



Utilization of Recycled Coarse Aggregate for Concrete Production

Nyo Nyo Tun

Department of Civil Engineering, Yangon Technological University, Myanmar

ABSTRACT

The utilization of recycled aggregate on compressive strength of concrete is investigated in this research. In the experimental, five types of concrete mixtures were tested: concrete made with natural aggregate as a control concrete and five types of concrete made with natural fine and recycled coarse aggregate (10%, 20%, 30% and 50%) replacement of coarse recycled aggregate). In this research, physical properties tests of each constitutes material are done according to ASTM procedures at laboratory. After that, concrete mix proportioning is done to obtain the specified 28-day characteristics cylinder compressive strength of 20 MPa (cube compressive strength of 25.64 MPa) and 75+ 25 mm slump according to ACI211 method. In this step, trial mixes are prepared using recycled coarse aggregates, with respect to the 7-day and 28-day compressive strength results. And then, appropriate mix design is selected for specified strength. Moreover, 120 concrete specimens for mix proportion of selected Grade is tested to the 7-day and 28-day compressive strength to establish a standard deviation and their results are compared. For standard deviation, total 720 cubes (120 cubes for each) are cast. In this research, concrete made with 30% recycled coarse aggregate performed best in specified target strength and also in selected slump control among the various proportions.

Keywords: *deviation, recycled aggregate, concrete mixture, physical properties, compressive strength.*

I. INTRODUCTION

Use of recycled aggregate in concrete can be useful for environmental protection and economical terms. Production and utilization of concrete is rapidly

increasing, which results in increased consumption of natural aggregate as the large concrete component. In order to reduce the usage of natural aggregate, recycled aggregate can be used as the replacement materials. Recycled concrete aggregate (RCA) is generally produced by two-stage crushing of demolished concrete, and screening and removal of contaminants. Concrete made with recycled concrete aggregate is called recycled aggregate concrete (RAC). The purpose of this paper is to determine the basis properties of RAC depending on the coarse recycled aggregate content, also compressive strength and to compare them to the properties of concrete made with natural aggregate (NAC) – control concrete. Recycled aggregate are the material for future. A comparative analysis of the experimental results of the properties of hardened concrete with different replacement ratios of natural with recycled coarse aggregate is presented in this paper. Recycled aggregate was made by crushing the precast concrete columns generally from building, bridges and sometime even from catastrophes, such as wars and earthquakes.

II. PHYSICAL PROPERTIES TESTS OF MATERIAL

The properties of concrete constituents play a vital role because the strength, durability, and other characteristics of concrete depend on these properties. Table 1 shows the physical properties test results of Elephant Cement, Table 2 shows physical properties tests results fine, coarse and recycles coarse aggregates.

Table1. PHYSICAL PROPERTIES OF ELEPHANTCEMENT

No	Tests	Results	Specification
1	Specific Gravity	3.07%	not greater than 10%
2	Consistency (%)	28.9%	26%-33%
3	Setting Times	Initial Setting Time	2 hr 46 min
		Final Setting Time	5 hr
4	Compressive	3-day	21.83
		7-day	29.719
		28-day	31.53

Table2. PHYSICAL PROPERTIES TEST RESULTS OF FINE, COARSE AND RECYCLED COARSE AGGREGATE

Aggre-gate Type	Physical Properties				
	Fineness Modulus	Abrasion (%)	Specific Gravity	Unit Weight	Absorption (%)
Fine Aggregate	2.2		2.64		1.73
Coarse Aggregate	2.1	38%	2.67	1667.5	0.42
Recycled Coarse Aggregate	2.4	36%	2.4	1655	0.62
Specifications			2.6-2.7	1200-1800	0.5-3.5

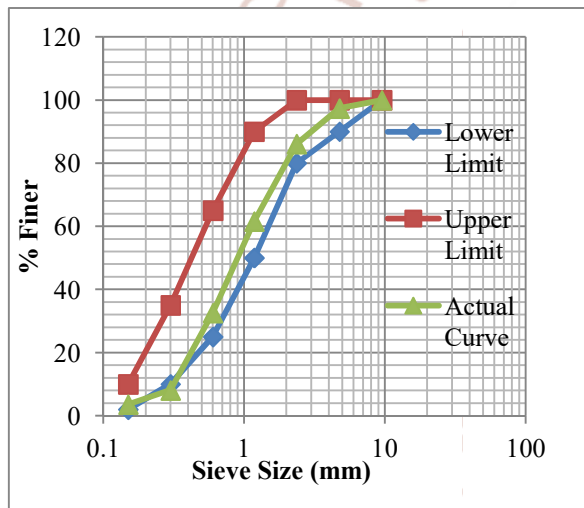


Fig1. Grading Curve of Fine Aggregate

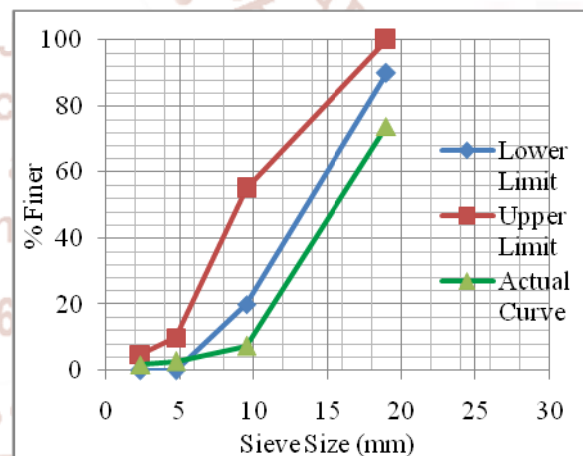


Fig3. Grading Curve of Recycled Coarse Aggregate

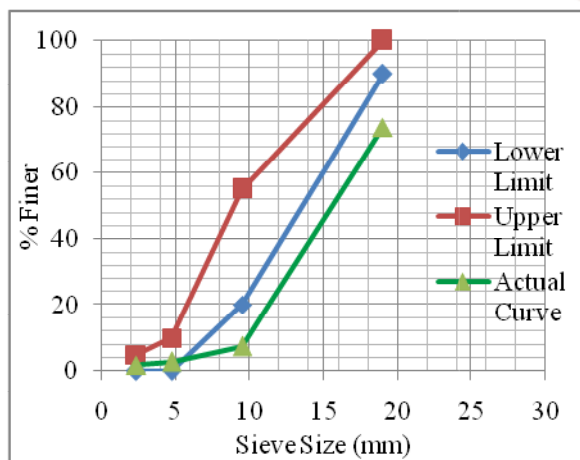


Fig2. Grading Curve of Coarse Aggregate

The fineness modulus of fine aggregate varies between 2.3 to 3.1 and coarse aggregate is generally between 5.5 and 8.0 as prescribed in ASTM standard. The absorption of aggregates generally lie between 0.5 to 4%.The moisture content of fine aggregate is between 0 to 10% and coarse aggregate is between 0 to 2%.In this research, the testing results of the aggregates are within the specified limits. But the grading curve of coarse aggregate falls below the specified limit, it indicates that the overall grading of the aggregate is coarser than the specified grading. Figure 1, 2 and 3 show the Grading Curve of Fine , Coarse and Recycled Coarse Aggregate.

Table 3
QUALITY OF WATER

No	Test	Result
1	pH	6.03
2	Total alkalinity	0.081mg/l as CaCO ₃
3	Chloride	0.024mg/l
4	Sulphate	2mg/l
5	Total solids	420mg/l

III. Compression Strength Test Results and Discussion

In this experimental study, there are three steps to study the compression strength of the various proportions (10, 20, 30 & 50%) of recycled coarse aggregate that compared with the normal concrete of selected mix design for specified strength Grade 20.

A. First Step: Pre-testing Trial Mixes for Estimating Proper Cement Amount

In first step, total seven trial mixes are made with different cement dosage according to ACI 211 mix design method for specified strength Grade 20. In this study, cements and water/cement ratios used in trial mixes are cement content of 366.45 with w/c 0.58, cement content of 400, 379.94 and 385.69 with w/c 0.52, cement content with 366.19 with w/c 0.54, cement content with 373.09 with w/c 0.53 and cement content with 363.64 with w/c 0.55.

Table 4. RELATIONSHIP BETWEEN CUBE STRENGTH AND CYLINDER STRENGTH [CQHP GUIDELINES]

$f'_c \leq 3500 \text{ psi}$	$f'_{cu} \approx f'_c/0.78$
$3500 < f'_c \leq 5000 \text{ psi}$	$f'_{cu} \approx f'_c/0.80$
$5000 < f'_c \leq 6000 \text{ psi}$	$f'_{cu} \approx f'_c/0.81$
$f'_c > 3500 \text{ psi}$	$f'_{cu} \approx f'_c/0.83$

Fig. 4 shows average cube compressive test results of trial mixes

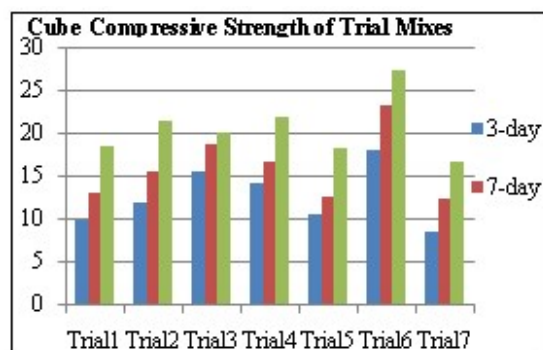


Fig. 4 Average Cube Compressive Strengths of Trial Mixes

B. Second Step: Selecting Mix Proportion for Target Strength

From the above trial mix proportions, mix proportion that gains the target strength is selected based on test results.

➤ Control Design is Trial-6 for Grade 20.

Amount of materials in volume (m³) for trial 6 are shown in Fig. 5

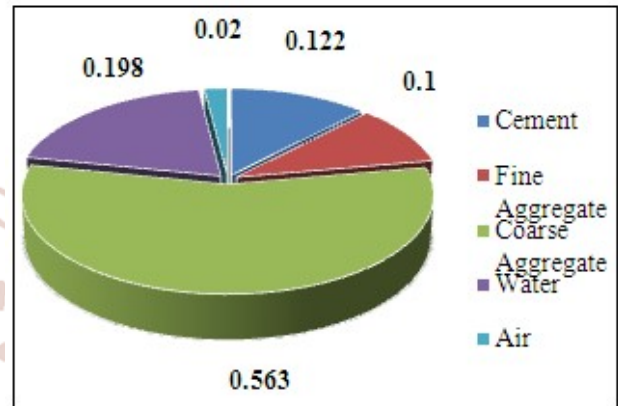


Fig. 5 Volume (m³) of Each Constituent From Trial -6

Amount of materials in normal and various present (10%, 20%, 30% & 50%) of recycled coarse aggregate concrete are shown in Fig. 6.

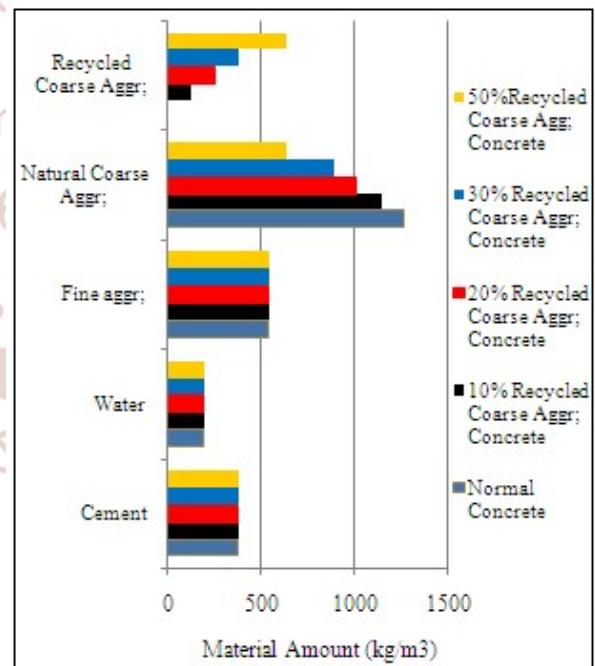


Fig. 6. Amount of materials with respect to Natural and 10%, 20%, 30% & 50% Recycled Coarse Aggregate Concrete

C. Third Step; Establishing Standard Deviations and Comparing Results

In this level, the concrete supplied for this concrete work satisfies the acceptance criteria that there is no

single strength test (28-day average) of two cubes falls below the specified strength (20MPa) by more than 500psi (3.5 MPa) and the average of each set of 3 consecutive strength test results in all types exceeds the specified strength 20MPa.

According to experimental results, all standard deviation values of all various present of recycled coarse aggregate concrete represent good quality control. The less standard deviation value, the better the quality control. Since all in my research are experimented in laboratory, their quality control is good. If quality control cannot be controlled to be good in field, strength will less without getting desired specified strength. In this research, average mean strength of all present of concretes are greater than required average compressive strength. Fig 7 shows the 28-day cube compressive strength of selected present of recycled coarse aggregate concretes and normal concrete for Grade 20 MPa ($f'_{cu} = 25.64$ MPa).

22	19.78	28.6
23	20.58	26.68
24	19.34	27.21
25	20.53	27.32
26	18.56	27.17
27	18.8	27.54
28	20.3	28.53
29	20.98	28.59
30	21.15	27.89

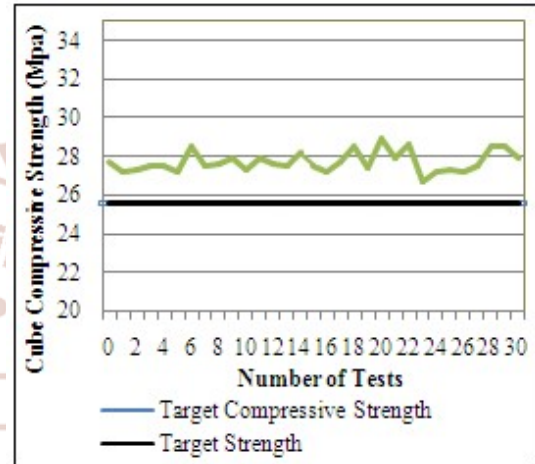


Figure7. 28-Day Average Cube Compressive Strengths of 0% recycled aggregate concrete for Grade-20

Table5. COMPRESSIVE STRENGTH TEST RESULTS FOR MIX PROPORTION OF NORMAL CONCRETE BY VOLUME METHOD (CUBE STRENGTH)

Number of tests	Average Compressive Strength 7days (MPa)	Average Compressive Strength 28days (MPa)
1	18.76	27.3
2	23.59	27.3
3	23.146	27.56
4	21.34	27.53
5	19.53	27.23
6	18.56	28.59
7	21.58	27.56
8	20.34	27.58
9	19.45	27.98
10	17.53	27.34
11	19.42	27.89
12	18.56	27.6
13	21.4	27.56
14	19.34	28.23
15	19.53	27.56
16	18.56	27.17
17	17.23	27.76
18	20.34	28.53
19	19.75	27.45
20	20.15	28.92
21	20.59	27.95

Table6. COMPRESSIVE STRENGTH TEST RESULTS FOR MIX PROPORTION OF 10% RECYCLED AGGREGATE CONCRETE BY VOLUME METHOD (CUBE STRENGTH)

Number of tests	Average Compressive Strength 7days (MPa)	Average Compressive Strength 28days (MPa)
1	20.68	28.78
2	21.58	28.6
3	20.48	29.78
4	23.88	29.21
5	24.88	28.56
6	21.1	29.17
7	21.58	28.76
8	23.88	28.56
9	24.88	28.04
10	22.74	28.92
11	21.68	27.8
12	20.48	26.49
13	19.95	27.05
14	20.02	27.92
15	21.1	27.27
16	20.75	27.23

17	20.85	28.36
18	19.85	29.18
19	19.78	28.36
20	20.23	27.01
21	23.88	28.17
22	23.88	27.95
23	21.1	28.3
24	20.68	29.64
25	21.53	27.38
26	20.88	28.96
27	19.91	27.85
28	20.13	27.85
29	20.54	28.78
30	22.88	27.23

12	19.83	29.6
13	18.51	29.78
14	18.72	30.21
15	28.26	29.94
16	18.71	29.17
17	24.83	28.75
18	24.39	28.56
19	20.91	29.04
20	24.83	28.26
21	25.26	29.8
22	25.26	28.56
23	23.08	29.99
24	19.6	30.56
25	21.58	29.26
26	20.71	28.17
27	20.75	28.89
28	20.51	29.45
29	24.89	30.31
30	22.98	30.86

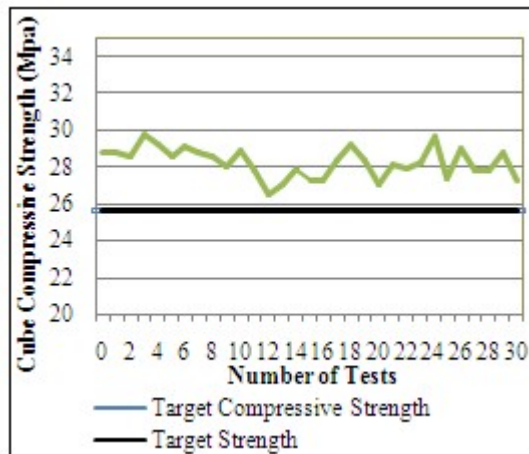


Figure8. 28-Day Average Cube Compressive Strengths of 10% recycled aggregate concrete for Grade-20

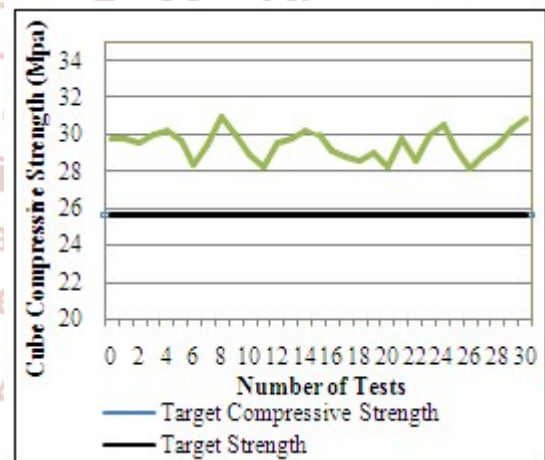


Figure9. 28-Day Average Cube Compressive Strengths of 20% recycled aggregate concrete for Grade-20

Table7. COMPRESSIVE STRENGTH TEST RESULTS FOR MIX PROPORTION OF 20% RECYCLED AGGREGATE CONCRETE BY VOLUME METHOD (CUBE STRENGTH)

Number of tests	Average Compressive Strength 7days (MPa)	Average Compressive Strength 28days (MPa)
1	21.58	29.78
2	24.48	29.6
3	21.58	30.01
4	24.88	30.21
5	21.1	29.62
6	20.71	28.31
7	20.51	29.4
8	24.89	30.92
9	22.98	29.94
10	23.24	28.92
11	23.6	28.26

Table8. COMPRESSIVE STRENGTH TEST RESULTS FOR MIX PROPORTION OF 30% RECYCLED AGGREGATE CONCRETE BY VOLUME METHOD (CUBE STRENGTH)

Number of tests	Average Compressive Strength 7days (MPa)	Average Compressive Strength 28days (MPa)
1	21.58	30.78
2	24.48	29.99
3	21.58	30.92
4	24.88	31.21
5	21.1	30.78
6	20.71	29.56

7	20.51	30.04
8	24.89	31.56
9	22.98	30.94
10	23.24	29.92
11	21.58	29.26
12	24.48	30.6
13	21.58	30.78
14	24.88	31.21
15	21.1	30.94
16	20.71	30.17
17	20.51	29.75
18	24.89	29.56
19	22.98	30.04
20	23.24	29.26
21	21.58	30.8
22	24.48	29.56
23	21.58	30.99
24	24.88	31.56
25	21.1	30.26
26	20.71	29.17
27	20.51	29.89
28	24.89	30.45
29	22.98	31.31
30	23.24	31.86

2	21.58	24.3
3	20.48	23.4
4	23.88	24.56
5	24.88	25.12
6	21.1	24.56
7	21.58	23.46
8	23.88	23.85
9	24.88	24.87
10	22.74	25.44
11	21.68	24.22
12	20.48	23.45
13	19.95	24.56
14	20.02	23.2
15	21.1	24.58
16	20.75	24.17
17	20.85	25.44
18	19.85	24.81
19	19.78	23.54
20	20.23	24.82
21	23.88	23.69
22	23.88	24.6
23	21.1	23.9
24	20.68	24.32
25	21.53	23.99
26	20.88	24.17
27	19.91	25.12
28	20.13	24.46
29	20.54	26.45
30	22.88	25.12

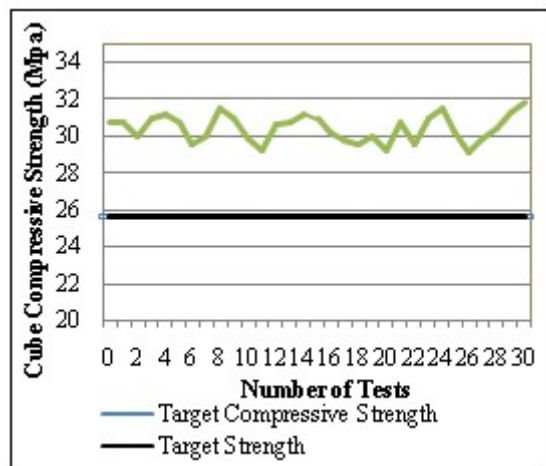


Figure10. 28-Day Average Cube Compressive Strengths of 30% recycled aggregate concrete for Grade-20

Table9. COMPRESSIVE STRENGTH TEST RESULTS FOR MIX PROPORTION OF 50% RECYCLED AGGREGATE CONCRETE BY VOLUME METHOD (CUBE STRENGTH)

Number of tests	Average Compressive Strength 7days (MPa)	Average Compressive Strength 28days (MPa)
1	20.68	24.73

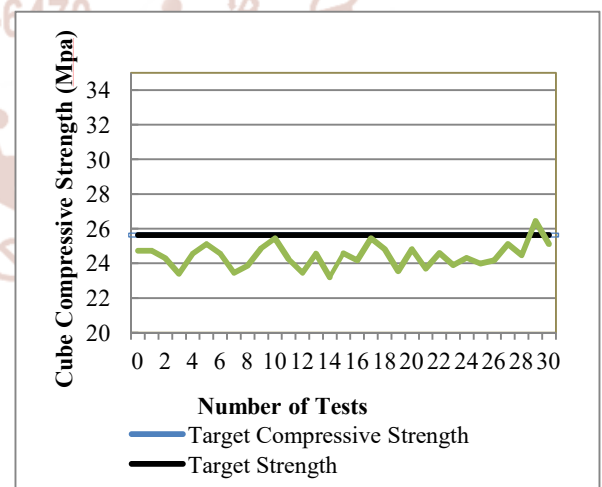


Figure11. 28-Day Average Cube Compressive Strengths of 50% recycled aggregate concrete for Grade-20

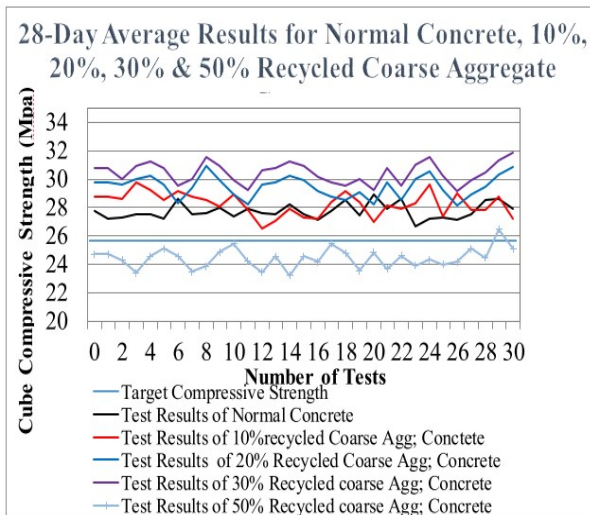


Figure12. Thirty consecutive 28-day test results on 0%, 10%, 20%, 30% and 50% recycled aggregate concrete for Grade-20

Slump Test Results and analysis

Series of test was carried out on the concrete cylinder to obtain the strength characteristics of recycled aggregate for potential application in high strength structural concrete. The slump test indicates a decreasing trend of workability when the percentage of recycled aggregate increased. Table shows the average slump recorded during the test.

Table 10
SLUMP VALUE

Natural Aggregate (%)	Recycled Coarse Aggregate (%)	Slump Value (mm)
100%	0%	98
90%	10%	93
80%	20%	85
70%	30%	79
50%	50%	59

According to the result, the highest slump obtained was 98mm and the lowest slump was 59mm. the average slump for each batch of mix was 80mm. Therefore, target slump had been achieved, where the range if from 50mm to 120mm. the workability was good and can be satisfactory handle for 0% recycled aggregate to 30% recycled aggregate. The workability was very low due to the slump was just 59mm. The reason was because of the high absorption capacity of

recycled aggregate. From the results obtained, it shows that the workability was getting lower when more recycled aggregate were used.

IV. CONCLUSION AND RECOMMENDATION

Based on the results of this investigation which have been discussed above, the following conclusion can be drawn.

The conclusion and achievement of these studies are as:

Total of five batches of concrete mixes required by the scope of the study. According to experimental results, recycled aggregate has the rough textured, angular and elongated particles where natural aggregate is smooth and rounded compact aggregate. The investigation and laboratory testing on recycled aggregate concrete specimens such as compression test. This study is determined the strength characteristics of recycled aggregate for potential application in the structural concrete. Furthermore, with the cheaper price recycled aggregate compared to natural aggregate, the builders can carry out the construction task with lesser material costs. Although recycled aggregate can be applied in the high strength structure, but one issue must not be neglected as recycled aggregate with reduce water content would have low workability. Whenever recycled aggregate is applied, water content in the concrete mix has to be monitored carefully due to the water absorption capacity of recycled aggregate will vary.

It is recommended that concrete made with 30 recycled aggregate performed best in compression and economy among the selected percent of replacement of recycled aggregate.

REFERENCES

- Irving Kett. Engineered Concrete, Mix Design And Test Methods, 2nd Edition.
- Nyi Hla Nge, 2008. Essentials of Concrete Inspection Concrete Mix Designs and Concrete Quality Control. 1st Edition.