THOMSON REUTERS ENDNOTE
[Patanaik*, 5(3): March, 2016] ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

DEVELOPMENT OF A SUSTAINABLE CONCRETE WASTE RECYCLING SYSTEM

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ABSTRACT

Construction solid waste has caused serious environmental problems. Reuse, recycling and reduction of construction materials have been advocated for many years, and various methods have been investigated. There may be six type of building materials: plastic, paper, timber, metal, glass and concrete which can be reused and recycled.

This paper examines the rate of reusable & recyclable concrete waste. On the other hand, the reuse of construction waste is highly essential from the viewpoint of Life Cycle Assessment (LCA) and effective recycling of construction resources. In order to promote the reuse of construction waste, it is necessary to achieve three basic concepts: (1) assurance of safety and quality, (2) decrease of environmental impact, and (3) increase of cost effectiveness of construction. This paper outlines the development of a recycling system, application of recycled aggregate concrete produced by the aggregate replacing method, which is effective in reducing both cost and environmental impact from the viewpoint of LCA for concrete waste generated by the demolition of large-scale buildings such as powerhouses. Moreover, with the adoption of the developed recycling system, it was confirmed possible to recycle concrete waste produced from the demolition buildings in a highly effective manner reducing both recycling cost and Environmental impact.

KEYWORDS: Recycled concrete, reuse solid waste, R0A MIX,RU50A MIX,RS2-50 MIX.

INTRODUCTION

According to an investigation conducted by Tokyo Electric power company (TEPCO) currently owns about 5800 buildings excluding 700 nuclear power facilities. These buildings include the thermal power plant houses, substations, head & branch of office buildings etc.

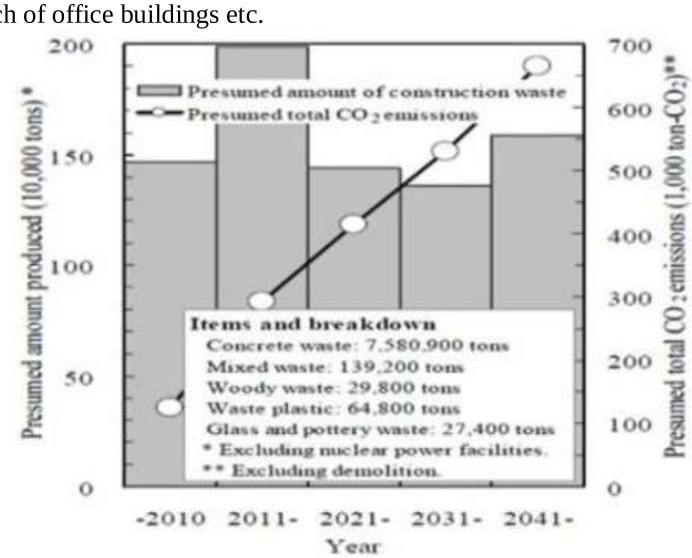


Fig. 1 Presumed amount of construction waste and CO2 emission (Building owned by TEPCO).

Figure-1 shows the breakdown and amount construction waste that will be produced when these 5800 buildings are demolished. The total predicted amount of construction waste is about 7.8 million tons of which 7.6 million is concrete waste. If the total amount of construction waste is treated through dumping in public/private disposal facilities ,the amount of CO_2 emissions is predicted to be about 0.67 million tons, which is also the major cause of our environmental pollution.

It is commonly known that the generation of solid construction waste represents one of the most significant problems of our civilization. The increase of population, the urbanization and the industrialization directly affect the increase in consumption of all kinds of materials and energy sources and, therefore, the increase of the amount of solid waste. The possible solution of this problem is presented by the philosophy of sustainable development. To recall, the so called "sustainable development" implies such a developing path, which will ensure the use of natural resources and will create assets in a manner to ensure meeting the needs of the present generations, without compromising the future generations. Sustainable development is one of the few ever present issues, which is, from day to day, more topical - primarily because it is of great importance for a modern society. The application area of sustainable development is practically inexhaustible, considering that the present concept is applicable to all forms of human activity. Thus, construction sector, sustainable development is applicable on many levels, one of which is the production and the use of the recycled materials, especially concrete (as a percentage of the most commonly used construction material). The term "recycling", in general, is defined as a single use or multiple usages of waste materials as an effective substitute for a commercial product or as raw material in further industrial process. According to the available data regarding the construction materials, the bricks have the highest percentage of recycling (35%), followed by concrete (20%) and wood (12%) etc.. Generally, construction is an activity, harmful to the environment. Its adverse effects include damage to the biosphere and the biodiversity, the exploitation and the transformation of the terrain, the depletion of natural resources (energy, minerals, water, fertile soil), chemical, physical and visual pollution (for land, air and water), the waste generation and the climate change. When we talk about concrete as a potential environmental or "green" material, first we should point out its basic flaws. Namely, the production of its component materials (cement, aggregates, chemical and mineral supplements) and, finally, the production of the concrete itself, require a large amount of energy and generally represent a significant source of environmental pollution. It is a known fact that the production of one ton of cement, releases into the atmosphere about the same amount of carbon dioxide (CO_2). Globally, about 5% of all CO_2 emissions come from the cement production. In doing so, the most ruined buildings are being partially or totally destroyed and the waste building material is removed from these sites. Also, due to degradation over time and the limited life cycle, many objects need to be replaced with new, technically and economically favorable solutions. In addition, especially lately, we are witnessing numerous devastating natural disasters (earthquakes, floods, typhoons, tsunamis, fires) and man-made disasters (wars, terrorist attacks and nuclear accidents). These events are inevitably followed by processes of clearing the debris and removing the waste building materials.

Although the major use of concrete waste was roadbed gravel but it is decreasing time to time, because the construction of gravel road is decreasing.

BASIC PROPERTIES OF RECYCLED AGGREGATE

The use of recycled aggregate as a component for producing new concrete requires a thorough database regarding the properties of such aggregates. Above all, properties such as: the absorption of water by volume, the gravity, the amount of fines and contaminants (for instance, organic matter and potentially harmful particles), the crushing resistance, the wear and freeze-thaw resistance are the most important ones that must be recognized. In fact, the investigations have shown that the recycled aggregate, in comparison to natural one, shows following properties: a higher water absorption, a lower density, a greater amount of contaminant particles, a higher content of organic and other potentially harmful substances, a lower crush resistance, a lower resistance to abrasion and a lower freeze-thaw resistance. Naturally, the quality and characteristics of the concrete made with the recycled aggregate will directly depend on the properties of the used recycled aggregate. It is known that the recycled concrete aggregate consists of the used - original aggregate and a layer of mortar remaining after crushing. The water absorption of the recycled concrete aggregate tends to be significantly greater than of natural aggregate, which is certainly related to: the type of the original aggregate, the initial strength of concrete and the largest aggregate grain in the original concrete [8]. The water absorption of recycled concrete aggregate tends to be even larger, if the quantity of mortar surrounding the original grains increases. Investigations showed that the water absorption of recycled aggregates increases with decreasing the size of grain used in the original concrete. This is due to larger specific surface area of smaller grains, to which a larger amount of mortar can be attached. The recycled aggregate's capacity of water absorption, which certainly depends on the quality and the thickness of mortar layers wrapped around the aggregate, should be determined as one of the fundamental properties - before incorporating recycled aggregates in the new concrete. Also, the recycled aggregate generally has a lower density than the natural one because of the presence of the porous layer of mortar, as discussed earlier. As many researchers reported, the impact and the wear resistance of the recycled aggregate is lower in comparison to the natural aggregate; this is also due to the existence of a porous mortar layer around the grain of the recycled aggregates, which spalls and crushes more easily.

All above mentioned features directly imply certain details in the technology of making concrete with recycled aggregate, which will be discussed later. Some authors proposed the division of the recycled concrete aggregates in classes based on the water absorption and the freeze-thaw resistance, determined using sodium sulfate (Na2SO4) method. Thus, three classes have been proposed for the coarse recycled aggregates, with a maximum water absorption ≤7%, and two classes for the fine recycled aggregates, with a maximum water absorption ≤10%.

Meanwhile, toxic substances such as hexavalent-chromium and lead are present in the concrete waste since they are originally contained in cements. Taking soil contamination into consideration, it is necessary to develop other uses apart from roadbed gravel. The most promising alternatives are recycled aggregate and recycled aggregate concrete.

MIXING, CASTING, AND CURING OF CONCRETE.

Two-stage mixing was performed in a rotating drum mixer as per procedure described by Ismail and Ramli [25]. In first stage, mixing procedure involved adding both coarse and fine aggregates into the drum mixer and dry mixed for 30 second to allow aggregates to mix homogeneously. Secondly, the first half portion of the mixing water was added into the mixer and the mixing continued for another 2 min. The mixer was then stopped for 3 min to facilitate the absorption of water into aggregates. The cement was added and the mixer continued for another half minute. Finally, the remaining half of the mixing water was added and further mixing was performed for approximately 2 min more. Mixing procedure and time have been kept constant for all the mixes. After completion of the mixing, slump cone test was performed as per IS: 1199: 1959 [26] to determine the workability of the mixes. To finalize the mix proportion, casting of cubes (150 × 150 × 150 mm), cylinders (150 mm diameter ×300 mm height) and prisms (100 ×100 ×500 mm) was carried out in two phases for determination of mechanical and durability properties shown in Table 1.

Mixes	Cement (kg)	Coarse aggregate (kg)	Fine aggregate (kg)	Water (kg/L)	Super plasticizer (%)	Slump (mm)
R0A	360	1251	658	162	—	27
RU50A	360	1251	658	162	—	22
RU100A	360	1251	658	162	—	18
R0B	360	1251	658	162	0.25	34
RU50B	360	1251	658	162	0.25	32
RU100B	360	1251	658	162	0.25	30
R0C	360	1251	658	151	0.25	32

RU50C	360	1251	658	151	0.25	30
RU100C	360	1251	658	151	0.25	28
RW100C	360	1251	658	151	0.25	32

Table 1: Mix proportions of concrete per cubic meter using natural and recycled coarse aggregates.

TECHNIQUES AND IMPLEMENTATIONS

1.Recycled Aggregate Concrete by Aggregate replacing method:

The appearance of recycled aggregate is shown in fig-2.Recycled aggregate consists of original aggregate and original mortar. Recycled aggregate using the aggregate replacing method is manufactured for the purpose of acquiring equivalent quality to natural aggregate such as gravel and/or sand, and being used as a substitute.

However in order to manufacture such recycled aggregate, removing the original mortar, an advanced processing technique using special facilities such as " Heating &rubbing" & "mechanical grinding" is needed .Moreover the recycling rate of " Heating &rubbing" and the "mechanical grinding" are as high as about 56% & about 50% respectively. If also can include both recycled coarse aggregate & recycled fine aggregate.

Heating and rubbing that can produce high quality recycled coarse aggregate, best among all aggregate replacing method that is about 35% of coarse aggregate ,21% of fine aggregate. The remaining 44% of fine powder contains a large amount of original mortar .Mechanical grinding method is also used to break the large pieces to small pieces of coarse aggregate. In this method, we use mechanical grinder to break into the small pieces .So it can also produce recycled coarse aggregate and fine aggregate. But the remaining fine powders cannot be recycled by these two methods .So to recycle these fine powders; we have to follow wet grinding method.

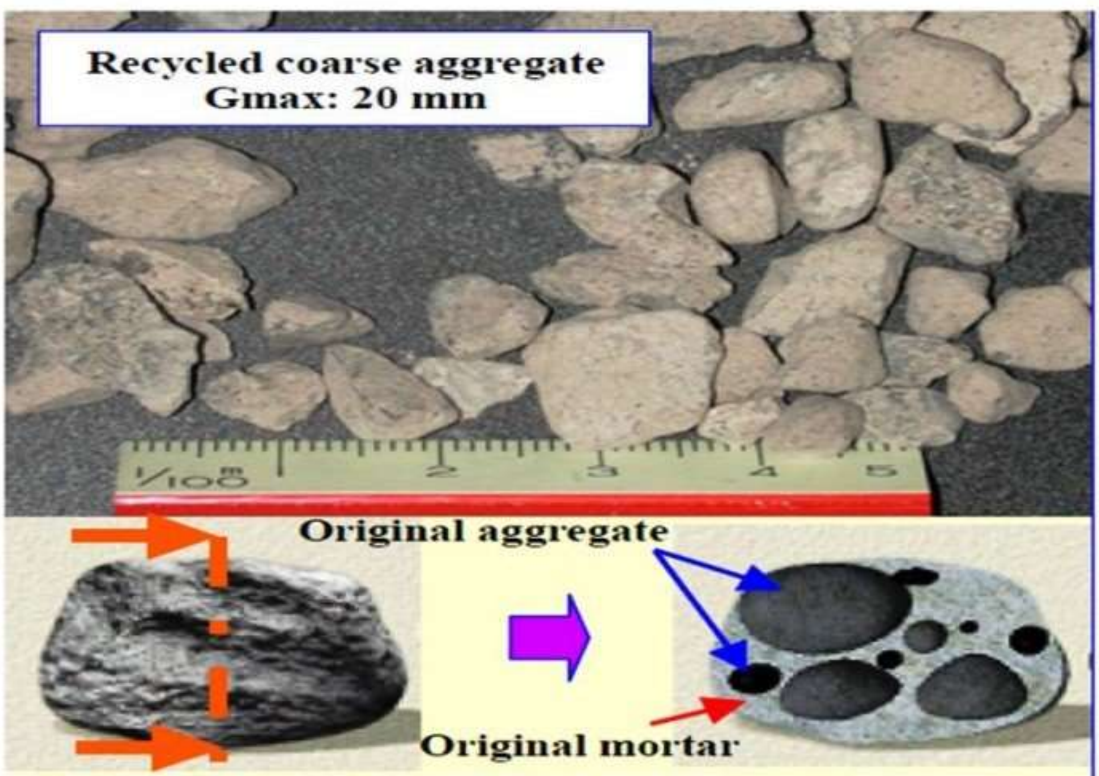


Fig. 2 Appearance of Recycled aggregate

Recycled fine aggregate by wet grinding method:

Recycling of fine aggregate &fine powers need to improve their strength. It is possible to improve the main properties such as absorption rate by applying wet grinding method, as shown in fig 3.The aggregate is ground by the rotation of a rotor positioned inside a cylindrical shell. Recycled fine aggregate &fine powder of 5mm or less is manufactured by passing through a screen. Impurities such as fine powder aggregate & wood chips are removed by a wet-type high speed centrifuge or cyclone.

In wet grinding method, we use natural aggregate concrete (CS-0) and the concrete using recycled fine aggregate (RS2). The mix proportions of natural aggregate concrete and the concrete using recycled fine aggregate of wet grinding method are shown in table-2.

KIND OF CON CRE RE	REPL ACE MEN T RATI O(%)	W/ C	S/A	CONTENT PER UNIT OF CONCRETE(KG/M3)						
				WAT ER	CEM ENT	AGGREGATE			ADMIXTURE	
						CS	RS2	CG	SP8N	M A1 01
CS-0	0	45	43	148	329	797	0	1075	3.62	.3
		55	46	151	275	853	0	1056	3.56	0
RS2- 50	50	45	43	148	329	399	358	1075	3.62	.3
		55	46	151	275	425	384	1056	3.85	0
RS2- 100	100	45	43	148	329	0	716	1075	3.62	.3
		55	46	151	275	0	766	1056	3.85	0

Table 2 Mix proportion of the natural aggregate concrete and the recycled fine aggregate concrete

TESTING

In aggregate replacing method, we have to check the size of coarse aggregate .The maximum sizeof coarse aggregate is 20mm and the minimum size of fine aggregate is 5mm.In this method the quality of recycled aggregate can be secured by mix proportion design in accordance with the appropriate index such as relative absorption rate, replacement ratio etc. Fig. 4 shows the correlation between the relative absorption rate& the main properties of recycled aggregate concrete (compressive strength, drying shrinkage accelerated Carbonation depth).

Kind of concrete	w/c (%)	slump	Air content (%)	Unit weight of concrete (kg/m3)
CS-0	45	7.1	5.3	2310
		6.3	4.2	2382
	55	7.6	5.2	2260
		9.3	3.8	2348
RS2-50	45	7.1	4.1	2300
		6.9	3.7	2366
	55	7.1	4.6	2260
		7.1	4.4	2279
RS2-100	45	6.5	4.1	2270

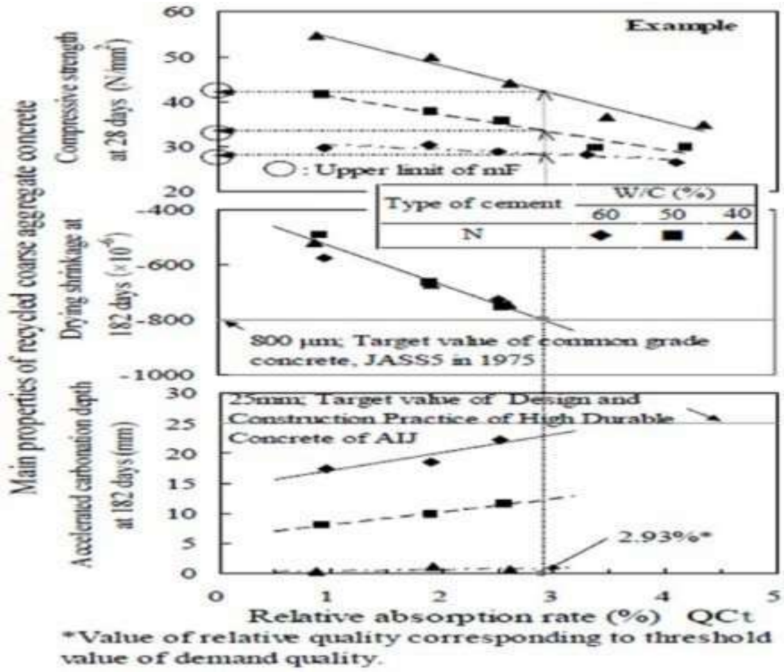
		8.9	4.2	2324
	55	7.6	4.4	2230
		7.5	4.0	2222

Table 3Test result on fresh concrete properties of recycled fine aggregate concrete

In wet grinding method the properties of fresh concrete or recycled concrete are shown in Table- 3.In the range of "slump 8±2.5cm"& "air content 4.5±1.5%", it is possible to knead the concrete using the same mix proportion as with natural aggregate concrete.

TYPES OF CEMEN T	MANAG EMNT AGE OF COMPR ESSIVE STRENG TH	MAXIM UM SIZE OF COARSE AGGREG ATE (MIN)	REP LAC EME NT RATI O(%)	TYPES OF ADMI XTRU RE	slu mp	Fe (n/mm2)				
						21	24	27	30	33
Ordinar y Portlan d cement (N)	28 days	20	30	AE and Water - reduci ng admix ture	18	-	0	-	-	-
Ordinar y Portlan d cement (N)	28 days	20	30	AE and Water - reduci ng admix ture	15	0	0	0	0	0
					18	0	0	0	0	0
			50		15	0	0	0	0	0
					18	0	0	0	0	0
			30	AE and Water - reduci ng admix ture	15	-	0	0	0	0
					18	-	0	0	0	0
			50		15	-	0	0	0	0
					18	-	0	0	0	0
			30	AE and Water - reduci ng admix ture	15	0	0	0	-	-
					15	0	0	0	-	-
		50								
Low heat Portl and cem ent (L)	91 days									

Table-4 gives the list of recycled coarse aggregate which can be used as a construction material .The specified slump is 15 & 18cm



Replacement ratio, which is volume ratio to be replaced by recycled coarse aggregate, is 30 & 50%. In addition to ordinary Portland cement, low-heat Portland cement (fc=21 to 27 N/mm 2), which can be used for mass concrete is also included in the approval.

Fig. 4 Example of relationship between relative absorption rate and main properties of recycled coarse aggregate concrete.

CONCLUSION

This paper presents recycle of concrete waste generated by the demolition of large scale buildings such as thermal power plants from the view point of LCA . The study results are summarized as follows:

1. Recycled coarse aggregate concrete using the aggregate replacing method can acquire sufficient quality as structural concrete through material design by using material conforming to all related quality standards.
2. Recycled fine aggregate concrete, as well as recycled coarse aggregate concrete, can also be designed by applying the value of relative quality method. Therefore, it is considered applicable as aggregate use in precast concrete products.

As environmental protection has been pressing hard around the world, high energy utilization & pollution generation from construction activities seems cannot be controlled .So by reusing, recycling & reducing construction materials have been encouraged & suggested for the practices in construction activities.

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