Experimental evaluation of the effort of dune sand replacement levels on flexural behaviour of reinforced beam

Zhiqiang Li*a, Sen Yang † and Yun Luo c

© College of Water & Architectural Engineering, Shihezi University, Shihezi, China; † Engineering Laboratory for Seismic and Energy Saving Building in High Earthquake Intensity and Cold Zone, Xinjiang Production & Construction Groups, Shihezi, China; c Chongqing University of Science & Technology, Chongqing, China

ABSTRACT
An experimental investigation was conducted to explore the flexural behaviour of reinforced beam made with dune sand (DS) from Gurbantunggut desert in northwest China’s Xinjiang province. In order to study the influence of DS replacement levels on the engineering properties of dune sand concrete (DSC) beam, the mechanical properties of DSC and the flexural behaviour of DSC beam were examined with the DS replacement levels ranged from 0% to 80%. Based on the test results, the equations for DSC were proposed to describe the effect of DS replacement levels on mechanical properties of DSC. Meanwhile, the crack pattern and failure modes of DSC beams were investigated, the formula to calculate flexural strength of DSC beam was established, and the concrete strain, strains in reinforcement and load–deflection curve of beams were discussed.

1. Introduction
Due to the scarcity of aggregates in the areas where aggregate resources are in short supply for environmental reasons, there has been a growing interest in utilization of dune sand (DS) in the production of concrete in structural engineering (Zhang et al. 2006; Al-Harthy et al. 2007; Bouziani, Bederina, and Hadjoudja 2012; Zaitri et al. 2014; Belferrag, Kriker, and Kenfen 2013; Abu Seif et al. 2016; Alhozaimy et al. 2014; Alawad et al. 2015; Jiang et al. 2016; Luo et al. 2013; Lee, Park, and Kim 2016). The Xinjiang province is located in the northwest of China, and nearly a quarter of Xinjiang is covered with DS due to dry continental climatic conditions (Wang, Xiao, and Li 2007), and the region of Xinjiang is characterized by a lack of fine natural aggregate resources. Therefore, using DS as a fine aggregate resource will provide an alternative solution to the problem.

So far, numerous studies have been done on ordinary concrete and its components (Sallam 2010; Sallam et al. 2010; Abou El-Mal, Sherbini, and Sallam 2015; Hawileh et al. 2015; Abdalla et al. 2016; Abou El-Mal, Sherbini, and Sallam 2018). However, the utilization of DS in concrete would improve the mechanical properties of concrete (Zhang et al. 2006). Therefore, several researches on the various properties of DS were carried out. The early research on concrete made with DS was carried out by Zhang et al. (2006) in China’s Inner Mongolia province, and it concluded that the properties of DSC were different when the DS came from different desert regions. Al-Harthy et al. (2007) studied the mechanical properties and workability of concrete made with DS in Oman, and tests found that the mechanical strength of dune sand concrete (DSC) was similar to that of conventional natural aggregate concretes (NAC), when the concrete mixes were designed properly. Bouziani, Bederina, and Hadjoudja (2012) researched the usage of DS in construction in Saharan regions of Algeria, and an optimal content of DS was obtained. Zaitri et al. (2014) optimized the composition of a high-performance concrete and developed high-performance concrete mixed with grinded DS and limestone rock in Algeria. Belferrag, Kriker, and Kenfen (2013) used waste metal fibres to improve the compressive strength of DSC and cement mortar. Abu Seif et al. (2016) studied the mortar and concrete made with DS in the area of Saudi Arabia, and tests indicated that the workability and compressive strength of the DSC and cement mortar were both suitable when the volume of sand did not exceed 50% of the total fine aggregate. Alhozaimy et al. (2014), Alawad et al. (2015) and Jiang et al. (2016) analysed the microstructure of DSC by XRD and SEM, and tests revealed the correlation between the compressive strength and the CaO/SiO2. Luo et al. (2013) studied on the properties of concrete made with DS from Australian deserts, and results showed that the performance of DSC would vary according to the S/C ratio. Lee, Park, and Kim (2016) investigated the drying shrinkage cracking of DSC and revealed the correlation between compressive strength and DS/FA.

Beam is one of the important components of the structure, so numerous studies have been carried out.

CONTACT Zhiqiang Li zhiqiangli2023@163.com College of Water & Architectural Engineering, Shihezi University, Shihezi 832003, China © 2020 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group on behalf of the Architectural Institute of Japan, Architectural Institute of Korea and Architectural Society of China. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.
in previously literatures (Sallam 2010; Sallam et al. 2010; Meraj, Pandey, and Rao 2014; Abou El-Mal, Sherbini, and Sallam 2015; Bhashya et al. 2015; Gopinath, Murthy, and Iyer 2015; Hawileh et al. 2015; Abdalla et al. 2016; Evangelista and de Brito 2017; Abou El-Mal, Sherbini, and Sallam 2018; Balaji and Thirugnanam 2018; Prusty, Patro, and Mohanty 2018; Sunayana and Barai 2018). However, comparably rare research on the flexural behaviour DSC beams has been carried out.

Therefore, the primary objective of this study was to study the effect of DS replacement levels on mechanical properties of DSC beam. The mechanical properties of DSC and the flexural behaviour of DSC beam were examined with the DS replacement levels ranged from 0% to 80%. Furthermore, a formula was proposed to calculate the flexural strength of DSC beam.

2. Materials and experimental methods

2.1. Concrete mixtures and properties

In this study, ordinary Portland cement with grade 42.5 and the fly ash with grade I were used for all the concrete mixtures according to Chinese specification (GB50081) (2002). The fine and coarse aggregates used were river natural sand taken from Manas River in China's Xinjiang province. The size of fine aggregates ranged from 0.4 to 2.5 mm, and the size of coarse aggregates ranged from 5 to 20 mm. The DS was taken from Gurbantunggut desert in Xinjiang province. Table 1 presents the chemical compositions of this DS. Superplasticizer was used in all the mixtures, and the superplasticizer used was HSC (see Table 2). The water used was tap water.

In order to investigate the effort of DS replacement levels on the engineering properties of DSC, five types of concrete mixtures were designed (see Table 3). The codified names of specimens included two parts. The first part “DSC” was the abbreviation of DSC. The second part “0-80” reflected DS added as a replacement for fine aggregates.

The dimensions and tested methods of all concrete specimens were based on Chinese specification (GB50081) (2002). The dimensions that measured the compressive strength and splitting strength were designed 150 mm in length, 150 mm in width and 150 mm in height, and the dimensions that measured the elasticity modulus and axial compressive strength were designed 150 mm in length, 150 mm in width and 300 mm in height. The dimensions that measured the flexural strength were designed 550 mm in length, 150 mm in width and 150 mm in height, while the length of the span of the specimens was 450 mm.

2.2. Description of beam specimens

A total of five longitudinally reinforced beams made of DSC were cast to carry out mechanical properties tests, as shown in Table 4. All the tested beams were designed 1600 mm in length, 150 mm in width and 300 mm in height. The length of the span of all beams was 1300 mm, and the shear span-to-height ratio (a/d) of all beams was kept equal to 1.56.

All the beams were defined by the reinforcement ratios $\rho_r=0.96(\text{aaa}\text{aaa}\text{aaa}\text{a})$. The codified names of beams included two parts. The first part “DSCB” was the abbreviation of DSC beam. The second part “0-80” reflected DS added as a replacement for fine aggregates.

The properties of longitudinal reinforcement and stirrup are shown in Table 5.

2.3. Test set-up and instrumentation

All the concrete specimens were tested based on Chinese specification (GB50081) (2002), and three specimens were tested for each mechanical property, and the mechanical properties of all the concrete specimens were evaluated at 28 days age.

The engineering properties of all concrete specimens were tested by the servo-controlled universal testing machine. The set-up for compressive strength test is shown in Figure 1(a). The diagram for splitting strength test is shown in Figure 1(b). The set-up for axial compressive strength and elasticity modulus test is shown in Figure 1(c). The diagram for flexural strength test is shown in Figure 1(d).

All the beams were tested at 28–30 days age, with a symmetrical two-point force control system applied at the third points of the beam span, as shown in Figure 2. The supports were placed to allow for deflection, 150 mm from each end of the beam. Loading protocol was based on Chinese specification (GB50152) (2012). All the beams were loaded until failure.

3. Results and discussion

3.1. Mechanical properties of DSC

In this paper, setting the ordinary concrete as the control specimen, the compressive strength, splitting strength, flexural strength, elastic modulus and axial compressive strength of DSC were compared with those of control specimen.

| Table 2. Superplasticizer properties (HSC). |
|-------------------------------------------|
| HSC | Shape | Colour | PH | Density |
|-----|-------|--------|----|---------|
| Properties | Liquid | Transparent | 6–8 | 1.08 ± 0.02 |

Table 1. The chemical composition of dune sand (Gurbantunggut desert).

| SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | Na$_2$O | CaO | K$_2$O | MgO | FeO | TiO$_2$ | P$_2$O$_5$ | MnO |
|---------|-------------|------------|---------|-----|--------|------|-----|---------|-----------|------|
| 67.1%   | 17.9%       | 1.35%      | 4.94%   | 4.22% | 3.48%  | 0.84% | 0.06% | 0.02%   | 0.03%     | 0.04% |
3.1.1. Compressive strength

The measured compressive strength of all the concrete specimens is shown in Table 6. Test results indicate that the compressive strength decreases with replacement of DS increasing when the replacement level is low, and this trend is consistent with previous literatures (Zhang et al. 2006; Al-Harthy et al. 2007; Zaitri et al. 2014; Belferrag, Kriker, and Khenfer 2013; Abu Seif et al. 2016; Alawad et al. 2015; Jiang et al. 2016; Luo et al. 2013). Also, notably, higher replacement of DS aggregates (60%, 80%) causes increasing compressive strength, and this increase is due to absorption of DS.

Table 3. The mix proportion of dune sand concrete.

| ID of specimens | Water cement ratio | Sand ratio | Materials consumption (kg/m³) |
|-----------------|--------------------|------------|-------------------------------|
|                 | Water | Cement | Fly ash | HSC | Coarse aggregate | Fine aggregate | Dune sand |
| DSC-0           | 0.40  | 0.30   | 160     | 370 | 30 | 1.6 | 1288 | 552 | 0 |
| DSC-20          | 0.40  | 0.30   | 160     | 370 | 30 | 1.6 | 1288 | 441.6 | 110.4 |
| DSC-40          | 0.40  | 0.30   | 160     | 370 | 30 | 1.6 | 1288 | 331.2 | 220.8 |
| DSC-60          | 0.40  | 0.30   | 160     | 370 | 30 | 1.6 | 1288 | 220.8 | 331.2 |
| DSC-80          | 0.40  | 0.30   | 160     | 370 | 30 | 1.6 | 1288 | 110.4 | 441.6 |

Table 4. Parameters of specimens.

| ID of beams | Dune sand replacement level (r) (%) | Reinforcement ratio (%) | Stirrup |
|-------------|------------------------------------|-------------------------|---------|
| DSCB-0      | 0                                  | 0.96                    | 8@150   |
| DSCB-20     | 20                                 | 0.96                    | 8@150   |
| DSCB-40     | 40                                 | 0.96                    | 8@150   |
| DSCB-60     | 60                                 | 0.96                    | 8@150   |
| DSCB-80     | 80                                 | 0.96                    | 8@150   |

Table 5. Properties longitudinal reinforcement and stirrup.

| Bar no | Yield strength $f_y$ (MPa) | Ultimate strength $f_u$ (MPa) | Elastic modulus of steel $E_s$ (MPa) |
|--------|---------------------------|-------------------------------|--------------------------------------|
| 8      | 441                       | 615                           | $200 \times 10^3$                    |
| 16     | 430                       | 611                           | $200 \times 10^3$                    |

Figure 1. Concrete test setup. (a) Setup for compressive strength test, (b) Diagram for splitting strength test, (c) Setup for axial compressive strength and elasticity modulus test, (d) Diagram for flexural strength test.
which could reduce the water–cement ratio of cement gel. In order to explore the compressive strength of DSC with DS replacement levels, the empirical expression was proposed by the regression analysis of the test results, as shown in the following equation:

\[ f_{cu} = (1 - 0.0000996R)f_{cu,NAC} \]  (1)

where \( f_{cu} \) and \( f_{cu,NAC} \) are the compressive strength of DSC and NAC, respectively, and \( R \) is the DS replacement level (%).

3.1.2. Splitting strength

The splitting strength of all the concrete specimens is given in Table 6. Test results indicate that, compared with compressive strength of DSC, the tendency of splitting strength of DSC is similar to that of compressive strength, and the splitting strength increases with compressive strength increasing.

The functional relationship between the splitting strength and the compressive strength of DSC could be obtained by the tests results, as shown in the following equation:

\[ f_t = 0.396f_{cu}^{0.5} \]  (2)

where \( f_t \) and \( f_{cu} \) are the splitting strength and compressive strength, respectively.

3.1.3. Flexural strength

The measured flexural strength of all the concrete specimens are shown in Table 6. The functional relationship between the flexural strength and the compressive strength for DSC could be obtained by the tests results, as shown in the following equation:

\[ f_t = 0.850f_{cu}^{0.5} \]  (3)

where \( f_t \) is the flexural strength and \( f_{cu} \) is the compressive strength.

3.1.4. Elasticity modulus

The results indicate that the elastic modulus (\( E_c \)) (see Table 6) increases first and then decreases with increasing replacement of DS. The functional relationship between the elasticity modulus and the compressive strength for DSC could be obtained by the test results, as shown in the following equation:

\[ E_c = 9730f_{cu}^{0.33} \]  (4)

where \( f_{cu} \) is the compressive strength.

3.1.5. Axial compressive strength

The axial compressive strength is the most important factor for the structural calculation and design (Xiao et al. 2014). The measured prisms’ axial compressive strength of all the concrete specimens are shown in Table 6. The functional relationship between the axial
compressive strength and the compressive strength was linear for conventional natural aggregate concrete.

The relationships between the axial compressive strength and the compressive strength for DSC could be obtained by the tests results, as shown in the following equation:

\[ f_c = 0.676f_{cu} \]  \( (5) \)

where \( f_c \) is the prisms axial compressive strength and \( f_{cu} \) is the compressive strength.

3.2. Mechanical properties of DSC beam

3.2.1. Crack pattern and failure modes

The experimentally obtained crack patterns of all beams are plotted in Figure 3. It is clear that the flexural cracks are evident, as are flexure-shear cracks, and the crack patterns of the ordinary beam are similar to those of DSC beams. The first crack was recorded at around 80 kN (Table 7) in the central flexural zone, and it could be concluded that the presence of DS might delay the first crack. At a load around 130 kN, the shear cracks emanated in both shear spans near the supports, but the diffusion of shear cracks in shear spans was different. At a load around 280 kN, all beams failed in flexure shear, and the eventual failure occurred at the load point for concrete crushing in the compression zone (Figure 4). The failure load of all beams is presented in Table 7, and it can be concluded that the presence of DS might reduce the failure load of beams. Although the first crack, failure load and shear cracks were different, the leading shear crack path and failure modes were almost identical.

Figure 3. Crack development of specimens. (a) DSCB-0 beam, (b) DSCB-20 beam, (c) DSCB-40 beam, (d) DSCB-60 beam, (e) DSCB-80 beam.
3.2.2. Concrete strain

Figure 5 shows the concrete strains along depth of beam’s midspan section with increasing loading. It is obvious that the change of measured concrete strains for DSC beams is similar to that of ordinary beam, and the strain distribution of all beams varies almost linearly along the height of the beam. This means that the contribution of DS is negligible in both tension and compression. The concrete strains of all beams were almost the same with Xiao’s research (2014); hence, it could be concluded that the plane cross-section assumption could be used for DSC beam, and the theoretical formula of Chinese code (GB50010) (2010) could be applied for DSC beam.

Table 7. First crack loads and failure loads.

| ID of beams | DSCB-0 | DSCB-20 | DSCB-40 | DSCB-60 | DSCB-80 |
|-------------|--------|---------|---------|---------|---------|
| First crack load (kN) | 80     | 85      | 90      | 80      | 80      |
| Failure load (kN)     | 294    | 280     | 280     | 275     | 285     |

3.2.3. Strains in reinforcement

The relations between load and reinforcement strains in the midspan are shown in Figure 6. It is clear that the trend of measured reinforcement strains for DSC beams is similar to that of ordinary beam. Initially relations between load and reinforcement strains of all beams showed linear behaviour. However, once cracking occurred at around 80 kN, the reinforcement strains increased rapidly. At a higher load level, the reinforcement strains for DSC beams were larger than that of ordinary beam.

3.2.4. Load–deflection curve

The experimentally obtained load–midspan deflection curves of the beams are plotted in Figure 7. It can be seen that for all beams, they show linear behaviour of load–deflection before cracking. After appearance of first cracks, before yielding of steel reinforcement, the overall slope of the curve at ascending stage is in accordance with the ordinary

Figure 4. Failure modes of beams. (a) DSCB-0 beam, (b) DSCB-20 beam, (c) DSCB-40 beam, (d) DSCB-60 beam, (e) DSCB-80 beam.
beam. However, there is a big difference in the descending stage; the larger the DS replacement levels, the greater the deflection capacity. It can be concluded that the DS could increase the ductility of beams.

3.2.5. Flexural strength
Since no formula could be used as standard method to calculate the flexural strength of DSC beam, the empirical formula was adopted according to Chinese code (GB50010) (2010), as shown in in the following equation:

\[
\begin{align*}
\alpha_1 f_y b x &= f_y A_i \\
M_c^C &= \alpha_1 f_y b x (h_0 - \frac{x}{2})
\end{align*}
\]

where \(\alpha_1\) is the equivalent coefficient of concrete; \(f_y\) and \(f_c\) are shown in Tables 5 and 6; \(x\) is depth of concrete compression zone; \(h_0\) and \(b\) are the effective depth of the section and the width of beam, respectively; \(A_i\) is the area of longitudinal reinforcement; and \(M_c^C\) is the ultimate moment of beam.

The \(x\) is one of the parameters of concrete, and it varies with the load. To simplify the calculation, the \(M_c^C\) could be expressed as in the following equation (Xiao et al. 2014):

\[
M_c^C = f_y' A_i' \times (h_0 - \frac{f_y' A_i'}{2 b} - \frac{x}{2})
\]

So \(M_c^C\) was a function of concrete, and the flexural strength of DSC beam could be calculated by Equation (7).

The test values and calculated values by Equation (7) are shown in Table 8. It can be seen that test values of flexural strength are larger than that of theoretical calculation of code. It was feasible to calculate flexural strength of DSC by Chinese code, but it was not economical. Meanwhile, Equation (7) did not take into account the replacement levels of DS. Therefore, the
correction factor of concrete considering the replacement levels of DS was introduced to improve the Equation (7), as shown in the following equation:

\[ M_u^p = K_u^c = K_r \times f_y' \times A_i' \times \left( h_0 - \frac{f_y' \times A_i'}{2' \times f_c \times b} \right) \]  

(8)

where \( K_r \) is the correction factor of concrete.

The \( K_r \) was determined by the method of regression analysis (see Figure 8). Hence, the modified formula of flexural strength of DSC beam could be expressed by Equation (9). Here, \( r \) was DS replacement level, as shown in Table 4.

\[ M_u^p = (0.3283r^2 - 0.3077r + 1.4145) \times f_y' \times A_i' \times \left( h_0 - \frac{f_y' \times A_i'}{2' \times f_c \times b} \right) \]  

(9)

As shown in Table 8, it can be seen that the calculated values by proposed formula are in agreement...
4. Conclusions

The following conclusions are drawn from this study:

(1) The equations were proposed to describe the effect of DS replacement level on the compressive strength, splitting strength, flexural strength, elastic modulus and axial compressive strength of DSC.

(2) The crack pattern and failure modes of DSC beams were similar to that of ordinary beam, and the concrete strates satisfied the plane cross-section assumption. Therefore, the theoretical formula of Chinese code (GB50010) could be applied for DSC beam.

(3) The strains in reinforcement and load–midspan deflection curve of DSC were larger than those of ordinary concrete beam, proving the DS could increase the ductility of beams.

(4) The proposed formula to calculate flexural strength of DSC beam could be applied to predict the flexural strength of DSC beams in the area of northwest China’s Xinjiang province.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the National Natural Science Foundation of China: [Grant Number 51668053].

ORCID

Zhiqiang Li http://orcid.org/0000-0002-7869-3578
Sen Yang http://orcid.org/0000-0002-1111-9897

References

Abdalla, J. A., F. H. Hraib, R. A. Hawileh, and A. M. Mirghani. 2016. “Experimental Investigation of Bond-slip Behaviour of Aluminum Plates Adhesively Bonded to Concrete.” Journal of Adhesion Science and Technology 2016: 1–18. doi:10.1080/01694243.2016.1204741.
Abou El-Mal, H. S. S., A. S. Sherbini, and H. E. M. Sallam. 2015. “Locating the Site of Diagonal Tension Crack Initiation and Path in Reinforced Concrete Beams.” Ain Shams Engineering Journal 6: 17–24. doi:10.1016/j.asjc.2014.10.006.
Abou El-Mal, H. S. S., A. S. Sherbini, and H. E. M. Sallam. 2018. “Structural Behaviour of RC Beams Containing a Pre-Diagonal Tension Crack.” Latin American Journal of Solids and Structures 15 (7): e82. doi:10.1590/1679-78254701.
Abu Seif, E. S., A. R. Sonbul, B. A. H. Hakami, and E. K. El-Sawy. 2016. “Experimental Study on the Utilization of Dune Sands as a Construction Material in the Area between Jeddah and Mecca, Western Saudi Arabia.” Bulletin of Engineering Geology and the Environment 75 (3): 1007–1022. doi:10.1007/s10064-016-0855-9.
Alawad, O. A., A. Alhozaimy, M. S. Jaafar, F. N. A. Aziz, and A. Al-Negheimish. 2015. “Effect of Autoclave Curing on the Microstructure of Blended Cement Mixture Incorporating Ground Dune Sand and Ground Granulated Blast Furnace Slag.” International Journal of Concrete Structures and Materials 9 (3): 381–390. doi:10.1007/s40069-015-0104-9.
Al-Harthi, A. S., M. A. Halim, R. Taha, and K. S. Al-Jabri. 2007. “The Properties of Concrete Made with Fine Dune Sand.” Construction and Building Materials 21 (8): 1803–1808. doi:10.1016/j.conbuildmat.2006.05.053.
Alhozaimy, A. O., A. Alawad, M. S. Jaafar, A. Al-Negheimish, and J. Noorzaei. 2014. “Use of Fine Ground Dune Sand as a Supplementary Cementing Material.” Journal of Civil Engineering and Management 20 (1): 32–37. doi:10.3846/13923730.2013.768541.
Balaji, S., and G. S. Thirugnanam. 2018. “Behaviour of Reinforced Concrete Beams with SIFCON at Various Locations in the Beam.” KSCE Journal of Civil Engineering 22 (1): 161–166. doi:10.1007/s12205-017-0498-9.
Belferrag, A., A. Kriker, and M. E. Khenfer. 2013. “Improvement of the Compressive Strength of Mortar in the Arid Climates by Valorization of Dune Sand and Pneumatic Waste Metal Fibers.” Construction and Building Materials 40: 847–853. doi:10.1016/j.conbuildmat.2012.11.079.
Bhaskaya, V., S. S. Kumar, G. Ramesh, B. H. Bharatkumar, T. S. Krishnamoorthy, and N. R. Iyer. 2015. “Long Term Studies on FRP Strengthened Concrete Specimens.” Indian Journal of Engineering and Materials Sciences 22 (4): 465–472.
Bouzian, T., M. Bederina, and M. Hadjoudja. 2012. “Effect of Dune Sand on the Properties of Flowing Sand-concrete (FSC).” International Journal of Concrete Structures and Materials 6 (1): 59–64. doi:10.1007/s40069-012-0006-z.
Evangelista, L., and J. de Brito. 2017. “Flexural Behaviour of Reinforced Concrete Beams Made with Fine Recycled Concrete Aggregates.” KSCE Journal of Civil Engineering 21 (1): 353–363. doi:10.1007/s12205-016-0653-8.
GB50010. 2010. Code for Design of Concrete Structures. Chinese Standard. GB 50010-2010. Beijing: Chinese Standard Institution.
GB50081. 2002. Standard Test Method for Mechanical Properties of Ordinary Concrete. Chinese Standard. GB 50081-2002. Beijing: Chinese Standard Institution.
GB50152. 2012. Standard Test Method for Concrete Structures. Chinese Standard. GB 50152-2012. Beijing: Chinese Standard Institution.

Figure 8. Regression analysis result of $K_r$ with the test values. It was more reasonable to calculate flexural strength of DSC beam by proposed formula.
Gopinath, S., A. R. C. Murthy, and N. R. Iyer. 2015. “Monotonic and Low Cycle Fatigue Behaviour of Concrete Beams Strengthened with Textile Reinforced Concrete U-wrap.” Indian Journal of Engineering and Materials Sciences 22 (3): 331–338.

Hawileh, R. A., W. Nawaz, J. A. Abdalla, and E. I. Saqan. 2015. “Effect of Flexural CFRP Sheets on Shear Resistance of Reinforced Concrete Beams.” Composite Structures 122: 468–476. doi:10.1016/j.compstruc.2014.12.010.

Jiang, C. H., X. B. Zhou, G. L. Tao, and D. Chen. 2016. “Experimental Study on the Performance and Microstructure of Cementitious Materials Made with Dune Sand.” Advances in Materials Science and Engineering 2016: 1–8. doi:10.1155/2016/2158706.

Lee, E., S. Park, and Y. Kim. 2016. “Drying Shrinkage Cracking of Concrete Using Dune Sand and Crushed Sand.” Construction and Building Materials 126: 517–526. doi:10.1016/j.conbuildmat.2016.08.141.

Luo, F. J., L. He, Z. Pan, W. H. Duan, X. L. Zhao, and F. Collins. 2013. “Effect of Very Fine Particles on Workability and Strength of Concrete Made with Dune Sand.” Construction and Building Materials 47: 131–137. doi:10.1016/j.conbuildmat.2013.05.005.

Meraj, T., A. K. Pandey, and B. K. Rao. 2014. “Flexural Behaviour of Latex Modified Steel Fiber Reinforced Concrete.” Indian Journal of Engineering and Materials Sciences 21 (2): 219–226.

Prusty, J. K., S. K. Patro, and T. Mohanty. 2018. “Structural Behaviour of Reinforced Concrete Beams Made with Ferrochrome Slag as Coarse Aggregate.” KSCE Journal of Civil Engineering 22 (2): 696–707. doi:10.1007/s12205-017-1294-2.

Sallam, H. E. M. 2010. “Discussion of ‘Flexural Strengthening of Steel Bridges with High Modulus CFRP Strips’ by David Schnurch and Sami Rizkalla.” Journal of Bridge Engineering 15: 117. doi:10.1061/(ASCE)BE.1943-5592.72.

Sallam, H. E. M., A. A. M. Badawy, A. M. Saba, and F. A. Mikhail. 2010. “Flexural Behaviour of Strengthened Steel–concrete Composite Beams by Various Plating Methods.” Journal of Constructional Steel Research 66: 1081–1087. doi:10.1016/j.jcsr.2010.03.005.

Sunayana, S., and S. V. Barai. 2018. “Flexural Performance and Tension-stiffening Evaluation of Reinforced Concrete Beam Incorporating Recycled Aggregate and Fly Ash.” Construction and Building Materials 174: 210–223. doi:10.1016/j.conbuildmat.2018.04.072.

Wang, Y. G., D. N. Xiao, and Y. Li. 2007. “Temporal-spatial Change in Soil Degradation and Its Relationship with Landscape Types in A Desert-oasis Ecotone: A Case Study in the Fubei Region of Xinjiang Province, China.” Environmental Geology 51 (6): 1019–1028. doi:10.1007/s00254-006-0371-5.

Xiao, J. Z., T. L. Pham, P. J. Wang, and G. Gao. 2014. “Behaviors of Semi-precast Beam Made of Recycled Aggregate Concrete.” Structural Design of Tall and Special Buildings 23: 692–712. doi:10.1002/tal.1071.

Zaitri, R., M. Bederina, T. Bouziani, Z. Makhloufi, and M. Hadjoudja. 2014. “Development of High Performances Concrete Based on the Addition of Grinded Dune Sand and Limestone Rock Using the Mixture Design Modelling Approach.” Construction and Building Materials 60: 8–16. doi:10.1016/j.conbuildmat.2014.02.062.

Zhang, G. X., J. X. Song, J. S. Yang, and X. Liu. 2006. “Performance of Mortar and Concrete Made with a Fine Aggregate of Desert Sand.” Building and Environment 41: 1478–1481. doi:10.1016/j.buildenv.2005.05.033.