Journal of Basic and Applied Engineering Research
p-ISSN: 2350-0077; e-ISSN: 2350-0255; Volume 3, Issue 11; July-September, 2016, pp. 948-954

http://www.krishisanskriti.org/Publication.html

A Review of the Use of Solid Waste Materials in Concrete Mix

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Abstract—*Now a days the increasing of municipal solid waste and construction waste is the massive problem for the nature. Not only these damage the environment but also covered a large ground area for dumping. This study is discussed about the problems arise for the waste and the environment friendly recycling process of these waste. Some of these wastes like fly ash, rubber, glass powder, plastic material can be used as a construction material for a certain ratio which helps in recycling process of the waste. So the land area required for dumping of these waste materials reduces. The crisis of construction land may be decreased due to the same reason. Maximum plastic wastes are generally used as High Density Polyethylene (HDPE) which is helpful for asphalt concreting in road construction. Similarly glass powder is used as fine aggregate by mixing it with sand with a controlled proportioning. Fly ash is a well known material which is used in concrete cement. It is also used to make bricks of higher strength. Mixing of fly ash in cement mortar can be increased the compressive strength of 7days than the normal cement mortar. The scraped bricks or concrete are broadly used as coarse aggregates in place of stone chips in concrete mix and village road construction. From the thorough study on this matter it can be reported that the municipal solid wastes have some good effects if these are used as proper manner. The recycling of these waste materials in civil engineering and structural construction helps to protect the nature from pollution and makes the construction more economical.*

1. INTRODUCTION

Solid waste is material which is not in liquid form and has no value to the person who is responsible for it. Generally three types of solid wastes are found. Firstly household waste which is classified as municipal waste like plastics, bottom ash, fly ash, copper slag etc. secondly, industrial waste which is familiar as hazardous waste such as chemicals, fertilizers, tires etc. and thirdly, biomedical waste which is known as infectious waste such as expired pharmaceutical drugs. It is generally known that the creation of solid production waste constitute one of the most significant problem in the industrial domain. The increase in depletion of all types of materials and energy sources are directly affected by the increase of population, the urbanization and the industrialization. For that reason the amount of solid waste was 613,000 tons in 1998, 692,000 tons in 1999 and still increasing day by day [1]. In Slovenia, nearly about 600 to 1000 kg of construction and demolition debris is generated per person per year, which is parallel to other European countries [2]. Recent exploration and implementation indicates the application of solid waste materials in the lower courses like as base, sub base etc of the road in huge proportion than the upper courses [3].

According to the obtainable data with respect to the construction materials, highest percentage of recycling materials are in bricks (35%), followed by concrete (20%) and wood (12%) etc. [4-6] (see Figure 1)

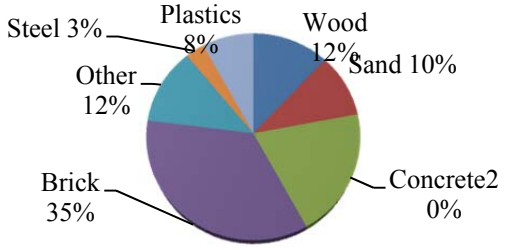

Figure 1. Recycling percentage of different construction materials [4-6]

General construction materials like as traditional bricks, hollow and solid blocks, pavement blocks produce from the existing natural resources. The environment is damaged due to continuous use and reduction of natural resources. The emission of toxic substances like as concentrated carbon monoxide, various types of oxides of sulphur and nitrogen as well as suspended particulate matters are polluting the environment continuously during the fabrication of construction materials. Moreover the costs of traditional construction materials are increasing gradually due to high demand, shortage of raw materials, and excessive cost of energy.

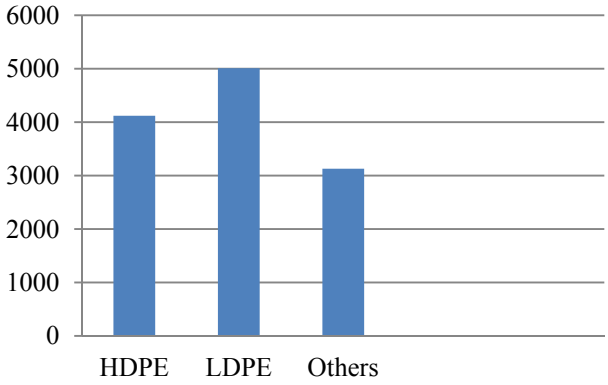

Figure 2. Types of plastics with quantities in USA [5]

Davis and Cornwell state that the uses of waste materials reduce some problems of solid waste management [7]. Recycling of waste materials serve two purposes. Firstly, it protects environment, reduces energy desolation, reduces pollution, reduces Global warming, conserves natural resources, expands the starvation of fresh crude materials, reduces green house gas emissions, prevents loss of biodiversity and secondly relevant material like aluminium cans, plastic, glass are restated in other form and they are not wasted.

A combination of cement, aggregates and water is known as conventional concrete. The theoretical value of water-cement ratio which is generally used is 0.55. Saravanan et al. said that capillary cavities is occurred due to use of more water-cement ratio than this value and using less than this value will cause of incomplete hydration [8]. In United States, bottom ash coming from municipal solid waste ignition is used as an aggregate replacement by construction materials [9]. Batayneh mentioned that 85% of 1721.8 tons solid waste per year is classified as building construction waste, among which 90% is basically scrap [10]. Each probable implementation of fly ash have three main advantages: firstly, utilization of a zero cost raw material, secondly, preservation of natural resources, thirdly, removal of waste [11]. Carbonization of solid waste in waste to energy (WTE) facilities intercept the probable pollution related to land filling and serves a source of authentic, renewable energy [12].

Different types of waste materials are available like as waste glass, steel slag, rubber waste, plastic waste, fly ash [13,14]. Construction and demolition scrap is typically disposed, salvaged or carbonized [15]. Zainab et al. recommended that glass powder and glass aggregate can be used in M40 concrete mix without any unfavourable reaction [16].

2. DIFFERENT SOLID WASTE MATERIALS

2.1. Plastic

Plastic is an indivisible and essential part of human life. Plastic has a wide use in packaging, industry application and it is also used in medical system, artificial implantation and other applications like as preservation of food, electronics industry etc. Various types of plastics are available. Types and quantities of plastic as a solid waste in USA are given in Figure 2. The largest element of plastic waste is low density polyethylene (LDPE) at about 23% and followed by high density polyethylene (HDPE) about 17.3% [5]. Recycled LDPE of 0.30mm and 0.92mm size replaced 15% aggregates in asphalt and increased the stability 15% [3].

Oriyomi et al. recommended that the polymer concrete has high resistance in both compression and flexion differentiating with traditional Portland cement concrete and over 80% of its mechanical strength developed within 1day but it has low resistance to temperature [6]. As bitumen modifier recycled plastic is used at 0.4% of mixture weight in asphalt and improve the Marshall Stability before and after water logging (60°C, 24hr) [17]. Kolisetty recommended that the development in the characteristics of aggregates with the utilization of waste plastic as a layer over aggregates and 6-8% optimum value based on the stability values is reported [23].

Table 1: Classification of recycled plastic [9]

Recycled Plastic	Length	Form
Virgin polypropylene	19 mm (3/4 in.)	Slender fiber-form
Recycled plastic (melted processed)	28 mm (1.1 in.)	Slender fiber-form
Recycled plastic (automobile shredded residue)	19 mm (3/4 in.)	Flake form
Recycled plastic (shredded)	25 mm (1 in.)	Flake form

The main advantage of using recycled plastics are firstly, depletion of municipal solid wastes being land filling, secondly, a replacement to pressure-treated lumber that leaches toxic chemicals into water.

2.2. Fly ash

Fly Ash is generated by oxidization of coal in nuclear power stations as a by-product. Normally it is finer than cement and it contains mainly spherical glassy amalgam of complex combination. It is also a lavish material and dumped on the nuclear power stations. Generally fly ash is utilized as an amalgam in Portland cement (PCC) for rigid road construction, but less use in flexible road construction. Inspite of slower strength development, the ultimate strength is higher than the traditional concrete for fly ash addition [9]. The advantages of using the fly ash as a construction material are durability, environmental assurance, easy availability [15]. Rigid pavement behaves like a semi rigid pavement because of using fly ash. Fly ash can reduce the cost 20% to 60% than Portland cement [24].

All parts of fly ash can be used for all purpose. But the effectiveness varies. Still all parts have suitable application.

Parts of fly ash are ESP ash or chimney ash, mound ash, bottom ash [20].

Ismail et al. (2007) conclude the following properties of fly ash with the help of XRF (X-ray fluorescence) set up [19].

Table 2: Chemical compositions of fly ash [19]

Compound	%wt.
SiO_2	59
Al_2O_3	21
CaO	6.9
Fe_2O_3	3.7
SO_3	1
LOI	4.62
MgO	1.4
K_2O	0.9

Table 3: Physical properties of fly ash [19]

Colour	Light grey
Moisture (%)	3.14
Specific gravity	2.29
Avg. particle size (μm)	6.92
Bulk density (g/cm^3)	0.994

2.3. Waste glass

A highly crystalline material manufactured by liquefying a combination of silica, soda, ash and calcium carbonate ($CaCO_3$) at very high temperature, and then the melted mixture is allowed to be cooled for solidification without crystallization is familiar as glass. Keeping in mind the importance of it in our daily life, it is mentioned that it creates a problem for solid waste disposal being non-biodegradable material. So, use of glass materials after recycle can be a good solution to reach the purpose of replacement as natural materials. Recycled glass also can be used in manufacturing of windows, filler materials, glass fibre, tiles and aggregate in construction [25].

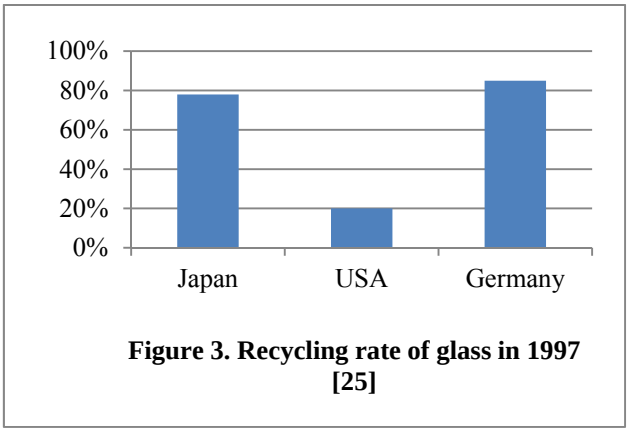

Figure 3. Recycling rate of glass in 1997 [25]

Shao et al. (2000) concludes that pure dry glass powder is useful as a replacement for Portland cement (PCC) in concrete. The finely ground glass (particle size finer than 38 μm) contains a high amount of amorphous silica, which shows a pozzolanic behavior [18]. So, in concrete the use of glass powder can be preferable. In addition, using of waste glass as a fine aggregate would produce a better workability in concrete, contributed its shape is almost spherical and fabricated a very workable mixture [13]. In UK, using of recycled glass as a fine aggregate in concrete is known as "ConGlassCrete", which is used for increasing the strength of concrete [21]. Huang recommended that in 2002, 10% recycled glass sand was also used in hot mix asphalt for pilot surfacing project [22].

Table 4: Chemical composition of waste glass [16, 23]

Chemical Composition	%
SiO_2	67.72
$Al_2O_3 + Fe_2O_3$	3.40
CaO	6.90
$Na_2O + K_2O$	10.75
MgO	6
SO_3	0.17

Table 5. Physical properties of waste glass [16, 23]

Physical Properties	
Density (Kg/m^3)	1672
Colour	Light grey
Finesse modulus	2.36
Water absorption	0.39
Specific gravity	2.19
Pozzolanic index	80%

3. RESULTS & DISCUSSION

Many experiments have been done by introducing solid waste in conventional concrete. The results are analyzed basically on the mechanical properties of concrete like compressive strength, flexural strength and split tensile strength after replacing plastic, glass powder and fly ash after 28days of proper curing.

Table 6: Strength of concrete using solid waste at 28days

	% Replacement	Compressive Strength (MPa)	Flexural Strength (MPa)	Split Tensile Strength (MPa)
Plastic	0	34	4.5	4.4
	5	28	4.5	3
	10	24.5	4	2.5
	15	20	3.5	2.3
	20	10.5	3.2	1.2
Glass powder	0	32	4.5	4.5
	5	35	4.7	4.5
	10	38	4.8	4.7
	15	41	4.85	4.8
	20	44	5	4.8

It is clearly seen from the table 6 that all the strength of concrete is decreasing with the increase of replacement of plastic but the opposite pattern of change in strength is observed with the increase in glass powder as a replacement of cement. However, the result is indicating waste glass is more effective than plastic in concrete. Compressive strength of concrete is the most important property which gives an idea of concrete as structural material. After 28days of curing compressive strength of concrete is increased gradually up to 20% replacement of glass powder.

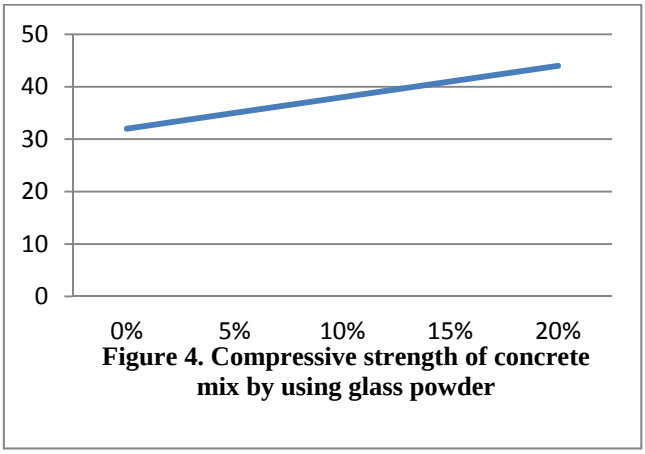

Figure 4. Compressive strength of concrete mix by using glass powder

For every 5% addition of glass powder in concrete mix, the increasing rate of compressive strength is equal. So it indicates that the service life of concrete after replacing glass powder is increased due to improved compressive strength. With the increase in compressive and flexural strength by replacing glass powder, shrinkage of concrete, cementitious factors as well as maintenance cost reduce.

Table 7: Slump value of concrete using solid waste

Cement (kg/m^3)	Coarse aggregate (kg/m^3)	Sand (kg/m^3)	% of waste	Slump value	
				By using plastic (cm)	By using glass powder (cm)
380	1020	715	0	7.5	7.5
380	1020	643.50	10	2.5	5.75
380	1020	607.75	15	0.9	5.25
380	1020	572	20	0.5	5

Slump test is performed to resolve the workability of concrete. It also indicates the consistency of concrete. Slump value is decreased with the increase of replacement of plastic and glass powder but the rate of decrease of glass powder is less than plastic. From the graph it states that rate of decrease of slump value using glass powder in concrete is less than using plastic.

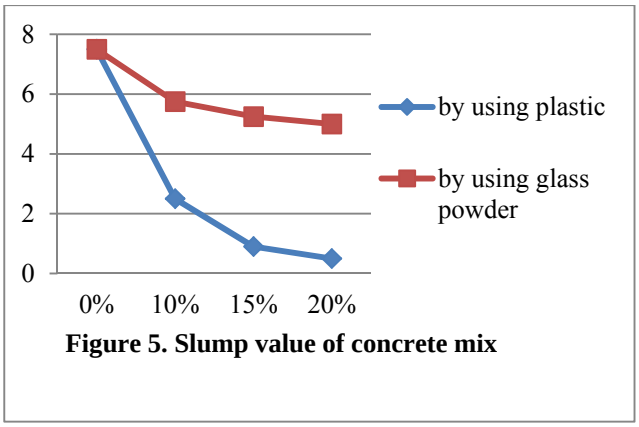

Figure 5. Slump value of concrete mix

Using of fly ash is durable, economic and eco-friendly for construction and enlargement in rural sector. Fly ash cement concrete does not obtain appropriate strength in 7 to 14 days; but after 28-days, the cement achieve rapid hardening characteristics, with 25% substitute of cement with fly ash. Up to 20% restoration with fly ash in concrete mix is good for durability and economic for road constructions. 15% of cost construction is decreased when 25% cement is replaced with fly ash [14]. In conventional concrete the flexural strength achieves a highest value between 14 and 28 days. When high volume fly ash is used in concrete, the strength gradually increases with age because of the pozzolanic chemical reaction of fly ash. The compressive strength of high volume fly ash concrete at later ages will be normally good due to slow pozzolanic chemical reaction. The properties strongly depend on the aspects of the cement and fly ash used. The ratios of the flexural and split tensile strength to compressive strength are equivalent to the traditional concrete.

Table 8: Strength of concrete using fly ash at 7days

% of fly ash	Compressive strength (MPa)	Flexural strength (MPa)	Split tensile strength (MPa)
1	17.5	2.2	1.1
2	17	1.9	1
3	16.75	1.82	0.85
4	16.2	1.7	0.8
5	15.85	1.65	0.7

In concrete mixture, when water and cement come in collision, a chemical reaction starts which produces binding material. The exothermic process is released heat which increases the temperature of concrete mass. It plays dual role for the development of strength when fly ash exists in the concrete mass. Fly ash produces binder material when it reacts with lime.

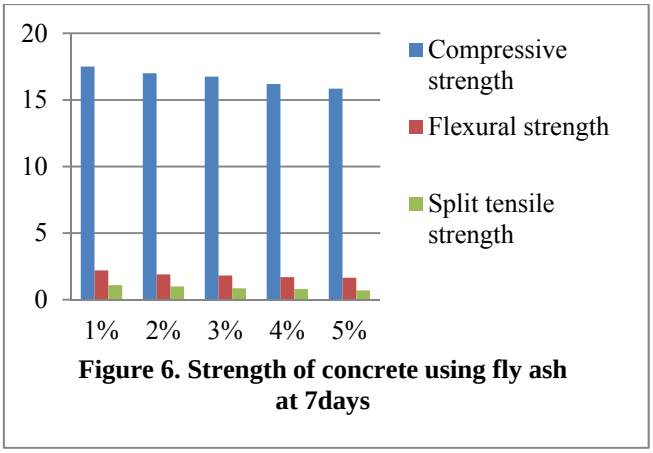

Figure 6. Strength of concrete using fly ash at 7days

Fly ash particles are normally spherical in shape and decrease the water requirement for a given slump. The spherical shape helps to minimize friction between concrete and aggregates which increases workability.

Table 9: Strength of concrete using fly ash at 28days

% of fly ash	Compressive strength (MPa)	Flexural strength (MPa)	Split tensile strength (MPa)
1	24.5	3.4	4.5
2	24	3.35	4.47
3	23.8	2.9	4.4
4	23.5	2.7	4.25
5	22.9	2.6	3.9

Fly ash use in concrete to improve fines volume and reduces water content which decreases bleeding of concrete. Fly ash increases the workability of the concrete. The fly ash concrete is more workable than a plain cement concrete at equivalent slump [21]. Safiuddin et al. stated that less water is required for the same slump; the concrete gets more cohesive if fly ash is used as a replacement [13].

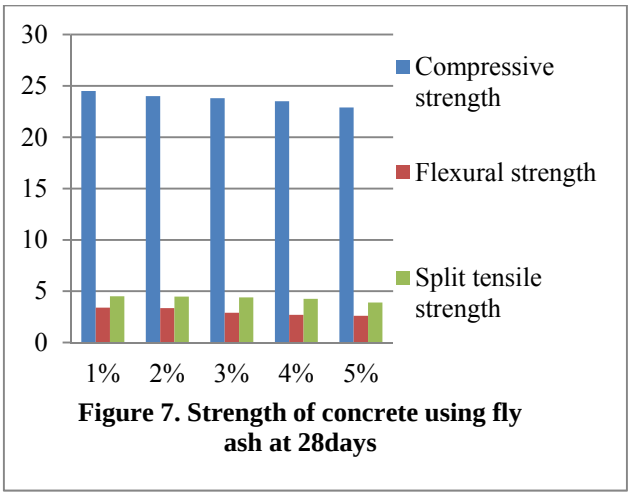

Figure 7. Strength of concrete using fly ash at 28days

4. CONCLUSION

The above study states that the scope of utilization of the municipal solid wastes as construction material. Keeping in mind the environmental degradation due to dumping and disposal of different solid wastes, which can be utilized as replacements of conventional natural raw materials of concrete. The following conclusions are obtained from the above study about introducing different solid wastes in different quantity in concrete.

Using of plastic wastes in concrete mix causes the decreasing of compressive strength, flexural strength and split tensile strength with respect to increasing of percentage of replacement.

Flexural strength is decreased 28.88% by increasing the replacement percentage from 0 to 20 where as compressive and split tensile strength are decreased 69.12% and 72.73% respectively by increasing the plastic percentage as same. So it can be conclude that flexural strength of concrete is effected very slightly than compressive strength and split tensile strength when the plastic particles are used. It is also found that there is no change in flexural strength when replacement range is in between 0-5%.

Due to softness and lesser strength than fine aggregate, the concrete strength is usually scaled down by utilization plastic particles.

All the strength of concrete mix is gradually increasing when glass powder is used in the place of plastic.

Though the increasing rate of split tensile strength is lower than the same of compressive strength but the flexural strength improves up to 20% replacement of glass powder.

The strength and surface texture of glass powder is quite more than fine aggregate. That is the reason behind the concrete strength increases gradually by utilization of the glass powder in concrete mix with respect to a rate of percentage increasing.

The slump value of concrete is also be effected by using plastic or glass powder. The above discussion shows that the reduction rate of slump value by using plastic is greater than by using of glass powder. Less slump value helps to make the concrete more workable. Therefore, where the low strength but highly workable concrete is needed, the plastic particles are used.

Fly ash can be also utilized in concrete mix as a substitute of cement. The strength of concrete is quite low if the fly ash is used rather than traditional concrete. This strength is being reduced by increasing the replacement percentage of fly ash. But the strength reaches the higher value after 28days of curing.

So, at the end of this discussion it can be recommended that fly ash and glass powder are useful up to some extend in concrete mix than plastic. Plastic is helpful for more workable

concrete. By this recycling method construction cost as well as environment pollution can be reduced.

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