

### **Practical No. 12 : Randomized Block Design (RBD)**

A chemist wishes to test the effect of four chemical agents on the strength of a particular type of cloth. There might be variability from one bolt to another, hence, the chemist decides to use a randomized block design, with the bolts of cloth considered as blocks. He selects five bolts and applies all four chemicals in random order to each bolt. The resulting tensile strength is as follows:

| Chemical Agents | Bolt |    |    |    |    |
|-----------------|------|----|----|----|----|
|                 | 1    | 2  | 3  | 4  | 5  |
| 1               | 73   | 68 | 74 | 71 | 67 |
| 2               | 73   | 67 | 75 | 72 | 70 |
| 3               | 75   | 68 | 78 | 73 | 68 |
| 4               | 73   | 71 | 75 | 75 | 69 |

Enter this data in Minitab and generate the following reports:

#### **Questions :**

- (a) Carryout two-way ANOVA .
- (b) Determine if the tensile strength is same for all four chemical agents? Use  $\alpha = 0.05$ .
- (c) Determine if the tensile strength is same for all five bolts? Use  $\alpha = 0.05$ .

#### **Solution :**

**Step 1 :** Type your data into the data pane of a worksheet. Make sure you put your data into columns. Use column headers for "Tensile Strength", "Chemical Agents" and "Bolt". Type the "Tensile Strength" data into column C1, "Chemical Agents" data into column C2 and "Bolt" data into column C3.

**Step 2 :** To perform randomized block design (RBD), under the drop-down menu "Stat", choose "ANOVA" then "General Linear Model" then "Fit General Linear Model...". A "General Linear Model" dialogue box will appear. Set the "Response:" as "C1 Tensile Strength" and "Factors:" as "C2 Chemical Agents" and "C3 Bolt" from the table on the left.

**Step 3 :** Click on the "Graphs..." option. A "General Linear Model: Graphs" dialogue box will appear. Set the "Residual for plots:" as "Regular". Under "Residual plots", check the "Four in one" radio box. Click "OK". Click "OK" again.

**Step 4 :** Under the drop-down menu "Stat", choose "ANOVA" then "General Linear Model" then "Comparisons...". A "Comparisons" dialogue box will appear. Set the "Response:" as "Tensile Strength", "Type of Comparison:" as "Pairwise". Under "Method", check the "Tukey" checkbox. Under "Choose terms for comparisons:" check the "Chemical Agents" and "Bolts" checkboxes. Click "OK". Click "OK" again.

**Method :**

Factor coding (-1, 0, +1)

**Factor Information :**

| Factor          | Type  | Levels | Values        |
|-----------------|-------|--------|---------------|
| Chemical Agents | Fixed | 4      | 1, 2, 3, 4    |
| Bolt            | Fixed | 5      | 1, 2, 3, 4, 5 |

**Test of significance of factor level :****Analysis of Variance :**

| Source          | DF | Adj SS | Adj MS | F-Value | P-Value |
|-----------------|----|--------|--------|---------|---------|
| Chemical Agents | 3  | 12.95  | 4.317  | 2.38    | 0.121   |
| Bolt            | 4  | 157.00 | 39.250 | 21.61   | 0.000   |
| Error           | 12 | 21.80  | 1.817  |         |         |
| Total           | 19 | 191.75 |        |         |         |

**Interpretation :**

- (i) Since the p-value of chemical agents (0.121) is greater than  $\alpha$ -value (0.05), we accept the null hypothesis that tensile strength is same for all chemical agents. Hence, chemical agent is not significant factor for tensile strength of cloth.
- (ii) Since the p-value of bolts (0.000) is smaller than  $\alpha$ -value (0.05), we reject the null hypothesis. That means tensile strength is same for all bolts types. Hence, bolt types is a significant factor for tensile strength of cloth.

**Model Summary :**

| S       | R-sq   | R-sq(adj) | R-sq(pred) |
|---------|--------|-----------|------------|
| 1.34784 | 88.63% | 82.00%    | 68.42%     |

**Interpretation :**

- (i) The adjusted coefficient of determination is 82 %. Hence the reliability of fitted linear model for RBD is high.
- (ii) The standard error of estimate  $S = 1.35$ , which is quite small, indicating high reliability of fitted linear model.

**Coefficients :**

| Term            | Coef   | SE Coef | T-Value | P-Value | VIF  |
|-----------------|--------|---------|---------|---------|------|
| Constant        | 71.750 | 0.301   | 238.07  | 0.000   |      |
| Chemical Agents |        |         |         |         |      |
| 1               | -1.150 | 0.522   | -2.20   | 0.048   | 1.50 |
| 2               | -0.350 | 0.522   | -0.67   | 0.515   | 1.50 |
| 3               | 0.650  | 0.522   | 1.25    | 0.237   | 1.50 |
| Bolt            |        |         |         |         |      |
| 1               | 1.750  | 0.603   | 2.90    | 0.013   | 1.60 |
| 2               | -3.250 | 0.603   | -5.39   | 0.000   | 1.60 |
| 3               | 3.750  | 0.603   | 6.22    | 0.000   | 1.60 |
| 4               | 1.000  | 0.603   | 1.66    | 0.123   | 1.60 |

**Regression Equation :**

Tensile Strength = 71.750 - 1.150 Chemical Agents\_1 - 0.350 Chemical Agents\_2 + 0.650 Chemical Agents\_3 + 0.850 Chemical Agents\_4 + 1.750 Bolt\_1 - 3.250 Bolt\_2 + 3.750 Bolt\_3 + 1.000 Bolt\_4 - 3.250 Bolt\_5

**Interpretation :**

This is the fitted regression model of RBD.

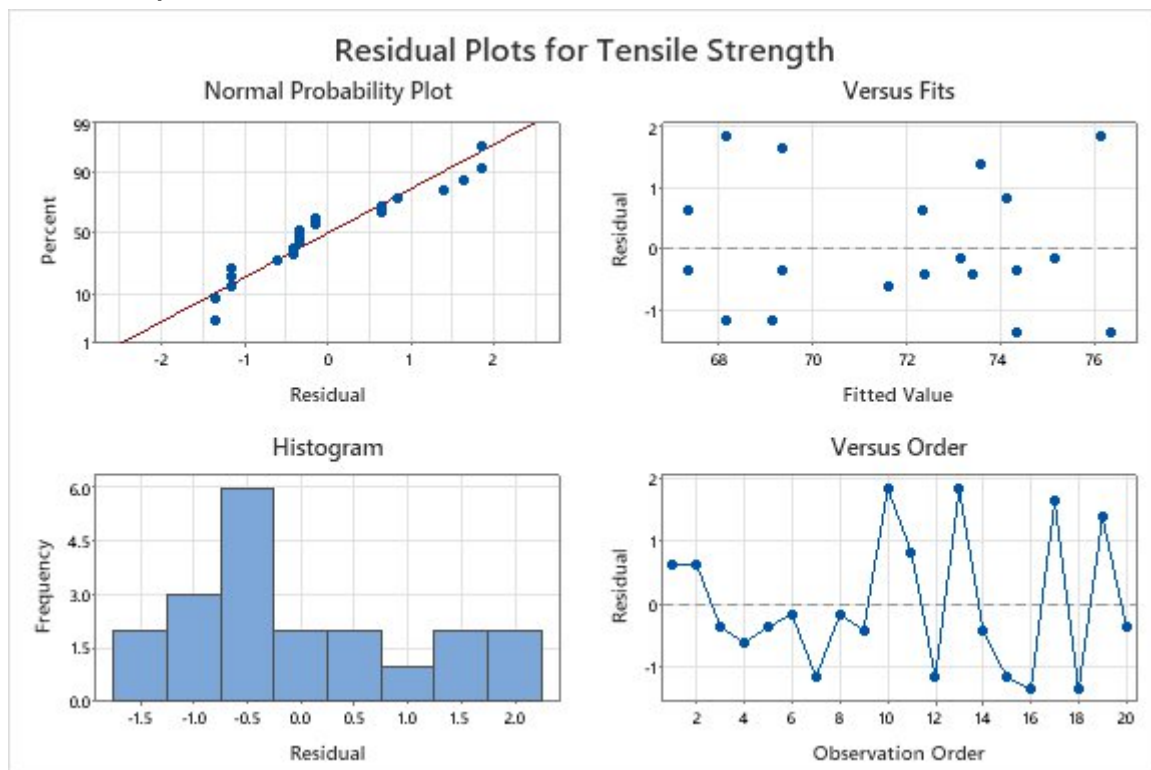
**Residual Analysis :**

Fig 1 : Residual Analysis

- (i) **Normality check of error distribution:** The histogram and normal probability plot shows that the error distribution is not normal i.e., it is right skewed. It may be due to the small sample size.
- (ii) **Equal variance check:** The second graph shows that the homogeneity of variance is maintained as dots in the graph do not exhibit any pattern below and above the reference line  $e = 0$ .
- (iii) **Linear relationship check:** The second graph also shows that the distribution of dots about the reference line  $e = 0$  (below and above the line) has no obvious pattern (pattern is random), indicating linear model is valid for RBD.
- (iv) **Independence of error check:** The fourth graph (graph of error vs observation order) shows that error distribution is in random pattern, indicating independence of errors. However, errors show some patterns in the first few observations and random afterwards.

**Grouping Information Using the Tukey Method and 95% Confidence :**

| Chemical Agents | N | Mean | Grouping |
|-----------------|---|------|----------|
| 4               | 5 | 72.6 | A        |
| 3               | 5 | 72.4 | A        |
| 2               | 5 | 71.4 | A        |
| 1               | 5 | 70.6 | A        |

*Means that do not share a letter are significantly different.*

**Interpretation :**

Multiple comparisons of levels of chemical agents shows that there is no significant difference in the mean effect of four levels of chemical agents (all chemical agents are grouped into one).

**Grouping Information Using the Tukey Method and 95% Confidence :**

| Bolt | N | Mean  | Grouping |
|------|---|-------|----------|
| 3    | 4 | 75.50 | A        |
| 1    | 4 | 73.50 | A        |
| 4    | 4 | 72.75 | A        |
| 2    | 4 | 68.50 | B        |
| 5    | 4 | 68.50 | B        |

*Means that do not share a letter are significantly different.*


**Interpretation :**

The multiple comparison shows that bolts effects are not the same. They are grouped into two: Group A comprising of bolt no. 1, 3 and 4 (showing higher effect). Group B comprising bolts no. 2 and 5 (showing lower effects).

**Conclusion :**

The final conclusion is that chemical agents is not a significant factor, but bolts is a significant factor. Type of the bolt do affect tensile strength of cloth. Since bolt type 1, 3, and 4 produce cloth of higher tensile strength we can choose any one of them for production. But bolt 3 could be the best choice as it has the highest mean effect.

**Worksheet :**

| ↓  | C1  | C2              | C3   | C4 |
|----|--|-----------------|------|----|
|    | Tensile Strength   | Chemical Agents | Bolt |    |
| 1  | 73   | 1               | 1    |    |
| 2  | 68   | 1               | 2    |    |
| 3  | 74   | 1               | 3    |    |
| 4  | 71   | 1               | 4    |    |
| 5  | 67   | 1               | 5    |    |
| 6  | 73   | 2               | 1    |    |
| 7  | 67   | 2               | 2    |    |
| 8  | 75   | 2               | 3    |    |
| 9  | 72   | 2               | 4    |    |
| 10 | 70   | 2               | 5    |    |
| 11 | 75   | 3               | 1    |    |
| 12 | 68   | 3               | 2    |    |
| 13 | 78   | 3               | 3    |    |
| 14 | 73   | 3               | 4    |    |
| 15 | 68   | 3               | 5    |    |
| 16 | 73   | 4               | 1    |    |
| 17 | 71   | 4               | 2    |    |
| 18 | 75   | 4               | 3    |    |
| 19 | 75   | 4               | 4    |    |
| 20 | 69   | 4               | 5    |    |
| 21 |  |                 |      |    |