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Seepage Rate through Concrete Rectangular Canal Sections with Different Levels of Partial Substitution of Rice Hull for Sand

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Abstract- This study was conducted to quantify the effect on the seepage rate through rectangular concrete canal sections with partial substitution of rice hull materials for sand and to evaluate its economic feasibility when practiced.

A 2x4 factorial experiment in randomized complete block design with four levels of partial substitution and two rice hull materials in three (3) replication was employed to assess the variation in seepage rate resulting from the partial substitution of rice hull materials for sand in concrete made into rectangular canal sections. The result showed that the average seepage rate of rectangular canal sections increases as the level of partial substitution increases. Furthermore, the results also confirmed the pre-experimental hypothesis of the researcher that the seepage rate through canal sections with partial substitution of rice will always be lower than the seepage rate through canal sections with partial substitution of whole rice hull for sand.

The analysis of variance revealed that the variation in the average seepage rates of different treatment combinations and the control treatment are significant. On the other hand, the economic analysis revealed that only the 15% level of partial substitution of rice hull chips generated a positive net savings for a 90-day annual canal usage.

The researcher concluded that rice hull chips are better substitute for sand than whole hulls. Hence, if there is a need to do partial substitution of rice hull chips for sand, a 15% level of partial substitution is highly recommended.

Index Terms- Seepage rate, rice hull chips, canal sections, partial substitution, block design

I. Introduction

Rice hull abounds in the rice producing areas of the country. This is now becoming an agent of pollution and so its utilization as a source of energy or as a concrete stabilizer/admixture would turn this agricultural waste material into something useful.

This study will prove the desirability of rice hull as a concrete admixture when pressed or crushed into smaller chips. This study was generally aimed to investigate into the seepage rate in rectangular canals made from concrete with partial substitution of whole rice hull and rice hull chips for sand. Iqbal, as cited by Fortuno (Fortuno, 2003), stated that seepage, in irrigated agriculture, has been defined as the movement of water in and out of earth canals through the pores in the bed and bank material. He stressed out that the seepage is not only a waste of water, but also lead to other problems such as water logging and salinization. Morever, Franzini et al (Franzini, 1992) stated that if water is expensive and the soil in which canal is constructed is quite permeable, it might be economical to provide a canal lining to reduce seepage from canal. They stressed that, in addition to reduction seepage, canal lining may permit higher water velocities and smaller cross sections in the canal, resulting in cost savings.

Mindess and Young (Mindess S., 1981) reported that the possibility of using solid wastes as aggregates in concrete has received increasing attention in recent years as one promising solution to the escalating solid waste disposal problems. According to him, an admixture is also a component sometimes added to concrete mixture for the purpose of creating or for neutralizing a normal characteristic of concrete or to correct the deficiency of mixture.

Should this study yield positive results, the mixing of pressed or crushed rice hull with concrete can be recommended to government agencies for adoption in their construction activities. Aside from converting rice hull into useful material, this technology of mixing rice hull chips in concrete will also reduce the cost of construction of concrete structures.

II. MATERIALS AND METHODS

2.1 Research Design

The complete randomized block design (CRBD) was employed to quantify the effect of partial substitution of whole rice hull and rice hull chips for sand on the seepage rate of rectangular concrete canal sections with four levels of partial substitution of whole rice hull and rice hull chips in three replications. The different levels of substitution were 15% (LS1), 30% (LS2), 45% (LS3), and 60% (LS4). A control treatment with mixing proportion of 1:2:4 (cement; sand; gravel) or without substitution was included for comparison purposes.

Figure 1. Experimental layout

The mixing proportion of concrete rectangular canals for the different levels of partial substitution are tabulated below.

LEVEL OF SUBSTITUTION	VOLUME OF CONCRETE AGGREGATES (ft^3)				MIXING PROPORTION
	Cement	Sand	Gravel	Rice Hull*	
0 (Control)	1	2.0	4	0	1:2:4
15% (L1)	1	1.70	4	0.30	1:1.85:4:0.30
30% (L2)	1	1.40	4	0.60	1:1.70:4:0.60
45% (L3)	1	1.10	4	0.90	1:1.70:4:0.90
60% (L4)	1	0.80	4	1.20	1:1.40:4:1.30

2.2 Production of Rice Hull Chips

The rice hull chips were produced by manually pounding the whole rice hulls until they are broken into chip. The densities of the rice hull materials were determined by measuring the air-dried and oven-dried masses of a pre-determined volume of sample rice hull materials. The whole rice hull had a bulk density of 160.5 kg/m^3 and a particle density of 824 kg/m^3, while the rice hull chips were found to have a bulk density of 253.5 kg/m^3 and a particle density of 1,020 kg/m^3.

2.3 Fabrication of Forms and Making of Rectangular Canal Sections

The forms used to mold the concrete-rice hull mixture into rectangular canal sections were fabricated using 6.35 mm ordinary plywood and 25 mm x 50 mm coconut lumber. The different constituents of concrete were mixed according to the different mixing proportions included in this study and was poured into the fabricated forms. All the experimental canal sections were subjected to a 28-day curing period as recommended by the American Concrete Institute.

2.4 Conduct of Experiment

The experiment was started by filling a particular rectangular canal section with water up to its rim. Then, the depth of water remaining in the canal section was monitored for 36 hours at predetermined observation times from the start of the experiment. In each of the observation times, after the depth in the canal section has been determined, water was added to the canal section to fill it up with water again up to its rim. The canal section under experiment was covered throughout the observation period to avoid untimely addition of water from rainfall. All the experiments were conducted in three trials.

2.5 Statistical and Economic Analysis

In this study, three (3) statistical procedures were employed. F-test ANOVA was employed to test whether the average seepage rates of the different treatment combinations were significantly different from each other. Duncan's Multiple Range Test (DMRT) was used to identify which treatment combination/s are significantly different from each other. Finally, linear and non-linear regression method were employed to relate the average seepage rate and the level of partial substitution.

Using the data on the average seepage rate, the cost of materials and the estimated labor cost, a simple economic analysis to evaluate whether the partial substitution of rice hull materials for sand is beneficial was undertaken. To be beneficial, the reduction of in the material cost of concrete rectangular canals should be greater than the cost of additional volume of water lost due to increase in seepage rate brought by rice hull substitution.

III. RESULTS AND DISCUSSION

3.1 Seepage Rate

The highest seepage rate of 0.4929 m^3/m^2/day was measured from the rectangular canal sections with 60% partial substitution of whole rice for sand (RHW +LS4).

The analysis of variance revealed that the variation in the seepage rate of rectangular canal sections with different levels of partial substitution of whole rice hull and rice hull chips for sand is highly significant. The DMR further revealed that the average seepage rate of rectangular canal sections with 15% and 30% level of partial substitution of both whole rice and rice hull chips for sand were not significantly higher than that of the control treatment. This implies that a lower level of partial substitution, the mixing of both whole rice hull and rice hull chips do not increase so much the porosity of concrete. However, at higher levels of partial substitution, especially 60%, the average seepage rate of rectangular canal sections made from concrete with whole rice hull is almost four times the average seepage rate from rectangular canal sections with rice hull chips; hence, it is more advantageous to use rice hull chips at that level of partial substitution.

3.1.1 Seepage Rate in Rectangular Canal Sections Made from Concrete with Different Levels of Partial Substitution of Whole Rice Hull and Rice Hull Chips

Table 1. The average seepage rate of rectangular canal sections made from concrete under different treatment conditions (type of rice hull material substituted for sand + level of partial substitution

TREATMENT CONDITIONS	AVERAGE SEEPAGE RATE * (m^3/m^2/day)
RHW +LS4	0.42936[a]
RHC + LS4	0.12174[b]
RHW +LS3	0.06592[c]
RHC + LS3	0.06038[c]
RHW +LS2	0.04195[cd]
RHC + LS2	0.03197[cd]
RHW +LS1	0.02256[d]
RHC + LS1	0.01872[d]
0% (Control)	0.01625[d]

*Means followed by the same letter are not significantly different from each other at 5% level (DMRT).

3.1.2 Relationship Between the Average Seepage Rate and the Level of Partial Substitution of hole Rice Hull and Rice Hull Chips for Sand

In this study, average seepage rate (ASR) is a function of the level of partial substitution (LS). However, this idea is not enough. There is a need to discover the kind of relationship that exists between ASR and LS. The data on the average seepage rate and the level of partial substitution fitted into exponential form:

$$Y = \alpha e^{ƁX}$$

which can be linearized into:

$Y' = \alpha'\ Ɓ X^2$, where $Y' = \ln Y$ and $\alpha' = \ln \alpha$. Assigning the average seepage rate data as the Y values and the level of partial substitution as the X values in the linearized regression equation, the following equations were derived at:

$$ASR_w = 0.01688\ e^{0.000853\ (Ls)} \quad (1)$$

$$ASR_c = 0.01790\ e^{0.000553\ (Ls)} \quad (2)$$

Where ASR_w and ASR_c represent the average seepage rate of rectangular canal sections made from concrete with partial substitution of whole rice and rice hull chips, respectively, and LS stands for the level of partial substitution (%). The computed correlation coefficients for the linearized equations (1) and (2) are 0.985 and 0.994, respectively.

3.2 Economic Analysis

3.2.1 Assumptions

In this analysis, the following assumptions were made: Economic life of the canal = 5 years; Rice Hull chips cost = PhP 30/m^3; Rice hull whole cost = PhP 20/m^3 and water rate = PhP 10/$m^{3.}$

3.2.2 Material cost per meter length of rectangular concrete canal with different levels of partial substitution of rice hull for sand

Table 2 clearly shows that as the level of partial substitution of rice hull material increase, the estimated cost of materials for the construction of rectangular canal section decrease.

The analysis of variance revealed that variations in the estimated cost of materials are highly significant. The DMR test further revealed that the material cost of the different treatment combinations differ from each other. This means that a 15% increase in the partial substitution of whole rice hull or rice hull chips for sand in concrete is enough to significantly lower the material cost.

Table 2. The material cost (per meter length) of rectangular canal sections made from concrete under different treatment combinations (type of rice hull materials substituted for sand + level of partial substitutions

TREATMENT CONDITIONS	MATERIAL COST * (PhP per meter length)
RHW +LS4	206.20[i]
RHC + LS4	206.45[h]
RHW +LS3	208.30[g]
RHC + LS3	208.49[f]
RHW +LS2	209.89[e]
RHC + LS2	210.53[d]
RHW +LS1	212.56[c]
RHC + LS1	212.62[b]
0% (Control)	214.67[a]

3.2.3 Cost of Seepage water lost per year from rectangular canal sections of the different treatment combinations

To be able to compute the cost of seepage water lost per meter length of the rectangular concrete canal per year, two values of annual canal usage were used: 90 days and 180 days. These values were chosen based on farmer's estimates of the number of days that irrigation canals are used to convey water to farmlands for one and two croppings per year, respectively.

Table 3 shows the average cost of seepage water from rectangular canal sections for the different treatment combinations for both 90 and 180-day annual canal usage. As expected, the control treatment had the lowest average costs of seepage water while treatment combination RHW +LS4 (partial substitution of 60% whole rice hull for sand) had the highest average costs of seepage water. The data in Table 3 clearly showed that as the level of partial substitution of rice hull material for sand increase, the average cost of seepage water increase also.

The analysis of variance of the data on the cost of seepage water for the different treatment combinations revealed that variations are highly significant. The DMR test further showed that only the treatment combination RHC +LS1 (15% partial substitution of rice hull chips for sand) had an average cost of seepage water that was not significantly different (higher) from the average cost of seepage water of the control treatment for both 90 days and 180 days annual canal usage.

Table 3 Estimated average cost of seepage rate from rectangular canal sections of the different treatment combination for annual canal usage of 90 and 180 days

TREATMENT CONDITIONS	ANNUAL CANAL USE * (PhP per meter length)	
	90 days	**180 days**
RHW +LS4	251.18[a]	502.36[a]
RHC + LS4	71.21[b]	142.42[b]
RHW +LS3	38.56[c]	77.12[c]
RHC + LS3	35.32[d]	70.64[d]
RHW +LS2	24.54[e]	49.08[e]
RHC + LS2	18.70[f]	37.40[f]
RHW +LS1	13.20[g]	24.40[g]
RHC + LS1	10.95[h]	21.90[h]
0% (Control)	9.53[h]	19.06[h]

3.2.4 Reduction in Material Cost, Cost of Additional Seepage Water, and Net Savings Resulting from the Partial Substitution of Rice Hull Materials for Sand in Concrete Made into Rectangular Canal Sections

The partial substitution of rice hull materials for the sand in concrete mixture is economically justified if the reduction in cost of materials used in concrete exceeds the cost of additional seepage water. The reduction in the cost of materials used for a particular treatment was computed by subtracting the material cost of said treatment combination from that of the control treatment. The cost of additional seepage water for a particular treatment combination was computed by subtracting the cost of seepage water for the control treatment from the cost of seepage water for that particular treatment combination.

Table 4 and 5 present the average values of the gross savings, cost of additional seepage water, and the net savings for the different treatment combinations assuming 90 and 180-day annual canal usage, respectively. With a 90-day annual canal usage, there was only one treatment combination (RHC + LS1) having a positive average net savings. This means that only the 15% partial substitution of rice hull chips for sand is economical since its gross savings exceeded the cost of additional seepage water.

On the other hand, with a 180-day annual canal usage, all the treatment combinations had negative net savings. This means that at longer annual canal usage, the cost of additional seepage water exceeds the gross savings. However, if water is cheaper than P10.00 per cubic meter, the net savings for the 180-day annual canal usage for the treatment combinations with 15% and 30% levels of partial substitution may be positive.

Table 4 The average gross savings, average cost of additional seepage water and the average net savings of rectangular concrete canals of the different treatment combinations, assuming a 90-day annual canal usage

TREATMENT CONDITIONS	AVERAGE GROSS SAVINGS (pesos per meter length)	AVERAGE COST OF ADDITIONAL SEEPAGE WATER (PhP/m length)	AVERAGE NET SAVINGS (PhP/m length)
RHW +LS4	8.49	241.65	-233.16
RHC + LS4	8.24	61.68	-53.44
RHW +LS3	6.38	29.03	-22.65

RHC + LS3	6.20	25.79	-19.49
RHW +LS2	4.80	15.01	-10.21
RHC + LS2	4.16	9.17	-5.01
RHW +LS1	2.13	3.67	-1.54
RHW +LS1	2.07	1.42	0.65

Table 5 The average gross savings, average cost of additional seepage water and the average net savings of rectangular concrete canals of the different treatment combinations, assuming a 90-day annual canal usage

TREATMENT CONDITIONS	AVERAGE GROSS SAVINGS (pesos per meter length)	AVERAGE COST OF ADDITIONAL SEEPAGE WATER (PhP/m length)	AVERAGE NET SAVINGS (PhP/m length)
RHW +LS4	8.49	483.30	-474.81
RHC + LS4	8.24	123.36	-115.12
RHW +LS3	6.38	58.06	-51.68
RHC + LS3	6.20	51.58	-45.38
RHW +LS2	4.80	30.02	-25.22
RHC + LS2	4.16	18.34	-14.18
RHW +LS1	2.13	7.34	-5.21
RHW +LS1	2.07	2.84	-0.77

Best Treatment Combination

Table 6 presents the average seepage rate and the net savings considering two annual canal usage for the different treatment conditions.

The table clearly shows that as the level of partial substitution increase, the average seepage rate also increase while the net savings decrease, especially at higher levels of partial substitution.

Table 6 The average seepage rate and average net savings for the different treatment combinations

TREATMENT CONDITIONS	AVERAGE SEEPAGE RATE * (m^3/m^2/day)	ANNUAL CANAL USE * (PhP per meter length)	
		90 days	**180 days**
RHW +LS4	0.42936	-233.16	-474.81
RHC + LS4	0.12174	-53.44	-115.12
RHW +LS3	0.06592	-22.65	-51.68
RHC + LS3	0.06038	-19.49	-45.38
RHW +LS2	0.04195	-10.21	-25.22
RHC + LS2	0.03197	-5.01	-14.18
RHW +LS1	0.02256	-1.54	-5.21
RHC + LS1	0.01872	0.65	-0.77
0% (Control)	0.01625	0	0

IV. CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the study, the following conclusions were formulated:

a. Generally, the canal sections of the control treatment still had the least average seepage rate compared to the average seepage rate through the canal sections of the other treatment combination.
b. Generally, the average seepage rate of canal sections made from concrete with rice hull chips are always lower than the average seepage rate of canal sections made from concrete with whole rice hull.
c. An exponential function exists between the level of partial substitution and average seepage rate for both whole rice hull and rice hull chips.
d. The economic analysis revealed that only the 15% partial substitution of rice hull chips for sand resulted to a positive net savings for a 90 day annual canal usage. Hence, this could be the best treatment combination.

e. The economic analysis further showed that at longer annual canal usage (180 days), partial substitution of rice hull materials is no longer economical.

Therefore, the researcher highly recommend, that in the conduct of studies involving concrete mixing, a concrete mixer should be used o mix aggregates to avoid significant variations in the compositions of concrete; also, a vibrator should be used in order to obtain equal distribution of the concrete mixture within the molder; and, if there is a need to do partial substitution of rice hull chips for sand, a 15% level is recommended.

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