# Correlation Between Slump, VeBe and Compaction Factor of Concrete Containing Shredded PET Bottles, Manufactured Sand (M-sand) and River Sand as Fine Aggregate

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**Abstract**. This paper investigates the effects of the properties of fresh concrete incorporating shredded Polyethylene Terephthalate (PET) bottles and Manufactured Sand (M-sand) together as fine aggregates replacement in concrete mixtures. The investigation to determine the correlation of the fresh properties of concrete were mainly experimental based and the experiments involved were Slump Test, VeBe Test and Compaction Factor Test. There were two different concrete batches were prepared, in which the first batch was partially replaced by M-sand and the second batch was partially replaced by M-sand and shredded PET bottles as fine aggregate replacements. The proportion of M-sand content and M-sand with shredded PET bottles were 25%, 50%, 75% and 100% (for M-sand) and 1.5% proportion of shredded PET bottles respectively. The mix design was prepared in accordance to the Department of Environment (DOE) method and utilizes M30 as the Class of Concrete. A novel empirical relationship between slump, VeBe, and compaction factor for the shredded PET bottles and M-Sand based M30 concrete was proposed. The outcomes of this research has proven beneficial to the construction industries as the utilisation of waste and recycled materials has the potential for sustainable construction.

## 1. Introduction

Recently, the growth of the building constructions has increased tremendously over years. This significantly affects the demand of raw materials particularly cement, coarse aggregates and fine aggregates in concrete production. Fine aggregate in particular is mainly referring to natural river sand and the excessive usage of this material has caused river beds to be exploited. Therefore due to this serious issue which is the increasing demand of the good quality of river sand has led recent search to conduct further study on the potential waste materials that can be used as river sand substitution in the concrete production. The production of aggregates by crushing hard granite stone produced an amount of waste volume which is unwanted and rejected by the industry namely Manufactured Sand (M- sand), also called granite quarry dust (GQD) or granite dust. Due to this abundance availability that has been produced in large quantities as well as to be known as waste product from the industry, M-

sand has been found to be suitable construction materials to be used as fine aggregate replacement to natural river sand[1].

In addition, excessive amount of plastic waste is another major problem faced worldwide because most of the plastic productions are non-biodegradable. The most commonly used plastic material are Polyethylene Terephthalate (PET) and this type of material can be easily found in plastic bottles or mineral water bottles [2]. In order to prevent further depletion of natural sand as well as to reduce the amount of plastic waste particularly PET, the usage of natural river sane as fine aggregate in concrete can be replaced with Manufactured sand (M-sand) and shredded plastic PET bottles.

This research was conducted to investigate the properties of fresh concrete containing M-sand and also concrete containing M-sand with some incorporation of shredded PET bottles as fine aggregate replacement to natural river sand as newly developed concrete material. As far as the properties of hardened concrete are concerned, the properties of fresh concrete are paramount important too since the workability of the concrete is with respect to the excellency of the properties of fresh concrete. A measure of how easy it is to transport, cast, compact, and surface finish of fresh concrete are directly proportional to the workability of concrete[3]. The consistency of fresh concrete indirectly measures its workability[4]. Slump Test, VeBE Test, and Compaction Factor Test were conducted to study the consistency of concrete.

The effects of substituting 5% of PET bottle aggregate waste as fine aggregate in concrete with different cement, coarse and fine aggregate content including water-cement ratio and after mixing the concrete in accordance to VeBe test (EN 12350-3) for every mixture having PET aggregates in place of natural sand are very close to the conventional concrete[2]. The results of 5 % to 20% natural river sand replacement with recycled PET particles have been studied for different water cement ratio (w/c) ratio. Studies revealed that recycled PET bottle aggregates containing concrete has poorer workability[3][5]. As the quantity of PET bottle aggregate in concrete rose, the factor of compaction decreased, so decline in the compaction factor means that the workability has reduced[6]. Although an increase in concrete workability is expected because PET particles have a smooth surface, but this is not always the case. As compared to natural sand, PET particles have more specific surface area due to their mercenary shape, thus, it leads to less workability in mixtures as there would be more friction between the particles[3].

Based on the previous study, it was found that when the proportion of natural fine aggregate replaced with M-sand is increased, the VeBe test results were decreased[7]. Meanwhile for Slump Test to investigate the workability of concrete, the results indicated that as more river sand is replaced with M-sand by weight, it lowers the workability of concrete[4][8]. Lastly for Compaction Factor Test, a study to produce concrete of grade M25 found that, as more natural fine aggregate in the concrete is replaced with M-sand, the compaction factor decreases. The decrease in the compaction factor means that the workability of concrete has fallen[9]. The fine content of particles in M-sand and the rough surface with angular shape particles of M-sand than natural sand are the possible reasons for the reduction of workability[4].

## 2. Experimental Program

The experiments for fresh properties of concrete were conducted under laboratory conditions. There were two different concrete batches were prepared. The first batch was partially replaced with M-sand and the other batch was partially replaced with M-sand with 1.5% incorporation of shredded PET as fine aggregate replacement. The proportion of M-sand and M-sand with 1.5% incorporation of sheredded PET bottles for both mixes were 25%, 50%, 75% and 100%. The mix design were prepared in accordance to the Department of Environment (DOE) method and utilised M30 as the Class of Concrete.

## 3. Experiments on fresh concrete

The workability of the concrete mixtures was determined by using Slump Test, VeBe Test and Compaction Factor Test with the same water cement ratio for all the mixtures. All the tests were

prescribed in accordance to BS EN 12350-4:2019, BS EN 12350-3:2019 and BS EN 12350-2:2019 respectively as shown in Figure 3,4 and 5.

## 4. Results and Discussion

### *4.1. Slump Test*

The results of the slump test for the various concrete mixtures were presented in Figure 6. Based on the figure, it was observed that the slump values of different percentage of M-sand with 1.5% incorporation of shredded PET bottles aggregates concrete is very high compare to the slump values of different percentage of M-sand concrete. However, it was also found that the slump values for different percentage of M-sand and M-sand with 1.5% incorporation of shredded PET bottles aggregates concrete was less compared to conventional concrete. M-sand with 1.5% incorporation of shredded PET bottles indicated the slump values were very close to conventional concrete as compared to M-sand concrete. High slump value shows the good workability of concrete.

### *4.2. VeBe Test*

The results of the VeBe test for the various concrete mixtures were presented in Figure 7. Based on Figure 7, it was observed that VeBe time of different percentage of M-sand with 1.5% incorporation of shredded PET bottles aggregates concrete was very less compare to VeBe time of different percentage of M-sand concrete. However, it was also observed that VeBe time of different percentage of M-sand and M-sand with 1.5% incorporation of shredded PET bottles aggregates concrete was more compared to conventional concrete. Hence, the M-sand with 1.5% incorporation of shredded PET bottles aggregates concrete VeBe time values are very close to conventional concrete as compared to M-sand concrete. This indicated less VeBe time shows the good workability of concrete.

**Table 1.** Fresh properties of M sand Concrete

| % of M-Sand | Slump in mm | VeBe in seconds | Compaction Factor |
|---|---|---|---|
| 0 | 31 | 6 | 0.93 |
| 25 | 13 | 12 | 0.86 |
| 50 | 7 | 15 | 0.83 |
| 75 | 6 | 20 | 0.81 |
| 100 | 5 | 26 | 0.76 |

**Table 2.** Fresh properties of M sand+PET Concrete

| % of M-Sand+1.5% PET | Slump in mm | VeBe in seconds | Compaction Factor |
|---|---|---|---|
| 0 | 31 | 6 | 0.93 |
| 25 | 28 | 6.39 | 0.91 |
| 50 | 26 | 7.32 | 0.9 |
| 75 | 26 | 7.69 | 0.88 |
| 100 | 5 | 26 | 0.76 |

*4.3. Compaction Factor Test*

The results of the compaction factor test for the various concrete mixtures are presented in Figure 8. From Figure 8, it was observed that the compaction factor values of different percentage of M-sand with 1.5% incorporation of shredded PET bottles aggregates concrete was more compare to the compaction actor values of different percentage of M-sand concrete. However, it is also observed that compaction factor values of different percentage of M-sand and M-sand with 1.5% incorporation of shredded PET bottles aggregate concrete is less compared to the conventional concrete. M-sand with 1.5% incorporation of shredded PET bottles aggregates concrete compaction factor values are very close to conventional concrete as compared to M-sand concrete. High compaction factor indicates the good workability of concrete.

**Figure 1.** Concrete mixing

**Figure 2.** Mixed Concrete

**Figure 3.** Compaction Factor Test **Figure 4.** VeBe test **Figure 5.** Slump Test

*4.4. Relation between Compaction Factor and Slump*

A polynomial relation is obtained with a correlation coefficient of 0.9979 and 0.9921 between compaction factor and slump for M-sand and M-sand with 1.5% incorporation of shredded PET bottles fine aggregate concrete. These relations can be used to predict the slump value of M-sand Concrete ($y = 1133.8x^2 - 1762.1x + 689.28$) and M-sand with 1.5% incorporation of shredded PET bottles concrete ($y = -330.18x^2 + 706.96x - 341.53$) is shown in Figure 9. It was observed that as compaction factor increases slump also increases.

*4.5. Relation between VeBe and Slump*

A polynomial relation is obtained with a correlation coefficient of 0.8699 and 0.9994 between VeBe and slump for M-sand and M-sand with 1.5% incorporation of shredded PET bottles concrete. These relations can be used to predict the VeBe time of M-sand Concrete ($y = 0.0485x^2 - 2.3816x + 33.293$) and M-sand with 1.5% incorporation of shredded PET bottles concrete ($y = 0.0224x^2 - 1.5802x + 33.344$) as shown in Figure 10. It was observed that as the VeBe time decreases, slump increases.

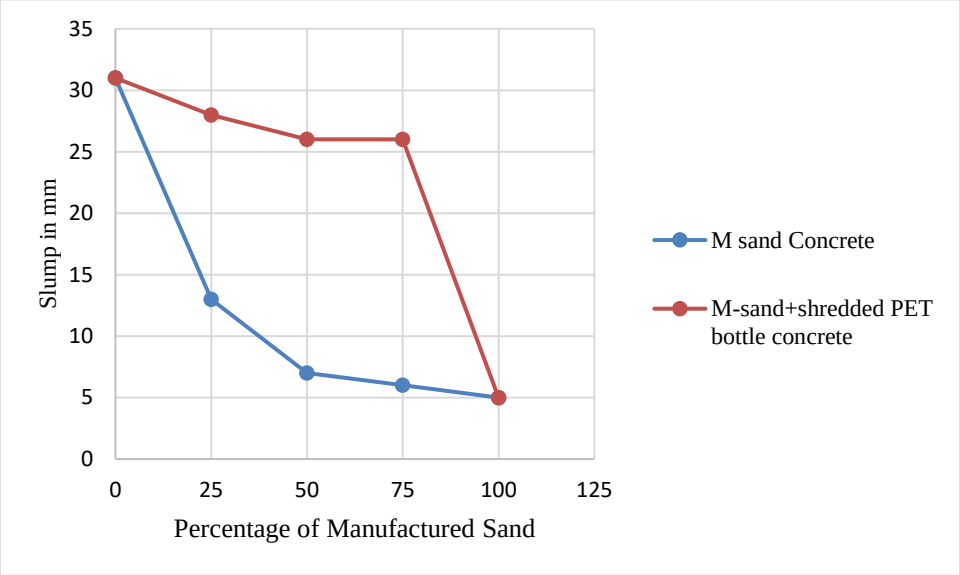


**Figure 6.** Variation in Slump for different percentage of M-sand and M-sand+1.5% PET Bottles Aggregates

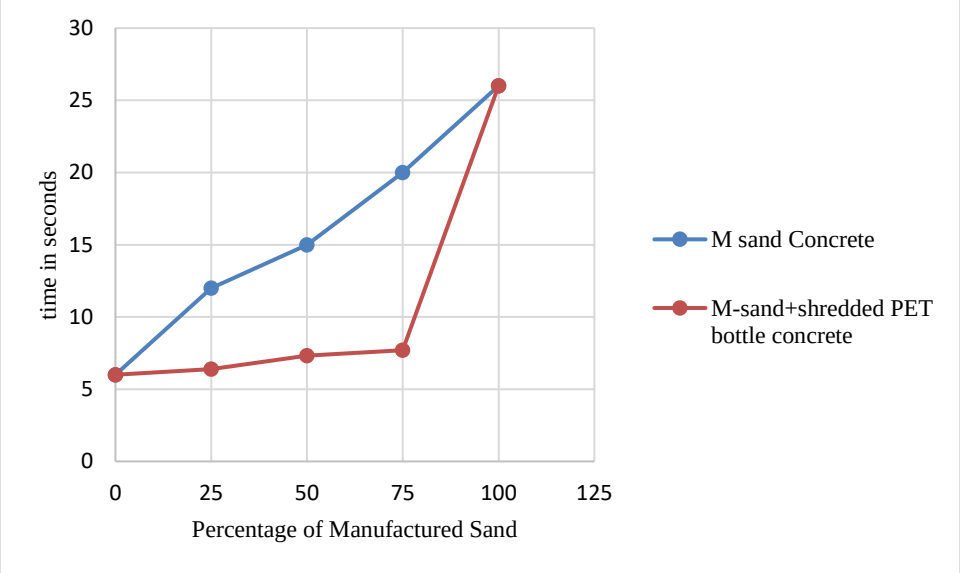


**Figure 7.** Variation in time for different percentage of M-sand and M-sand+1.5% PET Bottles Aggregates

## 5. Conclusion

The conclusions are as follows as per the above discussions

- The workability of M-sand with 1.5% incorporation of shredded PET bottles concrete is much better as compared workability of M-sand concrete.
- The workability of M-sand with 1.5% incorporation of shredded PET bottles and M-sand concrete is low as compared to conventional concrete, but workability of M-sand with 1.5% incorporation of shredded PET bottles concrete is very closed to conventional concrete
- The empirical formulae are obtained to predict the slump value and VeBe time for M-sand and M-sand with 1.5% incorporation of shredded PET bottles concrete.

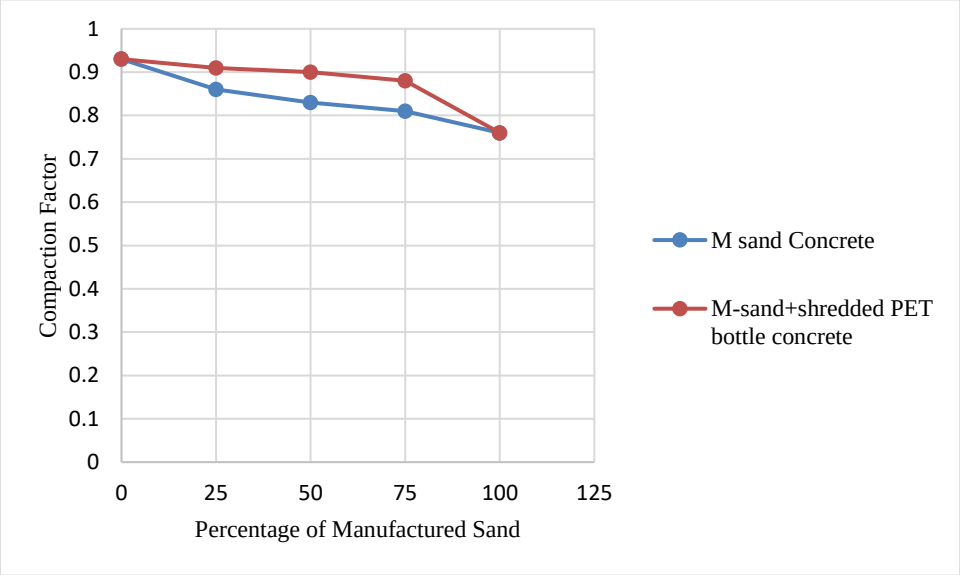


**Figure 8.** Variation in Compaction Factor for different percentage of M-sand and M-sand+1.5% PET Bottles Aggregates

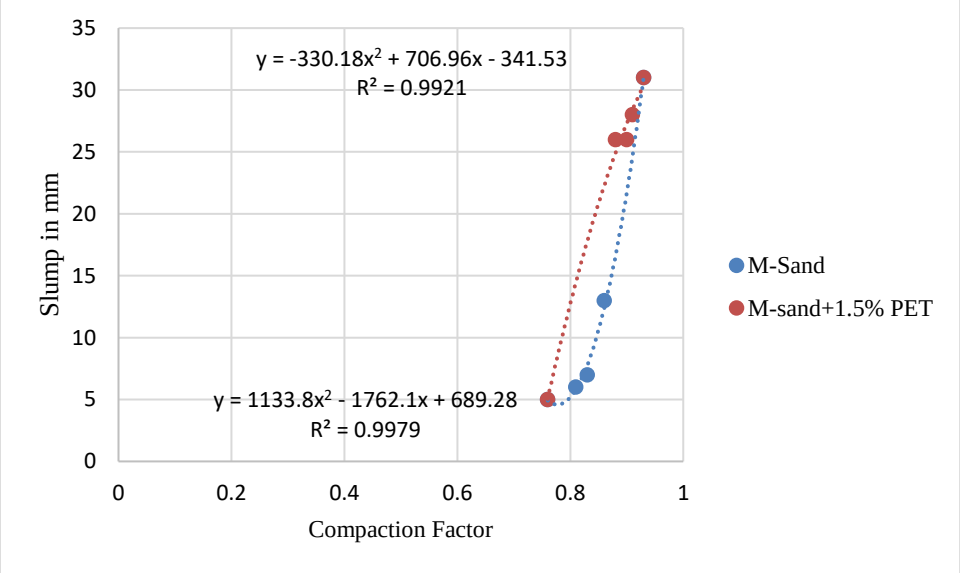


**Figure 9.** Relation between Compaction Factor and Slump

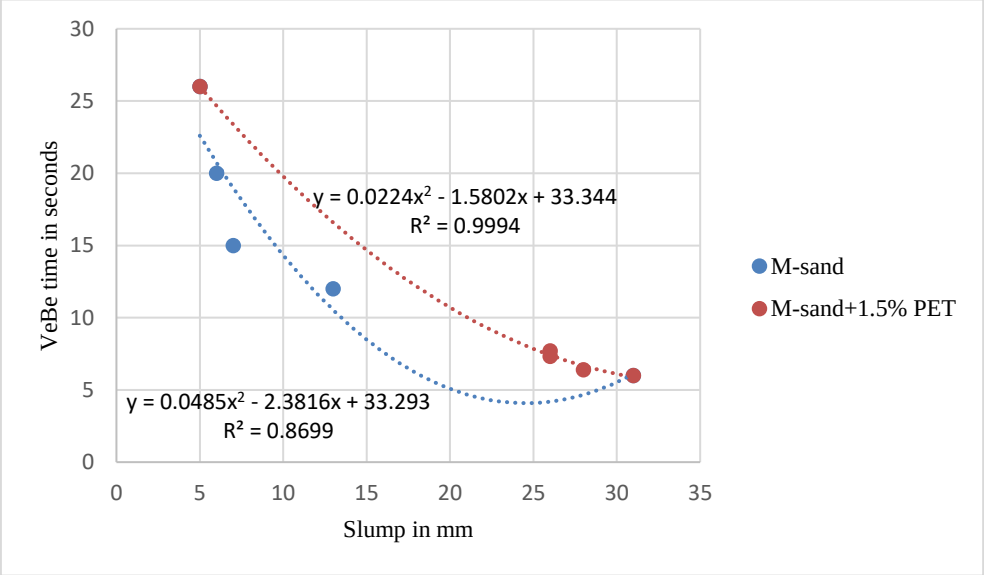


**Figure 10.** Relation between VeBe and Slump

**Acknowledgment**
The authors would like to thank International Islamic University Malaysia for funding the research work under Fundamental Research Grant Scheme for Research Acculturation of Early Career Researchers (FRGS-RACER) with project ID RACER19-057-0057. The authors also wish to extend profound gratitude to all personnel in Civil Engineering Department of International Islamic University Malaysia kind assistance in this research.

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