H0: β0% = β1.5% = β3%
H1: at least one treatment effect is different Here, the β's represents the treatment effect.
<u>Test Time:</u>
Test whether the concrete compressive strength is increased with time. H0: ω3days = ω7days = ω28days
H1: at least one treatment effect is different Here, the ω's represents the treatment effect.
Time is usually not a factor, but in this study particularly it was set as a factor to check whether our new concrete combinations have the same effect on time compared with the effect of the conventional concrete combinations described in the ASTM standard. However, the concrete compressive strength should increase with time.
Note: A significant level (α) of 0.05 is going to be used in all the report.

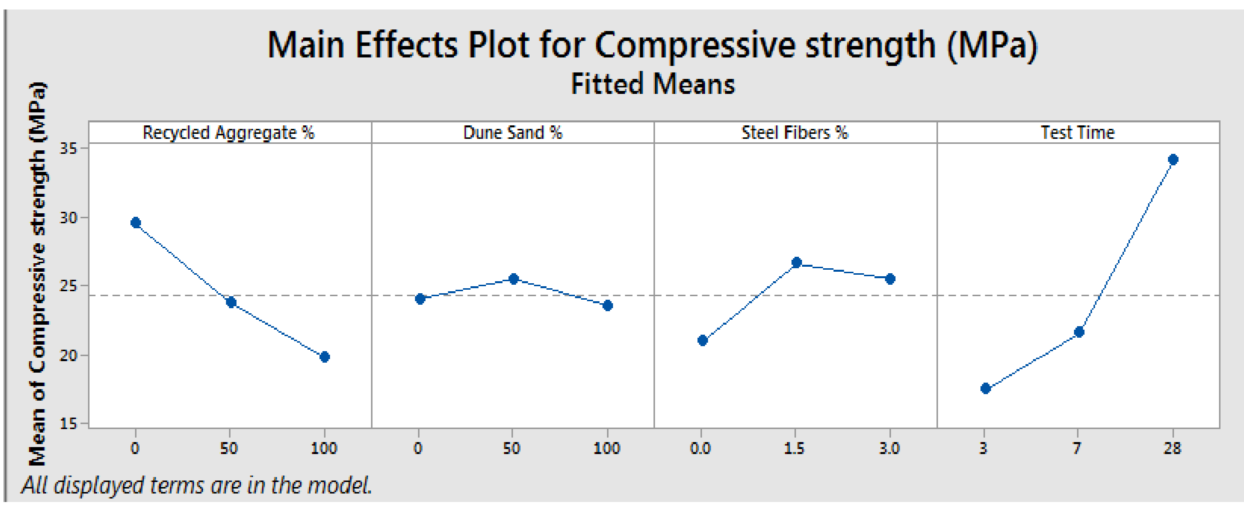
Full Factorial Design:

In this section, a complete full factorial analysis will be conducted for our collected experimental data in order to distinguish between the significant and insignificant factors and their interactions on our response which is the concrete compressive strength.

Main effect plot

The main effect plot is useful to understand the main effect of each factor on the response as well as the effect of each individual level. The main effect plots are shown in Figure 2. It shows that the effect of both the percentage of recycled aggregate and test time are highly effective. The compressive strength decreases with increasing the percentage of recycled aggregates. Whereas, the compressive strength of concrete increases with time.
The effect of dune sand was very interesting. Replacing 100% of the manufactured sand with dune sand showed that the compressive strength has not changed. However, it is noticeable that using the combination of both types of sand has improved the compressive strength of the concrete. When combining both types of sand, the voids between the sand particles will be reduced which will result in a more compacted concrete.
The inclusion of steel fibers by 1.5% to the concrete mix improved the compressive strength by almost 30%. Unexpectedly, when 3% of steel fiber was added the compressive strength increased by only 19%. This result could be due to the loss of workability and homogeneity of the concrete mix when adding 3% of steel fibers.

Figure 2: Main effects plots – Full factorial



Taguchi Design:

In this section, Taguchi analysis will be conducted for our collected experimental data in order to study the main effects of each factor and their levels. However, Taguchi design does not cover the effect of factor interactions.

The main effect plot is shown in Figure 3. The figure shows that the compressive strength decreases with increasing the percentage of recycled aggregates. Whereas, the compressive strength of concrete has a proportional relationship with time.
Using 100 % dune sand in the mix didn't change the compressive strength compared to 100 % manufactured sand. However, it is noticeable that using the combination of both types of sand has decreased the compressive strength of the concrete.
The addition of steel fibers by 1.5% and 3% to the concrete mix improved the compressive strength. Unpredictably, the addition of 3% steel fiber has less effect than that of 1.5%. This result could be due to the loss of workability and homogeneity of the concrete mix when adding 3% of steel fibers.

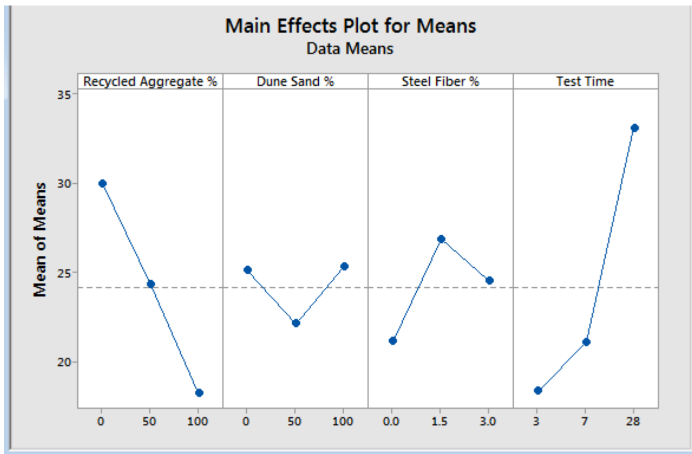


Figure 3: Main effects plot for means – Taguchi Design

Results discussion and comparison between the results of full factorial and Taguchi Designs:

Full factorial and Taguchi methods are methodology for systematically applying statistics to experimentation. Both methods cover the main effect of factors. However, the full factorial can find the interaction effect of factors while Taguchi can't. Moreover, the number of experiments in full factorial method is much higher than that of Taguchi. Therefore, full factorial method is more accurate and complex than Taguchi method.
In our study, the results of the main effect plots for both methods were the same except for the percentage of dune sand. In the full factorial method, when combining both types of sand, the compressive strength of concrete increased. In contrast, Taguchi showed opposites results.

Conclusion

Concrete compressive strength has been studied in this report. Four factors of interest were defined and variated throughout the experiment in order to study their effects on the target response, i.e. compression strength. The factors are percentage of recycled aggregate, percentage of dune sand, amount of steel fiber and test period. The full factorial design was used and found to be valid via testing data normality and equal variance. Then the results showed that all four factors and the two-way interactions were significant. The insignificants were the three- and four-way interactions. The model equation has been refined by taken out the insignificant factors and interactions. It was found that the R-Squared is high with value of 94.93% which means that our model is valid. After that, the response optimizer tool via Minitab was used to determine the optimal factors combination to obtain our target-quality concrete mixture. A high-quality concrete mixture with a compression strength of 35 MPa can be attained when using 50% replacement of recycled aggregate, 100% replacement of dune sand and only 1.5 % inclusion of steel fiber, then keeping the mixture to gain full strength for 28 days. After that, The Taguchi method was used to determine the main effects of factors. The results of both methods were the same except for the percentage of dune sand. In the full factorial method, when combining both types of sand, the compressive strength of concrete increased. In contrast, Taguchi showed opposites results.

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