EXPERIMENTAL INVESTIGATION ON CONCRETE WITH REPLACEMENT OF FINE AGGREGATES WITH STEEL SLAG

KARTHIK PRABHU.T[1*], SUBRAMANIAN.K [2], JAGADESH.P [1], NAGARAJAN.V [3]
Department of Civil Engineering, Coimbatore Institute of Technology, Coimbatore, Tamil Nadu, India
P.S.R. Engineering College, Sevalpatti, Sivakasi, Tamil Nadu, India
Department of Civil Engineering, Coimbatore Institute of Technology, Coimbatore, Tamil Nadu, India.

Experimental programme is conducted on steel slag blended concrete, by partially replacing offline aggregate by steel slag up to 50%. The mechanical properties were determined by conducting cylinder compressive strength (CRCS), modulus of elasticity (MSE) and modulus of rupture (MSR).Comparison was done with conventional concrete and steel slag blended concrete in terms of strength and economy. Further modeling of relationships between the mechanical properties as CRCS, MSE and MSR of the concretes with fine aggregate replacement was done and validated with NZS:3101 (New Zealand Standard code 3101), AS: 3600 (Australian Standard code 3600) and ACI: 318 (American Concrete Institute code 318)

Keywords:*Steel Slag, Cylinder Compressive Strength, Modulus of rupture, Modulus of Elasticity*

1. Introduction

In India where the development is seen progressing very rapidly, more concrete usage is abundantly found everywhere for the most of the construction activities [1]. The current study aims in evolving new techniques in substitute for the conventional method of concrete preparation. The study also focuses to improve the property of the concrete; to reduce the cost and pollution involved in the production. The concrete production generatesCO_2emission, which is second largest in the world [2, 3].The main technique of achieving the environment preservation in the construction sector is to develop a sustainable way to reuse and recycle the construction materials hence reducing dumping of the waste materials and extraction of the natural resource for construction [4].Hence steel slag which is the waste material resulted as a residue on the production of steel used in this study. With additions of steel slag as fine aggregates, the interface structure has been improved [5].

Even though many researches were done for utilizing these waste materials still the problem persists in large number and the disposal of the waste creating a huge menace to the government and environmentalists [6]. The replacement of fine aggregate with steel slag in concrete increases the resistance to carbonation, permeability and drying shrinkage being similarly to normal concrete [6]. The past researches were mostly confined to the improvement in properties by considering only of the mechanical property enhancement. The present study,focuses on the determination of the behaviour of the concrete in terms of CRCS, MSE and MSR and to be validated confining to various International Standards.

2. Experimental

2.1 Materials for the preparation of concrete

The Steel Slag is obtained from Agni steels, Ingur, Tamil Nadu, India. Steel slag as a by product in the manufacture of steel. It has highly angular in shape and rough surface texture. It has high bulk specific gravity and less water absorption (less than 3 percent) is shown in Table 1.

Table 1

Physical properties of steel slag

Property	Value
Specific Gravity	3.2
Unit Weight, kg/m^3	1788
Water Absorption, %	2.31

The chemical composition of slag is calculated from elemental analysis by x-ray fluorescence spectroscopy and expressed in terms of simple oxides. Table 2 lists the range of compounds present in steel slag. The important is the mineralogical composition of the slag, which is highly dependent of the rate of slag cooling in the steel-making process.

The cement used in the research work is of 53 Grade OPC conforming to IS 12269-1987. The

*Autor corespondent/*Corresponding author*,
E-mail: ntkarthikprabhu@gmail.com

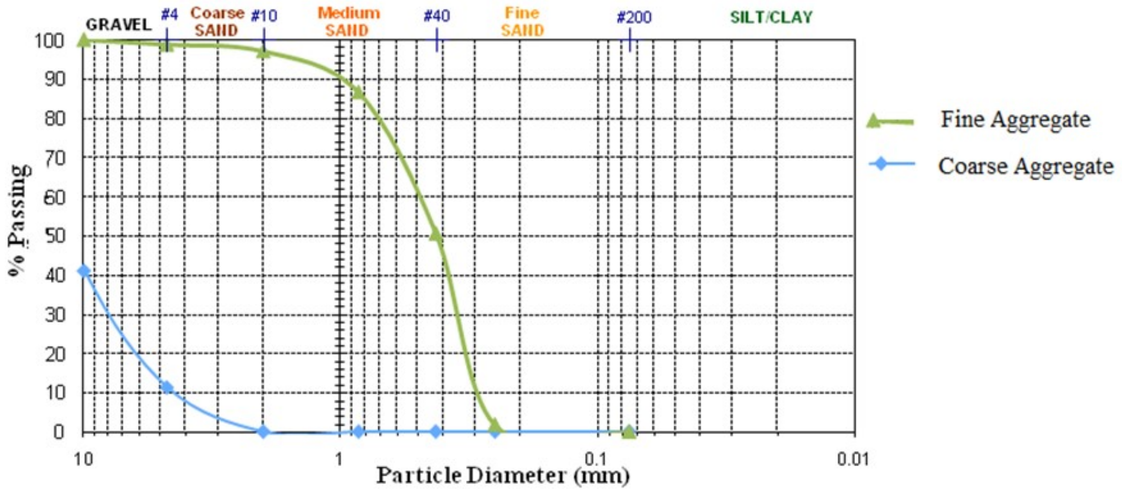

Fig. 1 - Sieve Analysis for Fine and Coarse Aggregates.

Table 2

Chemical composition of Steel slag

Constituent	Composition (%)
CaO	47
SiO_2	13
FeO	27
MnO	7
MgO	8
Al_2O_3	1
P_2O_5	8
S	0.08
Metallic Fe	4

OPC was dry, powdery and free of lumps. The fine aggregate used in the research work was procured from local dealer distributer of Karur sand, obtained from Karur, Tamilnadu, India. The test on the fine aggregate was conducted and confined according to IS: 2386-1986 and IS: 383-1970. Coarse aggregate having the maximum size of 10 mm is used in the research work. The aggregates are tested for their properties and found suitable as stated by Indian Standards, as per IS: 2386-1963 as shown in Figure1.

2.2. Casting and Curing of concrete

The percentages of the fine aggregate replacement with steel slag are depicted in Table 3. The specimens for compression and flexural strength determination were prepared by casting of the fresh concrete in cast iron steel moulds. Automatic Concrete Mixer machine were used for blending of the concrete by skilled labour and needle vibration is done to achieve a high quality of compacting. After 24 hours, the specimens were de-moulded and placed into curing tank till the period of testing.

Table 3

Mix ID with percentages

Mix ID	Percentage of replacement of Steel slag as Fine Aggregates
NL	0
S1	5
S2	10
S3	15
S4	20
S5	25
S6	30
S7	35
S8	40
S9	45
S10	50

2.3.Test Procedures

Six beams were casted from each mix for flexural strength determination after 7 days and 28 days of hardening. The average value of3 samples were taken into consideration for further study. Similarly six cylinders for each mix were casted in order to find out the poisons ratio by determining the lateral and longitudinal strain by CRCS at the age of 7 days and 28 days. The testing machine of 2000kN capacity as per IS: 516-1959 code was used for all determinations. Cube compression testing were done as per IS standards. For the Cylinder Compression test, the linear and lateral deflectometers are placed in the cylinder to measure the strain laterally and longitudinally. Due to the Poisson's effect cylinder specimen undergo lateral expansion. The load is applied 0.15 to 0.35 MPa/s (ASTM C 1077) and the deflection is noted on the corresponding longitudinal and lateral deflectometersuntil the first appearance of crack on the specimen. After the initial crack, the deflectometers are removed and further rate of loading is increased till failure of the specimen.

3. Results and Discussions

3.1 Predicted Modulus of Rupture

The replacement of fine aggregates by steel slag was done starting from 5% till 50% as S1, S2, …., S10 as shown in Table 3. The Nominal mix is designated as NL. The mixes S1 to S10 are tested for compression strength and compared with the models developed based on the International codes. The MSR (f_{fc}) at 28 days is determined using Eq. (1) as codified by AS (Australian Standard) 3600 and NZS: (New Zealand Standards) Code 3101 by using the value of CRCS (f_c) at 28 days.

$$MSR = 0.6\sqrt{CRCS} \qquad (1)$$

ACI (American Concrete Institute) code 318-14 codifies Eq. (2) to be the relationship between the MSR and the CRCS at 28 days. There are two significant for the above relationship viz., to determine the indirect tensile strength of concrete and bending stress of a flexural member The comparison of mean difference between the mixes indicates that MSR codified by Eq. (2) is relatively more accurate near to 98% when compared to Eq.(1).

$$MSR = 0.62\sqrt{CRCS} \qquad (2)$$

From the experimental data of MSR and CRCS, a relationship confining to Eq. (1) and Eq. (2) was developed by 0.5 power law regression analysis. The regression law is one of the most commonly used methods to model the equation in various engineering and science field (Liu et al., 2001). The following Eq. (3) for S series concrete, shows higher constant then the theoretical specification as per by AS 800-2009, ACI: 318 318–2014 and NZS:3101. R^2 value of the regression analysis was kept greater than the value of 98% accuracy for best results. Since the R^2 value of the regression analysis if it exceeds over 96% it is defined as an excellent fit to the results [7].

$$MSR = 0.6070\sqrt{CRCS} \qquad (3)$$

3.2. Predicted Modulus of Elasticity

The modulus of elasticity, density and CRCS can be studied by various statistical tools, which are vital parameter to study the properties of the concrete [8].The international codes ACI-318 and AS-3600 [Eq. (5)] and NZS:-3101 [Eq. (6)] codifie the relationship between MSE and CRCS of concrete as follows.

$$MSE = \rho^{1.5}\left[0.043\sqrt{CRCS}\right] \qquad (5)$$

$$MSE = 3320\sqrt{CRCS} + 6900 \qquad (6)$$

where

ρ is density of concrete (kg/m³)

The mechanical strength of concrete with steel slag is similar to that of the conventional

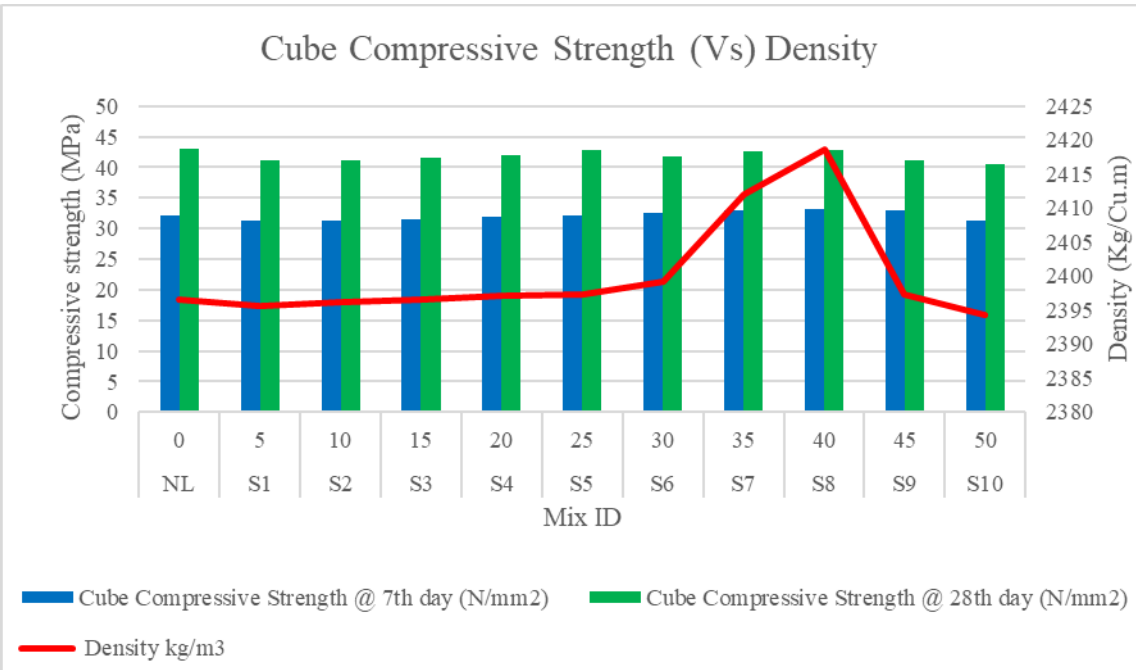

Fig. 2 - Cube Compressive Strength and Density versus concretes composition.

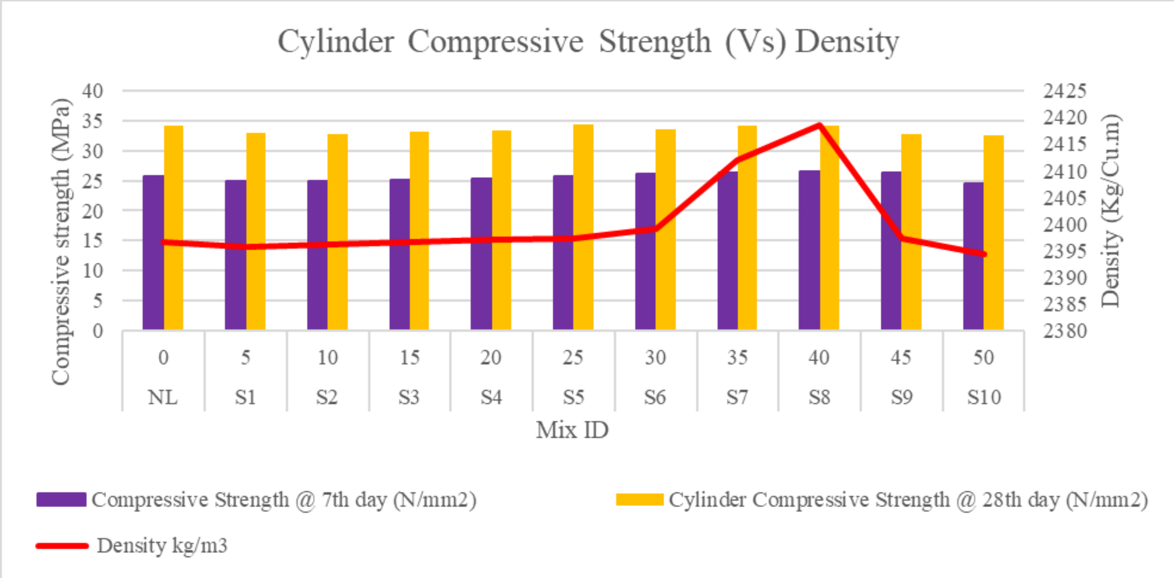

Fig. 3 - Cylinder Compressive Strength and Density versus concretes composition.

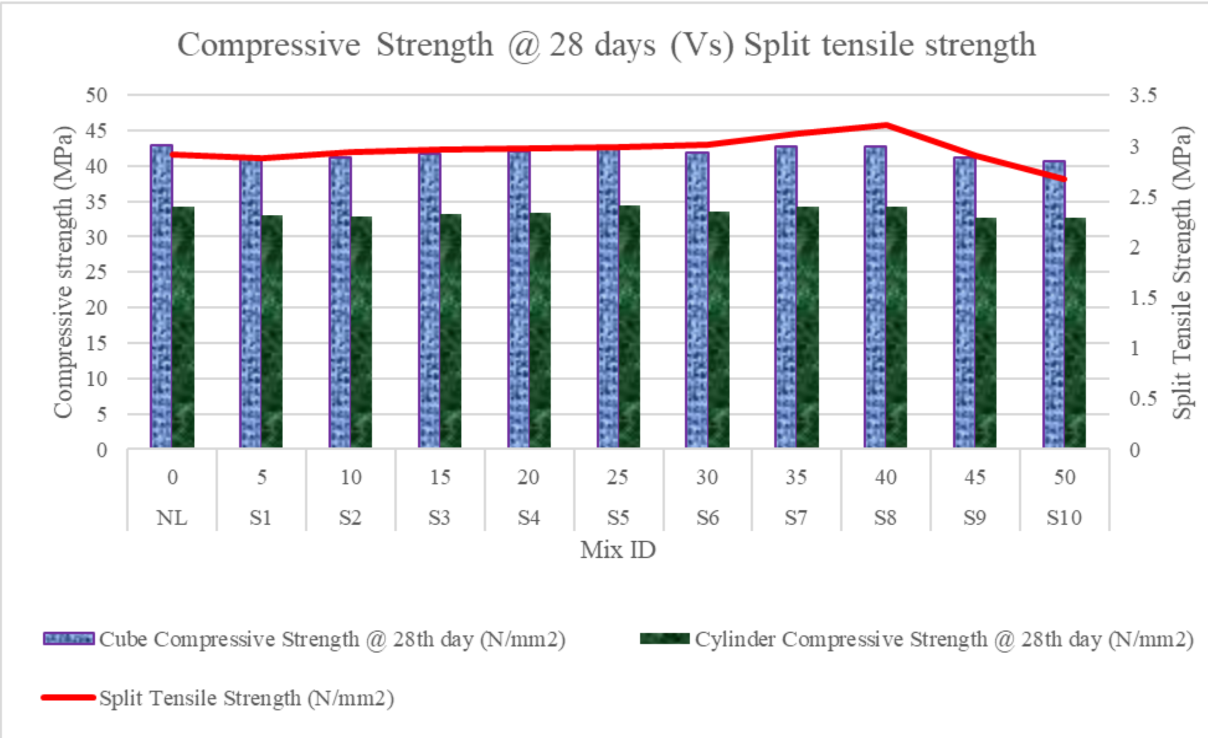

Fig. 4 - Compressive strength at 28 days and Split tensile strength versus concretes composition.

Concrete [7] though the flexural strength is lower than that of conventional mix but the shrinkage and volume change is less when compared to the nominal mix [9].

The equation has been modelled with respect to the experimental value and the values codified by the international codes namely the NS, ACI and AS. The difference between the MSE from experimental values and the codal value is found to 98% for S mixes. The replacement of fine aggregates with steel slag is found to be suitable as compared with natural aggregate and validated with European standards [10].

The equation modeled by the 0.5 multiple regression analysis by fitting the equation 5 and 6, derived0.5 power regression analysis and the equations are obtained as shown in equation 7:

$$MSE = 3548\sqrt{CRCS} + 5595 \qquad (7)$$

The main objective of this research is to findthe relationship between elastic constants (MSE and MSR)and compressive strength. The research focuses more on the codal validations on the elastic constant parameters with compressive

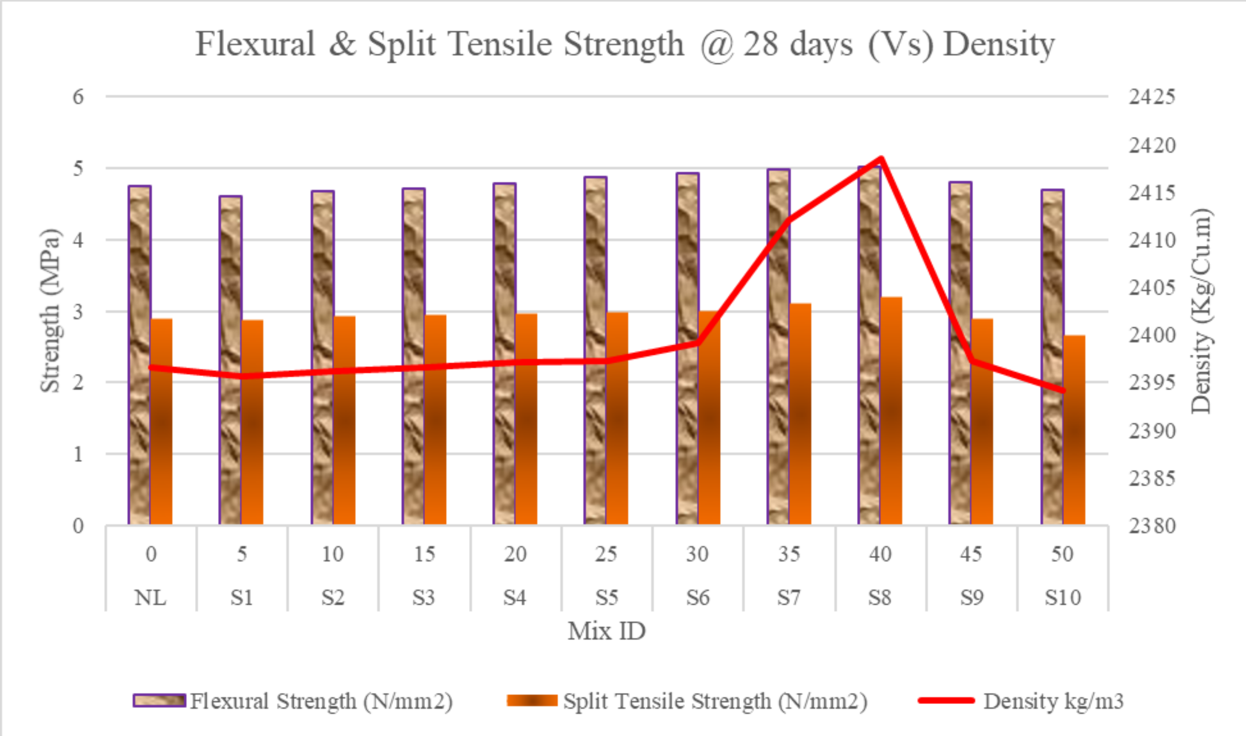

Fig. 5 - Flexural and split tensile strength result with Desity parameter.

strength. The compression strength of cube, cylinder and flexural strength as well as tensile strength are depicted in detail from Figures 2-5.

4. Conclusions

The effect of steel slag as fine aggregate in the concrete mix is studied. The replacement with of steel slag was done up to 50%for the fine aggregate in the concrete mix. The replacement degree was done in the multiples of 5 starting from 5% on further increment of 5%. The inclusion of steel slag enhances the overall strength of the mix when compared with the mix without steel slag, it also improves the durability of aspect in the concrete [11].

From the evaluation of mechanical properties of Steel slag blended concrete by experimental testing and the results are displayed in Figures 2 to 5, the elastic properties, CRCS, relationship constants, including the density with respect to NZ, ACI and AS standards, the following conclusions are drawn:

- The mean difference in the density mix is found to be varied to a extent 2348 kg/m^3 for the conventional concrete mix and 2418 kg/m^{3}forsteel slag fine aggregate blendedS1 mix
- Based on CRCS data, we can consider that the optimum percentage for replacement of fine aggregates by steel slag is 40%.
- By addition of the steel slag as fine aggregate the density is found to increase. The maximum increase by comparison with the nominal mix was found to be with 60% higher for the S8 mix. Hence the workability gets reduced and further replacement with steel slag which was found to be not feasible .
- The MSR valuesfor the concrete with steel slag replacement of 30% was found to be 25% higher than for the reference mix. S4 mix was found to have the next highest MR value nearly 10% more than those of the nominal mix .
- Equation was developed based on the MSR and CRCS values for S series respectively also the validations of the results are also compared with the international standard and accuracy was found to be around 99%.
- Based on the MSE and the test results the equation is developed according to the various international standards and validated with the linear power regression analysis with an accuracy of 98.5% minimum.

Acknowledgements

The authors wish to gratefully acknowledge the support of Structural Engineering Laboratory Technician and usage of DST-FIST sponsored UTM Machine of 3000 kN Capacity.

REFERENCES

[1] N S Martys Survey of concrete transport properties and their measurement. NISTIR 5592, US Department of Commerce. 1996, 1–40.
[2] P Yu, Structure of calcium silicate hydrate (C-S-H): near-, mid-, and far infrared spectroscopy. J. American Ceramic Society*,* 1999 , 82,742–748.
[3] P Jagadesh, A Ramachandramurthy, R Murugesan and K Sarayu, Micro analytical studies on sugar cane bagasse ash. *Sadhana* – Academy of science*,* 2015 ,40, 1629-1638.
[4] B Gonzalez-Fonteboa and F Martınez-Abella, Concretes with aggregates from demolition waste and silica fume. Materials and mechanical properties, J. Building and Environment*,* 2008, 43:429–437.

[5] Wang, Qiang, Yan, Peiyu, Yang, Jianwei and ZhangBo, , Influence of steel slag on mechanical properties and durability of concrete, J. Construction and Building Materials, 2013, **47**, 1414-1420.

[6] Ye Qing,Zhang Zenan, Kong Deyua and Chen Rongshen, Influence of nano-SiO_2 addition on properties of hardened cement paste as compared with silica fume", J.Construction and Building Materials, 2007, **21**, 539-545.

[7] T KarthikPrabhu and K Subramanian, Experimental Studies on RCP by using Cost Effective and Recycled Materials for Improving the Strength and Reducing the Cost of Pavement, Asian Journal of Research in Social Sciences and Humanities, 2016, **6**, 1 -14.

[8] P Jagadesh, A Ramachandramurthy and R Murugesan, Evolution of mechanical properties of sugar cane bagasse ash blended concrete, .J. Construction and Building Materials, 2017 (Accepted for publication) .

[9] Liu Chunlin, ZhaKunpeng and ChenDepeng, "Possibility of Concrete Prepared with Steel Slag as Fine and Coarse Aggregates: A Preliminary Study", J. Procedia Engineering, 2011, **24**, 412-416.

[10] Ivanka Netinger, DubravkaBjegović and Goran Vrhovac, "Utilisation of steel slag as an aggregate in concrete", J. Materials and Structures, 2011, **44** (9), 1565-1575.

[11] M Logeshwaran , P Iswarya ,P Priyanka ,M Tamilselvam, "Durability Properties Of Steel Slag As Coarse Aggregate In Concrete". J. International Research Journal of Engineering and Technology, 2018, **5** (5), 621-624.

****

MANIFESTĂRI ȘTIINȚIFICE / SCIENTIFIC EVENTS

International Construction Forum: Cement. Concrete. Dry Mixtures
27 November 2019 - 30 November 2019, Moscow

http://infocem.info/eng

On the 27 — 29 November 2019, at the Moscow Expocentre, one of the most important industry events will be held. For more than 20 years “Cement. Concrete. Dry mixtures” has been a place where guests and participants build new business contacts and get the latest news from the building industry and technology.

This year's programme includes the following:

- XX international “Cement. Concrete. Dry Mixtures” specialised exhibition.
- ConTech science conference and workshop on concrete technology, chemistry and production.
- Modern Technologies of Dry Mixtures in Construction – "MixBuild" – science conference and workshop .
- V International seminar-contest for young scientists and postgraduates working in the field of binders, concrete, and dry mixtures.
- Roundtable discussions on special cement types.
- Technical tours to the industry’s plants and manufactures.

The "Cement. Concrete. Dry Mixtures" exhibition will include the following:

- A specialized exhibition for producers, architects, manufacturers, suppliers and builders.
- Networking and mutual communication, negotiations and business contracts.
- Product promotion among Russian Federation and CIS countries.

Exhibitors will include suppliers of the following:

- Equipment for cement, concrete producing, reinforced concrete structures and dry mixtures.
- Turnkey plants.
- Additives, pigments, aggregates.
- Raw materials and processing machinery.
- Silages, mixture taps, dosing units.
- Energy-efficient technologies.
- Packing, packaging and transferring.
- Laboratory and analytical equipment.
- Cement, lime, gypsum.
- Supervision systems, quality control systems.
- Reinforcement, frameworks.

****