Non-consistent results in waste utilization in concrete

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Due to dwindling of natural resources like rocks, sand etc. researchers started to find alternative materials to these dwindling resources and to use available waste in construction industry. Cement concrete is a most common material of today's construction industry. Research on use of various waste in concrete is going on in last few decades. However most of the findings are not consistent. Everyone claims that there is improvement in properties of concrete but findings are not uniform. In this paper, the possible reasons for non-consistency in results are discussed and some suggestions have been made to have consistent results.

INTRODUCTION

The cost of building material is increasing rapidly due to high demand of construction material, their transportation cost and environmental restriction. The manufacturing process of conventional materials like cement, sand, coarse aggregate etc consumes a lot of natural resources. As such, studies have been carried out throughout the world to find some alternate material to save natural resources and to make use of available waste material which are otherwise polluting the environment.

Cement concrete is a most important material in construction industry. More than 80 percent works are done using concrete in one form or the other. Similarly large wastes material are produced in India and elsewhere. If these wastes could be used in construction industry, considerable economy can be achieved and the materials which are polluting the environment can be utilized making clean environment and clean India. Experimental studies on use of various available waste in concrete has been undertaken and still is in process by various researchers and academician in different parts of India, to use them in different forms. Most of these studies are on strength properties and durability of concrete by replacing cement or sand or coarse aggregate by one of the waste under consideration in different proportions.

Various waste materials used by various researchers are,

1. Fly ash and Silica flume waste from thermal power stations
2. Recycled aggregate from construction industry.
3. Glass waste from glass industry.
4. Plastic, rubber, tires etc from automobile industries.
5. Sugarcane baggage ash from sugar industry.
6. Rice husk, wheat husk, groundnut husk etc. from agriculture industry.
7. Foundry sand.
8. kiln dust from cement industry.
9. Red muds from aluminum industry
10. Fibers either of steel, carbon, aluminum, plastic, glass etc..
11. Reclaimed asphalt waste
12. Mill tailing from mineral processing industries.
13. Municipal wastes.
14. China clay from brick and tile industry.
15. Colliery spoils from coal mines.
16. Marble scum/dust from marble mines.
17. Various other wastes like cork, wood waste, Nano silica, roofing shingles, cinders, paper waste, coconut pith, coir waste, lime sludge, banana leaves, sisal fibers etc. from various industries.

Though researchers have done good amount of work and have proved that by use of the some of the above waste, the properties of concrete improves considerably, even then it has been observed that their results scatter to some extent though have used similar basic materials like cement, sand, coarse aggregate, water and one waste material of their research topic. They carried out experiments at different labs, their findings are appreciable, but their results vary considerably though experimental studies conducted in similar lab and environmental conditions. The variation in result/finding is not very large, but are of such an extent that no final conclusions can be drawn at national level. It shows that there must be some difference in quality of material used, lab condition, working methodologies etc. In subsequent paragraphs, the possible reasons for variation in findings are discussed.

CONSTITUENTS OF CONCRETE

Various materials used in concrete other than waste are cement, sand, coarse aggregate and water. The properties of these constituents vary considerably. The possible reasons for their variation are given herewith.

a) Cement

This is the main constituent of cement concrete and probably the main reason to have scattered results/findings. In India various companies manufacture cement using similar raw materials and confirm the requirements of Bureau of Indian Standards. Though all the companies produce good quality cement confirming to IS Specifications, but even then their properties particularly chemical properties vary to some extent as per quality of raw materials used. All the companies have their cement production plants at various places in India and use good raw material available in near vicinity .They have their own testing laboratories. Even then the quality of raw material used, process of manufacture used, temperature of calcinations of these raw materials, process and extent of grinding, quantity of gypsum added etc. all affect the quality of cement clinker and that of cement. Raw materials used to produce cement are calcareous rocks i.e. lime, siliceous rocks i.e. silica and argillaceous rocks i.e. alumina; all these materials also have some impurities in different proportions as per their geological formations. The chemical composition of these rocks therefore varies to a considerable extent from place to place. As such cement produced from these various rocks though confirms to IS specifications but their chemical composition may be varying to some extent from one plant to other.

When water is added to concrete, process of hydration starts. This process of hydration converts cement paste into a hard mass covering all aggregate to produce concrete. The process of hydration plays an important role in concrete formation and affects the results of final product. Similarly the quality and quantity of gypsum added, fineness of cement, temperature of water and that of environment during hydration play important role in cement hydration. Impurities present in raw materials also participate in chemical reactions with cement and waste material used. These all factors together play important role in concrete and may be one of the reasons to have scattered results.

b) Sand i.e. fine aggregate

Other constituent of concrete is sand, an inert material, used in concrete to fill the voids of coarse aggregate and do not participate in chemical reaction. It is true if sand used is pure silica i.e. standard sand. However it has been observed that most researchers use locally available clean sand as fine aggregate. The quality of sand varies from source to source to a considerable extent. Not only that varies from source to source, it also varies from season to season and morning to evening. Though all researchers use clean, washed, impurity free sand with required fineness but it cannot be that of the quality of standard sand. Moreover minor impurities might be having left in sand. Further particle size distribution of sand also plays an important role. Two sands with same fineness modulus can have different particle size distribution.

c) Coarse aggregate

In concrete, almost all the properties in general and strength properties in particular depend on quality of coarse aggregate used like its shape and size, particle size distribution, impurities present, water absorption, angularity number, flakiness index etc. But these properties vary considerably from place to place depending upon quality of raw material used. In India at most of the places uniformly distributed aggregate is available. This aggregate is then blended with other finer particles to have well graded aggregate for the experimental program. It may also one of the reasons for non-consistency of results.

d) Water

Quality of water used to make concrete also varies considerable from place to place, source to source and season to season. Even if treated water is used, type of treatment given also affects quality of water. Water is a most important constituent of concrete as almost all the chemical reactions take place because of water. In most of the experimental research work, quality of water is hardly tested; it is assumed that if water is potable, it is good for concrete. Chemical analysis of water used is rarely made and effect of chemicals present on properties of concrete in general and on waste

Table 1. Chemical analysis of some Indian fly ashes

Constituents	Delhi	Singrauli	Durga pur	Barauni	Bokaro	Chandra pur	Korba
SiO_2 %	59.00	56.80	49.30	60.28	51.60	60.30	66.53
Al_2O_3 %	28.10	28.80	20.05	22.58	22.00	26.80	18.90
Fe_2O_3e %	4.3	7.80	19.60	8.45	4.70	5.30	6.90
CaO %	2.5	2.70	2.28	1.10	0.86	1.18	3.60
MgO %	0.3	0.60	1.53	0.31	0.85	0.51	2.60
SO_3 %	0.1	0.10	Traces	1.40	2.10	1.60	0.20
Loss on ignition %	4.4	0.40	6.13	6.00	19.40	5.20	0.53
Surface area cm^2/ gram	3575	5660	4480	2842	6150	5700	5100

used in particular are hardly discussed. Chemicals present in water may be within permissible limit as per potable water, but may not be good for concreting. Chemicals present in water may be affecting the process of hydration and consequently on quality of concrete. This may be one of the reason for variation of results. Water temperatures, atmospheric temperature at the time of concreting are also affecting factors.

e) Reinforcing bars

In case of prototype sections or when studies are made on reinforced concrete sections like beam, column, slab etc. locally available steel is used as reinforcing material. Tested steel is rarely used, it also affects the properties of reinforced concrete as per carbon content and ductility of reinforcing bars used.

PROCESS OF CONCRETING

Concreting process consists of collection of materials, their batching, dry mixing, wet mixing, placing, compacting and curing. All these are specialized processes and require careful planning and execution. Even small variation in process affects concrete properties considerably. Good quality concrete constituents if not properly mixed, placed, compacted and cured, develop poor concrete. Tools and plants like mixer used to mix concrete, compaction / vibrating tables also affect concrete properties. Lab platform vibrators used are rarely calibrated. Even vibrating time is rarely given importance. It varies for each batch of moulds as such results vary.

WASTE MATERIALS

Waste materials used by researchers varies from place to place as per source and topic of their research. Though the basic material remains the same but the properties in general and chemical properties in particular and their percentage varies considerably. To quote a simple example, the fly ash at various thermal power stations have more or less similar chemical composition, but the percentages of their chemical composition vary to some extent from one thermal power station to other based on quality of raw material used, the process adopted, temperature maintained etc. Table 1 shows the chemical composition of some of the fly Ashes available in India. The variation can be seen. Table 2 shows the chemical composition of fly ash required as per IS 3812 (Part 1) 2013. The variation in available fly ashes and those required as per IS standards is large. These factors must be affecting the quality of concrete as such causing scattering of results/findings. Same may be true for other waste also.

Some of the observations and possible variations in these various processes are:-

a. In labs, mostly weight batching is done but these weights are rarely calibrated.

b. Rarely good quality of oil is applied on molds, concrete sticks to surfaces of mold and then cement-sand mixture is applied to test specimens to make surfaces plain.

Table 2. Chemical requirements for pulverized fly ash for use as pozzolana in cement, cement mortar and cement concrete as per IS 3812 (Part1) 2013

S.no.	Characteristics		Requirements	
			Siliceous FA	Calcareous FA
1	SiO_2+Al_2O3+Fe_2O_3	Min. %	70	50
2	SiO_2	Min. %	35	25
3	Reactive SiO_2	Min. %	20	20
4	MgO	Min. %	5.0	5.0
5	Total SO_3 By Mass.	Max. %	3.0	3.0
6	Available alkali (Na_2O_3)	Min . %	1.5	1.5
7	Total chlorides	Max. %	0.05	0.05
8	Loss on ignition	Max. %	5.0	5.0

c. Concrete is mixed manually.

d. Molds are compacted manually, no standard compacting process is adopted. Table vibrators if used, it is as per will of worker.

e. If concreting is done on Saturday, or if next day is a holiday, test specimens are removed from molds on next working day i.e. after 40 to 48 hours of casting and then put in curing tank.

f. At most places an open curing tank is provided and the molds are put in that water. The water of that curing tank is rarely changed, or whenever quantity of water gets reduced, it is not refilled. Dust particles get accumulated and specimens are cured in such non potable water. Only a few researchers use humidifiers for curing of concrete.

g. Most academic institutions are hardly getting their testing equipment calibrated regularly even hydraulic oil used is rarely checked for its quality. Such testing equipment particularly CTM if used, is likely to give non consistent results.

h. In most cases during testing, rate of loading is controlled manually and as per will of person, testing the specimens.

Therefore researchers doing research on similar materials at different places find that their results or findings are not consistent with each other. Their conclusions in general are the same but quantity wise they are different. As such, results or findings cannot therefore be generalized at national level. This creates confusion. Each and every user of waste material has to investigate the quality of waste before using and then has to take final decision regarding its use. Engineer and contractor, to some extent are therefore reluctant to use these waste as they are not confident of final products. If any structure fails, the responsibility goes to contractor. This is one of the reasons that though use of fly ash had started in sixties, its use in common construction started only in nineties and thereafter. Similarly use of Portland pozzolana cement became common in 21st century only. The use of other wastes is not yet common.

SOME REQUIRED CONDITIONS FOR CONSISTENT RESULTS

Based on above observations if some conditions are followed by researchers, consistency in results/findings can be achieved to some extent. Of course these conditions are difficult but not impossible.

a. Researchers should do chemical analysis of cement, water and waste used and try to correlate them with their findings.

b. Only standard sand be used for the experimental program in place of local sand, though it is costly, but in case of research there should be no compromise for the cost. It is likely to produce consistent and reliable findings.

c. Similarly if possible, researchers should be asked to use only a particular brand of cement to maintain uniformity in experimental program.

d. Mineral water should only be used for experimental program and curing of specimens should only be done in humidifiers or closed and covered curing tanks.

CONCLUSION

It can be therefore said that all researchers must do chemical analysis of all materials used including waste and must take this into consideration before making any final conclusion. Interpretation of results as per chemical analysis, if possible should be made. Moreover only standard sand and mineral water be used to conduct experimental work. The specimens be cured in closed and covered curing tanks if not possible to cure in humidifier. No doubt it is costly, but then only reliability and consistency in results can be achieved to some extent. However variation of other materials is certainly going to affect the findings, but non-consistency can be reduced considerably.

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