Wollastonite and Glass Powder's Impact on Concrete's Properties As Partial Cement Replacement

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Abstract

Currently, scientists are focusing on waste products, agricultural waste, and other natural elements to develop technologies that could be used as building materials. In contrast, recycling boosts the economy and helps create a safer, cleaner environment. In order to address this issue, a range of materials, including fly ash, GGBS, silica fume, wollastonite, waste glass powder, etc., are substituted for some cement. By substituting some of the cement with wollastonite and glass powder, you can reduce pollution in the environment. Glass cannot biodegrade, so filling it with broken glass is an environmentally harmful and unsustainable practice. The majority of glass is made of silica. Cement is more expensive than wollastonite, a naturally occurring substance. The primary objective of this study is to explore potential effects and ascertain how the wollastonite-glass powder (W-GP) mixture affects the mechanical characteristics and durability of M30-grade concrete. After adding wollastonite at 5%, 10%, 15%, and 20%, we examine the strength characteristics of the concrete. Glass powder (5%, 10%, 15%, and 20%) and other mineral admixtures can be used in place of additional cement to maintain the ideal percentage of wollastonite substitution. According to test results, using cement instead of 15% wollastonite produces better results than using the suggested mixture. The combination of 15% wollastonite and 15% GP showed the most increase in strength.

Keywords— Wollastonite, glass powder, mechanical qualities, and durability properties.

I. Introduction

Concrete's strength, durability, and versatility make it a popular building material. Concrete is made up of three main ingredients: cement, water, and aggregates, which can be crushed stone, gravel, or sand. Concrete use and manufacture have a substantial negative influence on the environment, mostly because cement production produces carbon dioxide emissions. Significant amounts of energy are required for the production of cement, and this process also releases large amounts of greenhouse gases, such CO2, which exacerbate the issue of global warming. Furthermore, the removal of raw materials like sand and gravel that are needed to make concrete can have a detrimental effect on ecosystems, landscapes, and natural habitats. To address these problems, scientists are looking into ways to reduce the environmental impact of concrete by developing more environmentally friendly production techniques and including substitute ingredients such GGBS, fly ash, slag, glass powder and wollastonite powder. Additionally, by extending the life and energy efficiency of infrastructure and buildings, the use of concrete in construction can benefit the environment. It is becoming more and more crucial to develop environmentally friendly concrete production and use procedures as the demand for sustainable construction grows.

Adding supplemental cementitious materials (SCMs) to concrete is one way to lessen the environmental effect of the cement production process. SCMs are substances that, when used in the making of concrete, can partially replace regular cement. This will reduce the energy used and greenhouse gas emissions associated with the production of cement. Waste materials from industrial operations such as fly ash, slag, lime sludge, wollastonite, GGBS, glass powder and silica fume are examples of common SCMs. These substances can increase workability, strength, and durability while lowering the required cement content. Furthermore, by decreasing shrinkage and cracking, enhancing resistance to chemical assault and freeze-thaw cycles, and extending the lifespan of structures, the use of SCMs will enhance the long-term performance of concrete. The use of SCMs in the manufacturing of concrete has the potential to improve the long-term performance and resilience of concrete structures while reducing the environmental impact of building practices. Adding SCMs to conventional cement mixtures is known as ternary and quaternary binders, and they are alternative methods for enhancing concrete performance. Several investigations have been carried out to examine the microstructure, strength, and durability of quaternary concrete composites, taking into account the impact of various elements. Additionally, studies employing methods like digital image correlation have been done on the fracture parameters and effectiveness of concretes made using quaternary mixed cements.

Partial substitution of cement with glass powder and wollastonite powder can improve the chemical, mechanical and physical qualities of concrete and assure the protection of the environment for the use of glass and its disposal as trash. It also decreases the consumption of natural resources. By employing waste glass powder and wollastonite powder, cement output may be lowered and the cost of cement manufacturing can also be reduced.

- Control environmental pollution.
- Produce low-cost concrete.
- An inexpensive and effective alternative to trash stoves.

Glass is an inert substance that may be used and reused many times without affecting its chemical characteristics. Research on the usage of shattered glass as shards has revised a decades-old record. Although research employing ground glass as a pozzolanic material began in the early 1970s, most work in this sector is relatively new and has been influenced by the continuous usage of waste glass and the accompanying and supportive participants. In addition to employing glass waste as cullet in glass manufacturing, glass waste is crushed according to size to be utilized as aggregate in various applications such as drainage, gravel plastering, sandstone coating for sports fields, and sand in stone replacement. Due to the increasing demand for concrete manufacturing, the use of hydrosand for better mixing has led to the consumption of natural resources, the depletion of groundwater, and the collapse of bridges and abutments. Efforts are being made to employ shattered glass as an excellent component instead of sand water. Crushed glass is also utilized as coarse aggregate in the construction of structures, although owing to its flat and long structure, this causes a decline in performance and compressive strength. The biggest concern regarding the use of glass waste in concrete is the reaction known as the alkali silicate reaction (ASR), which occurs between silica-rich glass particles and alkalis in the concrete pore solution, which is quite problematic for concrete. stability of concrete unless necessary measures are taken to reduce its effects. ASR may be prevented or minimized by adding minerals to the concrete mix. Minerals used to minimize ASR are fly ash (PFA), silica powder (SF) and kaolin clay (MK). Many studies have established the effectiveness of this substance to suppress ASR. It is known that the size of discarded glass used as aggregate would minimize the weight of concrete. The high silica concentration of glass has led to experimental studies of its usefulness as a raw material for cement manufacturing. Using glass powder instead of cement has proven advantageous. Partial substitution of cement with glass waste is advantageous for the microstructure and stability of cementitious materials. When waste glass partially substitutes cement, a denser (less porous) and better structure is created, which offers protection against moisture and so assures the long life of cementations materials.

Wollastonite is a naturally occurring mineral that is created when silica and limestone mix in heated magmas. Wollastonite, which is chemically calcium metasilicate, has been shown to have chemically reinforcing properties and to be resistant to chemical attack even at high temperatures. Wollastonite is a mineral that is mostly composed of Si02 and CaO. Each component makes up about half of the mineral by weight percentage in a pure CaSi03.It is a highly modulus white mineral. It is used to improve the tensile strength of plastics and reduce shrinkage cracks in ceramic tiles. Increasing the strength and longevity of concrete is one of the main advantages of adding wollastonite powder to it. Because of the special needle-like structure of wollastonite powder, concrete is strengthened and becomes more resilient to damage and cracking. Furthermore, the high aspect ratio of wollastonite powder indicates that it has a significant surface area relative to its volume. It therefore functions as a useful filler material that can assist reduce the quantity of cement used in the manufacturing of concrete, consequently reducing costs and lowering the impact on the environment. Increasing the workability of concrete is another advantage of adding wollastonite powder. Wollastonite powder is a fine substance that is simple to include into concrete mixtures, increasing their flowability and lowering the amount of water needed. As a result, handling concrete may be easier, requiring less manpower and time to finish building tasks. Additionally, wollastonite powder can enhance the thermal characteristics of concrete. Its low thermal conductivity can aid in lowering the amount of heat lost from buildings and other structures. Lower energy expenses and a more comfortable home or working environment may result from this.

Wollastonite powder can also enhance the chemical characteristics of concrete. Because of its high pH, it may be able to inhibit the growth of bacteria and other microbes that could harm the concrete. This may lengthen the concrete's lifespan and lessen the need for expensive maintenance or replacements. All things considered, wollastonite powder is a useful addition to concrete that can enhance its qualities in a number of ways. Strength, workability, and thermal and chemical qualities can all be improved, making it a more adaptable and efficient material for a range of building uses. Its use in concrete can also assist lower costs and lessen environmental effect, making it an environmentally beneficial and sustainable option for contractors and builders.

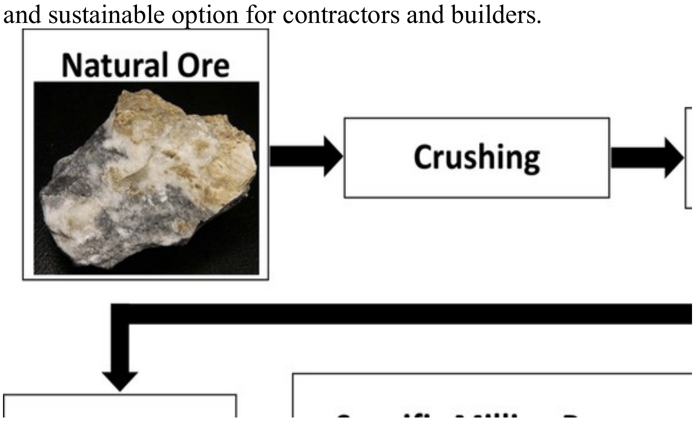

Figure 1: Production of wollastonite powder from natural ore

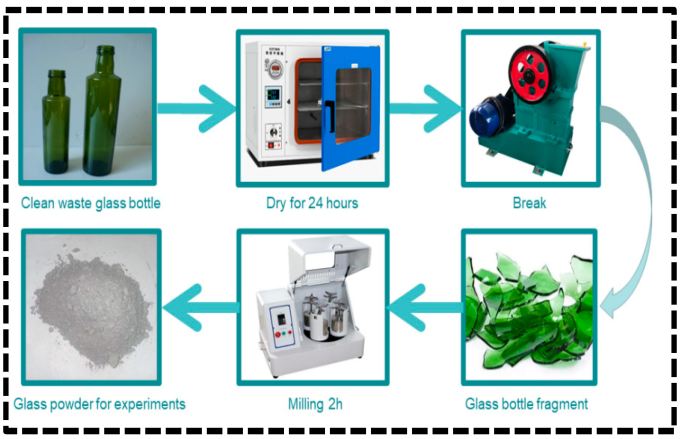

Figure 2: Transformation of glass waste into glass powder

II. LITERATURE REVIEW

The objective of literature review is to collect published information from numerous study publications. We choose valuable data for research investigations using data analysis.

Supriya and Xavier Lopes [1] Concrete is a strong, well-binding material used in construction. India is the second-largest producer of cement worldwide. Approximately 1.5 tons of raw materials are needed for every ton of cement produced. Cement additives are used to reduce the amount of cement used when making concrete. One of the minerals produced when heated magma combines with silica and limestone is silica. In this study, wollastonite was substituted for cement in concrete

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at percentages of 0%, 10%, 12%, 14%, 16%, and 18%. Wollastonite's effect on mixed concrete's tensile strength in the M30 class was investigated. IS 10262 (2019) has been used to composite design. To evaluate performance, the compression coefficient and slump are calculated. Find the compressive and flexural strengths of each concrete. The materials' resistance to sulfates and chlorides was utilized to evaluate their durability after being kept in HCl and MgSO4 solutions for 28 days. The results of the different combinations and the concrete blended results are then compared.

Mathur Renu and associates [2]. Wollastonite (10%) added to the concrete mixture shown an increase in flexural strength (36–42%) and compressive strength (28–35%) in 28 and 56 days, respectively. The study examined cement stone and cement fly ash mixtures utilizing silica as a substitute for cementitious materials and sand. The benefits of wollastonite addition include decreasing water absorption, drying shrinkage and abrasion loss of concrete, and boosting resistance to alternating freezing-thaw and sulfate assaults.

Wahab and colleagues [3]. Tests for drying shrinkage, flexural, compressive, and initial hardening were conducted. When 20% of the sand is substituted with wollastonite, the flexural strength and compressive strength increase to 45% and 28%, respectively. This causes a 60% delay the first time. The cement with a 30% wollastonite addition lost 17% and 35% of its flexural and compressive strengths after 28 days. Powdered wollastonite increases the material's ability to withstand dry shrinkage.

Dahiphale and colleagues [4]. Compressive strength tests were conducted at 3, 7, and 28 days. Because wollastonite contains silica, replacing it increased compressive strength by 10%, 12.5%, and 15%. However, use declines with higher percentages. 15% wollastonite replacement cement has been shown to be the best in terms of strength.

Chikkanagoudar and Lopes [5] studies on the application and efficacious use of adhesives. In terms of global cement production, India comes in second. To make one ton of cement, about 1.5 tons of basic ingredients are required. Use more cement ingredients when producing concrete to reduce the amount of cement needed. Wollastonite is a naturally occurring mineral that forms when silica and limestone combine in hot lava. In place of cement in the concrete, wollastonite was employed in this investigation at percentages of 0%,10%,12%,14%,16%, and 18%. It was looked into how wollastonite affected the M30 class composites' strength. The design process that is hybrid conforms with IS 10262 (2019). To measure performance, one calculates the compression coefficient and slump. The flexural and compressive strengths of various concretes were ascertained. The thermometers were immersed in HCl and MgSO4 solutions for 28 days in order to test their resistance to sulfates and chlorides. Next, the outcomes of different composites were contrasted with those of concrete composites.

Masthanvali, K. et al. [6] He conducted a study on concrete modified with 10% wollastonite and 15% slag The results showed that the compressive strength was 46.18 N/mm2 and the tensile strength was 3.09 N/mm2. Flexural strength is 46.18 N/mm2 Strength is 3.41 N/mm2 When 10% silica limestone and 10% silica fume are used as cement, the compressive strength is 47.20 N/mm2 and the tensile strength is 3.19 N/. mm2 and bending strength is 3.43 N/mm2. According to the test results, it is seen that the quality properties of cement containing a mixture of silica limestone and silica powder vary significantly depending on the mixture of silica limestone and fly ash.

Kartik Patel [7] Carbon dioxide emissions and the loss of natural resources are two significant developments that have an impact on cement production. Certain natural or waste minerals used in concrete, such as wollastonite, fly ash, GGBS, silica fume, and waste glass powder, can be substituted to address this issue. Pollution to the environment can be decreased by substituting wollastonite and ground granular blast furnace slag (GGBS) for part of the cement. Rajasthan's Udaipur belt in India is a fantastic location to get inexpensive gemstones. This study aims to investigate the effects of w-GGBS (wollastonite) combinations on the workability and durability of M50 class concrete. We investigate the strength of concrete with 5%, 10%, 15%, and 20% wollastonite addition. The optimal wollastonite percentage that corresponds to the stone's highest strength will be determined. To replace more cement while keeping the targeted wollastonite replacement percentage (5%, 10%, 15%, 20%), additional minerals like GGBS are added. The test indicates that it is more effective to use cement rather than 15% wollastonite in composite structures. The strongest blend was found to contain 15% GGBS and 15% wollastonite.

III. METHODOLOGY

1. The physical characteristics of the materials are checked according to the Indian standards.
2. A mix for M30 grade concrete is created following Is 10262:2019, taking into account the properties of the materials used.
3. The concrete mix is prepared by replacing 0%, 5%, 10%, 15%, and 20% of cement with a combination of Wollastonite and Glass powder at each interval.
4. The ease with which the concrete can be worked with is tested using the slump test.
5. The strength of the concrete mixes, including compressive strength, split tensile strength, and flexural strength, is measured at 7, 14, and 28 days. Additionally, tests are carried out to check the durability of the mixes.

IV. RESULTS

Table no 1 Slump Cone values

Mix % Replacement	Slump value in mm
0%BLA +0%CCA + 100% Cement	80
5%CCA + 95% Cement	82
10%CCA + 90 % Cement	86
12.5%CCA + 87.5% Cement	89
15%CCA + 85 % Cement	83
2.5%BLA + 75 % Cement	84
5%BLA + 95% Cement	87
7.5%BLA + 90 % Cement	92
10%BLA + 85% Cement	86

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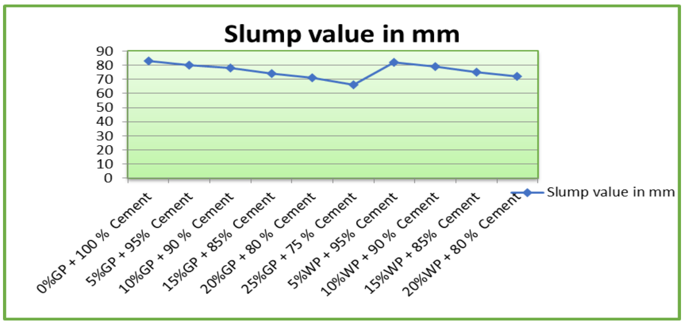


Graph no 1 Slump Cone values

Table no 2: Properties of Glass Powder & Wollastonite

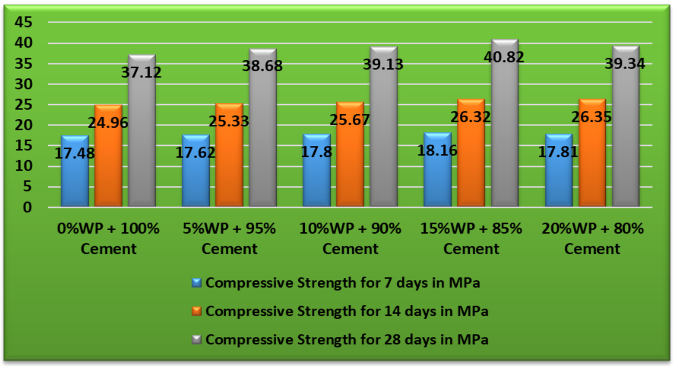
S. No	Physical Properties of Glass Powder	
1	Specific Gravity	2.60
2	Fineness passing 150µ	99.5
2	Colour	Greyish White
S. No	**Physical Properties of Wollastonite**	
1	Specific Gravity	2.97
2	Size (µm)	< 1 to20
2	Colour	White

Table no 3: Mix proportion of M25

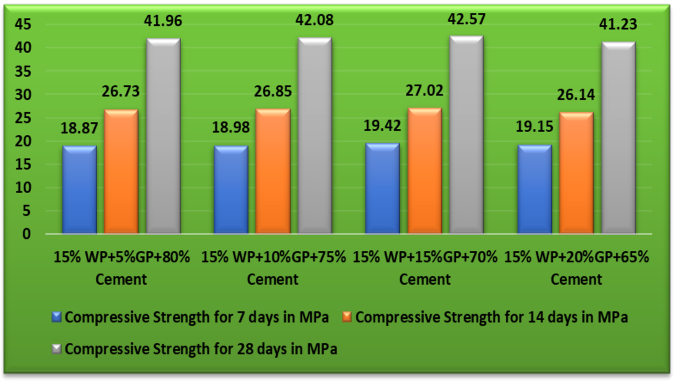
Grade	M30
Proportion	1: 2.27: 3.62
W/C ratio	0.47
Cement	332 Kg/m^3
Fine Aggregate	756 Kg/m^3
Coarse Aggregate	1204 Kg/m^3
Water	149 Kg/m^3
Chemical admixture	3.32 Kg/m^3

Table no 4 Test results of Compressive Strength at 7 days, 14 days & 28 days:

Mix % Replacement	Compressive Strength for 7 days in MPa	Compressive Strength for 14 days in MPa	Compressive Strength for 28 days in MPa
0%WP + 100% Cement	17.48	24.96	37.12
5%WP + 95% Cement	17.62	25.33	38.68
10%WP + 90% Cement	17.80	25.67	39.13
15%WP + 85% Cement	18.16	26.32	40.82
20%WP + 80% Cement	17.81	26.35	39.34
15% WP+5%GP+80% Cement	18.87	26.73	41.96
15% WP+10%GP+75% Cement	18.98	26.85	42.08
15% WP+15%GP+70% Cement	19.42	27.02	42.57
15% WP+20%GP+65% Cement	19.15	26.14	41.23



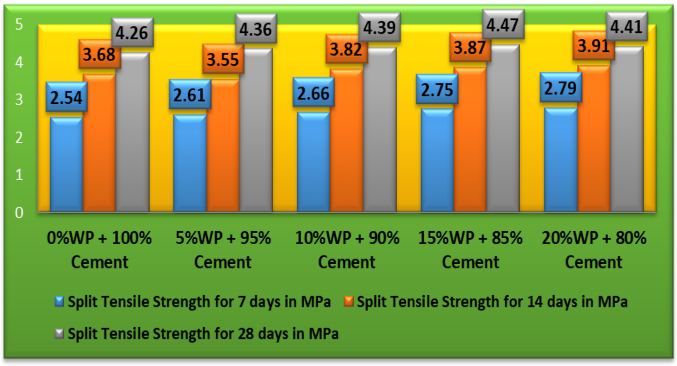
Graph No 2 Development of Compressive strength after curing 7, 14& 28 days for M30



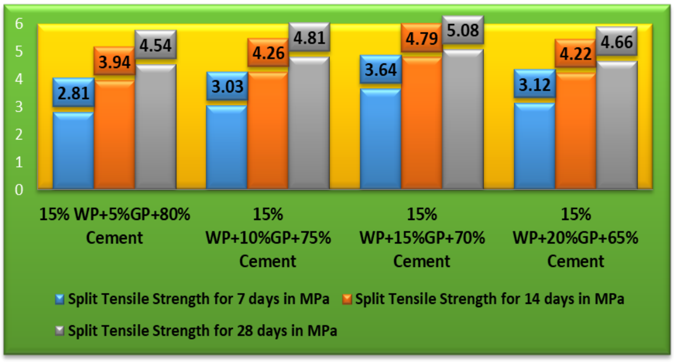
Graph No 3 Relation between optimum wollastonite (15%) +%GP replacement and Compressive strength

Table no 5 Test results of Split Tensile Strength at 7 days, 14 days & 28 days:

Mix % Replacement	Split Tensile Strength for 7 days in MPa	Split Tensile Strength for 14 days in MPa	Split Tensile Strength for 28 days in MPa
0%WP + 100% Cement	2.54	3.68	4.26
5%WP + 95% Cement	2.61	3.55	4.36
10%WP + 90% Cement	2.66	3.82	4.39
15%WP + 85% Cement	2.75	3.87	4.47
20%WP + 80% Cement	2.79	3.91	4.41
15% WP+5%GP+80% Cement	2.81	3.94	4.54
15% WP+10%GP+75% Cement	3.03	4.26	4.81
15% WP+15%GP+70% Cement	3.64	4.79	5.08
15% WP+20%GP+65% Cement	3.12	4.22	4.66



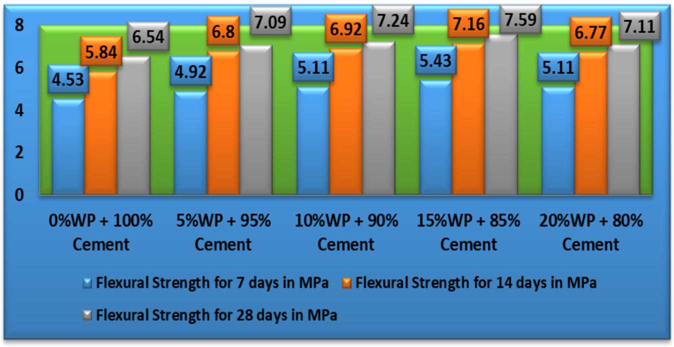
Graph No 4 Development of Split Tensile strength after curing 7, 14 & 28 days for M30



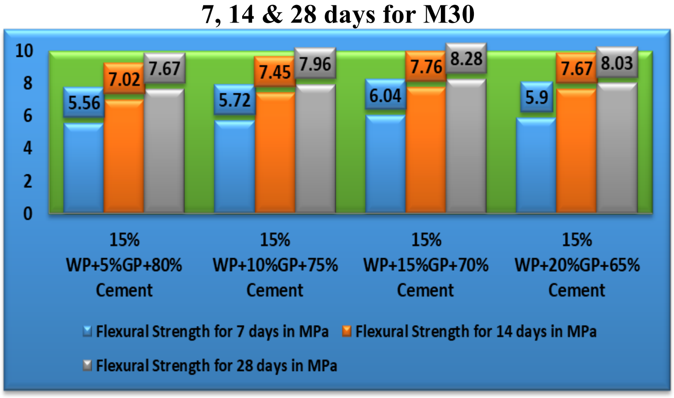
Graph No 5 Relation between optimum wollastonite (15%) +%GP replacement and Split Tensile strength

Table no 6 Test results of Flexural Strength at 7 days, 14 days & 28 days:

Mix % Replacement	Flexural Strength for 7 days in MPa	Flexural Strength for 14 days in MPa	Flexural Strength for 28 days in MPa
0%WP + 100% Cement	4.53	5.84	6.54
5%WP + 95% Cement	4.92	6.80	7.09
10%WP + 90% Cement	5.11	6.92	7.24
15%WP + 85% Cement	5.43	7.16	7.59
20%WP + 80% Cement	5.11	6.77	7.11
15% WP+5%GP+80% Cement	5.56	7.02	7.67
15% WP+10%GP+75% Cement	5.72	7.45	7.96
15% WP+15%GP+70% Cement	6.04	7.76	8.28
15% WP+20%GP+65% Cement	5.90	7.67	8.03



Graph No 6 Development of Flexural strength after curing 7, 14 & 28 days for M30



Graph No 7 Relation between optimum wollastonite (15%) +%GP replacement and Flexural strength

V. CONCLUSION

Based on the aforementioned research, the following analysis was done on artificial concrete that had wollastonite and the mineral addition GP in place of some of the cement.

1. Concrete becomes less workable as the wollastonite percentage shifts.
2. It was discovered that 15% wollastonite produced the highest strength in the overall percentage of cement modified with wollastonite.
3. Concrete compositions comprising 15% wollastonite and 15% GP produced the best concrete characteristics when compared to other mixtures.
4. The test findings showed that the combination of wollastonite and glass powder strengthened the concrete more than the wollastonite concrete mixture.
5. Compared to regular concrete, the addition of 15% wollastonite results in an increase in compressive strength of 9.66%, splitting tensile strength of 4.92%, and bending strength of 16.05%.
6. It is observed that adding 15% wollastonite and 15% glass powder to regular concrete raises its compressive strength by 14.68%, splitting tensile strength by 19.24%, and bending strength by 26.60%.
7. Compared to regular concrete, it has excellent resistance to chloride attack when half of it is substituted with 15% wollastonite cement and 15% glass powder cement.

REFERENCES

[1] Supraxia Xavier Lopes and R. S. Chikkanagoudar (2020) Wollastonite as a Partial Cement Replacement and Its Impact on the Mechanical and Durability Properties of Concrete The International Research Journal of Engineering and Technology (IRJET) Volume 07 Issue 08 | August 2020 e-ISSN: 2395-0056 p-ISSN: 2395-0072; www.irjet.net

[2] "Mechanical properties of micro and sub-micron wollastonite fibers in cementitious composites," Dey V, Kachala R, Bonakdar A, and Mobasher B (2015), Construction and Building Materials, Vol. 82, pp. 351 - 359.

[3] "Strength characteristics and microstructural properties of cement mortars incorporating synthetic wollastonite produced with a new technique" Hasan Erhan Yucel, Sumeyye Ozcan, July 2019. Elsevier Ltd. is the publisher.

[4] Kannula Mohankrishna Reddy and K. V. S. Gopala Krishna Sastry (2016).

[5] utilizing wollastonite-silica fume and wollastonite-flyash to test the strength qualities of concrete Vol. 6, issue 5, October 2016, 1–12, International Journal of Civil, Structural, Environmental, and Infrastructure Engineering Research and Development (ijcseierd), issn(p): 2249–6666; issn(e): 2249–7988.

[6] Mr Kartik Patel (2019) Result Of Wollastonite Then Ggbs By Way Of Part Paste Extra On The Assets Of Concrete, March 2019, Volume 6, Issue 1, International Journal of Research and Analytical Reviews, www.ijrar.org (E-ISSN 2348-1269, P- ISSN 2349-5138)

[7] Experimental Study on Mechanical Properties of Concrete Including Wollastonite and Ground Granulated Blast Furnace Slag As A Partial Replacement Of Cement, Vijay Bhudiya, Abbas Jamani, 2020 Journal of Engineering and Technology: International Research, Volume 7, Issue 6, pages 4559–4567

[8] Subramani, T. and Sankar Ram, S.B. "Experimental Study on Concrete Using Cement With Glass Powder" Department of Civil Engineering, VMKV Engg. College, Vinayaka Missions University,Salem, India Vol. 05, Issue||V3|| PP 43-53" 05 (May.2015)

[9] IS: 383 (Specification for >4.75mm and fine aggregates from natural sources for concrete), Indian Standard Code of Practice, 1970.

[10] Mix Design, Bureau of Indian Standards, "IS 10262- 2019, Recommended Guidelines for Concrete Mix Design" Standards, New Delhi, India, 2019..

[11] Grade Ordinary Portland Cement "IS 8112:1989, Specification (First Revision), Bureau of Indian Standards, New Delhi, India, 1989"

[12] Kumarappan N.(2013) P artial Replacement Cement in Concrete Using Waste Glass, International Journal of Engineering Research and Technology (IJERT) 2 (10), ISSN: 2278-0181.

[13] Vijayakumar G ., Vishaliny H. a nd Govindarajulu D. (2013) "Studies on Glass Powder as Partial Replacement of C ement i n C oncrete P roduction" I n ternational Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, I SO 9001:2008 Certified Journal, Volume 3, Issue 2, February).

[14] IS: 4 56-2000, Plain and Reinforced Concrete Code of Practice, Bureau of Indian Standards, Manak Bhavan, 9 Bahadur Shah Marg, New Delhi-110002.

[15] BIS 383: 1970 Coarse and fine aggregate from natural sources for concrete 9th Revision, B IS, New Delhi, 1970.

[16] Shetty M.S "Concrete technology", S.Chand & company limited 2009.

[17] Study of Strength and Workability of Different Grades of Concrete by Partial Replacement of Fine Aggregate by Crushed Brick and Recycled Glass Powder Tiwari Darshita Patel Anoop(2014)

[18] M. Adaway& Y. Wang: "Recycled glass as a partial replacement for fine aggregate in structural concrete – Effects on compressive strength" Special Issue: Electronic Journal of Structural Engineering 14 (1) 2015

[19] Ismail Ansari, Sheetal Sahare , "utilization of glass powder as a partial replacement of cement and its effect on concrete strength" Vishwakarma Institute of Information Technology, Pune, Maharashtra, India, IRF international conference, 13th December 2015, Pune, India.

[20] Effect of Using Glass Powder In Concrete: (By shipa raju, Dr. PR Kumar (ISO 3297-2007 certified organization) (volume 3, specialissue5, july2014).

[21] D.M. Patil, K.K. Sangle, Experimental investigation of waste glass powder as partial replacement of cement in concrete, Int. J. Adv. Technol. Civ. Eng. 2 (1) (2013

[22] G. S. Islam, M. Rahman, and N. Kazi, "Waste glass powder as partial replacement of cement for sustainable concrete practice," International Journal of Sustainable Built Environment, vol. 6, pp. 37-44, 2017.

[23] Misra, A., Chad, Y.B., Rana, A., Misra, P., and Csetenyi, L. (2015). Research on the durability of wollastonite-containing concrete. 726–734, Journal of Cleaner Production, 87.