Studies on Effect of Fly-Ash and Rice Husk Ash on Strength Characteristics of Pavement Quality Concrete

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Abstract— There is growing interest in the construction of concrete pavements, due to its high strength, durability, better serviceability and overall economy in the long run. The thrust nowadays is to produce thinner and green pavement sections of better quality, which can carry the heavy loads. The high strength is a concrete having compressive strength greater than 40MPa, made of hydraulic cements and containing fine and coarse aggregates; the present study aims at, developing pavement quality concrete mixtures incorporating fly ash and rice husk ash partial replacement of cement. The aim is to the design of slab thickness of PQC pavement using the achieved flexural strength of the concrete mixtures. In this study, compressive and flexural strength for pavement quality concrete mixtures for different percentage replacement of cement are reported. It is found that it is possible to achieve savings in cement by replacing it with fly ash. This study also shows that in view of the high flexural strength, high values of compressive strength the 20% replacement of cement with flyash is ideal for design of Pavement Quality Concrete (PQC).

Key words: High Strength Concrete, Pavement Quality Concrete (PQC), Flexural Strength, Compressive Strength, Fatigue, Partial Replacement

I. INTRODUCTION

Concrete is basically a mixture of two components: Aggregates and Paste (or binder). The paste comprises cement, supplementary cementing or supplementary cementitious materials and water. It binds the aggregates (sand and gravel or crushed stone) into a rock-like mass. The purpose is to fill up the voids and come with a dense and strong materials. The fine aggregates fill up the voids formed by the coarse aggregates; and cement fills up the voids of the fine aggregates. Lesser the voids more would be the strength of concrete. The chemical reaction of the cementitious materials and water, is called hydration. It is the process by which paste hardens and binds the aggregates.

The high modulus of elasticity and rigidity of concrete compared to other road making materials provides a concrete pavement with a reasonable degree of flexural or beam strength. This property leads to a wider distribution of externally applied wheel loads. This in turn limits the pressures applied to the sub-grade. The major portion of the load carrying capacity of a concrete pavement is therefore provided by the concrete layer alone. Its thickness is primarily determined by the flexural strength of the concrete and by the magnitude of the wheel or axle loads. Sub-bases do not make a significant structural contribution to concrete pavements.

By contrast, a flexible pavement is a structure comprising a number of layers of bound or unbound materials which can have a variety of surface treatments and in which the intensity of stresses from traffic loads requires a lot more depth to diminish. Both the base and sub-base layers in flexible pavements contribute significantly to the structural properties of the pavement. Concrete acts more like a bridge over the sub-grade. Much less pressure is placed on the material below the concrete, than bituminous pavements. Since the first strip of concrete pavement was completed in 1893, concrete has been now extensively used for paving the highways and airports as well as business and residential streets.

A. *Concrete Pavement*

A concrete pavement is a structure comprising of a layer of Ordinary Portland Cement Concrete which is usually supported by a sub-base layer on the sub-grade. Concrete pavements may be either unreinforced (plain) or reinforced depending on how the designer prefers to control shrinkage cracking, which will occur in the pavements.

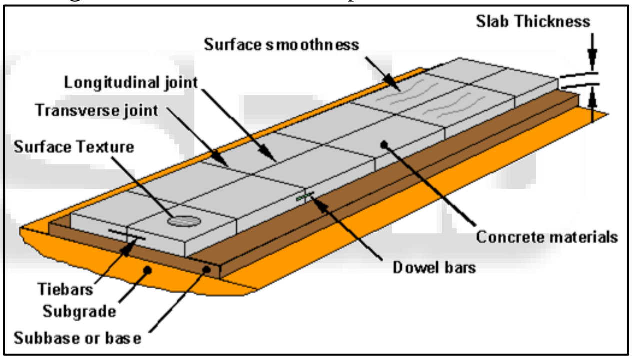

Fig. 1: Concrete Pavements

Types of Concrete Pavements

- Jointed Plain (unreinforced) Concrete Pavement – JPCP
- Jointed Reinforced Concrete Pavement – JRCP
- Continuously Reinforced Concrete Pavement – CRCP
- Steel Fiber Reinforced Concrete Pavement – SFCP

B. *Benefits of Concrete Pavements*

The beneficial attributes of concrete pavements can be summarized as below:

- Long lasting – 40 year Design Life
- Heavy duty Pavements have generally the lowest cost.
- Pavement maintenance costs are up to 10 times cheaper than the same for flexible pavements.
- Minimum maintenance requirements result in less traffic disruption, minimum congestion time and results Work Zone safety.
- Lowest Life Cycle Cost of all Heavy Duty pavements and highest salvage value.
- Can be constructed over poor sub-grades.
- Thinner overall pavement thickness = lower consumption of raw materials.
- Resistant to abrasion from turning actions.

- Not susceptible to high or low temperatures.
- Not affected by weather, inert to spills and fire.
- Completely recyclable.
- High abrasion durability.
- Profile durability.
- Safer because it maintains its shape, no deformation, resistance to rutting and potholes and excellent skid resistance.
- High sustainability rating through use of local materials.
- Use of waste products like fly-ash and slag.
- Riding quality does not deteriorate.
- Can be slip formed up to 13 m.
- Saving of fuel costs of at least 1.1% over asphalt (VTI Sweden – 1.1% 2008, NRC Canada – 0.8 to 6.9%).
- Light colour enhances night visibility.
- Less energy for street lighting (up to 30%).
- Less heat-sink effect (avg. 8°C lower than asphalt = less air conditioning energy in urban areas).
- Longitudinal diamond grinding, called Next Generation Concrete Surfacing (NGCS) now provides quieter surface than for example Open Graded Asphalt overlay.

C. Demerits of Concrete Pavements

- They involve heavy initial investment.
- Lots of joints are need to provide which prove additional places of weakness.
- 28 days curing is required after completion before they can be opened to traffic.
- It is not possible to adopt stage construction programmed in these roads.
- Cement concrete road surface after some time of use becomes very smooth and slippery.
- It is a noisy road, as bullock carts or steel tyred vehicles cause lot of noise while moving on them.

II. LITERATURE REVIEW

The relevant literature pertaining to the use of Fly-Ash(FA) and Rice Husk Ash(RHA) in concrete carried out in India and abroad has been reviewed and presented as under:-

A. Fly-Ash

1) Fresh Properties

Low calcium Class F fly ash normally acts as a fine aggregate of spherical form in early stages of hydration whereas high calcium Class-C fly ash may contribute to the early cementing reactions in addition to its presence as fine particulate in the concrete mix. Hydration of cement is an exothermic reaction and the released heat causes a rise of temperature of fresh concrete.

Brown, J.H. (1982) in his paper " The strength and workability of concrete with Fly Ash substitution" conducted several studies with fly ash replacing cement and fine aggregate at levels of 10-40% by volume. He concluded that for each 10% of ash substituted for cement, the compacting factor or workability changed to the same order as it would by increasing the water content of the mix by 3-4%. When fly ash was substituted for sand or total aggregate, workability increased to reach a maximum value at about 8% ash by volume of aggregate. Further substitution caused rapid decrease in workability.

Gebler and Klieger, (1983) in their paper "Effect of fly ash on the air void stability of concrete" investigated the requirements of Air Entraining Agent (AEA) for Class-C and Class-F fly ashes. They reported that (1) concretes made with Class C fly ash generally require less AEA than those made with Class F fly ashes; (2) for 6% air content in concrete, the AEA varied from 126 to 173% for fly ashes having more than 10% CaO, whereas it was in the range of 177 to 553% for fly ashes containing less than 10% CaO; and (3) increase in both total alkalies and SO3 contents in fly ash affect the air entrainment favorably. A concrete containing a Class F fly ash that has relative high CaO content and less organic matter or carbon tends to be less vulnerable to loss of air.

Owens, (1989) in his paper" Fly ash and its usage in concrete" reported that with the use of fly ash containing large fraction of particles coarser than 45µm or a fly ash with high amount of unburned carbon, exhibiting loss on ignition more than 1%, higher water demand was observed.

Sivasundram, et al. (1990) in their paper " Selected properties of high volume fly ash concretes" investigated the setting time of high-volume fly ash concrete mixes, and concluded that the initial setting time of 1.50 hours was comparable to that of the control concrete, whereas the final setting time was extended by about 3 hours as compared to that of the control concrete.

2) Hardened Concrete

Carette and Malhotra, (1983) in their research paper "Characterization of Canadian fly Ashes and their Performance in Concrete" studied the effect of Canadian fly ashes on the compressive strength of concrete mixes. Cement was replaced with 20% fly ash in all the mixes. Compressive strength was measured up to the age of 365 days. It was seen that compressive strength continued to increase with age, indicating pozzolanic action of fly ashes.

Joshi and Lohtia, (1993) in their paper "Effects of premature freezing temperatures on compressive strength, elasticity and microstructure of high volume fly ash concrete" tested a large number of fly concrete mixes made by using three different fly ashes containing about 10% calcium oxide. The replacement level varied between 40 and 60% by weight of cement. The mixes were super-plasticized and air-entrained to obtain 100 to 120 mm slump and 6 ± 1% air content. The cementitious material content varied from 380 to 466 kg/m^3, water to cementitious material ratio from 0.27 to 0.37, coarse aggregate ranged from 1,012 to 1,194 kg/m3, and fine aggregate or sand varied from 712 to 643 kg/m3. They reported that (1) at 7 days, the fly ash concretes obtained strength between 27.9 and 41.0 MPa compared to 44.1 MPa of control concrete. However at the age of 28 days, the fly ash concretes developed strength varying from 37.6 to 50.7 MPa against 58.7 MPa for control concrete. At 120 days, strength of fly ash concrete ranged from 54.8 to 74.6 MPa whereas it was 74.6 MPa of control concrete.

3) Durability Properties

Ho and Lewis, (1983) in their paper " Carbonation of concrete incorporating fly ash or a chemical admixture", investigated the carbonation rates of three types of concrete mixes (1) plain concrete; (2) the second containing a water reducing admixture; and (3) third in which fly ash was used to replace part of the cement. Accelerated carbonation was induced by storing specimens in an enriched CO2 atmosphere (4%) at 20_C and 50% RH for 8 weeks. One week under these conditions was approximately equivalent to 1 year in a normal atmosphere (0.003% CO_2). They concluded that (1) Concretes having the same strength and water-to-cement ratio do not necessarily carbonate at the same rate; (2) concrete containing fly ash showed significant improvement in quality when curing was extended from 7 to 90 days. This improvement was much greater than that achieved for the plain concrete; and (3) depth of carbonation is a function of the cement content for concretes moist-cured for 7 days. However, with further curing to 90 days, concrete containing fly ash showed a slower rate of carbonation as compared to plain and water-reduced concretes.

B. Rice Husk Ash

1) Fresh Properties

Zhang and Malhotra, (1996) in their paper " High-performance concrete incorporating rice husk ash as a supplementary cementing material" investigated the influence of RHA on the air-entraining admixture (AEA) requirement of concrete mixtures made with RHA (0, 5, 8, 10 and 15%) as partial replacement of cement. It was observed that AEA requirement increased with the increase in RHA content possibly because of high specific surface area of RHA in comparison to cement.

Bui et al. (2005) in their paper “Particle Size Effect On The Strength Of Rice Husk Ash Blended Gap-Graded Portland Cement Concrete.” investigated the workability of concrete and super plasticizer content to be added when cement is replaced by RHA in gap graded concrete. Two kinds of an ordinary Portland cement were employed, i.e., PC30 and PC40. Twenty four concrete mixtures were made, 12 mixtures for each of the two kinds of PC. Three levels of the water to binder ratio were investigated, i.e., 0.30, 0.32 and 0.34. The mixtures with water to binder ratio of 0.30 were made with a binder content of 550kg/m3 concrete. The binder content of all other mixtures was500kg/m3. Rice husk ash was used to replace 10%, 15% and 20% by mass of PC. The super plasticizer was added to all mixtures for obtaining high workability. In the mixtures with water to binder ratio of 0.34, the amount of super plasticizer was kept constant to investigate the influence of RHA on workability All the mixtures have high slump values and they all are stable. A reduction in slump of the blended concrete mixtures is found when a part of the PC is replaced by RHA at equal super plasticizer content. This decline in slump increases with replacement level of cement by RHA. The finer cement (PC40) requires a higher super plasticizer dosage for achieving equal slump. For the plain (PC30) concrete, a super plasticizer dosage of 1% by mass of the cement is required to attain a slump of 210mm. In case of the finer cement (PC40), the super plasticizer dosage is increased to 1.28% for obtaining approximately the same slump.

Ganesan et al. (2008) in his paper "Rice husk ash blended cement: assessment of optimal level of replacement for strength and permeability properties of concrete" reported the effect of cement replacement with RHA on the consistency and setting times of cement. Percentages of cement replacement were 0, 5, 10, 15, 20, 20, 25, 30, and 35. They observed that consistency of control mixture was approximate 32%, however, water required for standard consistency linearly increased with an increase in RHA content. The standard consistency with 35% RHA content was 44%. As ashes are hygroscopic in nature and the specific surface area of RHA is much higher than cement, it needs more water. The results of initial and final setting times are shown in Fig. 5.10. It was observed that up to 15%, RHA level increased the initial setting time. At 20, 25, 30 and 35%, there was reduction in initial setting time. The initial setting time measured for RHA blended cements up to 35% was higher than that of control OPC. On the other hand, the final setting time decreased with the increase in RHA up to 35%.

Khani et al. (2009) in their paper “The Effect of Rice Husk Ash on Mechanical Properties and Durability of Sustainable Concretes." studies the surface water absorption in rice husk ash concrete in comparison to controlled concrete. A total of 4 concrete mixtures were made; one corresponding to a control concrete (CTL) and three others with 7%, 10% and 15% RHA Replaced with cement by weight. Concrete cubes of 100×100×100 mm dimension were cast for water penetration tests. In this test, water was forced into the concrete samples from one side for three days and under constant pressure of 0.5 MPa. Then, the samples were split in a plane parallel to the direction of water penetration, and the greatest depth of water penetration into the concrete sample was measured. Depth of water penetration of concrete specimens decreased significantly with an increasing in RHA content and curing period.

2) Hardened Properties

Zhang et al. (1996) in their paper " Rice husk ash blended cement: assessment of optimal level of replacement for strength and permeability properties of concrete", this paper presents an experimental study on the effects of the incorporation of rice-husk ash (RHA) in cement concrete on the compressive strength of concrete is discussed, and the results are compared with those obtained with the control Portland cement concrete and concrete incorporating silica fume. Three types of mixes were made. The RHA and the control concrete had similar one-day strengths, but the RHA concrete had Somewhat higher strength than the control concrete thereafter up to 180 days. Compared with the silica fume concrete, the compressive strength of the RHA concrete was lower up to 28 days, but similar at 90 and 180 days.

Bui et al. (2004) in their paper "Concrete Incorporating Rice-Husk Ash: Compressive Strength and Chloride-Ion Penetrability " investigated the compressive strength of the mix when cement is replaced by RHA in gap graded concrete. Two kinds of an ordinary Portland cement were employed, i.e., PC30 and PC40. Twenty four concrete mixtures were made, 12 mixtures for each of the two kinds of PC. Three levels of the water to binder ratio were investigated, i.e., 0.30, 0.32 and 0.34. The mixtures with water to binder ratio of 0.30 were made with a binder content of 550kg/m3 concrete. The binder content of all other mixtures was 500kg/m3. Rice husk ash was used to replace 10%, 15% and 20% by mass of PC. Cubes of 100mm size were cast and compacted in two layers on a vibrating table. Compressive strength of the concretes was determined at 1, 3, 7, 28 and 90 days, using three specimens per test. Compressive strength of RHA blended concrete is higher than those of the plain cement concrete, irrespective of water to binder ratio and age. Compressive strength increases with blending percentage at corresponding values of water to binder ratio and age. Higher contents of RHA can be used without a strength loss. This will, however, cause an increase in the super plasticizer dosage required. The RHA blending increases the relative strength at all ages, however, most pronounced is the increase in the first 7 days. Concretes made with the fine cement (PC40) revealed considerable higher strengths than those made with the coarser cement (PC30). Partial cement replacement by RHA also significantly improved strength, although the effect was pronounced only at later ages. The compressive strength values of RHA blended concrete to be lower than those of plain cement concretes at ages up to 3 days. However, at later age, say from 7 days onward, the blended concretes have higher compressive strength than those of the control concretes.

Khani et al. (2009) in their paper "The Effect of Rice Husk Ash on Mechanical Properties and Durability of Sustainable Concretes", investigated split tensile strength of the concrete incorporating rice husk ash of 7%, 10% and 15% by weight of cement. Two 150 X 300 mm cylindrical concrete specimen was prepared for the test. Concrete containing RHA has a greater splitting tensile strength than that the control concrete at all ages. It is clear that, as the amount of RHA increases, the tensile strength increases up to 20%. For instance, at 90 days the 15%RHA concrete had a tensile strength of 5.62 MPa compared with 4.58 MPa for the control concrete. Concrete cubes of 100×100×100 mm dimension were cast for compressive strength. RHA concrete had higher compressive strengths at various ages and up to 90 days when compared with the control concrete. The results show that it was possible to obtain a compressive strength of as high as 46.9 MPa after 28 days. In addition, strengths up to 63.2 MPa were obtained at 90days.

III. MATERIAL

- Cement
- Aggregates
- Fly-ash
- Rice Husk Ash
- Super-Plasticizer

IV. MIX DESIGN OF PAVEMENT QUALITY CONCRETE (PQC)

A. *Step 1: As per clause 602 of MORT&H Specification*

- Cement – 43 grade OPC as per IS 8112 as per 602.2.2
- Coarse aggregate – 20 mm and 10 mm as per 602.2.4
- Los angles Abrasion value not greater than 35%
- Impact value not greater than 30%
- Fine aggregate – Natural sand as per IS 383
- Admixture – Conplast AEA (if required)
- Air entrained concrete 5% maximum (optional)

B. *Step 2: Design Parameter*

- Characteristics flexural strength required at 28 days = 4.5 N/mm2
- Maximum water cement ratio = 0.40 as per clause 602.3.3.1
- Maximum size of coarse aggregate = 25 mm
- Degree of quality control = Good
- Minimum cement content = 350 kg/m3 as per clause 602.3.2
- Maximum cement content = 425 kg/m3 as per clause 602.3.2

Mean Target Flexural strength (MPa)	Max. Size of Agg. (mm)	Mix (C: FA: CA-I: CA-II)	W/C Ratio	Materials for 1 m3 in kg				
				Water	Cement	F.A	C.A-I (20mm)	C.A-II (10mm)
4.5	20	1 : 1.828 : 1.936 : 0.83	0.4	156	390	713	755.30	323.70
5	20	1 : 1.815 : 1.921 : 0.82	0.35	140	400	726	768.60	329.40
5.5	20	1 : 1.805 : 1.908 : 0.82	0.3	123	410	740	782.60	335.40

Table 1: Mix Design of Pavement Quality Concrete

V. OBSERVATION

The present study was undertaken to investigate the compressive strength and flexural strength of concrete with different levels of replacement of cement with fly ash and rice husk ash in concrete mix. Cement was partially replaced by fly ash at three different levels of replacement i.e. 10%, 20% and 30% and same with rice husk ash. Concrete mixtures were also cast with combined replacements of flyash and rice husk ash. Tests were performed after 7 and 28 days of curing of concrete. Cubes and beams were prepared for determining compressive strength and flexural strength of concrete with different water-cement ratio as 0.30, 0.35 and 0.40 for minimum required flexural strengths of 5.5 N/mm2 5 N/mm2 4.5N/mm2, respectively. Super-plasticizer was used in all the mixes at 1% level by weight of cementitious material.

w/c = 0.4	7days			28days		
	Load (KN)	Average (KN)	fc (MPa)	Load (KN)	Average (KN)	fc (MPa)
Controlled (FR00)	863.7 889.9 825.6	859.73	38.21	1170 1246 1027	1147.66	51.01
10% F.A. (FR10)	809.9 861.4 873.6	848.33	37.70	1132 1075 1097	1101.33	48.94
20% F.A. (FR20)	791.7 729.2 799.1	773.333	34.3703	1034 1058 956.3	1016.1	45.16
30% F.A. (FR30)	638.1 660.8 672.3	657.066	29.2029	926.5 931.9 950	936.133	41.6059
10% R.H.A. (FR01)	496.3 541.6	508.67	22.60	731.8 713	734.36	32.63

	488.1			758.3		
20% R.H.A (FR02)	477.8 432.8 411.2	440.6	19.5822	621.2 655.9 661.3	646.133	28.7170
30% R.H.A. (FR03)	347.7 371.4 384.6	367.9	16.3511	560.1 549.7 617.9	575.9	25.5955
10% F.A 10%R.H.A. (FR11)	468.7 450.9 499.1	472.9	21.0177	689.6 765.7 728.5	727.933	32.3525
20% F.A. 10% R.H.A (FR21)	357.2 381.3 371.1	369.87	16.43	563.8 657.3 639.8	620.3	27.5688
10% F.A 20% R.H.A. (FR12)	343.6 358.1 376.3	359.33	15.97	596.2 572.3 579.2	582.56	25.89

Table 2: Compressive Strength of 4.5 MPa flexure Design (w/c = 0.4)

w/c = 0.4	7days			28days		
	Load (KN)	Average (KN)	fc (MPa)	Load (KN)	Average (KN)	fc (MPa)
Controlled (FR00)	907.2 980.5 873.8	920.5	40.911	1246 1289 1304	1279.66	56.874
10% F.A. (FR10)	822.5 851.9 878.4	850.933	37.819	1058 1221 1081	1120	49.78
20% F.A. (FR20)	760.7 788.9 825.4	791.666	35.185	1056 1108 1086	1083.33	48.148
30% F.A. (FR30)	767.4 730.2 705.8	734.466	32.642	1051 976.7 862.2	963.3	42.813
10% R.H.A. (FR01)	563.1 552.1 516.4	543.86	24.17	737.1 762.8 775.8	758.56	33.71
20% R.H.A (FR02)	468.4 482.8 509.3	486.833	21.637	687.3 699.3 751.3	712.633	31.672
30% R.H.A. (FR03)	450.3 469.2 387.1	435.533	19.357	630.1 610.4 572	604.166	26.851
10% F.A 10%R.H.A. (FR11)	521.3 511.6 580.4	537.766	23.900	801 813.6 745.3	786.633	34.961
20% F.A. 10% R.H.A (FR21)	456.2 453 501.2	470.133	20.8948	754.2 699.3 721	724.833	32.214
10% F.A 20% R.H.A. (FR12)	387.3 403.1 443.3	411.233	18.277	696.1 686.3 674.1	685.5	30.47

Table 3: Compressive Strength of 4.5 MPa flexure Design (w/c = 0.35)

w/c = 0.4	7days			28days		
	Load (KN)	Average (KN)	fc (MPa)	Load (KN)	Average (KN)	fc (MPa)
Controlled (FR00)	1053 1069 1021	1047.66	46.5629	1380 1416 1368	1388	61.6888
10% F.A. (FR10)	963.1 988.2 912	954.433	42.4192	1349 1037 1212	1199.33	53.3037
20% F.A. (FR20)	1027 1009 963.4	999.8	44.4355	1208 1143 1230	1193.66	53.0518

30% F.A. (FR30)	748.1 766.5 700.1	738.233	32.8103	1017 967.2 1135	1039.73	46.2103
10% R.H.A. (FR01)	644.4 569.3 591.3	601.67	26.74	1024 986.4 796.6	995.67	44.25
20% R.H.A (FR02)	542.4 506 531.8	526.73	23.61	744.9 701.5 730.7	725.7	32.2533
30% R.H.A. (FR03)	513.5 476.8 450.3	480.2	21.3422	588.7 593.4 647.3	609.8	27.1022
10% F.A 10%R.H.A. (FR11)	664.9 700.3 693.3	686.166	30.4963	1021 1014 981.8	1005.6	44.6933
20% F.A. 10% R.H.A (FR21)	563.6 589.5 601.1	584.733	25.9881	873. 893. 909.	892.16	39.6518
10% F.A 20% R.H.A. (FR12)	511.1 503.7 487	500.6	22.2488	836.4 800.2 792.5	809.7	35.98

Table 4: Compressive Strength of 4.5 MPa flexure Design (w/c = 0.3)

W/C = 0.30	Avg. Load (KN)	F.S. (MPa)	F.S. (kg/cm^2)
Controlled (FR00)	35.3475	6.284	62.84
10% FA (FR10)	34.0575	6.055	60.55
20% FA (FR20)	32.0775	5.703	57.03
30% FA (FR30)	29.67	5.275	52.75
10%RHA (FR01)	27.6525	4.916	49.16
20%RHA (FR02)	22.2275	3.952	39.52
30%RHA (FR03)	19.6075	3.486	34.86
10%FA,10%RHA (FR11)	22.5025	4.001	40.01
20%FA, 10%RHA (FR21)	21.0125	3.735	37.35
10%FA, 20%RHA (FR12)	19.70275	3.502	35.02

Table 5: Flexural Strength (F.S.) of 5.5 MPa flexure design. (w/c =0.30)

W/C = 0.30	Avg. Load (KN)	F.S. (MPa)	F.S. (kg/cm^2)
Controlled (FR00)	32.8575	5.842	58.42
10% FA (FR10)	32.0825	5.704	57.04
20% FA (FR20)	30.7375	5.465	54.65
30% FA (FR30)	27.9325	4.966	49.66
10%RHA (FR01)	26.2825	4.673	46.73
20%RHA (FR02)	21.4175	3.808	38.08
30%RHA (FR03)	17.99	3.199	31.99
10%FA,10%RHA (FR11)	21.7625	3.868	38.68
20%FA, 10%RHA (FR21)	19.6675	3.496	34.96
10%FA, 20%RHA (FR12)	18.0875	3.215	32.15

Table 6: Flexural Strength (F.S.) of 5.0 MPa flexure design (w/c =0.35)

W/C = 0.30	Avg. Load (KN)	F.S. (MPa)	F.S. (kg/cm^2)
Controlled (FR00)	29.4825	5.242	52.42
10% FA (FR10)	28.4525	5.059	50.59
20% FA (FR20)	27.955	4.977	49.77
30% FA (FR30)	25.045	4.452	44.52
10%RHA (FR01)	24.535	4.361	43.61
20%RHA (FR02)	18.9375	3.367	33.67
30%RHA (FR03)	16.29	2.896	28.96
10%FA, 10% RHA (FR11)	19.3575	3.442	34.42
20%FA, 10%RHA (FR21)	18.8075	3.343	33.43
10%FA, 20%RHA (FR12)	16.38	2.912	29.12

Table 7: Flexural Strength (F.S.) of 4.5 MPa flexure design (w/c =0.40)

VI. CONCLUSION

From the experimental results, the conclusions of compressive strength, flexural strength and the pavement quality concrete slab thickness are concluded as under:

A. Compressive Strength

- The mixes with only fly ash replacement has a lesser rate of increase in strength from 7days to 28 days despite the fact that they have high initial strength, than the mixes with rice husk ash replacement only. The mixes with the inclusion of both rice husk ash and fly ash as replacement material show the highest rate of increase of compressive strength for all water to cement ratios which indicates that pozzolanic activity initiates early for such mixes.
- Concrete mix with up to 30% percent replacement of cement with fly ash for all water-cement ratios have higher compressive strengths than minimum required as per MoRT&H specifications.
- Concrete mixes with 10% replacement of rice husk ash in w/c= 0.3 have higher compressive strengths than minimum required as per MoRT&H specifications.
- Concrete mixes with combined replacement of 10% each of fly ash and rice husk ash in w/c= 0.3 showed higher compressive strengths than minimum required as per MoRT&H specifications.

B. Flexural Strength

- The mixes containing only fly ash could achieve 85 to 95% of the control strength, whereas, the mixes containing only 30% rice husk as replacement achieved only 55% of the target controlled strength.
- Fly ash up to 20% replacement for all the water-cement ratios showed higher flexural strengths than minimum required flexural strengths as per PQC design standards. Thus, 20% cement replacement by fly ash can be used in designing pavement quality concrete mixes with significant saving in cost.
- Partial replacement of cement along with rice husk ash does not significantly contribute to gain in flexural strengths for all the replacement levels and for all water to cement ratios.
- Mixes with combination of fly ash and rice husk ash were unable to achieve desired flexural strengths.

C. Saving of Materials in Design of Slab Thickness Pavement

According to the results of the study, compiled for different mixes incorporating fly ash and rice husk ash in the figures 6.1 and 6.2, other than nominal mix, there is a noticeable change (i.e. decrease in material usage or saving of materials on economical basis) of following materials:

- Concrete Pavement Thickness
- Cement content (kg)
- Fine Aggregate (kg)
- Coarse Aggregates (kg)

A 10 to 30mm saving in the thickness of the quality concrete pavement containing 10 to 20% fly ash as cement replacement is achieved. The most economic pavement design was achieved by replacing 20% fly ash in minimum required 4.5MPa flexural strength design using w/c of 0.40.

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