Utilization of Pervious Concrete as Pavement Material

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Abstract— Pervious concrete has been gaining a lot of attention. Various environmental benefits such as controlling storm water runoff, restoring groundwater supplies, and reducing water and soil pollution have become focal points in many jurisdictions worldwide. In the present work three different types of mixes have been prepared mix#1, mix#2 and mix#3. In mix#1percentage of fine aggregate such as sand is kept zero, concrete mixes are prepared without any sand and varying water cement ratio from 0.3 to .45. Mix#2 have been prepared by taking 5% sand and varying water cement ratio. In mix#3 concrete mixes class F fly ash has been added in different proportions with 5% sand and variable water cement ratio. Compressive strength of prepared concrete cubes have been investigated for assessing the significance of pervious concrete.

Keywords: Concrete; Permeability; Strength; Pavement; Pervious

I. INTRODUCTION

Pervious concrete is a novel pavement that is being developed to aid in preventing storm water-related environmental problems. Pervious concrete has a network of interconnected voids, which allow water filtration to the sub base below. Limited studies indicate that a pervious concrete surface can have more elevated temperatures than those of similar traditional impervious pavements, but also that temperatures are lower under the pavements. Though pervious concrete can be used for various applications, its primary drawback is low compressive strength. Since the paste layer between aggregates is thin, it cannot provide sufficient compressive strength compared with traditional concrete. Thus, the usage of pervious concrete was limited in high volume pavements. Instead, pervious concrete was applied in parking lots, which do not require high compressive strength.

To broaden the application of pervious concrete through increased compressive strength, several factors should be considered such as the strength of paste, thickness of paste coating the aggregates, and the interface between aggregate and paste.

Using smaller coarse aggregate and mineral admixture is suggested as a suitable means to obtain higher strength with pervious concrete (Schaefer et al., 2006).

Zouaghi et al. (2000) introduced the relationship between compressive strength and unit weight. The mixtures were batched with water-cement ratio of 0.25. Since the unit weight of pervious concrete is directly linked to the percentage of voids in the material, it is not surprising that the compressive strength is linearly proportional to unit weight while inversely proportional to void ratio.

He also developed the relationship between compressive strength and cement content in water curing at 28 days. The compressive strength increases exponentially as cement content increases. Zouaghi et al. (2000) explained that the volume of cement paste between aggregate particles controls bonding so that volume of cement paste strongly influences the compressive strength of pervious concrete.

Wanielista and Chopra (2007) summarized previous studies on compressive strength of pervious concrete and stated that researchers agreed that factors affect pervious concrete compressive strength included: A/C ratio, W/C ratio, coarse aggregate size, compaction, and curing. “Researchers disagree as to whether pervious concrete can consistently attain compressive strengths equal to conventional concrete”. Meininger, 1988 found that mixtures including 10~20 % sand showed improved compressive strength and reduced air content versus those mixtures excluding sand entirely. Added sand fills air voids, which increases density and compressive strength.

Schaefer et al (2006) shows the influence of silica fume on the compressive strength of pervious concrete. Counter to intuition, the addition of silica fume resulted in a reduction in the seven-day compressive strength by 44%. He explained that the silica fume influences the void ratio, and that the decrease of strength was due to increased void ratio caused by the presence of the silica fume. However, this report did not mention the usage of water-reducing admixtures in the mixtures.

Fly ash can be used in pervious concrete as a substitute for a portion of the cement. Based on the publication of Headwaters Resources (2005), up to 20% percentage of Portland cement in pervious concrete can be replaced by fly ash. The usage of fly ash can help to improve the workability of the low slump mix so as to benefit the placing and mixing process.

Fibres can be used in pervious concrete if higher compressive strength is required. Experiments by Schaefer et al. (2006) showed that adding latex fibres increases strength of pervious concrete; Yang and Jiang used organic polymer fibres and found that they enhanced the strength of pervious concrete greatly. However, they typically also cause a decrease in hydraulic conductivity.

The most distinguished feature of pervious concrete is its high permeability, which is a measure of the ease by which fluid may flow through the material under a pressure gradient. Void ratio of typical pervious concrete ranges from 14% to 31% and permeability ranges from 0.0254 to 0.609 cm/sec (Schaefer et al., 2006).

Wang et al.2006, studied pervious concrete with a fine aggregate amount of 7% of total aggregate by weight. Wang’s tests illustrated that the compressive strength and freeze-thaw ability of pervious concrete were significantly improved with addition of fine aggregate while maintaining adequate water permeability. However, the amount of fine aggregate is recommended to be limited within 7% of the total aggregate by weight so that permeability is satisfied.

Water is a crucial component in pervious concrete. Wanielista and Chopra (2007) discussed the importance of adding appropriate amount of water in pervious concrete mix. Enough water should be added so that cement hydration is thoroughly developed. However, too much water will settle the paste at the base of the pavement and clog the pores. Meanwhile, too much water increases the distance between particles, causing higher porosity and lower strength.

Wanielista and Chopra11 stated that "the correct amount of water will maximize the strength without compromising the permeability characteristics of the pervious concrete."

Based on previous studies two permeability tests, the falling head tests and constant head tests were both used to measure the hydraulic conductivity of pervious concrete samples taken from sites or made in labs. Some lab testing also simulated the conditions of pervious concrete in actual applications. Experimental and field tests found that the typical permeability is larger than 0.1cm/sec or 140in/hour10, which is considered as the lower limit of pervious concrete permeability.

McCain and Dewoolkar (2009) published a study on pervious concrete, in which falling head permeability tests were carried out on three sets of specimens with diameter 3 inches, 4 inches, and 6 inches, respectively. The falling head permeability tests also simulated the situation of winter surface, which was covered by sand-salt mixture. The results showed that the hydraulic conductivity ranged from 0.68cm/s to 0.98cm/s.

Crouch et al. (2009) used a triaxial flexible-wall constant head permeameter to measure the permeability of pervious concrete in the range of 1to14,000 inches/hour(0.001 to 10 cm/sec). Crouch et al. found the constant head permeability was a function of three factors: effective air void content, effective void size, and drain down, where "drain down is a result of too much paste for the applied compacting effort or the paste being too fluid", sealing the lower surface of pervious concrete sample.

II. EXPERIMENTAL PROGRAMME

Three different types of mixes have been prepared mix#1, mix#2 and mix#3. In mix#1percentage of fine aggregate such as sand is kept zero, concrete mixes are prepared without any sand and varying water cement ratio from 0.3 to .45. Mix#2 have been prepared by taking 5% sand and varying water cement ratio. In mix#3 concrete mixes class F fly ash has been added in different proportions with 5% sand and variable water cement ratio.

Sample	Cement (Kg/m^3)	Sand (Kg/m^3)	Coarse Aggregate (Kg/m^3)	W/C ratio
M1-01	430	0	1940	0.3
M1-02	430	0	1940	0.35
M1-03	430	0	1940	0.4
M1-04	430	0	1940	0.45

Table 1: Mix # 1 pervious concrete with 0% sand

Sample	Cement (Kg/m^3)	Sand (Kg/m^3)	Coarse Aggregate (Kg/m^3)	W/C ratio
M2-01	430	98	1843	0.3
M2-02	430	98	1843	0.35
M2-03	430	98	1843	0.4
M2-04	430	98	1843	0.45

Table 2: Mix # 2 pervious concrete mix with 5% sand

Sample	Cement (Kg/m^3)	Sand (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Class F Fly Ash (Kg/m^3)	W/C ratio
M3-01	387	98	1843	43(10%)	0.3
M3-02	343	98	1843	86(20%)	0.3
M3-03	300	98	1843	129(30%)	0.3
M3-04	264	98	1843	171(40%)	0.3
M3-05	387	98	1843	43(10%)	0.35
M3-06	343	98	1843	86(20%)	0.35
M3-07	300	98	1843	129(30%)	0.35
M3-08	264	98	1843	171(40%)	0.35
M3-09	387	98	1843	43(10%)	0.4
M3-10	343	98	1843	86(20%)	0.4
M3-11	300	98	1843	129(30%)	0.4
M3-12	264	98	1843	171(40%)	0.4
M3-13	387	98	1843	43(10%)	0.45
M3-14	343	98	1843	86(20%)	0.45
M3-15	300	98	1843	129(30%)	0.45
M3-16	264	98	1843	171(40%)	0.45

Table 3: Mix # 3 Mix with 5% sand and partial replacement of cement with Fly ash

Sample	W/C ratio	Compressive Strength (Mpa)	
		7 days	28 days
Mix#1			
M1-01	0.30	6.53	10.3
M1-02	0.35	6.29	9.72
M1-03	0.40	5.48	8.04
M1-04	0.45	4.33	6.92
Mix#2			
M2-01	0.30	8.36	14.07
M2-02	0.35	8.22	13.80
M2-03	0.40	7.55	11.37

M2-04	0.45	6.90	10.08
Mix#3			
M3-01	0.30	7.59	12.06
M3-02	0.30	7.32	12.58
M3-03	0.30	6.50	13.33
M3-04	0.30	6.68	11.92
M3-05	0.35	7.21	11.46
M3-06	0.35	6.88	11.90
M3-07	0.35	6.14	12.43
M3-08	0.35	5.78	12.08
M3-09	0.40	6.95	9.77
M3-10	0.40	6.56	10.45
M3-11	0.40	5.79	10.97
M3-12	0.40	5.03	10.34
M3-13	0.45	5.94	7.45
M3-14	0.45	5.32	8.03
M3-15	0.45	4.85	8.68
M3-16	0.45	4.39	7.95

Table 4: Results of Compressive Strength Test

III. CONCLUSIONS

For comparing the pervious concrete with normal concrete several properties such as density, porosity, compressive strength and permeability have been studied. Following are the findings of the present research –

1) By capturing rainwater and allowing it to seep into the ground, pervious concrete is helpful in recharging groundwater.
2) A pervious concrete mixture contains little or no sand, creating a substantial void content.
3) Water is a crucial component in pervious concrete. Enough water should be added so that cement hydration is thoroughly developed. However, too much water will settle the paste at the base of the pavement and clog the pores.
4) This has been revealed from above table that compressive strength of prepared concrete mixes is low when compared to ordinary concrete.
5) With the increase of water cement ratio, in concrete mixes#1 and #2 7 and 28 compressive strength decreases.
6) In concrete mixes of category mix#3, 7 days compressive strength decreases with the increase in w/c ratio. However, 28 compressive strength increases with the increase in Marble powder content upto 30% and then decreases after 30%.
7) It has been observed that permeability of pervious concrete mixes reduces by increasing the w/c ratio.

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