

Management and Recycling of Construction and Demolition Waste in Kingdom of Saudi Arabia

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ABSTRACT: Construction and demolition waste, C&D, is one of the largely produced wastes in Kingdom of Saudi Arabia, KSA. Management of C&D waste is essential in formation, growth and renovation of urban areas. Current municipality legislation and directive sets out to implement C&D waste prevention and recycling measures. Main objective of this study is to determine indicators to estimate amount of C&D waste generated on site and to find best way of recycling waste into a useful product. Part of study in metropolitan area of Dammam, Khobar and Dhahran focuses on generation and management of C&D waste based on construction activity and waste load movements. Data needed to develop indicators is collected through survey studies by suitably designed questionnaires, site investigations and field visits for a reasonable sample of home owners, construction firms and municipality. Laboratory activities were conducted to create a recycled concrete and compare its mechanical properties to a normal mix. Questionnaires results show that largest amount of municipality C&D waste was approximately 252806.8 tons/year, and from private sector amount was more than 5000 tons/month. Results of laboratory experiments showed that cubic samples had highest compressive stress value of 51.95MPa.

KEYWORDS: C&D waste, solid waste recycling, concrete from waste.

I. INTRODUCTION

Presently, assembly and handing manner of C&D waste in the KSA, cannot replicate eco-efficiency well. The number of construction waste is 30% to 40% of total city's waste in the country. In line with statistics of construction materials loss of buildings like brick-concrete structure, full caste-in-concrete structure, bolstered concrete structure,

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etc. reveals that around 500 to 600 tons of construction waste are generated per ten thousand (10,000) m² construction, while about 7,000 to 12,000 tons construction waste are generated per ten thousand(10,000) m² when demolishing previous buildings. According to statistic (Arab Urban Development Institute, 1986), twenty thousand (20,000) million m² building is annually completed in KSA. Thus, three thousand tons (3,000) of C&D waste is made when flattening previous construction each year. Therefore, together four thousand million ton construction waste is made. Effective measures to cut back such quantities of waste are vital and necessary. Utilization of C&D waste for sustainable development is advocated by utilizing alternatives for handling and recycling such waste.

The research project focuses on determining an optimal and sustainable solution to problem of C&D solid waste in Dammam-Khobar province in KSA This research work is of paramount importance and fruitful significance for a number of reasons such as:

- Promoting a coherent, integrated approach, whereby the management of C&D waste is given due consideration throughout the life cycle and duration of a certain project.
- Advocating reuse and recycling of C&D waste in construction industry.
- Outlining manner in which clients, planners, designers, contractors, sub-contractors and suppliers can act co-operatively in order to reduce C&D waste arising and to improve the manner in which any waste generated is managed.
- Providing designers, developers, practitioners and competent authorities with an agreed basis for determining the adequacy of C&D Waste Management Plans for certain classes of projects which exceed a specified threshold size or level.
- Preventing illegal dumping problems and reducing the stress on landfill and disposal sites.
- Enhancing awareness of community towards malfunctions and usefulness of C&D waste towards minimizing ill-environmental impacts of C&D solid waste if used as a raw material.
- Advocating bylaws, guidelines and regulation that encourage government and contractors to cooperate in management of C&D solid waste.

Saudi Arabia generates a large amount of construction and demolition solid waste. Therefore, it is necessary to find a proper way to manage such problem. The project focuses on dealing with C&D solid waste through the following specific research questions:

- 1- What is C&D waste?
- 2- What are the sources and classification of C&D solid waste in the study area?
- 3- What are the amounts and properties of C&D waste generated?
- 4- How to reuse and recycle C&D waste problem in the study area in an integrated manner?

Hypotheses for this research work are set to manage C&D waste in Dammam and Khobar district at C&D sites.

Four hypotheses have been developed as follows:

- 1) Determining actual amount and characteristics of generated C&D solid waste in the site helps decision-making and management pattern.
- 2) Preventing C&D waste to extend out of the C&D site, improves community health and concerned environs.
- 3) Reusing or recycling C&D waste would add value to C&D stakeholders and construction industry in the region.
- 4) Making company of C&D to pay (polluter should pay) for landfill and disposal use helps its management and reuse.
- 5) Reusing and recycling C&D waste in construction industry aids C&D integrated management plans.
- 6) Determining laboratory experiments to investigate properties of C&D recycled waste.

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II. MATERIALS AND METHODS

To achieve the objectives of this research, a number of research tasks were defined and followed as per a reasonable operational plan. However, from these, certain tasks were defined as the constitutional bases in the operational design of the methodology of this research. To carry out this research, originally three research tasks were set up as follows:

- 1- Data collection from concerned municipality and authorized companies and enterprises.
- 2- Comparison of the normal and recycled concrete prepared from recycled C&D waste.
- 3- Deriving suitable conclusions and recommendations.

A universal testing machine is used to test tensile and compressive strengths of C&D materials. The universal testing machine utilized is an Instron 600DX. It is designed for high-capacity tension, compression, bending/flexural and shears testing. Plate (1) gives a photograph image of the universal testing machine used in this research work installed at the Structures and concrete laboratory of the Construction Engineering Department at Al-Gashla/Rakah locality.



Plate (1) The universal testing machine

The procedure for carrying out tests on prepared samples followed the standard format delineated by the Universal Testing Machine (UTM) as follow:

- 1- UTM connected with its computer is started.
- 2- BLUE HILL software is run as per machine built-in program.
- 3- At least five minutes relapse period is selected for UTM for before testing. This is to warm up the hydraulic system.
- 4- As per software menu, required parameters, information and test data were input before commencing examination:
 - a) A suitable file name is selected,
 - b) Test method (compression or tensile experiment) is chosen for a specified specimen shape (cube, cylinder), and a loading rate.
- 5- Desired test is run till failure.
- 6- Failure load and corresponding strength are recorded.

The concrete compression and flexural testing machine is specifically designed for testing on hardened concrete compression and flexural tests for varies standard specimen sizes. Plate (2) gives a photographic image of the machine used in this research work at the Structures and Concrete Laboratory of the Construction Engineering Department, UoD.

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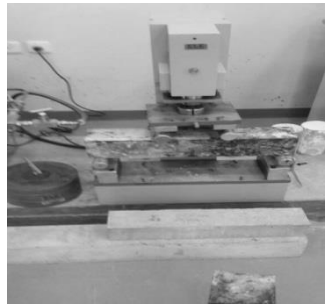


Plate (2) Concrete compression and flexural testing machine.

The procedure followed out in the Flexural Testing Machine for carrying tests on prepared samples is in accord with the standard one adopted for Flexural Testing Machine (FTM) as follow:

- 1- FTM is started.
- 2- Test method (Compression or Flexural) is selected,
- 3- The specimen shape is chosen.
- 4- The specimen size is nominated.
- 5- A specimen is inserted on the test area.
- 6- Load is applied by checking the “run” bottom on the display screen.
- 7- Failure load and associated strength are recorded.

Normal and Recycled Concrete Sample are prepared as follows:

- 1) 80 kg of normal and recycled C&D concrete waste is collected from study site Dammam, Khobar and Dhahran. Table (1) illustrates the amount of concrete needed for test experiments and laboratory investigations.
- 2) Sample is homogeneously mixed in the laboratory using the mixture concrete. Table (2) shows the concrete mix proportions for different ingredients used of cement, coarse and fine aggregate and sand. Table (3) offers the mix proportions as used for the normal and recycled concrete with super plasticizer.
- 3) Samples are then casted into 10 x 20 cm cylindrical column, 10 cm cubes and 10 x 10 to 50 cm rectangular cuboid beam. Table (4) illustrates the characteristics of the four samples casted for each of selected shapes cylindrical, cuboid and rectangular cuboid.

Table (1): Amount of concrete C&D for the experiment.

Sampl es	Volum e (m ³)	Wei ght (Kg)	Ceme nt (kg)	Sand (kg)	Fine Agg. (kg)	Coars e Agg. (kg)
Cylind er	0.0016	3.77	0.538	1.076	0.968	1.184
Cube	0.001	2.4	0.342	0.685	0.617	0.754
Beam	0.005	12	1.714	3.428	3.085	3.771

Table (2): Concrete mixture proportions.

Ingredient	Proportion
Cement	1
Coarse aggregates	2.2
Fine aggregates	1.8
Sand	2
Total	7

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Table (3): Mix for the normal and recycled concrete.

Component	Amount
Cement	10 Kg
Coarse aggregates	22 Kg
Fine aggregates	18 Kg
Sand	20 Kg
Water	5 Kg
Super plasticizer	200 ml
Water/ Cement	50%
Super plasticizer/ Water	4%
Super plasticizer/ Cement	2%

Table (4): Samples casted (cylinder, cube and beam)

Samples	Weight (Kg)	Cement (kg)	Sand (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)
Cylinder	3.768	2.153	4.304	3.872	4.736
Cube	2.4	1.368	2.74	2.468	3.017
Beam	12	6.857	13.714	12.342	15.085
Total for each component		10.378	20.758	18.682	22.838
Total for all components		72.659 kg			

Analysis and testing procedure for normal concrete is as follows:

- 1- The cement, sand, fine, and coarse aggregates were weighed and batched for any selected mix.
- 2- All ingredients were placed in a concrete mixer and mixed for three minutes.
- 3- Water was added to the mixture as per proportion.
- 4- 200 ml super plasticizer was added to the mix.
- 5- The normal concrete (Cube, Cylinder and Beam) was removed from the mixer and placed in the samples mold.
- 6- After 2 days, the samples were demolded and moist cured in a water tank for a curing period of 28 days.
- 7- The concrete specimens were removed from the curing tank and tested for strength using the universal testing machine (UTM).

For the recycled concrete, the following procedure was followed:

- 1- An 80 kg of C&D waste was collected from the construction demolition sites.
- 2- A Los Angeles crushing machine was used to break the demolition waste into smaller sizes suitable for use as aggregate.
- 3- The recycled aggregates were sieved in a set of sieves to separate the aggregates into coarse, fine and sand. The coarse aggregate was from sieve 12.5 mm to 19.5mm. The fine aggregates were from sieve #4 and #8. The sand was from sieve #16 to #100.

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- 4- Each size of aggregate was measured after separation to reach the quantity limit.
- 5- Cement, water and super plasticizer were prepared and weighted for the concrete mix.
- 6- The recycled concrete (Cube, Cylinder and Beam) was removed from the mixer and placed in the samples mold.
- 7- After 2 days, the samples were demolded and moist cured in a water tank for a curing period of 28 days.
- 8- The concrete specimens were removed from the curing tank and tested for strength using the universal testing machine (UTM).

III. RESULTS AND DISCUSSION

Prepared data collection questionnaires were distributed to different C&D potential sources and generation sites, collection and final disposal sites that included: Dammam, Khobar and Dhahran municipality. Received data from Dammam, Khobar and Dhahran municipality and ARAMCO was presented herein:

Municipality Data

Table (5) and figures (1) and (2) show the amount of C&D waste entering the landfill site as collected from Dhahran,

Khobar and Dammam metropolitan area for the period 1433H- 1435H. Data of table (5) was compiled for a range of daily, weekly, monthly and yearly data gathered at the site

Table (5): Monthly average amount of C&D waste entering the landfill (Compiled by Cleaning Services Department, Dr. Mohammed Al- Omani)

Month	1433H (Tons)	1434H (Tons)	1435H (Tons)
Muharram	14610.7	14708.75	3007.92
Şafar	21946.85	28229.64	2998.03
Rabī' I	24452	56955.26	7707.57
Rabī' II	23988.96	59266.08	14304.91
Jumādā I	28356.84	35816.22	19798.93
Jumādā II	25604.69	16917.43	22120.6
Rajab	17909.9	8306	26287.35
Sha'bān	17401.12	7474.19	15477.09
Ramaḍān	6224.51	10723.02	12142.65
Shawwal	6421.86	5582.89	10180.2
Dhū al-Qa'dah	9307.69	7034.54	14423.09
Dhu al-Hujjah	6502.79	1792.78	9816.26
Total	202727.91	252806.8	148264.6

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Community	Waste Source	C&D (Tons)
Dhahran	Aramco	5479
	Contractor Campus	0
	Municipality	0
	Sub-Total	5479
Ras Tanura	Aramco	304
	Contractor Campus	34
	Municipality	430
	Sub-Total	768
Abqaiq	Aramco	456
	Contractor Campus	76
	Municipality	988
	Sub-Total	1520
Udhailiyah	Aramco	388
	Contractor Campus	118
	Municipality	0
	Sub-Total	506
Tanajib	Aramco	307
	Contractor Campus	109
	Municipality	10
	Sub-Total	426
Shaybah	Aramco	0
	Contractor Campus	0
	Municipality	0
	Sub-Total	0
Total Monthly Tones		8699

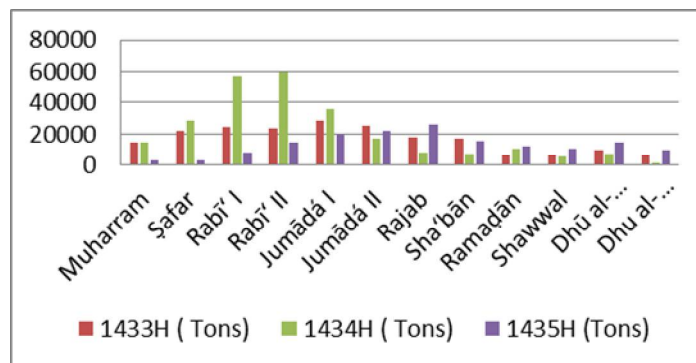


Figure (1): Amount of (C&D) Waste in Dhahran, Khobar and Dammam

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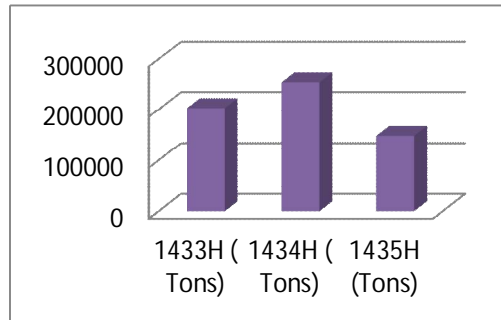


Figure (2): Total amount of (C&D) Waste in Dhahran, Khobar and Dammam per Year

Aramco Data

Data of C&D waste received from Saudi ARAMCO is as presented in table (6). Table (6): Total amount of C&D waste from Aramco company in July 2013.

Tests results for Concrete

Tests results for Normal Concrete are as depicted in table (7). Table (8) gives a clear picture of properties tested for normal concrete for different samples for each of: maximum load, compressive extension, compressive stress compressive strain and Young's modulus of elasticity.

Table (7): Results of normal cylinder (200 x 100d)

Tested By	Universal testing Machine
Material	Normal Concrete
Sample	Cylinder 200 x 100d

Table (8): Results of normal Cube (100 X 100 X 100)

Table (8): Results of normal Cube (100 X 100 X 100)

Tested By	Universal testing Machine
Material	Normal Concrete
Sample	Cube(100 X 100 X 100)

Specimen	Maximum Load (kN)	Compressive extension (mm)	Compressive stress (MPa)	Compressive strain (%)	Modulus Young's (MPa)
1- Cube	500.24	1.78573	50.02	1.79	3,770.41
2- Cube	447.06	2.10844	44.71	2.11	3,024.55
3- Cube	480.1	1.79498	48.01	1.8	3,677.40
4- Cub3	484.98	1.86676	48.5	1.88	3,820.81
Minimum	447.06	1.78573	44.71	1.79	3,024.55
Mean	478.1	1.88897	47.81	1.89	3,573.29
Maximum	500.24	2.10844	50.02	2.11	3,820.81
Standard deviation	22.3994	0.15072	2.23994	0.15093	370.62
Coefficient of variation	4.68513	7.9791	4.68513	7.96653	10.37

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Table (9): Results of normal Beam (500X 100 X 100)

Tested By	Flexure Testing Machine
Material	Normal Concrete
Sample	Beam (500X 100 X 100)

Specimen	Load (KN)	Compressive Stress (MPa)
1- Beam	9.25	4.16
2- Beam	9.71	4.37

Tests results for a recycled concrete sample were presented along table (10) and figure (6) for a 200X 100d recycled cylinder.

Table (10): Results of recycled Cylinder.

Tested By	Universal testing Machine
Material	Recycled Concrete
Sample	Cylinder 200 x 100d

Table (11): Results of recycled Cube (100 X 100 X 100)

Tested By	Universal testing Machine
Material	Recycled Concrete
Sample	Cube (100 X 100 X 100)

Specimen	Maximum Load (kN)	Compressive extension (mm)	Compressive stress (MPa)	Compressive strain (%)	Modulus Young's (MPa)
1- Cube	475.27	1.26999	47.53	1.27	4,004.44
2- Cube	519.46	1.76599	51.95	1.77	3,862.41
3- Cube	483.94	1.4733	48.39	1.47	4,031.83
4- Cube	542.25	1.63194	16.95	1.63	1,290.86
Minimum	475.27	1.26999	16.95	1.27	1,290.86
Mean	505.23	1.5353	41.2	1.54	3,297.38
Maximum	542.25	1.76599	51.95	1.77	4,031.83
Standard deviation	31.21861	0.21353	16.28448	0.21479	1,339.74
Coefficient of variation	6.17906	13.90814	39.5223	13.98119	40.63

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Table (12): Results of Recycled Beam (500X 100 X 100)

Tested By	Flexure Testing Machine
Material	Recycled Concrete
Sample	Beam (500X 100 X 100)

Specimen	Load (KN)	Compressive Stress (MPa)
1- Beam	6.08	2.73
2- Beam	6.79	3.05

The compressive strength of concrete is the most common performance measure and indicator used by the engineer in designing buildings and other structures. The compressive strength for different shapes is measured by breaking a cylindrical column, rectangular cuboid beam and concrete cube specimens in the laboratory compression-testing machine. The compressive strength is calculated as per Eq. (1).

$$\sigma = P/A \quad (1)$$

Where

σ = Compressive strength, Mpa

P = Failure load, N

A =Cross-sectional area resisting the load, m²

Cylinder Concrete:

Table (13) show the little difference observed in the compressive strength of a normal and recycled cylinder of the four tested specimens. The slight difference could be due to the top surface of the cylinder not being flat.

Table (13): Percentage difference between the normal and recycled Cylinder

Specimen:	Difference, %
1	19.76
2	17.11
3	7.56
4	28.20
Average Difference	18.15

It was observed that the concrete compressive strength requirements vary from 2500 psi (17 MPa) for residential concrete to 4000 psi (28 MPa) and higher in commercial structures. For that, the normal and recycled cylinder can be used in the residential concrete because the lowest value was in the recycled concrete in specimen number 3 and the highest was the normal concrete in specimen number 1.

Cube Concrete:

Figure (9) shows that the compressive stress of normal and recycled cube is better than that of the cylinder. This may be attributed to the surface area which was flat. Actually, the cube is considered to be the best for testing the strength of concrete. Specimen number 4 gave a false result for the recycled cube for a human error by entering wrong cuboid area (100X100 X100) mm. Table (14) gives 54.225 MPA strength for a maximum loading of 542.25 KN for the area of the cube. For both normal and recycled cylinder difference in strength is negligible for the four tested specimens.

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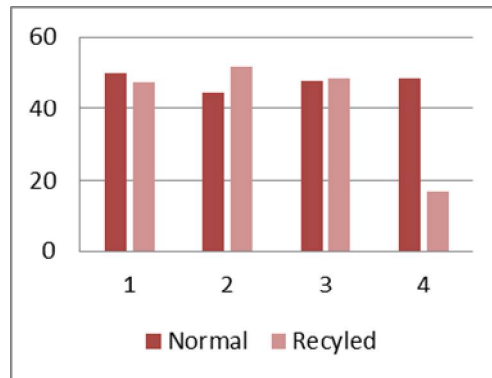


Figure (9) Compressive Stress of Normal and Recycled Cube

Table (14): Percentage difference between the normal and recycled Cube

Specimen: Percentage difference:

1- Cube 4.97%

2- Cube 0%

3- Cube 0%

Average Difference 1.65%

From the results obtained of this research work the normal and recycled cube can used in both residential and commercial structures. This is because the lowest value that was found is 46 MPa in specimen number 2 of the normal cube.

Beam Concrete:

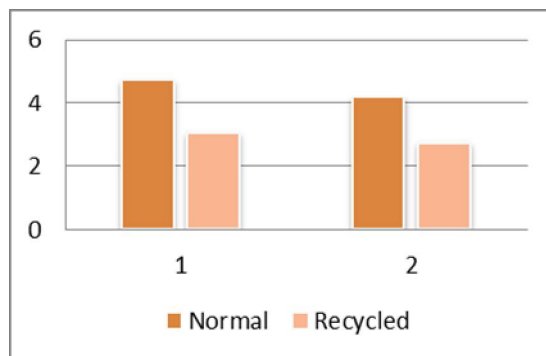


Figure (10): Compressive Stress of Normal and Recycled Beam.

Although, the beam is not usually used in the compressive stress, nonetheless the team members desired to evaluate the strength of the recycle beam and compared it with the normal one. Figure (10) show that the recycled beam will lose approximately 30% of its strength from the normal beam.

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IV. CONCLUSIONS

The following conclusions emerged from this research work:

- The collected questionnaire data showed that the amount of C&D waste is considerable in the study area.
- The gained data and information deposited that the C&D is not well addressed, not utilized beneficially & it may find its way to final disposal site and dumping area.
- No specialize treatment, reuse or recycling practiced within study area municipality or private sector.
- The laboratory testing on the recycled C&D waste showed a high potentially for its practice on a commercial format.
- Test result as per compressible concrete strength indicated a suitable use within the building industry in the Dammam metropolitan.

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BIOGRAPHY

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