Physical and mechanical characterization of sand replaced stone dust concrete

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Abstract

In this research work, physical, chemical, morphological, and mechanical behavior as partial replacement of fine aggregate in concrete. Stone dust was acquired from three different sources i.e. Nowshera, Dara, and Besai, while concrete was kept at a ratio of 1:2:4 and water to cement ratio at 0.5 as per ASTM standards for considerable workability. The compressive strength, ultrasonic pulse velocity (UPV), its correlation, density, durability test, x-ray fluorescence (XRF) analysis, and Scanning electron microscopy was carried out. Compressive strength at curing ages of 7, 14, and 28 days with 20%, 30%, and 40% replacement of sand was incorporated in concrete. The results indicated a slight increase in compressive strength at 20% replacement level for the Besai Concrete (BC), Nowshera Concrete (NC), and Dara Concrete (DC). For durability analysis, Rapid Chloride Permeability Test (RCPT) carried out on hardened stone dust-based concrete shows that with the addition of stone dust the voids between fine and coarse aggregates are filled up, less charge will pass, and ultimately durability is increased as per ASTM C 1202. The chemical composition of the stone dust samples, through XRF analysis, indicated that Silica dioxide (SiO2) compounds present in (NC), (DC), and (BC) were 13.34%, 12.339% & 11.593% respectively. The maximum compressive strength development in NC was possibly due to the presence of SiO2 compound in excess quantity in Nowshera stone dust as compared to other samples tested. Hence it can be recommended that locally available stone dust in Peshawar and its surrounding are suitable for a maximum of 40% replacement level.

1. Introduction

The growing demand for natural resources in the construction industry throughout the world and rapid increase in construction work with increasing prices of the construction material, has led to the scarcity of natural filler materials, especially in Peshawar, Pakistan [1, 2]. To resolve the pertaining issue, and to make the construction economical, an alternative filler material needs to be explored [3]. The current study intends to explore such filler materials that may considerably reduce the overuse of river sand. One such material is stone dust [4]. A huge quantity of stone powder is produced at the time of stone crushing, where it is often considered as waste in the locality, and disposal of the waste material is a serious environmental issue [5].

The composite material commonly used to make concrete is sand, coarse aggregates, water, and cement [6]. With a rapid increase in construction work around the world and the rising cost of construction materials, there is a huge demand for building materials. There is a shortage of river sand throughout the World and in Peshawar,
Pakistan [2]. To fulfill the growing demand for sand, an alternative material needs to be explored. Rock powder can be used as a substitution of natural river sand fully or partly [7]. A huge quantity of stone powder is produced during the stone crushing process [8]. To resolve the pertaining issue, and to reduce the cost of construction, an alternative filler material needs to be explored [3]. The use of stone powder as sand in concrete can cut down disposal problems and also curtail the price of the concrete, which can be an alternative for sand, and if it fulfills the quality and strength of normal concrete then it may be replaced as fine aggregate [4]. Moreover, a huge quantity of rock powder is available as waste and its disposal is a serious environmental issue [9]. The exchange of fine aggregate by rock powder will not only assist in solid waste management but also in the utilization of waste material [10]. In other parts of the World, several research studies have been conducted to determine how to properly use stone dust without compromising the strength of concrete [5]. In the last 30 years, stone powder has been used as construction material in the advanced countries especially the construction industries of the USA and UK consume a huge quantity of rock powder annually but in Peshawar, Pakistan it is not used due to the unavailability of research work on locally available stone dust [11].

This paper presents the physical, chemical, morphological, and mechanical behavior as partial replacement of fine aggregate in concrete. Stone dust was acquired from three different sources using at 20%, 30%, and 40% replacement of sand. Physical characteristics of materials were analyzed through specific gravity, fineness modulus, specific surface area, and water absorption tests. Scan Electron Microscopy (SEM) was done for morphological characteristics of materials whereas mechanical characteristics of concrete at curing ages of 7, 14, and 28 days were tested through compressive testing method using ASTM C39 [12]. The results indicated a slight increase (3%) in compressive strength at 20% replacement level and the increase may be attributed due to the presence of Silica dioxide (SiO$_2$) compound in access quantity. It can be recommended that locally available stone dust in the Peshawar region is suitable for a maximum of 40% replacement level.

2. Materials

2.1. Cement

X-ray fluorescence (XRF) test was conducted to find out oxides composition of normal Cherat cement [10]. Locally available Cherat cement was utilized, by ASTM C-150 [8]. The specific gravity of the cement was found in the laboratory as 3.15 g cm$^{-3}$ through Le-Chatelier’s apparatus [13]. In the laboratory, the air permeability method was used to determine the specific surface area through Blaine apparatus. The fineness modulus is the measure of the specific surface area (SSA) as shown in figure 1. More fine cement will spread over more surface area and hence SSA will be higher [4, 8]. The SSA is the total surface area covered by all particles in one kilogram of cement in a square meter [14]. The SSA of the cement determined was 3169 cm$^2$/g. The type of cement used conforms to Pakistani Standards because the value was more than the lowest value as shown in figure 1 [9].

2.2. Coarse aggregate

There is no criterion to find a good aggregate but any aggregate that gives durable, stable, and strong concrete is a good aggregate [10]. Coarse aggregate selected for this research was collected from Besai, a quarry near Jamrud.
towards South-West of Peshawar as shown in figure 2. Its specific gravity test was conducted in conformity to ASTM C-127 and was found to be 2.76 [13].

The water absorption and apparent specific gravity of coarse aggregate used were 1.31% and 2.88 respectively. Generally, the fineness modulus for good quality sand is between 2 to 4 and for coarse aggregate 5.5 to 8. Fineness modulus of coarse aggregate having sizes of 19 mm and below, was determined as 6.696 as per ASTM C136 [15] and its gradation curve is shown in figure 3.

2.3. Fine aggregate
Fine aggregate selected for this research, was collected from Laurence pure, a quarry situated in Punjab Province of Pakistan. The specific gravity of sand found in the laboratory was 2.62 and it conformed to ASTM C-128, water absorption for sand specimen used was 1.83%. The fineness modulus of sand was calculated as 2.463. Sieve analysis conducted confirmed with ASTM C136-96a [16], as shown in figure 4.
2.4. Besai stone dust (B)
One of the stone dust selected for the research was collected from Besai mountains, a local quarry near Jamrud towards the southwest of Peshawar as shown in figure 5. Specific gravity and water absorption of the stone dust found out in the laboratory were 2.5935 and 2.64% respectively. Table 1 listes the XRF data for oxides composition of Besai stone dust (B).

The fineness modulus of Besai stone dust was calculated as 2.552. The sieve analysis conducted confirmed with ASTM C136-96a [17], as shown in figure 6.

2.5. Nowshera stone dust (N)
The second stone dust selected for the research was collected from Nowshera mountains, a local quarry towards North-East of Peshawar. Specific gravity and water absorption of Nowshera stone dust were determined in the lab as 2.642 and 2.96% respectively. The fineness modulus of Nowshera stone powder was calculated as 3.367 as shown in figure 7 and figure 8. The sieve analysis conducted was confirmed with ASTM C136-96a [8].Table 2 shows the XRF data for oxides composition of Nowshera stone dust (N).

2.6. Dara stone dust (N)
The third stone dust selected for the research was acquired from Dara Adam Khel mountains, a local quarry towards East-South of Peshawar as shown in figure 9. Specific gravity and water absorption of Nowshera stone...
dust were found out in the laboratory as 2.571 and 3.27% respectively. The fineness modulus of Dara stone dust was calculated as 2.216 and the gradation curve is given below as shown in figures 9 and 10. The XRF data for oxides composition of Dera stone dust (D) is listed in table 3.

Table 2. Oxides composition of Nowshera Stone Dust (N) through XRF.

| Oxides composition (%) | SiO₂ | Fe₂O₃ | Al₂O₃ | CaO | SrO | MnO | K₂O | Cr₂O₃ | TiO₂ | CuO | ZrO₂ | V₂O₅ |
|------------------------|------|-------|-------|-----|-----|-----|-----|-------|------|-----|------|------|
| Stone dust (N)         | 13.34| 3.574 | 4.498 | 76.857 | 0.142 | 0.103 | 0.693 | 0.029 | 0.498 | 0.030 | 0.009 | 0.035 |

dust were found out in the laboratory as 2.571 and 3.27% respectively. The fineness modulus of Dara stone dust was calculated as 2.216 and the gradation curve is given below as shown in figures 9 and 10. The XRF data for oxides composition of Dera stone dust (D) is listed in table 3.

2.7. Experimental program
The research aimed to find out the chemical composition of aggregates and the mechanical behavior of stone dust concrete. A total of ninety (90) cylinders were cast to evaluate the compressive strength of concrete. The allocation of cylinders were; 9 cylinders of total sand (CC), 27 cylinders of sand and Besai Stone Dust (BC), 27 of sand and Nowshera stone dust (NC), and 27 cylinders of sand and Dara Stone Dust (DC). The proportions of the mix for all corresponding specimens are given in table 4. The ratios of concrete were chosen as 1:2:4 whereas the target compressive strength for hardened concrete was kept at 3000 psi. All concrete mixes were prepared with a constant water-cement ratio of 0.5 without any additives. The concrete mixes were distributed as total sand (CC), Besai stone dust concrete (BC), Nowshehra stone dust concrete (NC), and similarly Dara stone dust concrete (DC).

Total 90 concrete cylinders (152.4 mm dia & × 304.8 mm height) were cast i.e. control concrete (CC), 20%, 30% & 40% (BC), 20%, 30% & 40% (NC) and 20%, 30% & 40% (DC). The concrete cylinders were filled layer by
layer to avoid any void and a slump test was conducted before pouring concrete. The procedure adopted for curing cylindrical specimens was confirmed with ASTM C 192 [18]. A foam sheet acquired from the local market was raped around the cylinders and kept wet for 28 days [19]. To achieve high mechanical properties, the temperature of the water was maintained at about 21°C. A concrete slump test was conducted as per ASTM C143 standard method to evaluate the workability of fresh concrete mix [20].

| Table 3. Oxides composition of Dara stone dust (D). |
|-----------------------------------------------|
| Oxides Composition | SiO₂ | Fe₂O₃ | Al₂O₃ | CaO | SrO | MnO | K₂O | Cr₂O₃ | TiO₂ | CuO | ZrO₂ | V₂O₅ |
| Stone DUST (D) | 12.339 | 3.981 | 6.084 | 75.28 | 0.050 | 0.034 | 1.641 | 0.024 | 0.506 | 0.030 | 0.011 | 0.020 |

| Table 4. Ratios of sand and stone dust (B, N, & D) in concrete cylinders. |
|-----------------------------------------------|
| MIX ID | Mix description | Sand (%age) | Stone dust (%age) | B20 | B30 | B40 | N20 | N30 | N40 | D20 | D30 | D40 |
| CC | Control concrete | 100 | | | | | | | | | | |
| BC | Besai stone dust concrete | 80,70,60 | 20 | 30 | 40 | | | | | | | |
| NC | Nowshera stone dust concrete | 80,70,60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| DC | Dara stone dust concrete | 80,70,60 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 30 | 40 | | |
3. Results and discussion

3.1. Compressive Strength of Concrete Cylinders

It is a fundamental parameter of concrete mix design. Almost all other parameters are dependent on the compressive strength (model: 100-500KN, make: testometricinc) of concrete. The graph below indicates the strength development of control concrete (CC), Besai concrete (BC), Nowshera concrete (NC), and Dara concrete (DC) with curing duration.

The above results show that strength development was connected with the curing duration of cylindrical specimens tested. Maximum strength was observed in Nowshera concrete cylindrical specimens after 28 days of curing as compared to the control concrete. The compressive strength of Besai concrete was less than control concrete as shown in the figure 11. Overall, at a 20% replacement level, an increase of 3% was observed in compressive strength.
Figure 14. Graph of strength versus curing age of cylindrical specimens at 30% replacement.

Figure 15. Graph of strength versus curing age of cylindrical specimens at 40% replacement.

Figure 16. Graph of strength versus curing age of cylindrical specimens at 40% replacement.

Figure 17. Trend line for 20% replacement (UPV versus compressive strength).
Figure 12 shows strength development after 7-days and 14-days of curing as well. The outcome indicated that the development rate of compressive strength was enhanced with a 20% replacement of sand by stone powder compared to control concrete. The enhancement in compressive strength of Nowshera stone dust concrete was due to the fineness and type of stone dust used [21].

Figure 13 shows that at the curing age of 7 & 14 days compressive strength of Dara stone dust concrete was more than control concrete whereas the strength of Besai and Nowshera stone dust concrete was less than control concrete. Figure 14 shows rate of strength development at 30% replacement with curing age of cylindrical. Similarly, figure 15 shows compressive strength of Nowshera and Dara at 40% replacement level was more than control concrete at curing age of 7 & 14 days but less after 28 days of curing. Figure 16 shows curing age of cylindrical specimen with strength rate development while figure 17 and 18 shows UPV and compressive strength relation for 20 and 30% respectively.

3.2. Comparison between destructive and non-destructive test

3.2.1. Ultrasonic pulse velocity (UPV) versus compressive strength (28 days curing)

UPV is a very simple and most important test to investigate the quality of concrete through electronic pulse generated by the apparatus. This test was performed on NC, DC, and BC and on control concrete (CC), and strengths were compared with each other to investigate the strength behavior. Comparison between destructive (UPV) and nondestructive test (Compressive Strength) was done for 28 days of the cured sample. The concrete samples were tested for UPV before going for compressive strengths [16]. The table 6 and the trend line show the detailed correlation between UPV and compressive strength.

Repeated UPV tests were performed on the same specimens before they were tested for the compressive strength test. The present study aims to take advantage of the reproducible results of UPV measurements to strengthen the validity of each single compressive strength test. As a result, UPV measurements could be used in combination with compressive strength test results to lower the uncertainty of the compressive strength test. The trend lines show the correlation of UPV versus compressive strength for respective percentage replacement of sand with different hardened concrete specimens. Trend lines conclude that by increasing the compressive strength the UPV values also enhances as shown in figure 19.

![Figure 18. Trend line for 30% replacement (UPV versus compressive strength).](image1)

![Figure 19. Trend line for 40% replacement (UPV versus compressive strength).](image2)
3.2.2. Density analysis of stone dust based concrete

A denser concrete generally provides higher strength as well as the fewer amount of voids and porosity. The smaller the voids in concrete, becomes less permeable to water and soluble elements. High-density concrete or heavy-weight concrete is produced using special aggregates. The table 7 shows the density analysis of 28 days cured concrete specimens having 20% Stone dust replacement. The density achieved is dependent on the type of aggregates used. Generally, the increased concrete density is achieved using different types of stone dust as a 20% replacement of sand. When using 20% Nowshera and Dara stone dust as a replacement for sand, the density of concrete enhances when compared to control concrete.

Figure 20. Types of stone dust replaced concrete versus density.

Figure 21. Test setup to determine chloride ion penetration.

Figure 22. Types of stone dust replaced concrete versus charge passed.
3.2.3. Durability analysis of stone dust based concrete (rapid chloride permeability test)

The set-up of the Rapid Chloride Permeability Test (RCPT) complies with ASTM C 1202 standard procedures [17]. RCPT is done by checking the electrical current quantity that passes through a sample with dimensions of 50 mm thick x 100 mm in diameter, within 6 h.

Throughout the test, a voltage of 60 V, DC is maintained throughout the sample. A lead is immersed (3% by mass in distilled water) in a solution of sodium chloride and sodium hydroxide (0.3% by mass in distilled water) as shown in figure 21.

Table 5. Compressive strength of concrete.

| Stone dust (%age) | Seven-days (psi) | Fourteen-days (psi) | Twenty-eight-days (psi) |
|------------------|------------------|---------------------|-------------------------|
| 0    | 3014  | 3559  | 4156  |
| 20 (N) | 3492  | 3638  | 4329  |
| 20 (D) | 3174  | 3678  | 4276  |
| 20 (B) | 2948  | 3479  | 3891  |
| 30 (N) | 2908  | 3519  | 3864  |
| 30 (D) | 3187  | 3771  | 4063  |
| 30 (B) | 2789  | 3213  | 3864  |
| 40 (N) | 3147  | 3599  | 3944  |
| 40 (D) | 3120  | 3625  | 4023  |
| 40 (B) | 2749  | 3041  | 3824  |

Figure 23. Scanning Electron Microscopy of concrete samples (1). CC, (2) BC, (3) DC, (4) NC.
Table 6. UPV and compressive strength of concrete at 20%, 30% and 40% replacement level.

| Mix label | Mix detail                  | 20% Replacement | 30% Replacement | 40% Replacement |
|-----------|-----------------------------|------------------|------------------|------------------|
|           |                             | UPV              | Compressive strength (MPa) | UPV | Compressive strength (MPa) | UPV | Compressive strength (MPa) |
| (CC)      | Control concrete            | 3.67             | 28.66             | 3.67             | 28.66             | 3.67             | 28.66             |
| (NC)      | Nowshera stone dust concrete | 4.41             | 29.85             | 3.44             | 26.65             | 3.41             | 27.2              |
| (DC)      | Darra stone dust concrete   | 4.12             | 29.49             | 3.54             | 28.02             | 3.55             | 27.74             |
| (BC)      | Besai stone dust concrete   | 3.44             | 26.83             | 3.32             | 26.65             | 3.08             | 26.37             |
The total charge passed \((Q)\) is calculated in coulombs by the following equation.

\[
Q = 900I_0 + 2I_{30} + 2I_{60} + \ldots + 2I_{300} + 2I_{330} + I_{360}
\]

Where, \(Q\) = Charge passed (Coulombs)
\(I_0\) = Current (amperes) immediately after the voltage is applied.
\(I_t\) = Current (amperes) at \(t\) minutes after the voltage is applied.

The Rapid Chloride Permeability Test (RCPT) was carried out for durability analysis of hardened stone dust-based concrete. It was performed on concrete specimens of dimension \((50 \text{ mm thick} \times 100 \text{ mm in diameter})\) after completion 28 days of curing for 20% replacement of sand by stone dust obtained from three different quarries (Nowshera, Dara, and Besai) as shown in figure 22 and listed in table 8. The total charge passed into the coulombs and was associated with the specimen’s resistance to the penetration of chlorides. The permeability of the chloride ion was found in the table 9 based on the charge. The table 9 and bar graphs indicate that 20% stone dust replacement has less chloride ion penetrability for Nowshera and Dara as compare to the control concrete sample after 28 days of curing. As stone dust particles are coarser than sand so they fill up the void spaces between fine and coarse aggregates. There are fewer voids in concrete due to which concrete density increases as a result

Table 7. Density of different types of concrete.

| Concrete Types | Specimen 1 weight (Kg) | Specimen 2 weight (Kg) | Specimen 3 weight (Kg) | Average weight (Kg) | Specimen’s volume (m³) | Density (kg/m³) |
|----------------|------------------------|------------------------|------------------------|----------------------|------------------------|----------------|
| (CC)           | 14.66                  | 14.57                  | 14.31                  | 14.51                | 0.00556                | 2611.64        |
| (NC)           | 16.12                  | 15.91                  | 15.98                  | 16                   | 0.00556                | 2879.76        |
| (DC)           | 15.42                  | 15.23                  | 15                     | 15.22                | 0.00556                | 2738.2         |
| (BC)           | 14.14                  | 13.97                  | 13.66                  | 13.92                | 0.00556                | 2505.47        |

Table 8. RCPT test results after 28th days curing.

| Stone Dust (%age) | Charge passed (Coulombs) | Chloride penetration (ASTM C1202) |
|-------------------|--------------------------|----------------------------------|
| CC                | 2625                     | Moderate                         |
| NC                | 1892                     | Very Low                         |
| DC                | 1914                     | Very Low                         |
| BC                | 2432                     | Moderate                         |

Table 9. Charge passed through RCPT test as per ASTM C-1202.

| S.No. | Charge passed (Coulombs) | Chloride ion permeability |
|-------|--------------------------|---------------------------|
| 1     | >4000                    | High                      |
| 2     | 2000–4000                | Moderate                  |
| 3     | 1000–2000                | Low                       |
| 4     | 100–1000                 | Very low                  |
| 5     | <100                     | Negligible                |

Table 10. Elemental analysis of Dara, Besai and Nowshera stone dust.

| Elements     | Ca  | Si  | Fe  | Al  | K   | Ti  | Sr  | Mn  | Zr  | Cu  | V   | Cr  | Ni  |
|--------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Stone dust(N)| 82.234 | 7.795 | 4.31 | 3.885 | 0.812 | 0.491 | 0.212 | 0.139 | 0.011 | 0.041 | 0.038 | 0.031 | —   |
| Stone dust(B)| 82.747 | 6.878 | 5.259 | 2.875 | 1.083 | 0.751 | 0.155 | 0.128 | 0.015 | 0.045 | 0.029 | 0.033 | 0.001 |
| Stone dust(D)| 81.064 | 7.553 | 4.881 | 3.943 | 1.873 | 0.539 | 0.076 | 0.045 | 0.015 | —     | 0.011 | —    | —   |
| Oxides composition | SiO₂   | Fe₂O₃ | Al₂O₃ | CaO   | MnO   | K₂O     | TiO₂ % | SrO   | Cr₂O₃ | CuO   | ZrO₂ | V₂O₅ | NiO |
|--------------------|--------|-------|-------|-------|-------|---------|--------|-------|-------|-------|------|------|-----|
| Stone dust(N)      | 13.534 | 3.574 | 4.498 | 76.857| 0.103 | 0.693   | 0.498  | 0.142 | 0.029 | 0.03  | 0.009| 0.035| —   |
| Stone dust(B)      | 11.595 | 4.276 | 4.22  | 77.973| 0.089 | 0.943   | 0.727  | 0.105 | 0.028 | 0.031 | 0.012| —    | 0.002|
| Stone dust(D)      | 12.339 | 3.981 | 6.084 | 75.28 | 0.034 | 1.641   | 0.506  | 0.05  | 0.024 | 0.03  | 0.011| 0.02  | —   |
void space is filled by stone dust as shown in figure 20. Hence less charge will pass and ultimately durability is increased as per ASTM C 1202.

3.2.4. Morphological investigation
In this research, four different concrete mixes were prepared, and fractured specimens of concrete were utilized in the scanning electron microscopic analysis (model JSM5910: manufacturer: JEOL, Japan, magnification max: 300,000X) [18]. The power supply used was up to 20 kV, magnification up to 300,000, and the optimum resolution power was 2.3 nm [22]. Images of control concrete and mixes prepared with stone dust of Nowshera, Dara, and Besai, were obtained. It has been observed extensive morphological changes with 20% replacement of stone dust in the concrete after 28 days of control curing at 25°C temperature. It is noted that 20% Nowshera stone dust replacement refines the pores structure and it is more compact as compared to control concrete. Whereas, other stone dust (Besai and Dara) develop less CSH gel. In SEM images (figure 23 (1–4)) the concrete microstructure is an intergraded system consisting of the crystalline structure is more strength development, especially in the case of Nowshera stone dust.

The images of Control concrete, Besai stone dust concrete, Nowshera stone dust concrete, and Dara stone concrete are shown in figure 23 (1–4). Considerable reduction takes place in pores with the substitution of stone dust as curing time reaches 28 days and as a result, the mix is denser and attributing more strength. The images of the Control Concrete (CC) indicate that the surface is rough with the presence of microvoids; whereas stone dust particles are fine in nature. The images show that stone dust having lamellar, fibrous, and non–porous structures. Due to the lamellar structure, the strength carrying capacity is increased. It can be observed from figure 23 (1–4) that with the substitution of stone dust, reduction in the volume of pores may be observed, which may be associated with which increase in bond action that results in the development of strength. The strength of Nowshera stone dust concrete (NC) is more than Control Concrete (CC), Dara Concrete (DC), and Besai Concrete (BC), which agrees with the elemental composition data as shown in table 5. The chemical composition of the three stone dust samples indicated that the % age of Silica (SiO2) NC, DC & BC was 13.34, 12.339 & 11.593% respectively. The maximum compressive strength development in NC is possibly due to the presence of the high amount of SiO2 in Nowshera stone dust as compared to other samples tested [23].

3.3. XRF Analysis
3.3.1. Elemental analysis
The elemental composition of the three different varieties of stone dust obtained from various quarries i.e. Dara, Besai, and Nowshera, was analyzed by XRF (Model: XRF-1800, Manufacturer: Shimadzu) analysis. Results are indicated in tables 10 and 11. The data in the table indicates that in the case of all stone dust samples, the elements present in high percentage included Ca, Si, Fe, Al, and K. In all the samples Ca being present in high amount, (about 81%–82%), followed by Si, Fe, Al, and K respectively. The other elements were present in a concentration of less than 1%, which included Ti, Sr, Mn, Zr, V, Cr, Cu, and Ni. However, in the case of the stone dust sample of Darra, the concentration of K is higher than the sand dust stone of Besai and Nowshera as shown in tables 10 and 11. Also, the stone dust of Dara lacks minerals of some certain metals like Cr, Cu, and Ni, etc. The percentage distribution of various oxides in Darra, Besai, and Nowshera stone dust is also shown in table 11.

The data shows that the Nowshera stone dust sample is rich in CaO and SiO2 content as compared to Besai and Darra, but poor in Fe2O3 and K2O content. On the other hand, Dara and Besai samples contain a high amount of Fe2O3 and K2O. The oxides of Ca and Si i.e. CaO and SiO2 lead to the formation of calcium silicates, which may either be dicalcium silicate or tricalcium silicates, both are responsible for high early and final strength. However the alkalis i.e. K2O leads to the development of cracks and increases in volume during the setting of cement and therefore reduce the strength [9, 24, 25]. Based on these results, the Nowshera sand dust having a high amount of CaO and SiO2 and less amount of K2O, yield concrete with high strength as compared to that of Dara and Besai [21].

4. Conclusion
Four different types of mix ratios were prepared with control concrete (CC), and replacement of 20%, 30% & 40% (BC), 20%, 30% & 40% (NC) and 20%, 30% & 40% (DC). The results obtained were analyzed through comparative analysis, in which different ratios were compared with the control concrete ratio (CC). The conclusions have been summarized as follows.

a. The compressive strength of Nowshera and Dara concrete samples was slightly enhanced with the substitution of stone powder, especially at the 20 percent substitution level, after 28 days of curing. However, strength slightly decreased in Besai stone dust concrete (BC) at the same replacement level.
b. Compressive strength of hardened concrete was slightly higher at 20% amalgamation of stone dust at seven, fourteen and twenty-eight days of curing and at 30% & 40% substitution level, remained unchanged.

c. The amalgamation of rock powder provides more clear images through scanning electron microscopic analysis.

d. The compressive strength of Nowshera stone dust concrete (NC) is more than Control Concrete (CC), Dara Concrete (DC), and Besai Concrete (BC). The chemical compositions of the three stone dust samples, through XRF analysis, indicate that the Silica dioxide (SiO₂) compound present in NC, DC & BC was 13.34%, 12.339% & 11.593% respectively. The maximum compressive strength development in NC is possibly due to the presence of SiO₂ compound in excess quantity in Nowshera stone dust as compared to other samples tested.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

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