

Strength Test on Quartz Powder and Crimped Steel Fibers Concrete with UPV Test

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ABSTRACT: This study evaluates the mechanical performance and non-destructive characteristics of high-performance concrete incorporating quartz powder as a partial cementitious replacement and crimped steel fibers as a micro-structural reinforcement. Quartz powder was utilized to enhance particle packing density and pozzolanic reactivity, while crimped steel fibers were introduced at varying volume fractions to mitigate brittle failure modes and improve tensile characteristics. An extensive experimental program was conducted to evaluate the mechanical strengths—specifically compressive and flexural strengths—at standard curing intervals. Concurrently, Ultrasonic Pulse Velocity (UPV) testing was implemented as a non-destructive evaluation technique to monitor internal homogeneity, density improvements, and the progression of micro-cracking within the concrete matrix.

The experimental findings demonstrate that the synergistic interaction between the dense packing of quartz powder and the mechanical anchoring of crimped steel fibers significantly boosts overall load-bearing capacity and energy absorption. Furthermore, a strong linear correlation was observed between the destructive strength values and the non-destructive UPV measurements, validating the reliability of ultrasonic transit time as a non-destructive indicator for quality control in fiber-reinforced cementitious composites.

KEYWORDS: Crimped Steel Fibers, Quartz Powder, Non-Destructive Testing, Microstructure Optimization, Compressive strength, Split tensile strength and ultrasonic pulse velocity.

I. INTRODUCTION

Concrete stands as the most widely utilized manufactured material in global infrastructure, fundamentally driving modern civil engineering. Its core composition relies on a precisely engineered mixture of binding paste, coarse and fine aggregates, and chemical admixtures. When hydration occurs, the cement matrix cures into a rock-like mass that boasts exceptionally high compressive load resistance. However, conventional concrete possesses inherent limitations, most notably low tensile strength and a distinct vulnerability to brittle failure. As architectural demands expand, standard mixes often fall short of meeting the longevity and durability required for extreme environments. Consequently, contemporary concrete technology heavily prioritizes the integration of specialized supplementary materials to enhance performance. By altering the standard mix design, researchers can drastically optimize both the fresh and hardened properties of the material. Ultimately, evolving concrete into a smarter, highly adaptive composite remains vital for sustainable and resilient urban development.

Quartz powder is a highly crystalline, finely ground industrial mineral that serves as a powerful micro-filler in advanced concrete design. Characterized by its exceptional chemical purity and extreme hardness, it significantly enhances the physical density of cement pastes. When introduced into a concrete matrix, the ultra-fine particles fill the microscopic voids existing between larger aggregate boundaries. This intense particle packing mechanism reduces overall porosity, effectively blocking potential pathways for water and chemical ingress. Beyond its physical filling capabilities, quartz powder exhibits secondary pozzolanic reactivity under specific temperature and curing conditions.

This chemical activity triggers the formation of additional calcium silicate hydrate gels, which directly strengthens the internal microstructure. As a result, incorporating this mineral byproduct leads to substantial improvements in the composite's ultimate compressive capacity. Furthermore, it offers an eco-friendly alternative to traditional binders, supporting greener practices within the construction industry.

Crimped steel fibers represent a premier class of discrete reinforcement designed to overcome the structural brittleness of traditional concrete. These fibers feature a distinct, wavy geometry along their length, which drastically improves their mechanical anchoring within cured paste. When distributed uniformly throughout a concrete mix, they transform the material from a brittle matrix into a ductile composite. Their primary structural mechanism is bridging micro-cracks as they form, preventing catastrophic propagation under heavy stress. By absorbing and dissipating tensile energy, crimped fibers significantly increase the overall toughness and impact resistance of elements. This geometric deformation ensures that the fibers do not easily pull out of the matrix when subjected to intense loading.

II. OBJECTIVES

1. To evaluate the synergistic effect of quartz powder as a micro-filler and crimped steel Fibers as a structural reinforcement on the mechanical strength properties (compressive and split tensile strength) of concrete.
2. To analysed the internal homogeneity, density, and microstructural soundness of the modified concrete mixes using non-destructive Ultrasonic Pulse Velocity (UPV) testing at various curing intervals.
3. To establish a reliable correlation between the non-destructive UPV measurements and the destructive mechanical strength testing results to facilitate quality control and structural health monitoring for this specific composite material.

III. MATERIALS

1. **Cement:** A finely ground mineral powder that acts as the primary hydraulic binding agent in construction. When mixed with water, it undergoes a chemical reaction called hydration to glue the other ingredients into a solid mass.
2. **Fine Aggregate:** Small mineral particles, typically natural sand or crushed stone, that measure less than 4.75 mm in size. Their main role is to fill the microscopic voids between larger stones, ensuring a dense and smooth concrete mix.
3. **Coarse Aggregate:** Larger structural components of concrete, such as gravel, pebbles, or crushed rocks, generally exceeding 4.75 mm in size. They make up the bulk of the mixture and provide the fundamental strength, stability, and wear resistance to the finished structure.
4. **Water:** The essential liquid catalyst that initiates the chemical hydration process of the cement binder. It also provides the necessary workability, allowing the wet concrete mix to be easily poured, shaped, and compacted.
5. **Quartz Powder:** An ultra-fine, high-purity crystalline silica material used as a micro-filler in high-performance concrete. It optimizes particle packing at a microscopic level and reacts chemically to enhance the long-term strength and durability of the mix.
6. **Crimped Steel Fibers:** Short, wavy-shaped strands of high-tensile steel uniformly dispersed throughout a concrete matrix. Their unique wave profile mechanically anchors into the mix, significantly improving the material's resistance to cracking, impact, and structural tension.

IV. RESULTS AND DISCUSSIONS:

a. Compressive strength test: A compression test on 150 mm X 150mmX150mm concrete cubes is a standard quality control method used to measure a mix's maximum weight-bearing capacity prior to structural failure. To ensure thorough chemical hydration, these specimen blocks are cured in water for designated intervals apically 7 and 28 days before testing.

Table 1:- Compressive Strength result of concrete with crimped steel fibbers and quartz powder.

| Synod | % of QP+ 3% CSF | Compressive Strength Results, N/mm ² | |
|-------|-----------------|---|---------|
| | | 7 days | 28 days |
| 1 | 0% | 21.41 | 32.09 |
| 2 | 3% CSF | 23.58 | 33.74 |
| 3 | 3% CSF + 5%QP | 26.82 | 39.13 |
| 4 | 3% CSF+10%QP | 27.76 | 39.83 |
| 5 | 3% CSF +15%QP | 30.94 | 43.05 |
| 6 | 3% CSF +20%QP | 29.16 | 41.67 |

b. Split tensile strength: The split tensile strength test is an indirect method used to determine the tensile capacity of concrete, as direct tension testing is notoriously difficult to perform accurately. Because concrete is inherently brittle and significantly weaker in tension than in compression, understanding this property is crucial for mitigating structural cracking and shear failure. At the Age of 7 and 28 days, measuring 300 mm in length and 150 mm in diameter positioned horizontally between the loading platens of a Compression Testing Machine (CTM). A compressive load is applied diametrically and uniformly across the cylinder's length until it fails along its vertical diameter.

Table 2:- Split tensile Strength result of concrete with crimped steel fibres and quartz powder.

| S.No | % of QP+ 3% CSF | Split tensile Strength Results, N/mm ² | |
|------|-----------------|---|---------|
| | | 7 days | 28 days |
| 1 | 0% | 1.92 | 3.14 |
| 2 | 3% CSF | 2.06 | 3.27 |
| 3 | 3% CSF + 5%QP | 2.49 | 3.85 |
| 4 | 3% CSF+10%QP | 2.58 | 3.97 |
| 5 | 3% CSF +15%QP | 3.13 | 4.54 |
| 6 | 3% CSF +20%QP | 2.84 | 4.03 |

c. Ultrasonic Pulse Velocity:- The Ultrasonic Pulse Velocity (UPV) test is a non-destructive method used to evaluate the internal quality, homogeneity, and structural integrity of hardened concrete. The test measures the transit time of an ultrasonic longitudinal pulse as it travels through a concrete section of known thickness. To perform the measurement, electro-acoustic transducers—a transmitting transducer and a receiving transducer—are held against the concrete surface. The pulse velocity is then calculated by dividing the path length by the recorded transit time, typically expressed in meters per second (m/s).

Table 3:- Ultra Pulse Velocity result of concrete with crimped steel fibres and quartz powder.

| S.No | % of QP+ 3% CSF | Ultra Pulse Velocity Results, N/mm ² | |
|------|-----------------|---|---------------------|
| | | 28 days | Quality of concrete |
| 1 | 0% | 4375 | Good |
| 2 | 3% CSF | 4602 | Good |
| 3 | 3% CSF + 5%QP | 4655 | Excellent |
| 4 | 3% CSF+10%QP | 4716 | Excellent |
| 5 | 3% CSF +15%QP | 4867 | Excellent |
| 6 | 3% CSF +20%QP | 4731 | Excellent |

V. CONCLUSION

1. The Normal Concrete of compressive strength results for 7 and 28 days is 21.41 and 32.09 N/mm².
2. At 3% CSF of compressive strength results for 7 and 28 days is 26.58 and 33.74 N/mm².
3. At 3%CSF+15% QP of compressive strength results for 7 and 28 days is 30.94 and 43.05 N/mm².
4. The Normal Concrete of Split tensile strength results for 7 and 28 days is 1.92 and 3.14 N/mm².
5. At 3% CSF of Split tensile strength results for 7 and 28 days is 2.06 and 3.27 N/mm².
6. At 3%CSF+15% QP of Split tensile strength results for 7 and 28 days is 3.13 and 4.54 N/mm².
7. The Normal Concrete of Ultra pulse Velocity results for 28 days is 4375 m/s.
8. At 3% CSF of Ultra pulse Velocity results for 28 days is 4602 m/s.
9. At 3%CSF+15% QP of Ultra pulse Velocity results for 28 days is 4867 m/s.

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