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Original Article

Use of Concrete Waste from Industries as an Alternative Material for the Permeable Concrete Production

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Abstract

Every year, tons of demolished concrete waste items dump into the environment from the construction industry. With this process, a massive environmental pollution occurs. Therefore, in this research, the main aim is to find a solution for this environmental pollution by recycling this waste products. The main objective is to recycle these concrete waste materials from industries to use as an alternative material for the production of permeable concrete by maintaining the recommended compressive strength and the recommended permeability. Permeable concrete can be used for the concreting of floor areas like car parks. It provides environmentally friendly way to drain storm water without flooding. For this research, cement to aggregate ratio was used 1:5 and 14mm to 20mm size natural coarse aggregate and concrete waste were used. The control sample was prepared using 100% aggregate. With total amount of aggregate weight 5%, 10%, 20%, 30%, 40% amounts were replaced with the waste concrete after preparing 14mm to 20mm size samples. The slump test, compressive strength test and the permeability tests were conducted. According the results of the 28 days compressive strength test, the control sample was obtained 7.423MPa strength but neither of any other sample could not reached this strength. However, the sample which replaced with the 10% of waste concrete with 90% natural coarse aggregate has obtained 88.683% strength compared to the control sample. According to the permeability results it shows that there will not have a great impact by using concrete waste as an alternative material in permeable concrete production. The results were varied between 15.8L/m^2/s to 15.08L/m^2/s.

Keywords: Permeable concrete, Compressive strength, Permeability, Recycling

Introduction

Concrete comes in a variety of forms, some of them can be utilized for the same purpose. It depends on the purpose which wants to achieve. Permeable concrete is a different type of a concrete mix. This permeable concrete is a high-porosity concrete that allows water and air to pass through it and is used for flatwork applications. The permeable concrete mix mainly consists of cement, coarse aggregate, and water. Fine aggregates are rarely used in permeable concrete (Obla, 2010). The compressive strength and permeability of the permeable concrete mainly depend on the coarse aggregate size (Obla, 2010). Permeable concrete mainly uses in the construction field for parking areas, pedestrian walkways, and for greenhouses.

With the incensement of the construction activity, it causes to the incensement of the generation of construction waste. The traditional method of disposal of the construction waste is by disposed into a land. In a country like Sri Lanka, the land space to dump waste will not be enough in the future. This construction waste disposal causes to a massive environmental pollution. Many countries have already performed researches on this issue and many countries have already applied the solutions in practically to reduce this construction waste generation. However, in Sri Lanka, this method is not yet usually encountered.

There are many advantages in the use of permeable concrete. The permeable concert is a good solution for stormwater management. By using permeable concrete near tree areas, it allows water and air to go to the roots of the trees, and also there are many economic benefits also (Obla, 2010).

In permeable concrete production, coarse aggregate is a main element but when consider about the source depletion of natural resources, must move to use alternative materials.

In order to reduce the environmental pollution, either these construction wastes can be recycled or reused. Advantages by recycling of construction waste can be identified as to reduce the environmental pollution, solution for the resource shortage and permeable concrete becomes economical. Aim of this research has been identified to reduce the generation of concrete waste by producing permeable concrete using demolished concrete waste as an alternative material by replacing 14mm to 20mm coarse aggregate and maintaining the required strength for the permeable concrete.

Methodology

As the first step, the sieve analysis test was conducted for coarse aggregates to determine the particle distribution. Then the single range size natural coarse aggregates and the waste concrete parts were separated using the mechanical sieve shaker. Then the methodology was divided into two investigations. The first stage is to determine the best mix ratio to produce the control sample while achieving the height compressive strength. Therefore, by referring the previous research papers different mix ratios were chosen and from those eighteen cubes were casted for eighteen different mix ratios (Table 1). Seven days compressive strength test was conducted for these eighteen cubes and from the results, the mix ratio which obtained the highest compressive strength was selected for the second stage.

In the second stage, natural coarse aggregates were replaced with concrete wastes in six different ratios (0%, 5%, 10%, 20%, 30%, and 40%) with respect to the selected control sample (Table II). The slump test was conducted for each mix. And, four cubes were casted from each mix for seven days, fourteen days, twenty-eight days for compressive strength tests, and for the permeability test.

A. Mix Proportion

Sample no	Cement :Aggregate (V/V)	Water: Cement (V/V)	Cement	Coarse Aggregate (C/A)	Water
1	1:5	0.25	0.81	6.75	0.205
2	1:5	0.28	0.81	6.75	0.227
3	1:5	0.3	0.81	6.75	0.243
4	1:5	0.32	0.81	6.75	0.259
5	1:5	0.35	0.81	6.75	0.284
6	1:5	0.5	0.81	6.75	0.405
7	1:6	0.25	0.694	6.943	0.174
8	1:6	0.28	0.694	6.943	0.194
9	1:6	0.3	0.694	6.943	0.208
10	1:6	0.32	0.694	6.943	0.222
11	1:6	0.35	0.694	6.943	0.243
12	1:6	0.5	0.694	6.943	0.347
13	1:7	0.25	0.608	7.088	0.152
14	1:7	0.28	0.608	7.088	0.17
15	1:7	0.3	0.608	7.088	0.182
16	1:7	0.32	0.608	7.088	0.194
17	1:7	0.35	0.608	7.088	0.213
18	1:7	0.5	0.608	7.088	0.304

Table I: Material Quantity for 1-18 Sample (Material Weight for 150 *150*150 Sixe one cube)

Sample no	C/A %	Waste concrete %	Water :cement	Cement (kg)	C/A (kg)	Waste concrete (kg)	Water (kg)
19	100	0	0.5	0.81	6.75	0.000	0.41
20	95	5	0.5	0.81	6.41	0.334	0.41
1	90	10	0.5	0.81	6.07	0.675	0.41
22	80	20	0.5	0.81	5.40	1.350	0.41
23	70	30	0.5	0.81	4.72	2.025	0.41
24	60	40	0.5	0.81	4.05	2.700	0.41

Table II: Material Quantity fro 19-24 Sample (Material Weight for 150 *150*150 Sixe one cube) Selected control sample is 1:5 (Cement: Course Aggregate)

B. Permeability Test

To determine the permeability, the following model was made by the candidate.

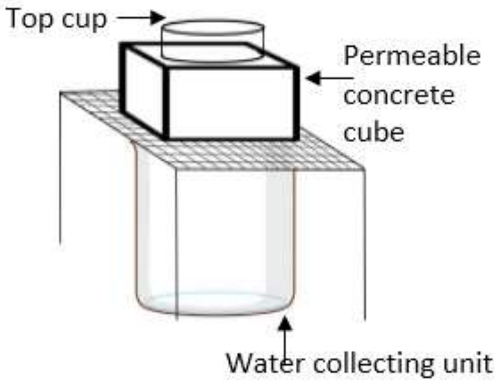

Fig. 1: Model to determine the permeability

Water was poured into the top cup and the stopwatch was started as immediately the water pouring starts. After 2L of water was collected to the water collecting unit the stopwatch stopped and the counted time was written down.

Results and Discussion

A. Sieve Analysis Test

This test was done according to the BS 812-103.1:1985. 50, 37.5, 20, 14, 10, 5, 2.36mm size sieves were used. According to the graph (Figure 1), majority of particles were distributed in between 10mm to 20mm. The results were shown in Table III.

Size (mm)	Mass retained (kg)	Cumulative retained (kg)	Mass passing (kg)	% Passing
50	0	0	1.001	100
37.5	0	0	1.001	100
20	0.058	0.058	0.943	94.21
14	0.545	0.603	0.398	33.76
10	0.356	0.956	0.042	4.2
5	0.037	0.996	0.005	0.5
2.36	0	0.996	0.005	0.5
pan	0.002	0.998	0.003	0.3

Table III : Sieve Analysis Results

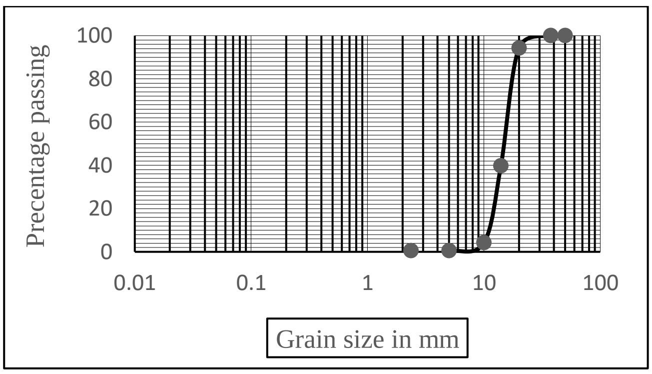

Fig 1: The particle size distribution graph for coarse aggregates

B. Workability

The slump test was conducted to sample 19, 20,21,22,23 and 24. The results of the slump test shown in Figure 2.

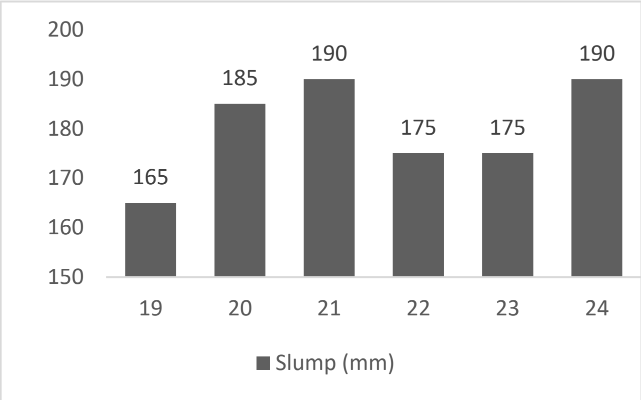

Fig. 2: Slump test results

According to results, the lowest slump value was obtained by the 19 – sample which was made only using natural coarse aggregates. All other five samples which were made with natural coarse aggregates and waste concrete. These test samples obtained the slump value between 175mm to 190mm. These tests were done on a typical windy day. Therefore, slump test results could be affected by the evaporation factor. Also, the slump is dependent on the factors like properties of concrete ingredients. With these results can conclude that the workability of the permeable concrete depends on aggregate types and properties.

C. Compressive Strength

Determine the best mix ratio:
To determine the best mix ratios eighteen samples were casted. The mix properties and the results of the eighteen samples were shown in table IV. These results were obtained by seven-day compressive strength test.

Sample no	Concrete: C/A	Water binder ratio	7days compressive strength (MPa)
1	1:5	0.25	Failed
2	1:5	0.28	0.399
3	1:5	0.3	0.708
4	1:5	0.32	2.966
5	1:5	0.35	5.565
6	1:5	0.5	6.663
7	1:6	0.25	Failed
8	1:6	0.28	0.025
9	1:6	0.3	1.046
10	1:6	0.32	2.504
11	1:6	0.35	2.263
12	1:6		2.42
13	1:7	0.25	Failed
14	1:7	0.28	1.334
15	1:7	0.3	1.451
16	1:7	0.32	1.276
17	1:7	0.35	1.36
18	1:7	0.5	2.469

Table IV: Compressive Strength Results (Sample no 1-18)

According to a previous research, the 28-Days compressive strength typically varies between 2.758MPa to 27.58MPa (Mohammed et al, 2017). Only sample numbers 4, 5, and 6 of this experiment were achieved more than 2.758MPa strength for seven days compressive strength. The height result obtained from the 7-Days compressive strength was 6.663MPa and it was achieved by sample no – 6. Therefore, for the further experiment, this mix ratio was selected to use.

Furthermore, from these results, it can be observed that the compressive strength was varying based on the water-cement ratio. The sample no 1, 7 and 13 were failed due to weak bonds between cement and coarse aggregate as a result of inadequate water amount.

Permeable Concrete Mix with Waste Concrete:
The mix properties were shown in table V and the seven days, fourteen days and twenty-eight days compressive strength test results were shown in Figure 2 with the replaced amount of waste concrete percentages.

Sample no	C/A %	Waste concrete %	Cement: C/A	Water binder ratio
19	100	0	1:5	0.5
20	95	5		
21	90	10		
22	80	20		
23	70	30		
24	60	40		

Table V: Mix Properties

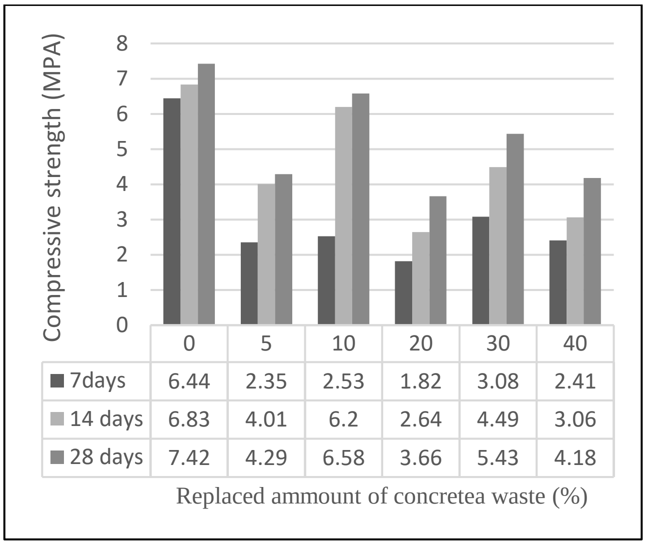

Fig. 2: Compressive strength result (Sample no 19 - 24)

According to the ACI 522 – 06, the minimum compressive strength of the permeable concrete is 2.758MPa and the control sample (sample no – 19) has achieved that value in seven days. However, the highest compressive strength was obtained by the control sample after twenty-eight days of the test. The fourteen days compressive strength of permeable concrete which made with natural coarse aggregate and concrete waste ranging from 2.638MPa to 6.095MPa. The highest compressive strength of these samples was obtained by replacing 10% of concrete waste with natural coarse aggregate. There is a clear difference in the compressive strength between the control sample (sample no – 19) and the other samples which consist of both natural coarse aggregate and concrete waste. The control sample (sample no 19) was obtained a strength of 7.423MPa in twenty-eight days. This was the highest compressive strength value which obtained from all six samples in twenty-eight days. All the other samples which consist of both natural coarse aggregates and waste concrete particles have obtained a value between 3.658MPa to 6.583MPa. For the decrease of the compressive strength, the aggregate size could not be affected because a single size range (14mm to 20mm) of natural coarse aggregate and concrete waste were used in the mixture. Therefore, it can be determined that the compressive strength was decreasing compared to the control sample due to the properties of the concrete waste because in used concrete waste there were aggregate particles and also grout particles. These grout particles could be the major reason to decrease the strength of the samples because it has a lesser strength.

E. Permeability

Figure 3 shows the results of the permeability. The test was performed with a constant water pressure and with a constant falling height. 2L amount of water used for each stage and the top cup area was $6.362 \times 10^{-3}\,m^{2}$. The test was performed three times for each sample and the average time was taken to calculate the permeability rate (k).

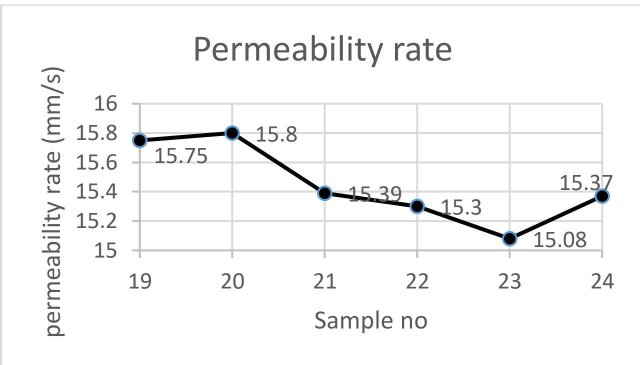

Fig. 3: Permeability rate

The highest permeability rate of 15.8mm/s was obtained by sample no 20. With respect to the sample 19 and 20, there is a decrement of the permeability rate in other four samples but all the samples varied between 15mm/s to 15.9mm/s. According to the results, it can be concluded that either there was variation in the permeability rate of each sample, by using concrete waste as an alternative material in permeable concrete production in the above replacement percentages, it does not affect to the permeability rate because the variation of the above results might occur due to the human error and a significant difference was not observed.

Conclusion

For this study, 14mm to 20mm size natural coarse aggregates and concrete waste aggregates were used with 1:5 cement, coarse aggregate ratio, and with 0.5 water binder ratio. The replacement was done with six different percentages.

According to the obtained results from the slump test can conclude that by using waste concrete particles to the permeable concrete mix can improve the workability of the mix. In this experiment, the control sample was obtained 165mm of slump value but all other samples which consist of both natural coarse aggregates and waste concrete particles have obtained a slum result of more than 165mm. The highest slump value result obtained from this study was 190mm and it was obtained by replacing 10% and 40% of concrete waste with natural coarse aggregate.

The twenty-eight days compressive strength of the control sample was 7.423MPa but neither of any other samples could not achieve this strength in twenty-eight days. According to the ACI 522-06 standards, the compressive strength of the permeable concrete is varying between 2.758MPa 28MPa. However, in this research, every sample have achieved a strength beyond the minimum value of the ACI 522-06 standards. The samples which made by replacing the natural coarse aggregates with the concrete waste were obtained a compressive strength between 3.658MPa to 6.583MPa in twenty-eight days. From those samples sample-no 21 which consists of 90% of natural coarse aggregates and 10% of concrete waste was obtained the highest compressive strength (6.53MPa) after the control sample and it was 88.683% of strength achievement with respect to the control sample.

The obtained results of the permeability rate were varied between 15.8L/m^2/s to 15.08L/m^2/s. the obtained results were vary between a small ranges. Because of that it can be concluded by using concrete waste as an alternative material with the above percentage amounts it will not affect to the permeability rate much. The control sample has achieved 15.75L/m^2/s of permeability rate. 15.8L/m^2/s is the highest permeability rate that could be achieved from this study. It was achieved by using 5% of concrete waste by replacing natural coarse aggregates. The sample no 21 has obtained 15.39L/m^2/s permeability rate.

This study shows that by replacing concrete waste with natural coarse aggregates to produce permeable concrete it will affect to the compressive strength negatively but according to the workability and the permeability, the use of concrete waste for the permeable concrete mix is suitable. However, according to this study, 10% of concrete waste is the most appropriate amount to replace the natural coarse aggregate for permeable concrete production because according to the results of this research it was obtained 88.683% of strength with relevant to the control sample, 190mm of slump and 15.39L/m^2/s of permeability rate.

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