# Kruskal-Wallis Test as Analytical Tool for Key Components of a Newly Developed Core Mixture

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**Abstract**

The use of Kruskal-Wallis test as an analytical tool for the key components of a newly developed core mixture was studied. The study showed that Kruskal-Wallis test can be use to analyze a core mixture using data collected on the properties of the core mixture. In this work the data used was the dry compression strength of cores produced using the core mixture. The key components of the core mixture; the binders and the sands were analyzed. The result showed that the dry compression strength values of the core mixture depend on the type of sand and on the nature of the binder used. This analysis agreed with previous works carried out by several other authors using conventional methods for analysis of core mixtures.

**Keywords**

Kruskal-Wallis test; Analytical Tool; Components; Newly Developed.

## Introduction

An organic binder based on plants extracts, and cement as the hardener has been developed. The binder is for the preparation of core mixtures for core making. Stringent regulations on the use of polluting binders had made it necessary to explore the possibility of using plant extracts and resins which are cheap and less polluting. Binders for core making could be inorganic and organic. Some of the binders require heat (baking) for them to develop strength when used for making cores. Others develop strength without the application of heat (self curing binders) [1].

Organic binders are produced synthetically from petroleum by-products, polymers, and plastics of different types are used in the production of various types of binders. Organic binders can also be produced from natural organic sources like plants. Carbohydrates and other resins from plants have been known to be good binders and adhesives [2-4]. The use of adhesive materials for holding together of particles and objects by surface attachment (adhesion) has been in practice for a very long time. The source of these adhesive materials varied from naturally occurring plants and animals to those produced by synthesis including the adhesive fish bones. In the plant kingdom adhesive gums, consisting mainly of polysaccharides and salts of magnesium, potassium, and calcium were obtained from trees such as acacia, pine, and some vegetable products such as cassava, corn, cocoyam, potato, maize, and tapioca starch [2-4]. Various methods for the modification of materials of plant (starch) and animal (bones) origin for the development of adhesives has been reported [2].

Various sand systems are in use in the metal casting industries that have been investigated in the past. Such investigation were carried out mostly by classical methods of single factor experiments involving a large number of trials; yet, the interactions between the variable factors have not been clearly understood. However, investigations using statistical design of experiment can yield maximum information about a system through a minimum number of trials. Further, the results of such investigations are easy to process for the search of optimal conditions [5, 6].

Kruskal-Wallis Test (H-Test) is a non-parametric alternative to the one-way analysis of variance. Non-parametric test can be used on data that is not normal or that contain extreme values or not enough is known to be able to make any assumption about the type of distribution. The mathematical concepts are simpler than for parametric tests, it is called "quick and easy" or "short cut" technique and the test can be used under more general conditions [7, 8]. The objective of this work was to use Kruskal-Wallis test as an analytical tool for the study and analysis of the key components of a newly developed core mixture.

## Methodology

### *The Newly Developed Core Mixture*

The newly developed core mixture sand, and binder (Cement, manihot esculenta, and water) as the components of the core mixture.

### *Procedure*

The process of developing the above core mixture involved several experiments. Various binders and different types of sands were used; as received sands and washed sands were used with the binders. The binders used included, manihot esculenta, glycine max, and ipomoea batatas. The extracts in the form of resins from these binders were used. Core mixtures produced from the various components were produced using core mixer. Standard test specimen (DIN50×50mm) were produced using the sand rammer manufactured by Ridsdale and Co. Ltd. with serial No.342. The standard test specimen was then used for testing the compression strength of each of the core mixtures using universal strength testing machine manufactured by Ridsdale and Co. Ltd. with serial No. M8415.

Test for the hypothesis:

- The different sands used are identical and equally effective
    - Null hypothesis: All the sands are identical and equally effective
    - Alternative hypothesis: The sands are not identical and equally effective
    - Level of significance: $\alpha = 0.05$.
    - Criterion: Reject the null hypothesis if $H > 9.488$ the value of $\chi^2_{0.05}$ for 4 degrees of freedom, where H is given by the formula below

$$H = \frac{12}{n(n+1)} \sum_{i=1}^{K} \frac{R_i^2}{n_i} - 3(n+1) \quad (1)$$

where H is the Kruskal-Wallis test; n is the number of measurements; $R_i$ is the sum or addition of the ranks; $n_i$ is the number of experiments in a row.

- The binders used are identical and equally effective:
    - Let ▪ Ipomea batatas Resin = A, ▪ Manihot esculenta Resin = B
    - Manihot esculenta - Glycine max Resin = C
    - Manihot esculenta – Ipomea batatas Resin = D
    - Glycine max Resin = E
- Test for the hypothesis that all the binders used are identical and equally effective. Solution.
    - Null hypothesis: All the sands are identical and equally effective. Alternative hypothesis: The sands are not identical and equally effective
    - Level of significance: α = 0.05.
    - Criterion: Reject the null hypothesis if H> 9.488 the value of $\chi^2_{0.05}$ for 4 degrees of freedom, where H is given by the formula in equation 1.

## Results

### *Different Sands used with Binder*

Let:

- sand $SP_2$ = A
- sand $SP_3$ (As Received) = B
- Rukuba NMC Dam Sand = C
- Washed $SP_3$ Sand = D
- Washed Rukuba stream sand = E

The dry compression strength of cores made using manihot- esculenta resin and the different types of sands listed above are given below in kPa.

| A | B | C | D | E |
|---|---|---|---|---|
| 1275.58 | 606.76 | 537.81 | 282.76 | 356.82 |
| 603.31 | 635.72 | 427.49 | 475.76 | 408.87 |
| 948.06 | 655.03 | 617.10 | 443.00 | 427.49 |
| 861.88 | 644.68 | 503.34 | 527.47 | 398.53 |
| 879.11 | 648.13 | 374.40 | 496.44 | 429.21 |
| 689.50 | 541.26 | 354.40 | 398.53 | 463.69 |

Key: $sp_2$ =River Benue Sand, $Sp_3$ = North Bank Sand.

***Different Binders used with Sand***

The dry compression values in kPa of cores made with the different binders listed above are given below

| A | B | C | D | E |
|---|---|---|---|---|
| 324.07 | 1275.58 | 163.76 | 144.80 | |
| 265.46 | 603.31 | 196.51 | 101.70 | |
| 403.36 | 948.06 | 155.14 | 106.87 | |
| 227.54 | 861.88 | 168.93 | 106.87 | |
| 337.86 | 879.11 | 170.40 | 134.45 | |
| 375.78 | 689.50 | | 168.93 | |

Resin E = No values, samples crumbled.

**Analysis using Kruskal-Wallis Test**

***Hypothesis: Different Used Sands Are Identical and Equally Effective***

Calculations

| A | B | C | D | E |
|---|---|---|---|---|
| 1275.58 | 606.76 | 537.81 | 282.76 | 356.82 |
| 603.31 | 635.72 | 427.49 | 475.76 | 408.87 |
| 948.06 | 655.03 | 617.10 | 443.00 | 427.49 |
| 861.88 | 644.68 | 503.34 | 527.47 | 398.53 |
| 879.11 | 648.13 | 374.40 | 496.44 | 429.21 |
| 689.50 | 541.26 | 354.40 | 398.53 | 463.69 |

$R_1 = 30 + 19 + 29 + 27 + 28 + 26 = 159$

$R_2 = 20 + 22 + 25 + 23 + 24 + 18 = 132$

$R_3 = 17 + 8.5 + 21 + 15 + 4 + 2 = 67.5$

$R_4 = 1 + 13 + 11 + 16 + 14 + 5.5 = 60.5$

$R_5 = 3 + 7 + 8.5 + 5.5 + 10 + 12 = 46.0$

$$H = 12/30(30+1)\ [159^2+132^2+67.5^2+60.5^2+46.0^2/\ 6]- 3(30+1) = 21.03 \quad (2)$$

Since H = 21.03 exceeds 9.488 the Null hypothesis must be rejected; the conclusion is therefore that the five (5) sands are not identical neither are they equally effective.

***Hypothesis: All the Binders Used are Identical and Equally Effective***

Calculations

| A | B | C | D |
|---|---|---|---|
| 324.07 | 1275.58 | 163.76 | 144.80 |
| 265.46 | 603.31 | 196.51 | 101.70 |
| 403.36 | 948.06 | 155.14 | 106.87 |
| 227.54 | 861.88 | 168.93 | 106.87 |
| 337.86 | 879.11 | 170.40 | 134.45 |
| 375.78 | 689.50 | | 168.93 |

$R_1 = 14 + 13 + 17 + 12 + 15 + 16 = 87$

$R_2 = 22 + 17 + 21 + 19 + 20 + 18 = 117$

$R_3 = 7 + 11 + 6 + 8.5 + 10 = 42.5$

$R_4 = 5+ 1 + 2.5 + 2.5 + 4 + 8.5 = 23.5$

$$H = 12/23(23+1)\ [(87^2+117^2+42.5^2+23.5^2)/\ 6]- 3(23+1) \approx 14.9 \quad (3)$$

Since H ≈ 14.9 exceeds 7.815, the null hypothesis must be rejected; the conclusion is therefore that the four (4) resin binders are not equally effective.

## Discussions

Kruskal-Wallis test has been used in 4.1 to prove that the different sands used are identical and equally effective. The result showed that the five sands used in the testing of the new binder are not identical, neither are they equally effective. The null hypothesis was therefore discarded. A look at the result in 3.1 agrees with the analysis that the sands are not equally effective this is because the different sands gave different strength values, with sand A giving the highest strength values. Several authors [9, 10] have also explained that the strength of core mixtures depend not only on the nature of the binder but also on the nature of the sand. This has to do with the particle size distribution, shape and compactability of the sand. In an earlier work carried out by one of the authors on the effect of different sand on the dry strength property of core mixture it was clear that the type of sand used for preparing a core mixture also determines the strength value of the cores produced [1].

Kruskal-Wallis test has been used to prove the hypothesis that all the binders used are identical and equally effective. The result of the test has shown that the four different resin binders used are not equally effective. The Kruskal-Wallis analysis agrees with the data result in 3.2. The same sand is used in the testing of the different binders, however, resin B has distinguished itself by having the highest dry strength values of cores produced using the binder. It is suggested [5, 6] that investigations by application of statistical design of experiments yield maximum information about a system through a minimum number of trials. Further, the results of such investigations are easy to process for the search of optimal conditions. Large data from single factor experiment and the interaction of the components can easily be analyzed through statistical approach. This suggestion is true and agrees with the application of Kruskal-wallis test in this work. Previous works carried out by several authors [5, 6, 9, 10] have pointed out the same fact that different binders used with the same sand for the production of core mixture for core making will not have the same dry compression strength. In a work carried out at NMDC Jos different organic binders were used in producing core mixtures for core making using the same sand. The core test specimens had different dry compression strength. The authors explained that the binders were not equally effective. The performance and quality of the binders was not the same, but some were better than others [3]. The analysis of the Kruskal-Wallis test is therefore in line with existing theories and findings on core mixtures for core making using conventional methods of tables and graphs for explanations.

## Conclusions

- The study on the use of Kruskal-Wallis test as an analytical tool for the key components of a newly developed core mixture has shown that the test can be use to analyze a core mixture based on any chosen property of the core mixture.
- The Test (Kruskal-Wallis) has been used to analyze the effectiveness of the sands used during the experiments for the development of the new binder. The measure for the effectiveness of the sands was the property of the core called dry compression strength.
- The result showed that some of the sands are better than others
- Kruskal-Wallis test also revealed that some binders are better than other even when the same sand is used for preparing core mixtures for core making
- The result of the analysis using Kruskal-Wallis agrees with previous works by several authors and also agrees with existing theories that the dry compression strength of a core

depends on the nature of sand used (shape, size etc.) and on the nature of the binder used for making the core.

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