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A Methodology of Waste Material Utilization in Concrete Mix for Rigid Pavement Construction

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Abstract: The demand of concrete for rigid pavement construction is constantly growing. Thus, the extraction of fine aggregate, coarse aggregate and cement from natural resources also increases. The more extraction of these virgin materials from the natural resources enhances the cost of these materials progressively. Therefore, it has severely affected the financial viability of the government for rigid pavement construction. Further, due to urbanization and industrialization the amount of waste material is also increased. This state creating an ecological problem that must be addressed. Therefore, there is an urgent need to preserve natural resources by using recycled or discarded wastes as a construction material. Hence the main objective of this work is to study of utilization of waste material in concrete production for rigid pavement construction. A four stages methodology is proposed in this study. these stages are (I) Determination of quantity of various materials for development of concrete mix (II) Identification of significant waste materials and their properties (III) Prepare concrete mix using replacement of cement, sand, and aggregate by waste material and (IV) Comparative evaluation of different properties of developed concrete mix. This study to check the suitability of waste foundry sand (WFS), granulated blast furnace slag (GBFS), and waste rubber tyre (WRT) as a replacement of fine aggregate, cement, and coarse aggregate respectively. The analysis and results indicated that WFS, GBFS, and WRT can be used as a replacement of fine aggregate, cement, and coarse aggregate respectively. Thus, it is expected that the proposed methodology will be useful for researcher to determination of suitability of different alternative materials for replacement of cement, fine aggregate, and coarse aggregate
Keywords: Concrete mix, Waste Material, GGBS, WFS, WRT etc.

I. INTRODUCTION

The demand of concrete is constantly increasing globally. Annual production of concrete in year 2014 the world reaches 12000 Mega tons [A. Kanellopoulos, A et al (2014)]. Thus, the requirement of constitute of concrete like fine aggregates, coarse aggregate, and cement also increases day by day. In year 2011 approximately 3600 Mega tons of cement were produced worldwide. Further, cement production is forecasted to increase to 5800 Mega tons in 2050 [Juenger and Siddique (2015)]. It is revealed that the production of cement in India is very high. Further, during the production of cement a large amount of waste produced (i.e. cement dust). these cement dust is very harmful to the environment as well as human health. The sand is extracted mainly from natural resources like waterway bed, river, sea and lake. Due to more extraction of sand water holding capacity is decreased and widening of river banks is increased. The extraction of sand from the natural resources enhances the cost of sand day by day. The demand of coarse aggregate is increasing results in the depletion of excellent quality aggregates deposits of natural rocks, posing a serious threat to the environment. The more extraction of coarse aggregate from the rocks enhances its cost progressively. It has severely affected the financial viability of the government. Due to urbanization and industrialization the quantity of waste material is also increased. This condition is creating an ecological problem that must be addressed. The production of these materials are required a huge amounts of energy, fossil fuels and raw materials. Approximately 40% to 50 % energy and natural resources are required to production of these materials. The natural resources are in finite quantity. Therefore, India are facing a major problem in scarcity of quality materials for the construction of cement concrete roads. Furthermore, the waste produced from the different industries is significantly increasing. Pappu et al. (2007) identified that in India 960 metric tonne solid waste is being generated yearly. Out of 960 metric tonne solid waste 290 metric tonne are unwanted inorganic waste of mining & industrial division. Srivastava and Chini (2012) found that the different categories waste production is vary from 0.10 to 5.14 million tons per year in India. The important few examples of waste materials are steel slag, crushed ceramic tiles, fly ash, glass powder, rubber tyre, foundry sand, copper slag wooden aggregate, plastic and recycled concrete aggregate etc. Some of them are recycled materials, while others are by-products of industries. Improper disposal of these waste is mainly responsible for generating a variety of human illnesses as well as water contamination. These material can be used as an alternative of virgin materials in concrete mix. The use of waste products in concrete makes it less expensive, environmentally friendly, and solution of waste disposal.

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Therefore, most of the researchers made efforts to use various types of industrial waste in concrete. Therefore, it is the need to propose an effective alternative of the fine aggregate, cement, and coarse aggregate for the construction of concrete mix. Therefore, The main objective of this study is to develop a simple methodology for utilization of waste materials in concrete mix. A four stages methodology is proposed in this study. these stages are (I) Determination of quantity of various materials for development of concrete mix (II) Identification of significant waste materials and their properties (III) Prepare concrete mix using replacement of cement, sand, and aggregate by waste material and (IV) Comparative evaluation of different properties of developed concrete mix. This study to check the suitability of waste foundry sand (WFS), granulated blast furnace slag (GBFS), and waste rubber tyre (WRT) as a replacement of fine aggregate, cement, and coarse aggregate respectively. The analysis and results indicated that WFS, GBFS, and WRT can be used as a replacement of fine aggregate, cement, and coarse aggregate respectively. Thus, it is expected that the proposed methodology will be useful for researcher to determination of suitability of different alternative materials for replacement of cement, fine aggregate, and coarse aggregate.

II. LITERATURE REVIEW

According to Topcu and Canbaz (2004), a rise in quantity of waste glass in concrete mix reduces not only compressive strength but also the specific weight owing to decreased. According to Cazacliu et al. (2010) and Ling and Poon (2012) found that reducing particle size reduces the compressive strength of concrete while increasing its workability. De Castro and De Brito (2013) employed a mix of fine and coarse glass aggregate and found that not only does the water absorption improve, but the shrinkage of concrete is reduced to its lowest value. Perlite, scoria, and polystyrene light-weight aggregates were utilized in concrete mix by Wanet et al. (2018) in different amounts. according to the study's findings, adding more percentage of waste material to concrete mix will reduce its compressive strength. Huda et al. (2014) investigated the physical and mechanical properties of recycled coarse aggregate (RCA) used in place of virgin coarse aggregate in concrete. In India, Kumar and Baskar (2014) studied the use of recycled plastic in building construction. Mohammadinia et al. (2017) combined fly ash with reclaimed asphalt pavement (RAP) and crushed brick (CB) and used in flexible pavement. According to Balbo et al. (2015), the crushed stone treated cement may be utilised as a subbase layer for rigid pavement at five different replacement rates (0/0.5 mm, 5/2 mm, 2/4 mm, 4/8 mm, 8/16 mm, 16/32 mm). of control mix. Deepika et al. (2017) investigate the building properties of bagasse ash. When bagasse ash is mixed with concrete, an alkaline by-product is generated, which improves the mix's durability. Steel slag, fly ash, and phosphogypsum as road foundation course materials were investigated by Shen et al. (2009).

III. PROPOSED METHODOLOGY

A framework for the proposed methodology is presented in Figure 3.1. It is expected that the proposed methodology can be useful for the determination of an effective and environmentally friendly alternative of cement, fine aggregate, and coarse aggregate without compromising with its properties for the production of concrete.

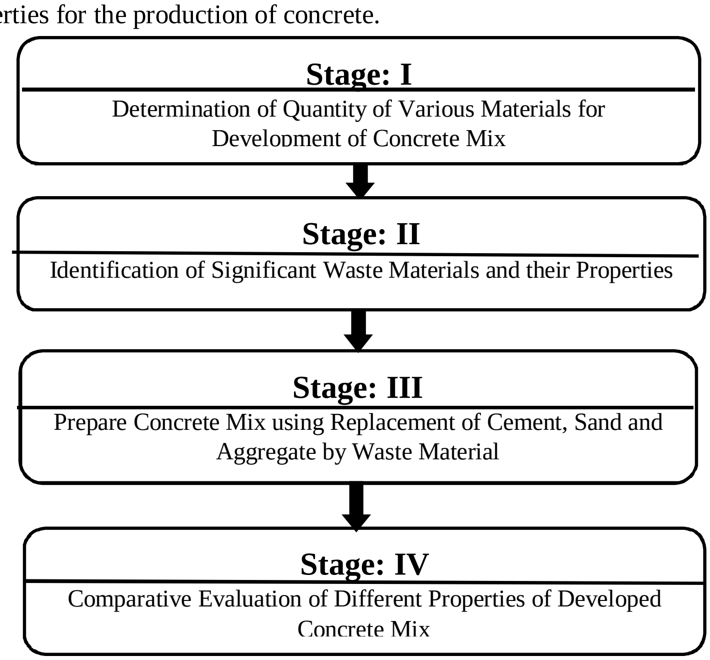

Figure 1: A Framework for Proposed Methodology

A. Stage I: Determination of Quantity of Various Materials for Development of Concrete Mix

Concrete mix design is the process of determining the safe, economical, and accurate proportions of different materials for concrete to achieve the target strength of concrete for particular structural members. Hence, the quantity of various materials is determined in Stage-I from guidelines of IRC:44-2017.

B. Stage-II: Identification of Different Waste Materials and their Properties

The main objective of the first stage of the proposed methodology is to identify the appropriate waste materials for the replacement of fine aggregate, cement, and coarse aggregate.

C. Stage-III: Prepare Concrete Mix using Replacement of Cement, Sand, and Aggregate by Waste Material

The main objective of this stage is to comparative analysis of different properties like compressive strength, flexural strength, and density of developed concrete mix with different proportions of waste materials.

D. Stage-IV: Comparative Evaluation of Different Properties of Developed Concrete Mix

The main objective of this stage is to comparative analysis of different properties like compressive strength, flexural strength, and density of developed concrete mix with different proportions of waste materials.

IV. ANALYSIS AND RESULTS

The effect on various properties of concrete when virgin aggregate is partially replaced by various types of waste materials are analysed in this section. The splitting tensile strength test, compressive strength test, and flexural strength test was performed to check the suitability waste materials. Table 4.1 presents different cases considered in this study considering different waste materials.

Table 1: Different Cases Considered in this Study

Cases	% Replacement of Cement by GBFS	% Replacement of Fine Aggregate by WFS	% Replacement of Coarse Aggregate by WRT
Case-I	Vary	No replacement	No replacement
Case-II	No replacement	Vary	No replacement
Case-III	No Replacement	No replacement	Vary

The granulated blast furnace slag (GBFS), Waste foundry sand and waste rubber tyre are used replacement of cement, sand and coarse aggregate. GBFS extracted from blast furnaces and used in five different proportion i.e. 0%, 6%, 12%, 18%, and 24%. The foundry sand is used as a substitute for fine aggregate in five different substitution rates i.e. 10%, 20%, 30%, 40%, and 50%. WRT used as a substitute for coarse aggregate of size 20 mm in five different substitution rates i.e. 58%, 16%, 24%, 32% and 40%.

The analysis and results of strength properties of concrete mix with replacement of cement by GGBS at 28 days curing is presented in Table 2. The analysis results indicated that strength properties initially increases and then decreases with an increasing percentage of GBFS. The optimum value is occurred approximate 12 % replacement.

Table 2: Variation in Strength Properties of Concrete with GBFS

S. No.	Cement Replaced by GBFS (%)	Compressive Strength	Splitting Tensile Strength	Flexural Strength
1	0	38.01	3.10	4.19
2	6	40.31	3.15	4.44
3	12	42.63	3.26	4.70
4	18	38.98	3.13	4.31
5	24	35.89	3.04	4.01

The analysis and results of strength properties of concrete mix with replacement of sand by WFS at 28 days curing is presented in Table 3. The results indicated that strength properties decreases up to the addition of 30% of WFS and then decreases.

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Table 3: Variation in Strength Properties of Concrete with WFS

S. No.	Sand Replaced by WFS (%)	Compressive Strength	Splitting Tensile Strength	Flexural Strength
	0	38.01	3.08	4.19
	10	37.58	3.04	4.17
	20	35.24	2.97	4.04
	30	33.48	2.89	3.93
	40	35.23	2.97	4.04
	50	29.37	2.71	3.69

The analysis and results of strength properties of concrete mix with replacement of coarse aggregate by WRT at 28 days curing is presented in Table 4. The results indicated that strength properties increases up to the addition of 8% of WRT. If again the percentage of WRT is increased, the value of strength properties of concrete decreases.

Table 4: Variation in Strength Properties of Concrete with WRT

S. No.	Coarse Aggregate Replaced by WRT (%)	Compressive Strength	Splitting Tensile Strength	Flexural Strength
	0	38.01	3.08	4.19
	8	41.44	3.56	4.28
	16	37.88	3.36	4.16
	24	35.69	3.23	4.10
	32	34.24	2.94	4.00
	40	32.67	2.85	3.94

V. CONCLUSIONS

The following conclusions have been drawn based on the study:

1) Critical literature indicated that there is an urgent need to preserve natural resources and environment by using recycled or discarded waste materials. Therefore, in this study fine aggregate, cement, and coarse aggregate is replaced partially with different waste materials.

2) A four stages methodology is proposed in this study. these stages are (I) Determination of quantity of various materials for development of concrete mix (II) Identification of significant waste materials and their properties (III) Prepare concrete mix using replacement of cement, sand, and aggregate by waste material and (IV) Comparative evaluation of different properties of developed concrete mix.

3) This study identified granulated blast furnace slag (GBFS), waste foundry sand (WFS), and waste rubber tyre (WRT) as a replacement of cement, fine aggregate, and coarse aggregate respectively. The important conclusions are as follows:

a) GBFS used as a substitute for cement in four different proportions i.e. 6%, 12%, 18%, and 24%. The analysis results indicated that the splitting tensile strength, compressive strength, and flexural strength initially increases with an increasing percentage of GBFS. The optimum value is occurred approximate 12 % replacement. If again the percentage of GBFS is increased, the value of strength properties of concrete decreases. It is recommended that the replacement of cement by FBFS up to 12 % is desirable.

b) WFS used in five different proportions i.e. 10%, 20%, 30%, 40% and 50% as a substitute for fine aggregate. The analysis results indicated that the split tensile strength, compressive strength as well as flexural strength, decreases up to the addition of 30% of WFS. If again the percentage of WFS is increased the value of strength properties of concrete increases upto 40%, and then decreases. It is recommended the replacement of fine aggregate by foundry sand up to 15 % is desirable because it is cost effective and environment friendly.

c) WRT used in five different proportions i.e. 8%, 16%, 24%, 32% and 40% as a substitute for coarse aggregate. The analysis results indicated that the compressive strength, split tensile strength as well as flexural strength increases up to the addition of 8% of WRT. If again the percentage of WRT is increased, the value of strength properties of concrete decreases. It is recommended to replace 8% of WRT aggregate with coarse aggregate which will be the optimum replacement in concrete composites.

Thus, it is expected that the proposed methodology will be useful for the determination of an effective and environmentally friendly alternative of cement, fine aggregate, and coarse aggregate without compromising with its properties for the production of concrete.

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