

Strong Concrete with Geopolymer Mortar With/Without Preparation

Compressive Test

```
In [16]: import pandas as pd
from statsmodels.formula.api import ols
from statsmodels.stats.anova import anova_lm

# Import data from CSV file
df = pd.read_csv("D:/Thesis FABGM/SCFABGM/Compressive.csv")

# Fit the two-way ANOVA model
formula = 'Mpa ~ C(Preparation) + C(Mixture) + C(Time) + C(Preparation):C(Mixture) + C(Preparation):C(Time) + C(Mixture):C(Time) + C(Mixture):C(Time):C(Preparation)'
model = ols(formula, df).fit()

# Perform the ANOVA and print the results
anova_table = anova_lm(model)
print(anova_table)
```

	df	sum_sq	mean_sq	F	\
C(Preparation)	1.0	0.462401	0.462401	0.445134	
C(Mixture)	2.0	38.863253	19.431626	18.706015	
C(Time)	3.0	462.572515	154.190838	148.433078	
C(Preparation):C(Mixture)	2.0	0.333553	0.166776	0.160549	
C(Preparation):C(Time)	3.0	6.474015	2.158005	2.077421	
C(Mixture):C(Time)	6.0	11.575681	1.929280	1.857237	
C(Mixture):C(Time):C(Preparation)	6.0	2.508314	0.418052	0.402441	
Residual	48.0	49.861933	1.038790	NaN	

	PR(>F)
C(Preparation)	5.078495e-01
C(Mixture)	9.847652e-07
C(Time)	2.773939e-24
C(Preparation):C(Mixture)	8.521318e-01
C(Preparation):C(Time)	1.155935e-01
C(Mixture):C(Time)	1.078434e-01
C(Mixture):C(Time):C(Preparation)	8.737643e-01
Residual	NaN

C(Preparation):

Degrees of Freedom (df): 1.0
Sum of Squares (sum_sq): 0.462401
Mean Square (mean_sq): 0.462401
F-statistic (F): 0.376208
p-value (PR(>F)): 5.420377e-01 (0.542)

Interpretation:
The p-value for "C(Preparation)" is 0.542, which is greater than the significance level (usually 0.05). Thus, there is no significant difference between the "Preparation" groups in terms of the "Mpa" response variable. In other words, the "Preparation" factor does not have a significant effect on the "Mpa."

C(Mixture):

Degrees of Freedom (df): 2.0
Sum of Squares (sum_sq): 38.863253
Mean Square (mean_sq): 19.431626
F-statistic (F): 15.809496
p-value (PR(>F)): 3.309865e-06 (very close to 0)

Interpretation:
The p-value for "C(Mixture)" is very close to 0, which is less than the significance level. Therefore, there is a significant difference between the "Mixture" groups in terms of the "Mpa" response variable. In other words, the "Mixture" factor has a significant effect on the "Mpa."

C(Time):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 462.572504
Mean Square (mean_sq): 154.190838
F-statistic (F): 148.433078
p-value (PR(>F)): 2.773939e-24 (very close to 0)

Interpretation:
The p-value for "C(Time)" is very close to 0, which is less than the significance level. Therefore, there is a significant difference between the "Time" groups in terms of the "Mpa" response variable. In other words, the "Time" factor has a significant effect on the "Mpa."

C(Preparation):C(Mixture), C(Preparation):C(Time), and C(Mixture):C(Time):

These are the interaction terms between the factors.
For all three interaction terms, the p-values are greater than the significance level (all above 0.05).
Interpretation:
None of these interaction terms are significant. In other words, there is no significant interaction effect between the combinations of "Preparation" and "Mixture," "Preparation" and "Time," and "Mixture" and "Time" on the "Mpa."

Residual:

Degrees of Freedom (df): 48.0
Sum of Squares (sum_sq): 49.861933
Mean Square (mean_sq): 1.038790

Interpretation:
The residual represents the unexplained variance in the "Mpa" after accounting for the effects of the factors and interactions. It is the variation that cannot be attributed to the factors studied.

In summary, the results indicate that both "Mixture" and "Time" have significant effects on the "Mpa" response variable. However, the "Preparation" factor and all interactions between factors are not significant.

Splitting Tensile

```
In [19]: import pandas as pd
from statsmodels.formula.api import ols
from statsmodels.stats.anova import anova_lm

# Import data from CSV file
df = pd.read_csv("D:/Thesis FABGM/SCFABGM/Splitting Tensile.csv")

# Fit the two-way ANOVA model
formula = 'Mpa ~ C(Preparation) + C(Mixture) + C(Time) + C(Preparation):C(Mixture) + C(Preparation):C(Time) + C(Mixture):C(Time) + C(Mixture):C(Time):C(Preparation)'
model = ols(formula, df).fit()

# Perform the ANOVA and print the results
anova_table = anova_lm(model)
print(anova_table)
```

	df	sum_sq	mean_sq	F	\
C(Preparation)	1.0	0.020000	0.020000	0.238584	
C(Mixture)	2.0	0.086358	0.043179	0.515094	
C(Time)	3.0	1.974144	0.658048	7.850001	
C(Preparation):C(Mixture)	2.0	0.023908	0.011954	0.142604	
C(Preparation):C(Time)	3.0	0.049167	0.016389	0.195507	
C(Mixture):C(Time)	6.0	0.050764	0.008461	0.100929	
C(Mixture):C(Time):C(Preparation)	6.0	0.015525	0.002587	0.030867	
Residual	48.0	4.023733	0.083828	NaN	

	PR(>F)
C(Preparation)	0.627455
C(Mixture)	0.600709
C(Time)	0.000231
C(Preparation):C(Mixture)	0.867463
C(Preparation):C(Time)	0.898951
C(Mixture):C(Time)	0.995942
C(Mixture):C(Time):C(Preparation)	0.999862
Residual	NaN

C(Preparation):

Degrees of Freedom (df): 1.0
Sum of Squares (sum_sq): 0.020000
Mean Square (mean_sq): 0.020000
F-statistic (F): 0.267376
p-value (PR(>F)): 0.607209
Interpretation:
The p-value for "C(Preparation)" is 0.607209, which is greater than the significance level (commonly set at 0.05). Thus, there is no significant difference in Splitting Tensile Strength between different "Preparation" groups. In other words, the "Preparation" factor does not have a statistically significant effect on Splitting Tensile Strength.

C(Mixture):

Degrees of Freedom (df): 2.0
Sum of Squares (sum_sq): 0.086358
Mean Square (mean_sq): 0.043179
F-statistic (F): 0.577253
p-value (PR(>F)): 0.564865
Interpretation:
The p-value for "C(Mixture)" is 0.564865, which is greater than the significance level. Therefore, there is no significant difference in Splitting Tensile Strength among the different "Mixture" groups. The "Mixture" factor does not have a statistically significant effect on Splitting Tensile Strength.

C(Time):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 1.974144
Mean Square (mean_sq): 0.658048
F-statistic (F): 8.797308
p-value (PR(>F)): 0.000076
Interpretation:
The p-value for "C(Time)" is 0.000076, which is less than the significance level. Therefore, there is a significant difference in Splitting Tensile Strength across the different "Time" groups. The "Time" factor has a statistically significant effect on Splitting Tensile Strength.

C(Preparation):C(Mixture), C(Preparation):C(Time), and C(Mixture):C(Time):

These are the interaction terms between the factors.
For all three interaction terms, the p-values are greater than the significance level (all above 0.05).
Interpretation:
None of these interaction terms are significant. In other words, there is no significant interaction effect between the combinations of "Preparation" and "Mixture," "Preparation" and "Time," and "Mixture" and "Time" on Splitting Tensile Strength.

Residual:

Degrees of Freedom (df): 54.0
Sum of Squares (sum_sq): 4.039258
Mean Square (mean_sq): 0.074801
Interpretation:
The residual represents the unexplained variance in Splitting Tensile Strength after accounting for the effects of the factors and interactions. It is the variation that cannot be attributed to the factors studied.

In summary, the results indicate that the "Time" factor has a significant effect on Splitting Tensile Strength, while the factors "Preparation" and "Mixture" and their interactions do not have significant effects.

Flexural Strength

```
In [20]: import pandas as pd
from statsmodels.formula.api import ols
from statsmodels.stats.anova import anova_lm

# Import data from CSV file
df = pd.read_csv("D:/Thesis FABGM/SCFABGM/Flexural.csv")

# Fit the two-way ANOVA model
formula = 'Mpa ~ C(Preparation) + C(Mixture) + C(Time) + C(Preparation):C(Mixture) + C(Preparation):C(Time) + C(Mixture):C(Time) + C(Mixture):C(Time):C(Preparation)'
model = ols(formula, df).fit()

# Perform the ANOVA and print the results
anova_table = anova_lm(model)
print(anova_table)
```

	df	sum_sq	mean_sq	F	\
C(Preparation)	1.0	0.931612	0.931612	10.984377	
C(Mixture)	2.0	1.486108	0.743054	8.761140	
C(Time)	3.0	2.375938	0.791979	9.338000	
C(Preparation):C(Mixture)	2.0	1.079575	0.539787	6.364480	
C(Preparation):C(Time)	3.0	0.211660	0.070553	0.831873	
C(Mixture):C(Time)	6.0	0.636825	0.106137	1.251437	
C(Mixture):C(Time):C(Preparation)	6.0	0.303069	0.050512	0.595568	
Residual	48.0	4.071000	0.084812	NaN	

	PR(>F)
C(Preparation)	0.001754
C(Mixture)	0.000571
C(Time)	0.000057
C(Preparation):C(Mixture)	0.003534
C(Preparation):C(Time)	0.482943
C(Mixture):C(Time)	0.297517
C(Mixture):C(Time):C(Preparation)	0.732297
Residual	NaN

C(Preparation):

Degrees of Freedom (df): 1.0
Sum of Squares (sum_sq): 0.931612
Mean Square (mean_sq): 0.931612
F-statistic (F): 11.501206
p-value (PR(>F)): 0.001307
Interpretation:
The p-value for "C(Preparation)" is 0.001307, which is less than the significance level (commonly set at 0.05). Thus, there is a significant difference in Flexural Strength between different "Preparation" groups. In other words, the "Preparation" factor has a statistically significant effect on Flexural Strength.

C(Mixture):

Degrees of Freedom (df): 2.0
Sum of Squares (sum_sq): 1.486108
Mean Square (mean_sq): 0.743054
F-statistic (F): 9.173363
p-value (PR(>F)): 0.000372
Interpretation:
The p-value for "C(Mixture)" is 0.000372, which is less than the significance level. Therefore, there is a significant difference in Flexural Strength among the different "Mixture" groups. The "Mixture" factor has a statistically significant effect on Flexural Strength.

C(Time):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 2.375938
Mean Square (mean_sq): 0.791979
F-statistic (F): 9.777365
p-value (PR(>F)): 0.000030
Interpretation:
The p-value for "C(Time)" is 0.000030, which is less than the significance level. Therefore, there is a significant difference in Flexural Strength across the different "Time" groups. The "Time" factor has a statistically significant effect on Flexural Strength.

C(Preparation):C(Mixture), C(Preparation):C(Time), and C(Mixture):C(Time):

These are the interaction terms between the factors.
For "C(Preparation):C(Mixture)" and "C(Mixture):C(Time)," the p-values are less than the significance level (both below 0.05).
However, for "C(Preparation):C(Time)," the p-value is 0.461864, which is greater than 0.05.
Interpretation:
The interactions between "Preparation" and "Mixture" and between "Mixture" and "Time" have statistically significant effects on Flexural Strength. However, the interaction between "Preparation" and "Time" does not have a statistically significant effect on Flexural Strength.

Residual:

Degrees of Freedom (df): 54.0
Sum of Squares (sum_sq): 4.374069
Mean Square (mean_sq): 0.081001
Interpretation:
The residual represents the unexplained variance in Flexural Strength after accounting for the effects of the factors and interactions. It is the variation that cannot be attributed to the factors studied.

In summary, the results indicate that all main effects of "Preparation," "Mixture," and "Time," as well as the interactions between "Preparation" and "Mixture" and between "Mixture" and "Time," have significant effects on Flexural Strength. However, the interaction between "Preparation" and "Time" does not significantly influence Flexural Strength.

Bond Strength

```
In [21]: import pandas as pd
from statsmodels.formula.api import ols
from statsmodels.stats.anova import anova_lm

# Import data from CSV file
df = pd.read_csv("D:/Thesis FABGM/SCFABGM/Bond.csv")

# Fit the two-way ANOVA model
formula = 'Mpa ~ C(Preparation) + C(Mixture) + C(Time) + C(Preparation):C(Mixture) + C(Preparation):C(Time) + C(Mixture):C(Time) + C(Mixture):C(Time):C(Preparation)'
model = ols(formula, df).fit()

# Perform the ANOVA and print the results
anova_table = anova_lm(model)
print(anova_table)
```

	df	sum_sq	mean_sq	F	\
C(Preparation)	1.0	3.749235	3.749235	4.990542	
C(Mixture)	2.0	1.773636	0.886818	1.180428	
C(Time)	3.0	2.530538	0.843513	1.122785	
C(Preparation):C(Mixture)	2.0	3.067786	1.533893	2.041739	
C(Preparation):C(Time)	3.0	1.218826	0.406275	0.540786	
C(Mixture):C(Time)	6.0	0.287742	0.047957	0.063835	
C(Mixture):C(Time):C(Preparation)	6.0	0.905436	0.150906	0.200868	
Residual	48.0	36.060867	0.751268	NaN	

	PR(>F)
C(Preparation)	0.030180
C(Mixture)	0.315904
C(Time)	0.349197
C(Preparation):C(Mixture)	0.140926
C(Preparation):C(Time)	0.656677
C(Mixture):C(Time)	0.998875
C(Mixture):C(Time):C(Preparation)	0.974906
Residual	NaN

C(Preparation):

Degrees of Freedom (df): 1.0
Sum of Squares (sum_sq): 0.931612
Mean Square (mean_sq): 0.931612
F-statistic (F): 11.501206
p-value (PR(>F)): 0.001307
Interpretation:
The p-value for "C(Preparation)" is 0.001307, which is less than the significance level (commonly set at 0.05). Thus, there is a significant difference in Flexural Strength between different "Preparation" groups. In other words, the "Preparation" factor has a statistically significant effect on Flexural Strength.

C(Mixture):

Degrees of Freedom (df): 2.0
Sum of Squares (sum_sq): 1.486108
Mean Square (mean_sq): 0.743054
F-statistic (F): 9.173363
p-value (PR(>F)): 0.000372
Interpretation:
The p-value for "C(Mixture)" is 0.000372, which is less than the significance level. Therefore, there is a significant difference in Flexural Strength among the different "Mixture" groups. The "Mixture" factor has a statistically significant effect on Flexural Strength.

C(Time):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 2.375938
Mean Square (mean_sq): 0.791979
F-statistic (F): 9.777365
p-value (PR(>F)): 0.000030
Interpretation:
The p-value for "C(Time)" is 0.000030, which is less than the significance level. Therefore, there is a significant difference in Flexural Strength across the different "Time" groups. The "Time" factor has a statistically significant effect on Flexural Strength.

C(Preparation):C(Mixture), C(Preparation):C(Time), and C(Mixture):C(Time):

These are the interaction terms between the factors.
For "C(Preparation):C(Mixture)" and "C(Mixture):C(Time)," the p-values are less than the significance level (both below 0.05).
However, for "C(Preparation):C(Time)," the p-value is 0.461864, which is greater than 0.05.
Interpretation:
The interactions between "Preparation" and "Mixture" and between "Mixture" and "Time" have statistically significant effects on Flexural Strength. However, the interaction between "Preparation" and "Time" does not have a statistically significant effect on Flexural Strength.

Residual:

Degrees of Freedom (df): 54.0
Sum of Squares (sum_sq): 4.374069
Mean Square (mean_sq): 0.081001
Interpretation:
The residual represents the unexplained variance in Flexural Strength after accounting for the effects of the factors and interactions. It is the variation that cannot be attributed to the factors studied.

In summary, the results indicate that all main effects of "Preparation," "Mixture," and "Time," as well as the interactions between "Preparation" and "Mixture" and between "Mixture" and "Time," have significant effects on Flexural Strength. However, the interaction between "Preparation" and "Time" does not significantly influence Flexural Strength.

Weak Concrete with Geopolymer Mortar With/Without Preparation

Compressive Test

```
In [22]: import pandas as pd
from statsmodels.formula.api import ols
from statsmodels.stats.anova import anova_lm

# Import data from CSV file
df = pd.read_csv("D:/Thesis FABGM/WCFABGM/Compressive.csv")

# Fit the two-way ANOVA model
formula = 'Mpa ~ C(Preparation) + C(Mixture) + C(Time) + C(Preparation):C(Mixture) + C(Preparation):C(Time) + C(Mixture):C(Time) + C(Mixture):C(Time):C(Preparation)'
model = ols(formula, df).fit()

# Perform the ANOVA and print the results
anova_table = anova_lm(model)
print(anova_table)
```

	df	sum_sq	mean_sq	F	\
C(Preparation)	1.0	0.783335	0.783335	0.297519	
C(Mixture)	2.0	3.952144	1.976072	0.750533	
C(Time)	3.0	55.487082	18.495694	7.024863	
C(Preparation):C(Mixture)	2.0	3.253911	1.626956	0.617935	
C(Preparation):C(Time)	3.0	6.307549	2.102516	0.798558	
C(Mixture):C(Time)	6.0	1.304656	0.217443	0.082587	
C(Mixture):C(Time):C(Preparation)	6.0	0.808622	0.134770	0.051187	
Residual	48.0	126.378733	2.632890	NaN	

	PR(>F)
C(Preparation)	0.587968
C(Mixture)	0.477574
C(Time)	0.000520
C(Preparation):C(Mixture)	0.543289
C(Preparation):C(Time)	0.500775
C(Mixture):C(Time)	0.997674
C(Mixture):C(Time):C(Preparation)	0.999401
Residual	NaN

C(Preparation):

Degrees of Freedom (df): 1.0
Sum of Squares (sum_sq): 0.783335
Mean Square (mean_sq): 0.783335
F-statistic (F): 0.297519
p-value (PR(>F)): 0.587968
Interpretation: The p-value for "C(Preparation)" is 0.587968, which is greater than the significance level (commonly set at 0.05). Thus, there is no significant difference in Compressive Strength between different "Preparation" groups. In other words, the "Preparation" factor does not have a statistically significant effect on Compressive Strength.

C(Mixture):

Degrees of Freedom (df): 2.0
Sum of Squares (sum_sq): 3.952144
Mean Square (mean_sq): 1.976072
F-statistic (F): 0.750533
p-value (PR(>F)): 0.477574
Interpretation: The p-value for "C(Mixture)" is 0.477574, which is greater than the significance level. Therefore, there is no significant difference in Compressive Strength among the different "Mixture" groups. The "Mixture" factor does not have a statistically significant effect on Compressive Strength.

C(Time):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 55.487082
Mean Square (mean_sq): 18.495694
F-statistic (F): 7.024863
p-value (PR(>F)): 0.000520
Interpretation: The p-value for "C(Time)" is 0.000520, which is less than the significance level. Therefore, there is a significant difference in Compressive Strength across the different "Time" groups. The "Time" factor has a statistically significant effect on Compressive Strength.

C(Preparation):C(Mixture), C(Preparation):C(Time), C(Mixture):C(Time), and C(Mixture):C(Time):C(Preparation):

For all these interaction terms, the p-values are greater than the significance level (all above 0.05).
Interpretation: None of these interaction terms are significant. In other words, there is no significant interaction effect between the combinations of "Preparation" and "Mixture," "Preparation" and "Time," "Mixture" and "Time," and "Mixture," "Time," and "Preparation" on Compressive Strength.

Residual:

Degrees of Freedom (df): 48.0
Sum of Squares (sum_sq): 126.378733
Mean Square (mean_sq): 2.632890
Interpretation: The residual represents the unexplained variance in Compressive Strength after accounting for the effects of the factors and interactions. It is the variation that cannot be attributed to the factors studied.

In summary, the results indicate that the "Time" factor has a significant effect on Compressive Strength. However, the factors "Preparation" and "Mixture" and their interactions with other factors do not have significant effects on Compressive Strength.

Splitting Tensile

```
In [23]: import pandas as pd
from statsmodels.formula.api import ols
from statsmodels.stats.anova import anova_lm

# Import data from CSV file
df = pd.read_csv("D:/Thesis FABGM/WCFABGM/Splitting Tensile.csv")

# Fit the two-way ANOVA model
formula = 'Mpa ~ C(Preparation) + C(Mixture) + C(Time) + C(Preparation):C(Mixture) + C(Preparation):C(Time) + C(Mixture):C(Time) + C(Mixture):C(Time):C(Preparation)'
model = ols(formula, df).fit()

# Perform the ANOVA and print the results
anova_table = anova_lm(model)
print(anova_table)
```

	df	sum_sq	mean_sq	F	\
C(Preparation)	1.0	0.006235	0.006235	0.604987	
C(Mixture)	2.0	0.364369	0.182185	17.678302	
C(Time)	3.0	1.302260	0.434087	42.121608	
C(Preparation):C(Mixture)	2.0	0.087619	0.043810	4.251078	
C(Preparation):C(Time)	3.0	0.005782	0.001927	0.187017	
C(Mixture):C(Time)	6.0	0.091753	0.015292	1.483872	
C(Mixture):C(Time):C(Preparation)	6.0	0.097681	0.016280	1.579739	
Residual	48.0	0.494667	0.010306	NaN	

	PR(>F)
C(Preparation)	4.404988e-01
C(Mixture)	1.766971e-06
C(Time)	1.727339e-13
C(Preparation):C(Mixture)	1.996315e-02
C(Preparation):C(Time)	9.047231e-01
C(Mixture):C(Time)	2.038273e-01
C(Mixture):C(Time):C(Preparation)	1.735654e-01
Residual	NaN

C(Preparation):

Degrees of Freedom (df): 1.0
Sum of Squares (sum_sq): 0.006235
Mean Square (mean_sq): 0.006235
F-statistic (F): 0.604987
p-value (PR(>F)): 0.4404988
Interpretation: The p-value for "C(Preparation)" is 0.4404988, which is greater than the significance level (commonly set at 0.05). Thus, there is no significant difference in Splitting Tensile Strength between different "Preparation" groups. In other words, the "Preparation" factor does not have a statistically significant effect on Splitting Tensile Strength.

C(Mixture):

Degrees of Freedom (df): 2.0
Sum of Squares (sum_sq): 0.364369
Mean Square (mean_sq): 0.182185
F-statistic (F): 17.678302
p-value (PR(>F)): 1.766971e-06
Interpretation: The p-value for "C(Mixture)" is 1.766971e-06, which is much less than the significance level. Therefore, there is a significant difference in Splitting Tensile Strength among the different "Mixture" groups. The "Mixture" factor has a statistically significant effect on Splitting Tensile Strength.

C(Time):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 1.302260
Mean Square (mean_sq): 0.434087
F-statistic (F): 42.121608
p-value (PR(>F)): 1.727339e-13
Interpretation: The p-value for "C(Time)" is 1.727339e-13, which is much less than the significance level. Therefore, there is a significant difference in Splitting Tensile Strength across the different "Time" groups. The "Time" factor has a statistically significant effect on Splitting Tensile Strength.

C(Preparation):C(Mixture), C(Preparation):C(Time), C(Mixture):C(Time), and C(Mixture):C(Time):C(Preparation):

For "C(Preparation):C(Mixture)," the p-value is 0.01996315, which is less than the significance level (0.05).
For all other interaction terms, the p-values are greater than the significance level (all above 0.05).
Interpretation: The interaction between "Preparation" and "Mixture" has a statistically significant effect on Splitting Tensile Strength. However, the other interaction terms do not significantly influence Splitting Tensile Strength.

Residual:

Degrees of Freedom (df): 48.0
Sum of Squares (sum_sq): 0.494667
Mean Square (mean_sq): 0.010306
Interpretation: The residual represents the unexplained variance in Splitting Tensile Strength after accounting for the effects of the factors and interactions. It is the variation that cannot be attributed to the factors studied.

In summary, the results indicate that the "Mixture" and "Time" factors have significant effects on Splitting Tensile Strength. The "Preparation" factor does not have a significant effect. Additionally, there is a significant interaction effect between "Preparation" and "Mixture" but not between other combinations of factors.

Flexural Strength

```
In [24]: import pandas as pd
from statsmodels.formula.api import ols
from statsmodels.stats.anova import anova_lm

# Import data from CSV file
df = pd.read_csv("D:/Thesis FABGM/WCFABGM/Flexural.csv")

# Fit the two-way ANOVA model
formula = 'Mpa ~ C(Preparation) + C(Mixture) + C(Time) + C(Preparation):C(Mixture) + C(Preparation):C(Time) + C(Mixture):C(Time) + C(Mixture):C(Time):C(Preparation)'
model = ols(formula, df).fit()

# Perform the ANOVA and print the results
anova_table = anova_lm(model)
print(anova_table)
```

	df	sum_sq	mean_sq	F	\
C(Preparation)	1.0	2.753422	2.753422	22.018081	
C(Mixture)	2.0	4.998503	2.499251	19.985573	
C(Time)	3.0	2.322417	0.774139	6.190497	
C(Preparation):C(Mixture)	2.0	0.297086	0.148543	1.187843	
C(Preparation):C(Time)	3.0	0.378800	0.126267	1.009707	
C(Mixture):C(Time)	6.0	0.526775	0.087796	0.702070	
C(Mixture):C(Time):C(Preparation)	6.0	0.536925	0.089487	0.715598	
Residual	48.0	6.002533	0.125053	NaN	

	PR(>F)
C(Preparation)	2.278993e-05
C(Mixture)	4.848683e-07
C(Time)	1.212985e-03
C(Preparation):C(Mixture)	3.136797e-01
C(Preparation):C(Time)	3.966537e-01
C(Mixture):C(Time)	6.492875e-01
C(Mixture):C(Time):C(Preparation)	6.388250e-01
Residual	NaN

C(Preparation):

Degrees of Freedom (df): 1.0
Sum of Squares (sum_sq): 2.753422
Mean Square (mean_sq): 2.753422
F-statistic (F): 22.018081
p-value (PR(>F)): 2.278993e-05
Interpretation: The p-value for "C(Preparation)" is 2.278993e-05, which is much less than the significance level (commonly set at 0.05). Thus, there is a significant difference in Flexural Strength between different "Preparation" groups. In other words, the "Preparation" factor has a statistically significant effect on Flexural Strength.

C(Mixture):

Degrees of Freedom (df): 2.0
Sum of Squares (sum_sq): 4.998503
Mean Square (mean_sq): 2.499251
F-statistic (F): 19.985573
p-value (PR(>F)): 4.848683e-07
Interpretation: The p-value for "C(Mixture)" is 4.848683e-07, which is much less than the significance level. Therefore, there is a significant difference in Flexural Strength among the different "Mixture" groups. The "Mixture" factor has a statistically significant effect on Flexural Strength.

C(Time):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 2.322417
Mean Square (mean_sq): 0.774139
F-statistic (F): 6.190497
p-value (PR(>F)): 1.212985e-03
Interpretation: The p-value for "C(Time)" is 1.212985e-03, which is less than the significance level. Therefore, there is a significant difference in Flexural Strength across the different "Time" groups. The "Time" factor has a statistically significant effect on Flexural Strength.

C(Preparation):C(Mixture), C(Preparation):C(Time), C(Mixture):C(Time), and C(Mixture):C(Time):C(Preparation):

For all these interaction terms, the p-values are greater than the significance level (all above 0.05).
Interpretation: None of these interaction terms are significant. In other words, there is no significant interaction effect between the combinations of factors on Flexural Strength.

Residual:

Degrees of Freedom (df): 48.0
Sum of Squares (sum_sq): 6.002533
Mean Square (mean_sq): 0.125053
Interpretation: The residual represents the unexplained variance in Flexural Strength after accounting for the effects of the factors and interactions. It is the variation that cannot be attributed to the factors studied.

In summary, the results indicate that the "Preparation" and "Mixture" factors have significant effects on Flexural Strength. Additionally, the "Time" factor also has a significant effect on Flexural Strength. However, there are no significant interaction effects between any combinations of factors on Flexural Strength.

Bond Strength

```
In [25]: import pandas as pd
from statsmodels.formula.api import ols
from statsmodels.stats.anova import anova_lm

# Import data from CSV file
df = pd.read_csv("D:/Thesis FABGM/WCFABGM/Bond.csv")

# Fit the two-way ANOVA model
formula = 'Mpa ~ C(Preparation) + C(Mixture) + C(Time) + C(Preparation):C(Mixture) + C(Preparation):C(Time) + C(Mixture):C(Time) + C(Mixture):C(Time):C(Preparation)'
model = ols(formula, df).fit()

# Perform the ANOVA and print the results
anova_table = anova_lm(model)
print(anova_table)
```

	df	sum_sq	mean_sq	F	\
C(Preparation)	1.0	0.449668	0.449668	0.417177	
C(Mixture)	2.0	1.795936	0.897968	0.833086	
C(Time)	3.0	1.343915	0.447972	0.415604	
C(Preparation):C(Mixture)	2.0	0.049886	0.024943	0.023141	
C(Preparation):C(Time)	3.0	0.057960	0.019320	0.017924	
C(Mixture):C(Time)	6.0	0.331397	0.055233	0.051242	
C(Mixture):C(Time):C(Preparation)	6.0	0.204469	0.034078	0.031616	
Residual	48.0	51.738333	1.077882	NaN	

PR(>F)

C(Preparation)	0.521425
C(Mixture)	0.440893
C(Time)	0.742573
C(Preparation):C(Mixture)	0.977136
C(Preparation):C(Time)	0.996689
C(Mixture):C(Time)	0.999399
C(Mixture):C(Time):C(Preparation)	0.999852
Residual	NaN

C(Preparation):

Degrees of Freedom (df): 1.0
Sum of Squares (sum_sq): 0.449668
Mean Square (mean_sq): 0.449668
F-statistic (F): 0.417177
p-value (PR(>F)): 0.521425
Interpretation: The p-value for "C(Preparation)" is 0.521425, which is greater than the significance level (commonly set at 0.05). Thus, there is no significant difference in Bond Strength between different "Preparation" groups. In other words, the "Preparation" factor does not have a statistically significant effect on Bond Strength.

C(Mixture):

Degrees of Freedom (df): 2.0
Sum of Squares (sum_sq): 1.795936
Mean Square (mean_sq): 0.897968
F-statistic (F): 0.833086
p-value (PR(>F)): 0.440893
Interpretation: The p-value for "C(Mixture)" is 0.440893, which is greater than the significance level. Therefore, there is no significant difference in Bond Strength among the different "Mixture" groups. The "Mixture" factor does not have a statistically significant effect on Bond Strength.

C(Time):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 1.343915
Mean Square (mean_sq): 0.447972
F-statistic (F): 0.415604
p-value (PR(>F)): 0.742573
Interpretation: The p-value for "C(Time)" is 0.742573, which is greater than the significance level. Therefore, there is no significant difference in Bond Strength across the different "Time" groups. The "Time" factor does not have a statistically significant effect on Bond Strength.

C(Preparation):C(Mixture), C(Preparation):C(Time), C(Mixture):C(Time), and C(Mixture):C(Time):C(Preparation):

For all these interaction terms, the p-values are greater than the significance level (all above 0.05).
Interpretation: None of these interaction terms are significant. In other words, there is no significant interaction effect between the combinations of factors on Bond Strength.

Residual:

Degrees of Freedom (df): 48.0
Sum of Squares (sum_sq): 51.738333
Mean Square (mean_sq): 1.077882
Interpretation: The residual represents the unexplained variance in Bond Strength after accounting for the effects of the factors and interactions. It is the variation that cannot be attributed to the factors studied.

In summary, the results indicate that neither the "Preparation" nor the "Mixture" factors have a significant effect on Bond Strength. The "Time" factor also does not significantly influence Bond Strength. Additionally, there are no significant interaction effects between any combinations of factors on Bond Strength.

Strong Concrete with Cement Mortar With/Without Preparation

Compressive Test

```
In [26]: import pandas as pd
from statsmodels.formula.api import ols
from statsmodels.stats.anova import anova_lm

# Import data from CSV file
df = pd.read_csv("D:/Thesis FABGM/SCCM/Compressive.csv")

# Fit the two-way ANOVA model
formula = 'Mpa ~ C(Preparation) + C(Day) + C(Preparation):C(Day)'
model = ols(formula, df).fit()

# Perform the ANOVA and print the results
anova_table = anova_lm(model)
print(anova_table)
```

	df	sum_sq	mean_sq	F	PR(>F)
C(Preparation)	1.0	0.598504	0.598504	0.133345	0.719771
C(Day)	3.0	215.783746	71.927915	16.025276	0.000045
C(Preparation):C(Day)	3.0	0.319046	0.106349	0.023694	0.994859
Residual	16.0	71.814467	4.488404	NaN	NaN

C(Preparation):

Degrees of Freedom (df): 1.0
Sum of Squares (sum_sq): 0.598504
Mean Square (mean_sq): 0.598504
F-statistic (F): 0.133345
p-value (PR(>F)): 0.719771
Interpretation: The p-value for "C(Preparation)" is 0.719771, which is greater than the significance level (commonly set at 0.05). Thus, there is no significant difference in Compressive Strength between different "Preparation" groups. In other words, the "Preparation" factor does not have a statistically significant effect on Compressive Strength.

C(Day):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 215.783746
Mean Square (mean_sq): 71.927915
F-statistic (F): 16.025276
p-value (PR(>F)): 0.000045
Interpretation: The p-value for "C(Day)" is 0.000045, which is much less than the significance level. Therefore, there is a significant difference in Compressive Strength across the different "Day" groups. The "Day" factor has a statistically significant effect on Compressive Strength.

C(Preparation):C(Day):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 0.319046
Mean Square (mean_sq): 0.106349
F-statistic (F): 0.023694
p-value (PR(>F)): 0.994859
Interpretation: The p-value for "C(Preparation):C(Day)" is 0.994859, which is greater than the significance level. Therefore, there is no significant interaction effect between the "Preparation" and "Day" factors on Compressive Strength.

Residual:

Degrees of Freedom (df): 16.0
Sum of Squares (sum_sq): 71.814467
Mean Square (mean_sq): 4.488404
Interpretation: The residual represents the unexplained variance in Compressive Strength after accounting for the effects of the factors and interactions. It is the variation that cannot be attributed to the factors studied.

Splitting Tensile

```
In [27]: import pandas as pd
from statsmodels.formula.api import ols
from statsmodels.stats.anova import anova_lm

# Import data from CSV file
df = pd.read_csv("D:/Thesis FABGM/SCCM/Splitting Tensile.csv")

# Fit the two-way ANOVA model
formula = 'Mpa ~ C(Preparation) + C(Day) + C(Preparation):C(Day)'
model = ols(formula, df).fit()

# Perform the ANOVA and print the results
anova_table = anova_lm(model)
print(anova_table)
```

	df	sum_sq	mean_sq	F	PR(>F)
C(Preparation)	1.0	0.005704	0.005704	0.974377	0.338284
C(Day)	3.0	0.044579	0.014860	2.538316	0.093194
C(Preparation):C(Day)	3.0	0.001112	0.000371	0.063345	0.978446
Residual	16.0	0.093667	0.005854	NaN	NaN

C(Preparation):

Degrees of Freedom (df): 1.0
Sum of Squares (sum_sq): 0.005704
Mean Square (mean_sq): 0.005704
F-statistic (F): 0.974377
p-value (PR(>F)): 0.338284
Interpretation: The p-value for "C(Preparation)" is 0.338284, which is greater than the significance level (commonly set at 0.05). Thus, there is no significant difference in Splitting Tensile Strength between different "Preparation" groups. In other words, the "Preparation" factor does not have a statistically significant effect on Splitting Tensile Strength.

C(Day):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 0.044579
Mean Square (mean_sq): 0.014860
F-statistic (F): 2.538316
p-value (PR(>F)): 0.093194
Interpretation: The p-value for "C(Day)" is 0.093194, which is slightly greater than the significance level. Therefore, there is no strong evidence to conclude a significant difference in Splitting Tensile Strength across the different "Day" groups. However, the p-value is close to the significance level, so there may be some indication of a potential effect that requires further investigation.

C(Preparation):C(Day):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 0.001112
Mean Square (mean_sq): 0.000371
F-statistic (F): 0.063345
p-value (PR(>F)): 0.978446
Interpretation: The p-value for "C(Preparation):C(Day)" is 0.978446, which is much greater than the significance level. Therefore, there is no significant interaction effect between the "Preparation" and "Day" factors on Splitting Tensile Strength.

Residual:

Degrees of Freedom (df): 16.0
Sum of Squares (sum_sq): 0.093667
Mean Square (mean_sq): 0.005854
Interpretation: The residual represents the unexplained variance in Splitting Tensile Strength after accounting for the effects of the factors and interactions. It is the variation that cannot be attributed to the factors studied.

In summary, the results indicate that the "Preparation" factor does not have a significant effect on Splitting Tensile Strength. The "Day" factor also does not show a statistically significant effect, although there may be some potential indication that requires further investigation. There is no significant interaction effect between "Preparation" and "Day" on Splitting Tensile Strength.

Flexural Strength

```
In [30]: import pandas as pd
from statsmodels.formula.api import ols
from statsmodels.stats.anova import anova_lm

# Import data from CSV file
df = pd.read_csv("D:/Thesis FABGM/SCCM/Flexural.csv")

# Fit the two-way ANOVA model
formula = 'Mpa ~ C(Preparation) + C(Day) + C(Preparation):C(Day)'
model = ols(formula, df).fit()

# Perform the ANOVA and print the results
anova_table = anova_lm(model)
print(anova_table)
```

	df	sum_sq	mean_sq	F	PR(>F)
C(Preparation)	1.0	0.057038	0.057038	1.298151	0.271322
C(Day)	3.0	0.268546	0.089515	2.037332	0.149178
C(Preparation):C(Day)	3.0	0.080813	0.026938	0.613087	0.616340
Residual	16.0	0.703000	0.043938	NaN	NaN

C(Preparation):

Degrees of Freedom (df): 1.0
Sum of Squares (sum_sq): 0.057038
Mean Square (mean_sq): 0.057038
F-statistic (F): 1.298151
p-value (PR(>F)): 0.271322
Interpretation: The p-value for "C(Preparation)" is 0.271322, which is greater than the significance level (commonly set at 0.05). Thus, there is no significant difference in Flexural Strength between different "Preparation" groups. In other words, the "Preparation" factor does not have a statistically significant effect on Flexural Strength.

C(Day):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 0.268546
Mean Square (mean_sq): 0.089515
F-statistic (F): 2.037332
p-value (PR(>F)): 0.149178
Interpretation: The p-value for "C(Day)" is 0.149178, which is greater than the significance level. Therefore, there is no significant difference in Flexural Strength across the different "Day" groups. The "Day" factor does not have a statistically significant effect on Flexural Strength.

C(Preparation):C(Day):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 0.080813
Mean Square (mean_sq): 0.026938
F-statistic (F): 0.613087
p-value (PR(>F)): 0.616340
Interpretation: The p-value for "C(Preparation):C(Day)" is 0.616340, which is much greater than the significance level. Therefore, there is no significant interaction effect between the "Preparation" and "Day" factors on Flexural Strength.

Residual:

Degrees of Freedom (df): 16.0
Sum of Squares (sum_sq): 0.703000
Mean Square (mean_sq): 0.043938
Interpretation: The residual represents the unexplained variance in Flexural Strength after accounting for the effects of the factors and interactions. It is the variation that can not be attributed to the factors studied.

In summary, the results indicate that neither the "Preparation" nor the "Day" factors have a significant effect on Flexural Strength. Additionally, there is no significant interaction effect between "Preparation" and "Day" on Flexural Strength.

Bond Strength

```
In [31]: import pandas as pd
from statsmodels.formula.api import ols
from statsmodels.stats.anova import anova_lm

# Import data from CSV file
df = pd.read_csv("D:/Thesis FABGM/SCCM/Bond.csv")

# Fit the two-way ANOVA model
formula = 'Mpa ~ C(Preparation) + C(Day) + C(Preparation):C(Day)'
model = ols(formula, df).fit()

# Perform the ANOVA and print the results
anova_table = anova_lm(model)
print(anova_table)
```

	df	sum_sq	mean_sq	F	PR(>F)
C(Preparation)	1.0	0.000104	0.000104	0.000246	0.987674
C(Day)	3.0	11.163412	3.721137	8.796842	0.001121
C(Preparation):C(Day)	3.0	0.072146	0.024049	0.056851	0.981549
Residual	16.0	6.768133	0.423008	NaN	NaN

<div style="text-align: justify">

C(Preparation):

Degrees of Freedom (df): 1.0
Sum of Squares (sum_sq): 0.000104
Mean Square (mean_sq): 0.000104
F-statistic (F): 0.000246
p-value (PR(>F)): 0.987674
Interpretation: The p-value for "C(Preparation)" is 0.987674, which is much greater than the significance level (commonly set at 0.05). Thus, there is no significant difference in Bond Strength between different "Preparation" groups. In other words, the "Preparation" factor does not have a statistically significant effect on Bond Strength.

C(Day):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 11.163412
Mean Square (mean_sq): 3.721137
F-statistic (F): 8.796842
p-value (PR(>F)): 0.001121
Interpretation: The p-value for "C(Day)" is 0.001121, which is less than the significance level. Therefore, there is a significant difference in Bond Strength across the different "Day" groups. The "Day" factor has a statistically significant effect on Bond Strength.

C(Preparation):C(Day):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 0.072146
Mean Square (mean_sq): 0.024049
F-statistic (F): 0.056851
p-value (PR(>F)): 0.981549

Interpretation: The p-value for "C(Preparation):C(Day)" is 0.981549, which is much greater than the significance level. Therefore, there is no significant interaction effect between the "Preparation" and "Day" factors on Bond Strength.

Residual:

Degrees of Freedom (df): 16.0
Sum of Squares (sum_sq): 6.768133
Mean Square (mean_sq): 0.423008
Interpretation: The residual represents the unexplained variance in Bond Strength after accounting for the effects of the factors and interactions. It is the variation that cannot be attributed to the factors studied.

In summary, the results indicate that the "Preparation" factor does not have a significant effect on Bond Strength. However, the "Day" factor has a significant effect on Bond Strength. There is no significant interaction effect between "Preparation" and "Day" on Bond Strength.

Weak Concrete with Cement Mortar With/Without Preparation

Compressive Strength

In [32]:

```
import pandas as pd
from statsmodels.formula.api import ols
from statsmodels.stats.anova import anova_lm

# Import data from CSV file
df = pd.read_csv("D:/Thesis FABGM/WCCM/Compressive.csv")

# Fit the two-way ANOVA model
formula = 'Mpa ~ C(Preparation) + C(Day) + C(Preparation):C(Day)'
model = ols(formula, df).fit()

# Perform the ANOVA and print the results
anova_table = anova_lm(model)
print(anova_table)
```

	df	sum_sq	mean_sq	F	PR(>F)
C(Preparation)	1.0	0.400417	0.400417	0.265916	0.613136
C(Day)	3.0	70.039833	23.346611	15.504457	0.000054
C(Preparation):C(Day)	3.0	7.720350	2.573450	1.709025	0.205288
Residual	16.0	24.092800	1.505800	NaN	NaN

C(Preparation):

Degrees of Freedom (df): 1.0
Sum of Squares (sum_sq): 0.400417
Mean Square (mean_sq): 0.400417
F-statistic (F): 0.265916
p-value (PR(>F)): 0.613136
Interpretation: The p-value for "C(Preparation)" is 0.613136, which is much greater than the significance level (commonly set at 0.05). Thus, there is no significant difference in Compressive Strength between different "Preparation" groups. In other words, the "Preparation" factor does not have a statistically significant effect on Compressive Strength.

C(Day):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 70.039833
Mean Square (mean_sq): 23.346611
F-statistic (F): 15.504457
p-value (PR(>F)): 0.000054
Interpretation: The p-value for "C(Day)" is 0.000054, which is less than the significance level. Therefore, there is a significant difference in Compressive Strength across the different "Day" groups. The "Day" factor has a statistically significant effect on Compressive Strength.

C(Preparation):C(Day):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 7.720350
Mean Square (mean_sq): 2.573450
F-statistic (F): 1.709025
p-value (PR(>F)): 0.205288
Interpretation: The p-value for "C(Preparation):C(Day)" is 0.205288, which is greater than the significance level. Therefore, there is no significant interaction effect between the "Preparation" and "Day" factors on Compressive Strength.

Residual:

Degrees of Freedom (df): 16.0
Sum of Squares (sum_sq): 24.092800
Mean Square (mean_sq): 1.505800
Interpretation: The residual represents the unexplained variance in Compressive Strength after accounting for the effects of the factors and interactions. It is the variation that cannot be attributed to the factors studied.

In summary, the results indicate that the "Preparation" factor does not have a significant effect on Compressive Strength. However, the "Day" factor has a significant effect on Compressive Strength. There is no significant interaction effect between "Preparation" and "Day" on Compressive Strength.

Splitting Tensile Strength

In [34]:

```
import pandas as pd
from statsmodels.formula.api import ols
from statsmodels.stats.anova import anova_lm

# Import data from CSV file
df = pd.read_csv("D:/Thesis FABGM/WCCM/Splitting Tensile.csv")

# Fit the two-way ANOVA model
formula = 'Mpa ~ C(Preparation) + C(Day) + C(Preparation):C(Day)'
model = ols(formula, df).fit()

# Perform the ANOVA and print the results
anova_table = anova_lm(model)
print(anova_table)
```

	df	sum_sq	mean_sq	F	PR(>F)
C(Preparation)	1.0	0.003037	0.003037	0.103595	0.751724
C(Day)	3.0	0.339312	0.113104	3.857468	0.029819
C(Preparation):C(Day)	3.0	0.050212	0.016737	0.570840	0.642270
Residual	16.0	0.469133	0.029321	NaN	NaN

C(Preparation):

Degrees of Freedom (df): 1.0
Sum of Squares (sum_sq): 0.003037
Mean Square (mean_sq): 0.003037
F-statistic (F): 0.103595
p-value (PR(>F)): 0.751724
Interpretation: The p-value for "C(Preparation)" is 0.751724, which is much greater than the significance level (commonly set at 0.05). Thus, there is no significant difference in Splitting Tensile Strength between different "Preparation" groups. In other words, the "Preparation" factor does not have a statistically significant effect on Splitting Tensile Strength.

C(Day):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 0.339312
Mean Square (mean_sq): 0.113104
F-statistic (F): 3.857468
p-value (PR(>F)): 0.029819
Interpretation: The p-value for "C(Day)" is 0.029819, which is less than the significance level. Therefore, there is a significant difference in Splitting Tensile Strength across the different "Day" groups. The "Day" factor has a statistically significant effect on Splitting Tensile Strength.

C(Preparation):C(Day):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 0.050212
Mean Square (mean_sq): 0.016737
F-statistic (F): 0.570840
p-value (PR(>F)): 0.642270
Interpretation: The p-value for "C(Preparation):C(Day)" is 0.642270, which is much greater than the significance level. Therefore, there is no significant interaction effect between the "Preparation" and "Day" factors on Splitting Tensile Strength.

Residual:

Degrees of Freedom (df): 16.0
Sum of Squares (sum_sq): 0.469133
Mean Square (mean_sq): 0.029321
Interpretation: The residual represents the unexplained variance in Splitting Tensile Strength after accounting for the effects of the factors and interactions. It is the variation that cannot be attributed to the factors studied.

In summary, the results indicate that the "Preparation" factor does not have a significant effect on Splitting Tensile Strength. However, the "Day" factor has a significant effect on Splitting Tensile Strength. There is no significant interaction effect between "Preparation" and "Day" on Splitting Tensile Strength.

Flexural Strength

```
In [35]: import pandas as pd
from statsmodels.formula.api import ols
from statsmodels.stats.anova import anova_lm

# Import data from CSV file
df = pd.read_csv("D:/Thesis FABGM/WCCM/Flexural.csv")

# Fit the two-way ANOVA model
formula = 'Mpa ~ C(Preparation) + C(Day) + C(Preparation):C(Day)'
model = ols(formula, df).fit()

# Perform the ANOVA and print the results
anova_table = anova_lm(model)
print(anova_table)
```

	df	sum_sq	mean_sq	F	PR(>F)
C(Preparation)	1.0	0.180267	0.180267	3.274351	0.089196
C(Day)	3.0	0.913200	0.304400	5.529100	0.008457
C(Preparation):C(Day)	3.0	0.112600	0.037533	0.681753	0.575998
Residual	16.0	0.880867	0.055054	NaN	NaN

C(Preparation):

Degrees of Freedom (df): 1.0
Sum of Squares (sum_sq): 0.180267
Mean Square (mean_sq): 0.180267
F-statistic (F): 3.274351
p-value (PR(>F)): 0.089196
Interpretation: The p-value for "C(Preparation)" is 0.089196, which is greater than the significance level (commonly set at 0.05). Thus, there is no strong evidence to suggest that there is a significant difference in Flexural Strength between different "Preparation" groups. In other words, the "Preparation" factor does not have a statistically significant effect on Flexural Strength, although it is borderline significant.

C(Day):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 0.913200
Mean Square (mean_sq): 0.304400
F-statistic (F): 5.529100
p-value (PR(>F)): 0.008457
Interpretation: The p-value for "C(Day)" is 0.008457, which is less than the significance level. Therefore, there is a significant difference in Flexural Strength across the different "Day" groups. The "Day" factor has a statistically significant effect on Flexural Strength.

C(Preparation):C(Day):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 0.112600
Mean Square (mean_sq): 0.037533
F-statistic (F): 0.681753
p-value (PR(>F)): 0.575998
Interpretation: The p-value for "C(Preparation):C(Day)" is 0.575998, which is much greater than the significance level. Therefore, there is no significant interaction effect between the "Preparation" and "Day" factors on Flexural Strength.

Residual:

Degrees of Freedom (df): 16.0
Sum of Squares (sum_sq): 0.880867
Mean Square (mean_sq): 0.055054
Interpretation: The residual represents the unexplained variance in Flexural Strength after accounting for the effects of the factors and interactions. It is the variation that cannot be attributed to the factors studied.

In summary, while the "Preparation" factor does not have a statistically significant effect on Flexural Strength (borderline significant), the "Day" factor has a significant effect. There is no significant interaction effect between "Preparation" and "Day" on Flexural Strength.

Bond Strength

```
In [45]: import pandas as pd
from statsmodels.formula.api import ols
from statsmodels.stats.anova import anova_lm

# Import data from CSV file
df = pd.read_csv("D:/Thesis FABGM/WCCM/Bond.csv")

# Fit the two-way ANOVA model
formula = 'Mpa ~ C(Preparation) + C(Day) + C(Preparation):C(Day)'
model = ols(formula, df).fit()

# Perform the ANOVA and print the results
anova_table = anova_lm(model)
print(anova_table)
```

	df	sum_sq	mean_sq	F	PR(>F)
C(Preparation)	1.0	1.161600	1.161600	4.252608	0.055818
C(Day)	3.0	4.813217	1.604406	5.873716	0.006666
C(Preparation):C(Day)	3.0	0.223567	0.074522	0.272825	0.844092
Residual	16.0	4.370400	0.273150	NaN	NaN

C(Preparation):

Degrees of Freedom (df): 1.0
Sum of Squares (sum_sq): 1.161600
Mean Square (mean_sq): 1.161600
F-statistic (F): 4.252608
p-value (PR(>F)): 0.055818
Interpretation: The p-value for "C(Preparation)" is 0.055818, which is slightly greater than the significance level (commonly set at 0.05). Thus, there is some evidence to suggest that there may be a significant difference in Bond Strength between different "Preparation" groups. However, the p-value is close to the significance level, so it is borderline significant.

C(Day):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 4.813217
Mean Square (mean_sq): 1.604406
F-statistic (F): 5.873716
p-value (PR(>F)): 0.006666
Interpretation: The p-value for "C(Day)" is 0.006666, which is less than the significance level. Therefore, there is a significant difference in Bond Strength across the different "Day" groups. The "Day" factor has a statistically significant effect on Bond Strength.

C(Preparation):C(Day):

Degrees of Freedom (df): 3.0
Sum of Squares (sum_sq): 0.223567
Mean Square (mean_sq): 0.074522
F-statistic (F): 0.272825
p-value (PR(>F)): 0.844092
Interpretation: The p-value for "C(Preparation):C(Day)" is 0.844092, which is much greater than the significance level. Therefore, there is no significant interaction effect between the "Preparation" and "Day" factors on Bond Strength.

Residual:

Degrees of Freedom (df): 16.0
Sum of Squares (sum_sq): 4.370400
Mean Square (mean_sq): 0.273150
Interpretation: The residual represents the unexplained variance in Bond Strength after accounting for the effects of the factors and interactions. It is the variation that cannot be attributed to the factors studied.

In summary, while the "Preparation" factor may have a borderline significant effect on Bond Strength, the "Day" factor has a significant effect. There is no significant interaction effect between "Preparation" and "Day" on Bond Strength.