mixed with concrete water.

Table 4. Lubricant specifications.

Physical State	Liquid
Chemical basis	Polycarboxylate-based superplasticizer
Specific gravity	1.25 g/cm3

2.2.3 | Rock wool fibers

The rock wool samples used in this study had a chemical analysis according to *Tables 3-5* and a bulk specific gravity of 50 to 250 kg/m3 depending on the amount of pressure applied and also had a density of 50 kg/m3.

Table 5. Chemical analysis of used rock wool.

Silicon Oxide	Aluminum Oxide	Iron Oxide	Calcium Oxide	Magnesium Oxide	Titanium Oxide
Sio2	Al2 o3	Fe2 o3	CaO	MgO	Ti o2
45-48%	12-18%	6-12%	8-12%	8-10%	1-2%

Fig. 3. Rock wool fibers.

2.3 | Mixing Plan

The mixing plan of this study includes 4 series of concrete samples, including one sample without fibers and 3 series of concrete samples containing (0.2, 0.4, 0.6) rock wool fibers. Based on the review of the research background, the use of more rock wool fibers reduces the strength of concrete, and for this reason, more fibers were not used in this study.

The values of the mixing plan are constant in all samples, and more sand than sand was used in the samples. Since it is expected that adding rock wool fibers to concrete will reduce its strength, a lubricant has been used that, in addition to increasing the strength of concrete, can also increase the resistance of concrete against cold and frost. The amount of lubricant used was chosen so that the amount of lubricant also increases with the addition of more rock wool fibers [10]. The amount of lubricant and the mixing plan of sand, sand, cement, etc., are shown in the table below.

Table 6. Mixing plan specifications (Kg/m3).

Specifications	Cement	Water	Sand	Sand	Lubricant	Rock Wool Fibers
K1 Witness	460	240	680	1040	0	0
Kp1 0/2	460	240	680	1040	4.6	0.92
Kp2 0/4	460	240	680	1040	6.9	1.84
Kp3 0.6	460	240	680	1040	9.2	2.76

2.4 | Making Samples

The following steps were taken to make laboratory samples:

I. In this experiment, cubic molds measuring 15*15*15 cm were used to test the compressive strength of concrete.

II. First, sand and sand are mixed in a mixer and mixed for 30 seconds.

III. Next, cement, water and lubricant are added to the desired mixture, which includes sand and sand, and mixed for 1 minute.

IV. Rock wool fibers are gradually added to the mixture in a certain amount to prevent the rock wool fibers from lumping.

V. After the concrete mixture is well mixed, they are poured into molds that have been previously greased with oil. And this should be done in 3 stages. And each time the concrete is poured into the mold, we give it 30 blows to remove the air inside the concrete.

VI. After 24 hours, the samples are removed from the mold and placed in water to achieve the required strength and to prevent the heat generated by the hydration process from causing cracks and damage to the concrete.

Fig. 4. Concrete samples.

2.5 | Tests

Concrete is the most widely used construction material. This material is used in the construction of many structures. The characteristics of the concrete used in each structure must comply with the construction standards of that structure. The quality of concrete structures is checked and controlled by concrete testing. The set of activities carried out to control, evaluate and confirm the quality of concrete is called concrete testing. This section describes the types of tests carried out in this study.

2.5.1 | Compressive strength test

The compressive strength test is the most common test for evaluating concrete samples. The concrete cube test actually gives us a general idea of all the characteristics of concrete. With this test, we can determine whether the concrete is sufficiently suitable for the intended work or not. The compressive strength of concrete depends on various factors such as water-to-cement ratio, cement strength, quality of concrete materials, quality control during concrete production, etc.

The concrete compressive strength test is carried out on cube-shaped pieces of concrete, which is why it is called the cube test. This test is also common on cylindrical concrete pieces. After pouring the concrete samples into the mold, they are left for 24 hours without being moved, and then after the desired time, we remove them from the mold and start curing the concrete. The curing process is carried out in such a way that the concrete sample is placed in humid air for 24 hours and then placed in water. The water used in curing the concrete is checked every 7 days, and its temperature is about 27 degrees Celsius.

Concrete samples are removed from the water after 7 and 28 days of curing and left in the open air for 24 hours to reduce their humidity. Then, we place it under the compressive strength test jack. In these machines, the loading increases by 140 kg/cm2 per minute until the sample breaks. The amount of loading at the moment of concrete failure tells us the compressive strength of the concrete.

In each test, 2 concrete samples are tested, whose resistances differ by 15 percent, in which case we consider the average of the two concrete samples.

Fig. 5. Concrete compressive strength determination device.

2.5.2 | Tensile strength test

To determine and evaluate the tensile strength of concrete, tests are used, one of the most famous of which is the Brazilian test or indirect test. During this test, concrete breaks along its diameter due to forces resulting from tensile and shear stress. Therefore, this type of failure is more reliable and valid. This test is carried out based on the Iranian National Standard (No. 6047). The quality of the concrete sample, the method of curing the concrete, the type of concrete, and the compressive strength of the concrete are among the factors that affect the Brazilian test process. Samples that are of lower quality will usually have lower tensile strength. Also, if the curing of this sample is not done well, it will show lower tensile strength. Usually, the higher the compressive strength in a sample, the higher the tensile strength will be.

2.5.3 | Slump test

To perform the slump test, pour fresh concrete into the slump cone in three layers and tap each layer 30 times using a mallet to remove air from the concrete so that the height of each layer after compaction is approximately one-third of the height of the mold. If, after compacting the upper layer, the concrete surface is lower than the edges of the mold, pour some concrete on it again and smooth its surface. The mold lifting action should be done within approximately five seconds and in a continuous upward motion without any lateral movement.

Fig. 6. Slump test mold.

3 | Data Analysis

3.1 | Compressive Strength Test

In this study, all concrete samples were tested after curing and placed in a cold place after 7 and 28 days of age. From each concrete mix design, 2 samples were tested at the age of 7 days and 2 samples at the age of 28 days, the average of which is considered as the compressive strength. The results of the compressive strength test are shown in the table below.

Table 7. Results of concrete compressive strength tests at cold temperatures.

Test Sample Name	7-Day Concrete Compressive Strength (Mpa)	28-Day Concrete Compressive Strength (Mpa)	7-Day Sample Average (Mpa)	Average 28-Day Sample (Mpa)
K1	25.19 28.16	31.12 33.47	26.67	32.29
Kp1 0/2	22.18 25.39	32.75 34.18	23.78	33.46
Kp2 0/4	28.47 30.68	37.69 38.76	29.57	38.22
Kp3 0/6	21.17 19.29	25.84 24.28	20.23	25.06

Table 8. Results of concrete compressive strength tests at ambient temperature.

Test Sample Name	Compressive Strength of 7-Day Sample at Ambient Temperature (Mpa)	Compressive Strength of 28-Day Sample at Ambient Temperature (Mpa)
K1	27.43	35.84
Kp1 0/2	24.39	36.18
Kp2 0/4	28.67	38.13
Kp3 0/6	22.78	27.73

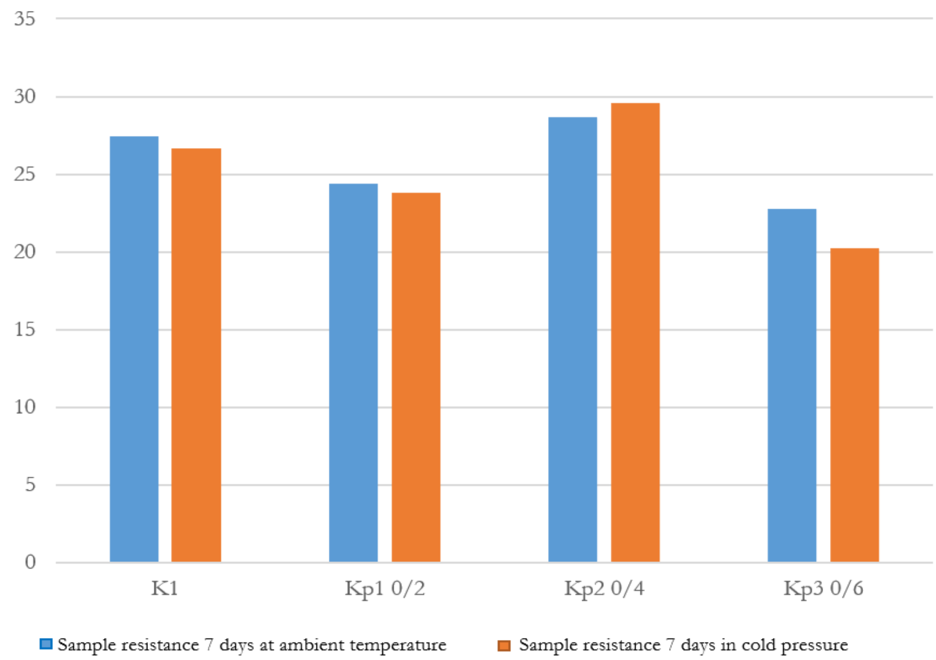

Fig. 7. Comparison of compressive strength of 7-day sample at ambient temperature and cold temperature.

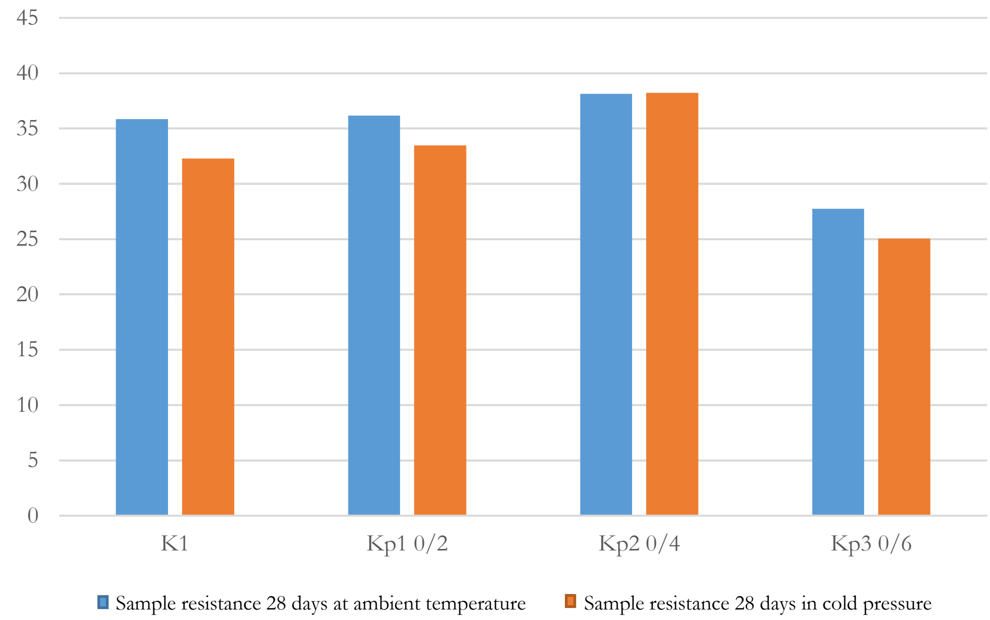

Fig. 8. Comparison of compressive strength of 28-day sample at ambient temperature and cold temperature.

Based on the results obtained from the compressive strength test, the control sample is considered a concrete sample with the desired strength, with which the other fiber-containing samples are compared. In this test, it was found that concrete containing rock wool fibers can have good compressive strength. It also had good resistance to cold and freezing compared to concrete without fibers.

Cold is an important factor in reducing the strength of concrete, which causes cracks and microcracks in concrete due to moisture in the concrete and the porosity of the concrete, but the presence of fibers causes the cracks in the concrete to decrease and the concrete to be less damaged.

In this test, the compressive strength of concrete with 0.2% fibers increased somewhat against cold. The best result was obtained in concrete with 0.4% rock wool fibers, which increased the compressive strength of the concrete, but in the next sample, which contained 0.6% rock wool fibers in the concrete, in addition to not showing good resistance to pressure, its resistance was even lower than the control sample. The reason for this could be due to the presence of more rock wool fibers, which absorbed water from the concrete and also increased the porosity of the concrete due to balling.

Fig. 9. 28-day sample with 0.2% rock wool fibers.

Fig. 10. Cracking in the sample with 0.4% fibers.

Fig. 11. 28-day concrete sample with 0.4% fibers.

Fig. 12. Cracking in a sample without fibers.

In the figures above, cracking in concrete without rock wool fibers is scattered across the entire surface of the concrete, but in the sample with rock wool fibers, in addition to showing good resistance to cold and frost, less cracking occurred in the concrete, and only the side parts of the sample and the corners of the concrete were destroyed.

3.2 | Tensile Strength Test

The tensile strength of concrete is an important parameter that is used in calculations related to concrete cracking and determining the minimum required rebar. In this study, the indirect tensile test (Brazilian) was used to measure the tensile strength of concrete at the age of 28 days. The table below shows the tensile strength of concrete with different percentages of fibers.

Table 9. Results of tensile strength test of the sample at cold temperature.

Test Sample Name	Tensile Strength of 7-Day Sample (Kg/Cm2)	Tensile Strength of 28-Day Sample (Kg/Cm2)	Tensile Strength of 28-Day Sample (Mpa)
K1	24.2	25.1	2.461
Kp1 0/2	24.4	25.5	2.50
Kp2 0/4	24.7	26.1	2.559
Kp3 0/6	25.3	26.3	2.579

Table 10. Tensile strength test results at ambient temperature.

Test Sample Name	Tensile Strength of 7-Day Sample (Kg/Cm2)	Tensile Strength of 28-Day Sample (Kg/Cm2)	Tensile Strength of 28-Day Sample (Mpa)
K1	23.6	24.9	2.441
Kp1 0/2	24.3	25.6	2.510
Kp2 0/4	25.4	25.9	2.539
Kp3 0/6	25.7	26.4	2.588

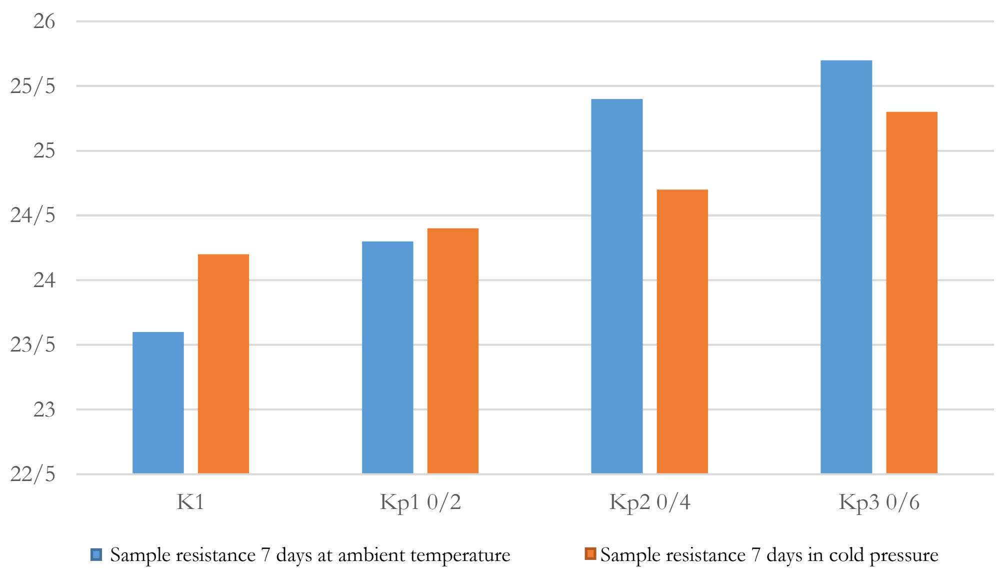

Fig. 13. Comparison of tensile strength of 7-day sample at ambient temperature with sample at cold temperature.

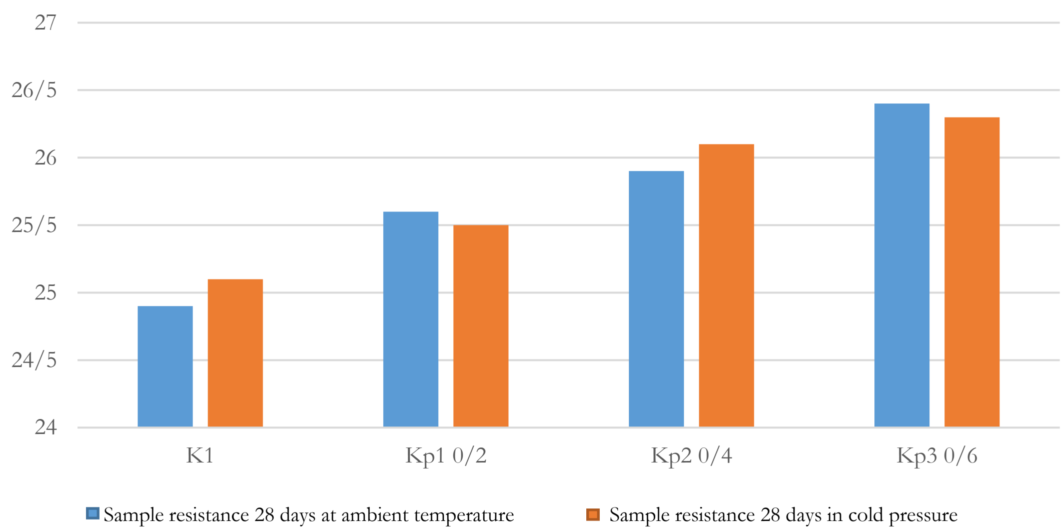

Fig. 14. Comparison of tensile strength of 28-day sample at ambient temperature with the sample in a cold environment.

3.3 | Cold and Freeze Control

In this study, concrete samples exposed to cold and freezing weather were tested with concrete samples at ambient temperature, and the results of both tests were compared to prove how much the strength of fiber concrete containing rock wool fibers had increased compared to regular concrete. The percentage of fibers was the same in both cold and ambient temperature conditions for each sample, and each sample was subjected to compression and tensile tests separately. The test results showed that the Kp2 0.4 sample showed the best performance in a cold environment because its compressive strength in a cold environment increased compared to the sample in a normal environment, and also, the tensile strength of this concrete sample increased compared to the concrete at ambient temperature. Also, the tensile strength of the Kp3 0.6 sample, although it increased at ambient temperature, decreased when it was exposed to cold and freezing. Therefore, the Kp2 sample can be a fiber-reinforced concrete resistant to cold and frost. Increasing the amount of rock wool fibers in concrete reduces the concrete's resistance to cold because it increases the porosity of the concrete somewhat, and during freezing and cold weather, cold factors cause significant damage to the concrete due to its high porosity.

3.4 | Comparison of Compressive and Tensile Strength and Examination of Concrete Performance

According to the experiments conducted in the previous sections, we observed that adding rock wool fibers can increase the compressive strength of concrete and also increase the tensile strength of concrete against cold, and we observed that the higher the compressive strength of fiber concrete, the higher the tensile strength and the higher the concrete resistance. In this experiment, the compressive strength of concrete with 0.4% rock wool fibers performed best against other samples against cold, but the tensile strength of concrete with 0.6% fibers was slightly higher than the strength of concrete with 0.4 fibers. As a result, the presence of rock wool fibers can increase the resistance of concrete against cold and transform concrete from a brittle state to a concrete with good resistance to cold. It was also observed that the strength of concrete increases with the age of concrete. The table below shows how much of its original strength concrete gains at each time point of curing.

Table 11. Acquired strength of concrete at different ages.

Age	Percentage of Acquired Resistance
1 day	16%
3 days	40%
7 days	65%
14 days	90%
28 days	99%

3.5 | Comparison of Test Results with Other Researchers

According to the tests conducted in the previous sections, fiber concrete showed good resistance to cold and frost. In most of the research conducted on rock wool fibers in concrete, these fibers have been used as a factor that makes concrete resistant to heat or brittleness. However, in this research, the appropriate amount of fibers have been used in a way that can make concrete resistant to cold, which is a destructive factor in concrete, and to make ordinary concrete brittle and increase the compressive and tensile strength of concrete. In most of the research, concrete with rock wool fibers has been used as a composite. In this research, concrete is used as reinforced concrete that has appropriate resistance and is even resistant to abrasion and impact and can be used in construction works.

In this study, the desired mixing plant for fiber concrete with rock wool fibers was designed to be able to resist cold factors, and we also reduced the amount of sand to sand to reduce the porosity to a certain extent, which could protect the concrete from the penetration of cold and destructive factors [7].

4 | Conclusion

I. The use of rock wool fibers in concrete increases the compressive strength of concrete and creates high-strength concrete that is resistant to atmospheric factors. The use of 0.4% of fibers showed the best performance.

II. The use of fibers improves the tensile strength of concrete. The tensile strength of pure concrete is low, and steel (rebar) is used to improve it in the construction industry, but the presence of rock wool fibers increases the strength of concrete to some extent.

III. The use of rock wool fibers in concrete is very cost-effective is abundant in our country, and has a reasonable price.

IV. Excessive use of rock wool fibers in concrete, in addition to not increasing the strength of concrete, reduces the strength and efficiency of concrete. For this reason, the appropriate percentage of 0.4% of rock wool fibers in concrete was identified as the most appropriate percentage for the mixing design in this study, and adding more reduced the strength.

V. The use of rock wool fibers reduces the porosity of concrete, so destructive factors such as cold, frost, chemical attacks, etc., penetrate less into the concrete and cause less damage to the concrete.

VI. The use of rock wool fibers has led to the creation of recycled concrete with resistance that can be used in the construction industry, road construction, urban development, etc., and it also allows the disposal of rock wool fibers and is also very suitable for the environment and reduces the problems caused by the disposal of rock wool waste.

References

[1] Lin, W. T., Cheng, A., Huang, R., Wu, Y. C., & Han, T. Y. (2013). Rock wool wastes as a supplementary cementitious material replacement in cement-based composites. *Computers and concrete*, *11*(2), 93–104. https://B2n.ir/z12687

[2] Li, V. C. (2003). On engineered cementitious composites (ECC) a review of the material and its applications. *Journal of advanced concrete technology*, *1*(3), 215–230. https://doi.org/10.3151/jact.1.215

[3] Martinie, L., Rossi, P., & Roussel, N. (2010). Rheology of fiber reinforced cementitious materials: classification and prediction. *Cement and concrete research*, *40*(2), 226–234. https://doi.org/10.1016/j.cemconres.2009.08.032

[4] Faghihmaleki, H., Nejati, F., & Masoomi, H. (2017). In vitro evaluation of additives allowed for high strength concrete (HSC) and foam concrete. *Pamukkale university journal of engineering sciences*, *23*, 1–8. http://dx.doi.org/10.5505/pajes.2016.82584

[5] Huang, G., Pudasainee, D., Gupta, R., & Liu, W. (2021). Thermal properties of calcium sulfoaluminate cement-based mortars incorporated with expanded perlite cured at cold temperatures. *Construction and building materials*, *274*, 122082. https://doi.org/10.1016/j.conbuildmat.2020.122082

[6] Nicula, L. M., Corbu, O., Ardelean, I., Sandu, A. V., Iliescu, M., & Simedru, D. (2021). Freeze–thaw effect on road concrete containing blast furnace slag: NMR relaxometry investigations. *Materials*, *14*(12), 1–20. https://doi.org/10.3390/ma14123288

[7] Yap, Z. S., A. Khalid, N. H., Haron, Z., Khu, W. H., Yeak, S. H., & Amran, M. (2022). Rock wool-reinforced concrete: Physico-mechanical properties and predictive modelling. *Journal of building engineering*, *59*, 105128. https://doi.org/10.1016/j.jobe.2022.105128

[8] Hussein, F. K., Ismael, M. Q., & Huseien, G. F. (2023). Rock wool fiber-reinforced and recycled concrete aggregate-imbued hot asphalt mixtures: design and moisture susceptibility evaluation. *Journal of composites science*, *7*(10), 1–23. https://doi.org/10.3390/jcs7100428

[9] Zhou, Z., Shen, Y., Hao, J., Bai, Z., Liu, Y., & Kou, H. (2021). Inexpensive anti-icing concrete material for application to tunnel and slope engineering infrastructures in cold regions. *ACS applied materials & interfaces*, *13*(44), 53030–53045. https://doi.org/10.1021/acsami.1c14046

[10] Zollo, R. F. (1997). Fiber-reinforced concrete: an overview after 30 years of development. *Cement and concrete composites*, *19*(2), 107–122. https://doi.org/10.1021/acsami.1c14046