Performance of sustainable concrete with crushed rock fines – A Review

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Abstract: This review paper gives the performance of various concrete types by replacing the natural river sand by crushed rock fines. Nowadays, owing to the infrastructure developments in the developing countries natural river sand will be becoming scarce and ecological imbalance will be started occurring due to the lifting of more sand from the river beds. Many of the researchers will be working on it for selecting the appropriate material for replacing the natural river sand. Currently, the effect of alternate materials such as geosynthetic aggregates, recycled aggregates, crushed rock fines, quarry dust, slag, etc. in various types of concrete will be tested. One such material is crushed rock fines; it would be shown better performances with concrete by replacing the natural river sand by 50% replacement. This review paper has given the analysis of utilization of crushed rock fines as the partial replacement of natural river sand with compared with control concrete by various strength tests, physio-chemical properties. The utilization of crushed rock fines will be solving ecological imbalance and environmental hazards which is created by many of the crushers.

1. Introduction

In general, aggregate is a group of coarse to intermediate grained particulate materials such as gravel, sand, crushed stone[1], recycled aggregate[2], slag[3] and geosynthetic aggregates. These aggregates give strength to the concrete materials. Crushed rock fines or rock dust is formed through the crushing process during the manufacture of coarse aggregates[3]. Currently, which is unusable material and it is creating environmental pollution due to dumping on the vacant lands. Manufactured sand and crushed rock fines are the coarse part of crushed rock dust, is being used as a substitute to river sand in the concrete mixing formed good courtesy by the construction engineering in the direction of a substitute fine aggregate [4]. Fast development in the infrastructure has ended cement the utmost generally utilized building material all throughout global[5][6]. The expense of concrete manufacturing principally relies upon the expense of its ingredient materials to be cement, coarse aggregates, fine aggregates and water[7]. Amid the constituent materials, the common constituent natural river sand as fine aggregate which structures about 35% of the solid volume assumes a significant job in choosing the expense of concrete[8]. Exhausting of regular stream sand and severe ecological rules on mining
has slowly moved the consideration of the construction industry towards an appropriate alternative fine aggregate which can supplement the river sand. For efficient utilization of the alternative material, technical and economic feasibility, durability of processed concrete was to be examined, crushed stone dust satisfies the parameters [9].

G. C. Cordeiro et al. studied the performance of concrete such as mechanical and rheological properties with the partial substitute of crushed granite stone as fine aggregate. To avoid the negative results, 20% of rice husk rusk with volume of cementitious material was mixed in the concrete mixtures. They concluded that, 50% of crushed granite aggregates showed better performance in compressive strength and young’s modulus, reduction in water absorption was also observed[10]. K. S. Kou et al. conducted the investigation for the properties of concrete that were manufactured with alternative fine aggregates such as furnace bottom ash, crushed rock fines, river sand and recycled fine aggregates as replacement to normal fine aggregates. Results showed that at a constant slump, chloride ion-penetration resistance was improved in all the alternative fine aggregate replaced concrete than that of the control concrete [11]. The rheology of crushed rock fine materials were studies with materials from 10 different crushers. Concrete had been prepared with all the 10 types of rock material replacement with composition and the physical properties were well documented. Conclusions showed that low importance should be given with regard influence of the shape of the crushed rock fines because equi-dimensionality of the materials was achieved normally by all the high-speed vertical shaft impact crushers [12].

A. M. Ajao et al. conducted the investigation of properties such as specific gravity, grain size distribution, bulk density, moisture content and compressive strength with natural river sand, crushed stones, half replacement of natural sand with crushed stones were presented in the table form and also bar charts for the better understanding[13]. S. Mundra et al. prepared the optimized concrete mix with crushed rock sand, as an economical alternative to the natural river sand. They prepared the concrete mixes based on Bureau of Indian Standards, ACI and British codes by using crushed rock sand and natural river sand as an ingredient. Their study concluded that strength properties by using the crushed rock sand concrete mix showed similar results to that of the concrete mix with natural river sand[14]. Hardened and fresh concrete properties are affected by shape and texture of the aggregates available in the concrete mix. Rough angular and elongated aggregates reduce the workability of the concrete instead we can use the smooth and rounded aggregates for the improved workability[15]. Crushed rock stone would be angular and elongated aggregates in which workability decreased to avoid that proper screening and washing of the crushed materials to obtain better workability in the concrete mixes [16]. Thangapandi et al. investigated the strength properties of cement mortar with different grades and also replacing the natural river sand by crushed rock powder by 0, 20, 40, 60, 80 and 100 percentages and in parallel they investigated fines particles (less than 150 micron) of crushed rock fines as replacement of natural river sand [17]. The concrete grades such as M20 and M25 were design by replacing the natural river sand by crushed stone from 0 – 100% by incrementing of about 10%. From the varying percentage replacement of crushed stone, strength properties of both the grades were examined[18].

2. Need for this study
In most of the areas all over the India, because of the disposal of crushed stone dust lands have become barren. Effective utilization of this disposal waste material in the concrete becomes environmentally friendly. A. K. Sahu et al. conducted various investigations with better prospects by utilizing the crushed stone dust as a replacement of natural river sand by manufacturing the quality concrete[1]. Madiha Z. J. Amari et al. informed that excavating the natural sand from river or sea areas in excess will be hazardous to the environment. Various grades of coarse and fine crushed aggregates were made by crushing the parent rock which was more sustainable and economical way of replacing the natural sand [19]. K. Shyam Prakash et al. described that quarry dust must be used in the concrete construction works, which would be reducing the cost of construction cost and the natural construction materials would be saved. Most of the infrastructure developing countries, they were in the situation that replacing the naturally available fine aggregate to some other materials without changing the quality of concrete mix used in the construction works [20]. Among many of the solid waste, quarry stone powder is also one of the wastes was creating obvious environmental issues. For
giving the better solution to avoid the issues, partial percentage of cement was replaced by quarry stone powders (limestone and basalt) which would be resolving the issue of more amount of carbon dioxide emission from the cement production and also solving the environmental issue from dumping the quarry waste materials. Fig. 1 shows the environmental effect occurred due to the utilization of quarry waste powder by replacing the cement content[21].

In construction industry, enormous utilization of natural river sand was making them to scarce and cause environmental issues like erosion, soil infertility. Currently, many researchers were searching for the effective material for replacing the river sand[22][23]. The crushed stone dust was not a new term, one of the waste materials which was obtained from stone crushers. The effective utilization of crushed stone dust for the replacement of natural river sand rectifying the land disposal problem, health and environmental hazards also [24].

![Figure 1. Ultra-high-performance concrete with quarry stone powder environmental effect illustration](image)

3. Properties of crushed rock fines

N. Venkata Sairam Kumar et al. used the crushed stone aggregates conforming to IS 383, with 20 mm maximum size, 2.88 of specific gravity, 6.88 fineness modulus and 0.5% of water absorption capacity. Crushed rock dust by weight was replaced to Ordinary Portland cement by 0, 10, 20, 30 and 40% [25]. Crushed granite aggregates with nominal size of 20 mm as coarse aggregate and the replacement of naturally available fine aggregate by crushed stone dust which was obtained from the crushers were used for the preparation of M30 and M20 grade concrete. Crushed stone dust replacement percentages such as 0, 20, 40% with river sand were studied[26]. G. C. Coldeiro et al. were used the crushed granite fine aggregate with physical properties such as density of 2640 kg/m$^3$, fineness modulus of 2.60, 0.6684 packing density, 10% sphericity and 20% roundness [10].

Crushed fine stone properties such as density of 2610 kg/m$^3$, 2.18 fineness modulus and 1-h water absorption of 0.89% were replaced with river sand of 0, 25, 50, 75 and 100% by weight[27]. R. Cepuritis et al. had taken 30 different crushed aggregate fine powder samples from 10 different variant of rocks in the three particle size ranges for each specific type of rock. The range of particle size from 10% & 90% of the particles smaller than that number. Mineralogical composition of each type of rock crushed aggregates fines were determined by quantitative X-ray diffraction analysis, X-ray microcomputed tomography [5]. Madiha Z. J. Ammari et al. selected the coarse crushed stones used for their concrete mix available in UAE itself with angular crushed stone with 2.59 of specific gravity, 1480 kg/m$^3$ of bulk density and 25 mm is the least allowable aggregate size. Fine crushed stone with various fineness modulus of 2.4, 2.75, 2.6, 2.92 were prepared for mixing in the concrete mix [19]. He used
the crushed granite materials in the concrete mix with specific gravity of 2.67, 99.9% of gravel particles, 0.11% of sand particles, 0% of fines, coefficient of uniformity as 1.35 [9].

4. Results and discussion

The partial replacement of crushed rock dust with ordinary portland cement showed that decrease in slump was observed with increase in the crushed rock dust in concrete. Regarding the strength properties, 20% replacement level showed better performance and 30% replacement showed better performance in ultrasonic pulse velocity and dynamic elastic modulus [1]. A. K. Sahu et al. concluded based on the investigations that 40% river sand replaced by crushed stone dust showed better compressive strength, split tensile strength and modulus of rupture. Meanwhile, workability was decreased in the concrete mixes by increasing the crushed stone dust which would be rectified by increasing the superplasticizers [2]. The mechanical and rheological properties of concrete were identified with replacement of natural river sand by crushed granite fine aggregates. The conclusions observed from the investigations with 50% replacement of river sand were better strength properties, efficient Young’s modulus and reduction in water absorption [3]. The compressive strength of the crushed fine stones concrete was increased upto 50% replacement and decreased with the replacement levels of 75 and 100%. Chloride-ion penetration resistance was more for the concrete with crushed fine stones at a fixed slump [4].

R. Cepuritis et al. concluded the investigation on 30 different crushed aggregate fine powder samples from 10 different variant of rocks as specific surface area of the material along interaction with superplasticizer molecules decides the rheological properties of cement paste, flow resistance was improved by means of higher specific surface of the fine particles[28]. Madiha Z. J. Ammari et al. conducted the grading, workability and compressive strength findings of the various fineness modulus of fine crushed stones. Their research findings concluded that, 2.78 fineness modulus of crushed stones which was given the optimum grading and efficient workability of 415 mm and obtained the better compressive strength when compared all other control and various fineness modulus crushed stone available concrete mixes [6]. A. M. Ajao et al. tabulated all the properties of natural river sand, crushed stones separately and half replacement of natural river sand with crushed stones. Crushed stones alone were given higher than the allowable standards in all the properties with regarding to compressive strength decreased. The results showed that partial replacement of natural river sand with crushed stones obtained the optimum results closer to the properties of river sand alone and as an interlocking of stones is efficient in this juncture [7].

S. Mundra et al. conducted investigation on crushed rock stone, concluded that higher blending ratio of crushed rock stone with natural river stone would be decreasing the workability, in order to increase that higher percentage of fine particles such as flyash and superplasticizers would be suggested. Compressive strength of concrete mixes with crushed rock stones were obtained higher than the desired strength, if we were using the concrete mix with 70-100% crushed rock stone replacement [8]. Based on the investigations conducted, 50% replacement of crushed granite materials with natural river sand obtained higher strength. Compaction factor results showed that by increasing the percentage of crushed granite, value decreased. To increase that, water/cement ratio would be increased to rectify that or usage of superplasticizer would be recommended[29]. K. Shyam Prakash et al. based on their investigations concluded that, 40% replacement of quarry dust with natural river sand obtained maximum strength with control specimens after that, strength decreases and the workability also decreases. They recommended that effective usage of quarry dust in the concrete mix significantly reducing the environmental pollution and maintaining the ecological balance [10].

Nagabhushana et al. studies revealed that cement mortars with 40% replacement of natural river sand by crushed rock powder showed better results than control specimens with only natural river sand. And also conditioned crushed rock powder (more fine particles) showed less strength than the crushed rock powder containing cement mortar. They recommended that for preparing the lean mortar mixes, 100% replacement by crushed rock powder is possible[30]. The ultra-high-performance concrete by replacing the cement by quarry stone dust by varying percentages was examined. They revealed that 22.2- 44.4 % of quarry stone powder would be replaced with cement for achieving better strength and other properties. Though the early strength showed lesser with the control specimens, but
strength gained at 56 days testing of samples. The autogenous shrinkage in the ultra-high-performance concrete was also reduced by the utilization of quarry stone powder [31].

Investigation was conducted for determining the characteristic properties of cement mortars and concrete by replacing the crushed stone dust with river sand. Their investigation revealed that grading zone limits of crushed stone dust was similar to the river sand grading zone II as per IS 383. Also, the crushed stone dust mortars showed better strength properties and other physical properties than river sand mortars [32]. Ikram et al., examined the strength properties of concrete by replacing the crushed stone dust in varying percentages from 0 – 100%. Their studies concluded that 40–50% replacement of natural river sand by crushed stone dust showed better strength properties [33].

Swapnil S. Fate reviewed the various concrete properties with manufactured sand and given their recommendations as concrete with higher grades showed better strength properties by replacing the natural river sand by manufactured sand, workability would be reduced by utilization of manufactured sand that could be improved by using the admixtures, manufactured sand was free from chemical impurities which would be increasing the concrete strength and durability[34]. B. K. Meisuh et al. examined the flexural strength of concrete by replacing the natural river sand by 25% and 100% of quarry rock dust. They concluded that concrete with full replacement of natural river sand by quarry dust showed higher flexural strength and also they derived the expression for determining flexural strength of concrete by replacing the fine aggregate as quarry dust by utilizing the results of compressive strength[35].

4. Conclusions
Based on diverse experimental studies done by the various researchers to examine the performance of crushed rock fines as a partial replacement of natural river sand in the concrete by test methods such as physical, chemical and strength test methods. The following are the conclusions made by the previous studies as:

- The concrete with 50% replacement of crushed rock fines with natural river sand showed better strength properties.
- The workability of the concrete with crushed rock fines was lesser, that could be improved by adding the suitable admixtures in the concrete.
- The durability and strength of the concrete will be improved by the utilization of crushed rock fines which is free from chemical and inorganic impurities.
- The utilization of crushed rock fines in the concrete becomes more economical when compared to the natural river sand.
- Use of crushed rock fines also reducing the environmental hazards and ecological imbalance and it will be making the concrete to be sustainable.

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