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A review: sustainable compressive strength properties of concrete mix with replacement by marble powder

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ABSTRACT

Purpose: Over the years, various experiments have been performed to investigate the impact of marble powder within the concrete mixture. In the present study, a review has been done to check the persistence of marble dirt as the substitute for concrete constituents.

Design/methodology/approach: Furthermore, the impact of marble powder as a replacement of cement and aggregates were reviewed. By reviewing previous studies, the result indicates that the use of waste marble powder in cement and aggregate was adequate to a certain range.

Findings: By replacing cement with marble powder in a range between 5% to 10% by weight, it increases the compressive strength of concrete mix by 11.30% to 24.56%, compared to the nominal mix. According to the study, any further increase in the amount of marble powder in place of cement i.e, 12.5% to 20% replacement by weight, results in the reduction of compressive strength of concrete mix by 7.5% to 26.01%. Replacement of aggregates from 5% to 75% with marble powder increases the compressive strength of about 3.22% to 23.91% as compared to the nominal mix.

Research limitations/implications: It was also concluded from the current study that, to obtain higher compressive strength, it is advantageous to replace fine aggregates with marble powder than the replacement of cement with the marble powder.

Keywords: Marble powder, Strength properties, Cement, Aggregates

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PROPERTIES

1. Introduction

In the rapid growth of industrialization and infrastructure, scaling up of infrastructure leads to the depletion of natural construction materials. In addition to that, industries produce a lot of waste which negatively affects the environment. Remedial or a more effective way to deal with this issue is to find a different methodology to minimize excess usage of natural materials. One such method can be a rational use of industrial waste in a concrete mix. Various by-products of industries can be used as an additive in a concrete mix. Some of the

properties of these by-products coincide with the primary components of the concrete mix. Fly-ash has fineness similar to the portland cement. Slag (not more than 65%), is also used in cement because of resistance to seawater attacks [1]. Some researchers found that marble waste has cementitious properties which can be used for the production of concrete. Additives like fly ash, silica fumes, slag can increase the demand for water in the concrete mix, for which, superplasticizer can also be used [2]. The emission of CO_2 is maximum in the cement industry due to the use of clinker in the process of limestone calcination. It can be reduced by adding additives in the concrete mix which do not produce CO_2 in the calcination process [3]. Marble is widely used in our country for decorative purposes. The formation of marble for this purpose involves cutting, sawing and polishing processes, which in result produce a lot of waste in the form of sludge [4]. Recycling of marble sludge is used in virgin components of concrete mix which can be utilized in the construction of road pavements land fillings etc. [5]. It is found in the previous study that marble can be used as a micro-filler which can help in the hydration process and improve the strength properties of concrete by replacing marble dust as a replacement of sand in the control mix [6]. This paper reviews the effect of marble waste as a substitute for a composite mix of concrete.

2. Literature review

Ergun [7] experimented on different samples with varying proportions of waste marble powder and diatomite in the concrete mix as a substitute for cement. Diatomite was used with waste marble powder in cement or only diatomite in cement. It was analyzed that due to the presence of SiO_2 present in diatomite it can react with $Ca(OH)_2$ and produce calcium silicate hydrates (CSH) which is the main factor for improving the strength of concrete. But there is one disadvantage that it increases the demand for water which in result reduces the strength; to fill this gap, super-plasticizers are used. As compressive strength is the important property of concrete and it can be improved by using marble powder in the concrete mix with different forms. It was observed that by using diatomite and waste marble powder in a combination with varying percentage i.e. 5% and 10% as shown in Figure 1(a), showed the highest compressive strength as compared to the other mixes. Aliabdo et al. [4] showed maximum compressive strength at 10% replacement as shown in Figure 1(d).

Rai et al. [8], experimented with different samples with varying percentages of marble powder as a partial replacement of cement and sand which results in high strength as shown in Figure 1(f) and Figure 2(g) respectively. Also it showed a medium degree of workability.Vaidevi [20], explore the area by replacing cement with marble powder. The strength comparison is shown in Figure 1(g). Various experiments were performed to identify the utilization of marble powder in the concrete mix.

Aruntaş et al. [9], experimented with varying marble powder ratio as a replacement of cement and check the strength properties of concrete after 7, 28 and 90 days as shown in Figure 1(h). Shirule et al. [10], check the properties of concrete by partially replacing portland pozzolana cement with marble powder shown in Figure 1(i).

Rana et al. [11], concluded that adding 10% of marble slurry in cement as a partial replacement gives strength to the concrete mix. Due to the large surface area of marble slurry, the workability of the mix decreases. Marble slurry was acted as a micro-filler in concrete mix and fill the voids which improve the resistance to permeation and corrosion. But the further increase of marble slurry degrades the strength properties of the concrete matrix because the further decrease of cement content in a matrix will lose the binding characteristics of cement and further affects the mechanical properties of concrete.

Buyuksagis et al. [12], in the experimental study, marble waste was used in cement-based adhesive mortar in different proportions of 20%, 40%, 60%, 80% and 100%. In this study, the result shows that the compressive strength of the mortar mix with marble powder had a slight increase after 7 days but the analysis of 3 days and 28 days showed a decrease in compressive strength. But adhesive mortar with marble powder showed a great effect on tensile strength by using 80% of marble dust instead of dolomite. This is due to the effect of density of the marble powder which is 2.7 g/cm^3, which is slightly greater than the density of bonding mortar. Sountharajan et al. [25], investigated that the highest compressive 28 days strength increase is 1.11% only at 7.5% replacement of cement as shown in Figure 1(e).

Keleştemur et al. [13] performed the experimental test on a concrete mix of different proportions of glass fibre i.e. 0.25 kg/m^3,0.50 kg/m^3 and 0.75 kg/m^3 and marble dust i.e. 0% and 40% in higher temperatures and from Figure 2(a) it was analyzed that when glass fibre is used in place of fine aggregates in different proportion it does not give required compressive strength. Further, it is mixed with marble dust it attains a maximum compressive strength as compared to the control mix. The reason behind this change is poor adhesion between glass fibre and mortar but by adding marble dust it acts as a filler agent and improves its strength. But when it is exposed to a higher temperature, shrinkage occurs due to the dissociation of the main compound of cement paste that is calcium hydroxide.

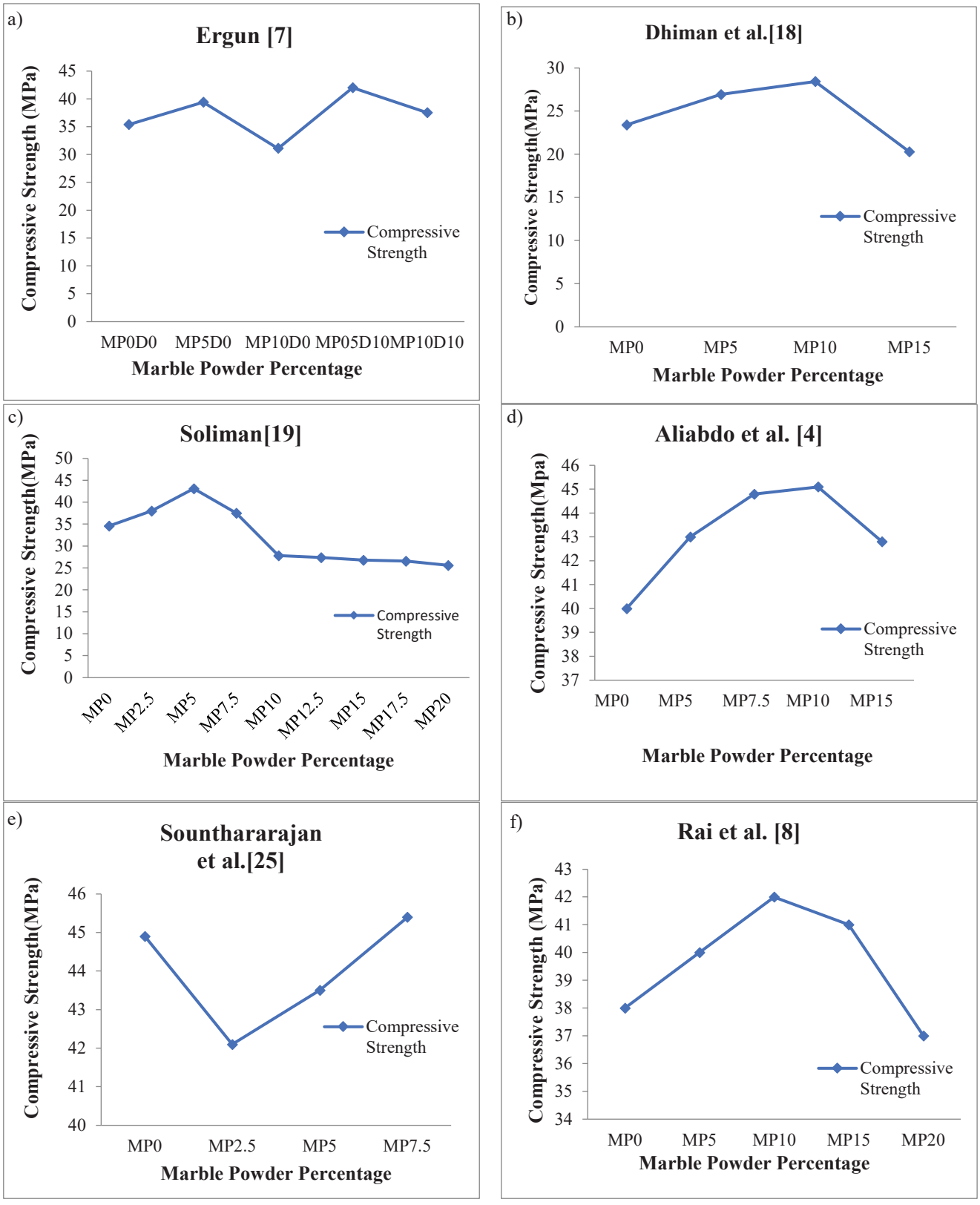

Fig. 1 a)-f). Concrete mix using marble powder in cement

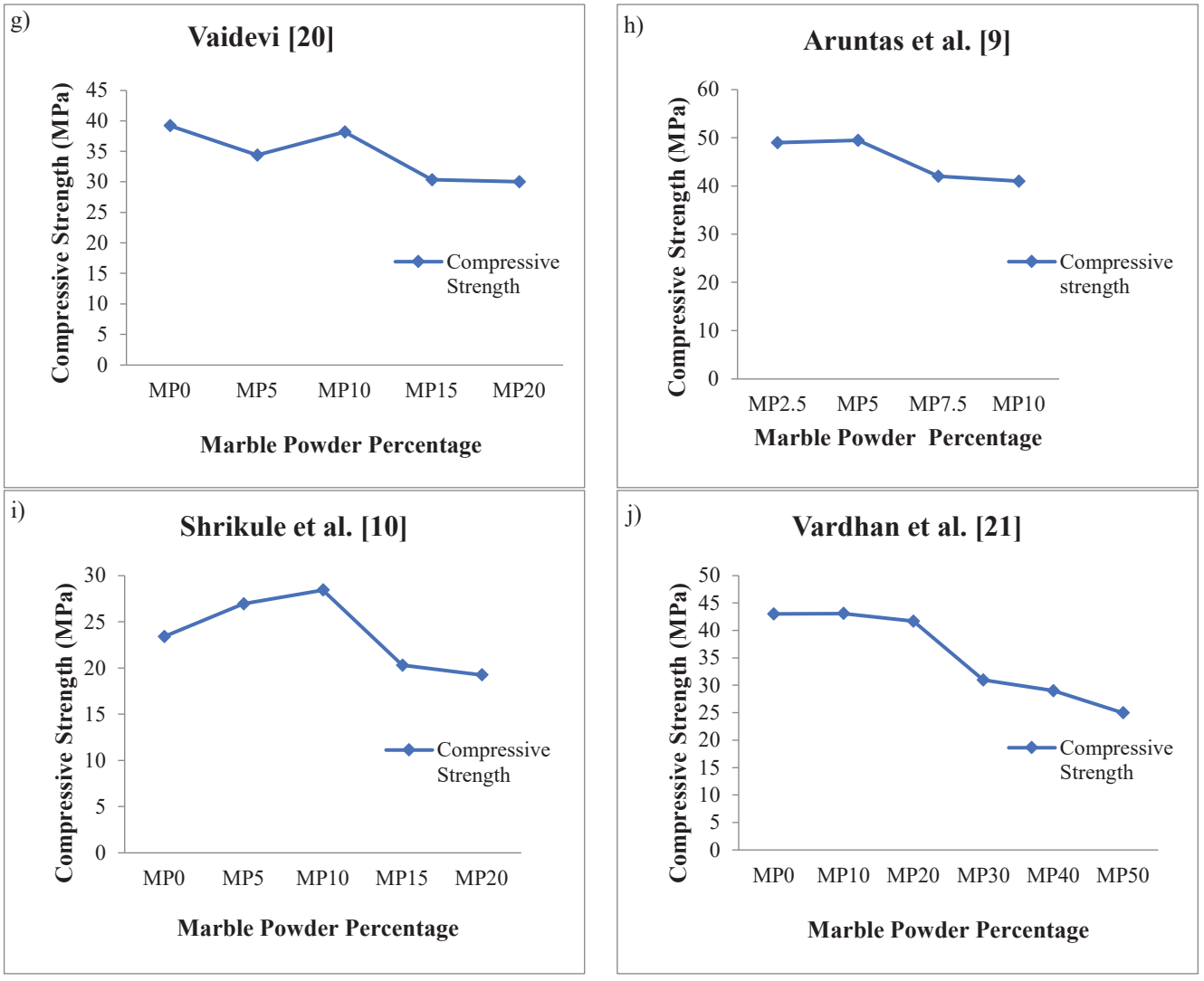

Fig. 1 g)-j). Concrete mix using marble powder in cement

In Demirel [14] experimental study, the mechanical property of concrete mix by using waste marble dust as a partial replacement of fine sand in different proportions was analyzed. According to the study, it was investigated that compressive strength of concrete at different age i.e. 3, 7, 28 and 90 days. From Figure 2(b), it was analyzed that by replacing sand with waste marble dust, comparatively good strength in the concrete mix was obtained because of the specific gravity of waste marble dust. Marble dust has a high specific gravity than the fine sand. Due to this reason, the unit weight of concrete with marble dust increases as the percentage of waste marble dust increases. In a study, it was also found that the compressive strength of mix increases 10% at the curing stage of 28 days but after 90 days curing stage, it increases up to 5% as compared to composite mix. This decrease in a comparative study is due to the dilute C_2S and C_3S present in cement.

Kore et al. [15] In this study, the coarse aggregate of a lean concrete is replaced with marble waste as 0-100% by weight. The water-cement ratio remains constant i.e. 0.60. Different tests were performed i.e. compressive strength test, permeability, acid resistance, microstructure analysis e.g. SEM (scanning electron microscope) and X-ray diffraction. It was found that when coarse aggregate is replaced by 80% of marble aggregates by weight it gains the maximum strength which is mainly due to the presence of a higher amount of dolomite. Dolomite has a chemical composition of $CaMg(CO_3)_2$ which forms due to MgO and CaO present in marble aggregate. Dolomite provides a better bond between components of concrete.

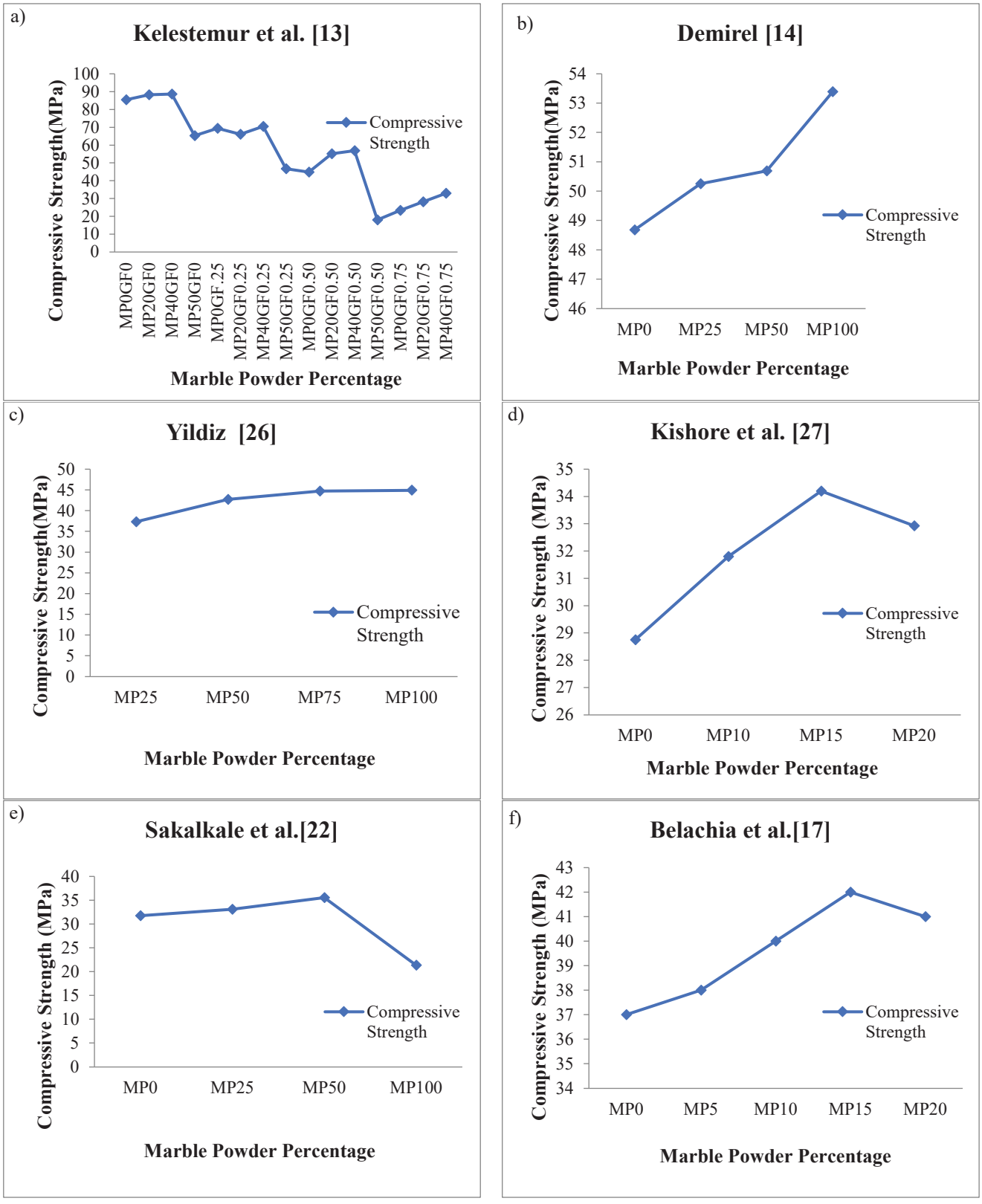

Fig. 2 a)-f). Concrete mix using Marble Powder in Aggregate

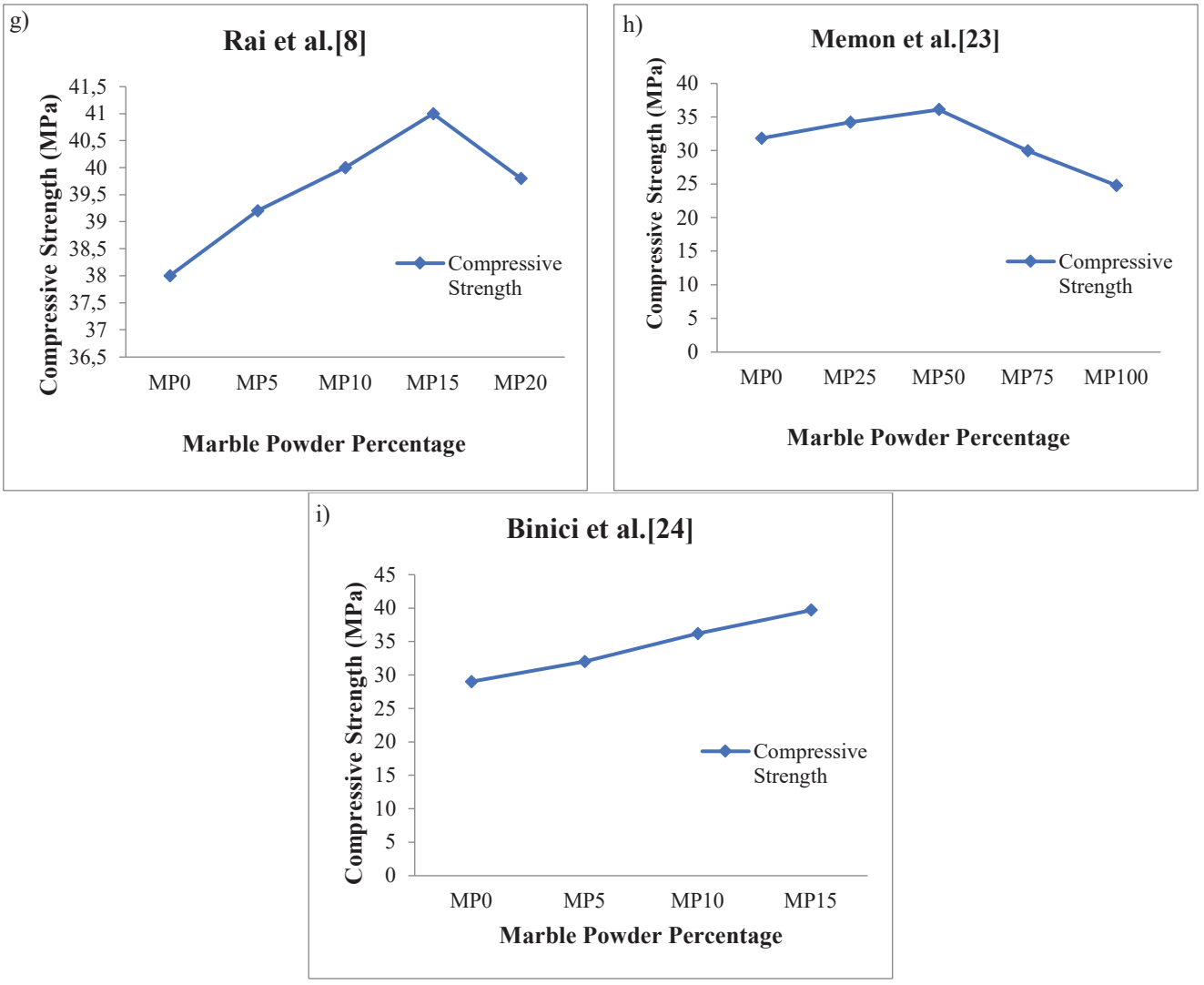

Fig. 2 g)-i). Concrete mix using Marble Powder in Aggregate

Tugrul Tunc [16] the study found that the utilization of marble waste can be effective when it is used in a concrete mix.

Aliabdo et al. [4] used marble dust in the concrete mix as a substitute for cement and fine aggregate was studied separately. The experiments showed that partial replacement of cement and sand with marble dust gave appreciable compressive strength to the concrete mix.

Belachia et al. [17] experimented on marble waste in different proportions as the replacement of aggregates. Recycled marble waste use in concrete mix showed in Figure 2(f), that by adding 25% of marble waste by weight can give maximum compressive strength to the concrete mix. It was found that replacing recycled marble waste can be used because it gave satisfactory results in workability and strength properties concerning the control mix. Marble dust acts like a micro filler in concrete mix and performed better in case of sand replacement as compared to cement replacement.

Soliman [19] observed that at 5% replacement of cement with marble powder gives maximum 28 days compressive strength of about 24.56% compared to the nominal mix. Further increase in the percentage of marble powder in the nominal concrete mix in place of cement starts decreasing the strength. At 20% replacement 28 days compressive strength and split tensile strength reduced to 26% and 47 % respectively as shown in Figure 1(c).

Kumar et al. [18] observed that replacing 10% cement with marble powder 28 days compressive strength increased by 21.48% as shown in Figure 1(b). Kishore [27]

determined that 15% replacement of marble powder with fine aggregate as shown in Figure 2(d).

Vardhan [21] focused on cement replacement with marble powder. As shown in Figure 1(j) 10% replacement with marble powder increased by 0.23%. Sakalkale et al. [22] replaced fine aggregate with marble dust and found that full replacement had increased up to 32.80% as shown in Figure 2(e).

Memon [23] as shown in Figure 2(h), 50% replacement of fine aggregate with marble powder compressive strength increased by 13.52% whereas Binici [24] experimented that up to 15% it will be increased up to 36.89% as shown in Figure 2(i). Yildiz [26] experimented with fine aggregate replacement and found that an increase in marble percentage increases the strength as shown in Figure 2(c).

3. Research findings

In this section, the results of various experiments performed by the aforesaid researchers were studied and comparison was made between the replacement of marble powder with cement (Tab. 1) and aggregates (Tab. 2). Figure 1 and Figure 3 show the relation of replacement of cement with marble dust results.

Similarly, Figure 2 and Figure 4 show a pictorial view of the replacement of aggregates with marble powder.

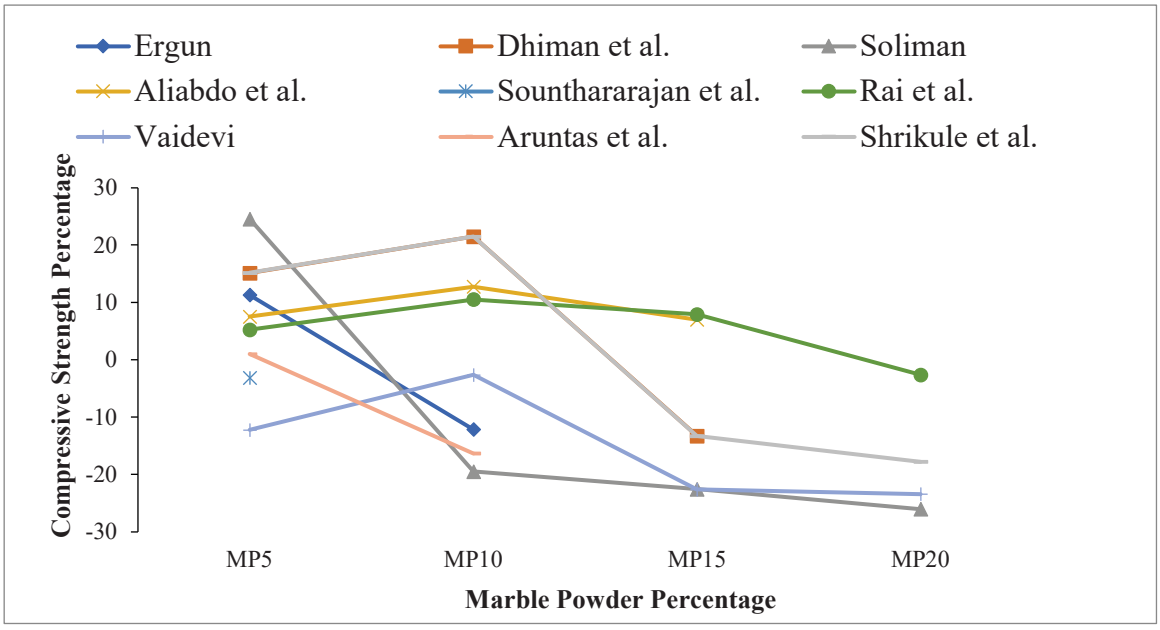

Fig. 3. Variation in Compressive Strength with Marble Powder

Table 1.
Result using Marble powder waste in Cement

No.	Author's Description	MP, %	Compressive strength, MPa	Increased, %
1	Ergun (2011) [7]	0	35.4	-
		5	39.4	11.30
		10	31.1	-12.14
2	Kumar et al. (2015) [18]	0	23.41	-
		5	26.95	15.12
		10	28.44	21.48
		15	20.30	-13.28
3	Aliabdo et al. (2014) [4]	0	40	-
		5	43	7.5
		7.5	44.8	12
		10	45.1	12.75
		15.0	42.8	7

Table 1 continuation.
Result using Marble powder waste in Cement

No.	Author's Description	MP, %	Compressive strength, MPa	Increased, %
4	Soliman (2013) [19]	0	34.6	-
		2.5	38	9.80
		5	43.1	24.56
		7.5	37.5	8.38
		10	27.80	-19.47
		12.5	27.40	-20.89
		15	26.80	-22.54
		17.5	26.60	-23.12
		20	25.60	-26.01
5	Sounthararajan et al. (2013) [25]	0	44.90	-
		2.5	42.10	-6.23
		5	43.50	-3.11
		7.5	45.40	1.11
6	Rai et al. (2011) [8]	0	38	-
		5	40	5.26
		10	42	10.52
		15	41	7.89
		20	37	-2.63
7	Vaidevi (2013) [20]	0	39.2	-
		5	34.4	-12.24
		10	38.17	-2.62
		15	30.33	-22.62
		20	30.02	-23.41
8	Aruntas et al. (2010) [9]	2.5	49	-
		5	49.5	1.02
		7.5	42	-14.28
		10	41	-16.32
9	Shriule et al. (2012) [10]	0	23.41	-
		5	26.96	15.16
		10	28.44	21.48
		15	20.30	-13.28
		20	19.25	-17.77
10	Vardhan et al. (2015) [21]	0	43	-
		10	43.1	0.23
		20	41.67	-3.09
		30	31	-27.90
		40	29	-32.55
		50	25	-41.86

4. Comparative study

Comparative studies have been done for replacement of cement and fine aggregates by marble powder with compressive strength as in Figure 5 and Figure 6. Compressive strength of concrete mix with 10% cement replacement increases by 21.48% whereas 75% of aggregate replacement with marble powder increases compressive strength by 23.91%. Previous researches establish that concrete mix gives more compressive strength when fine aggregates are replaced with marble powder. In case of more increase in marble powder content in cement, concrete strength properties start reducing due to a lack of cementitious properties.

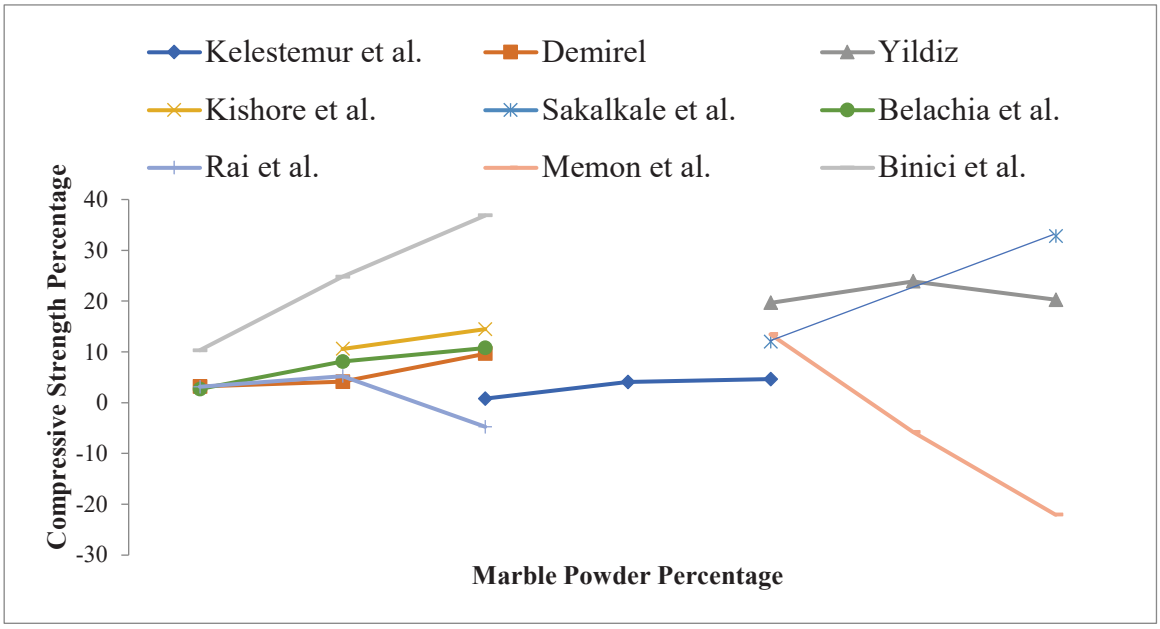

Fig. 4. Variation in Compressive Strength with Marble Powder

Table 2.
Result using Marble powder waste in Aggregates

No.	Author's Description	MP, %	Compressive strength, MPa	Increased, %
1	Demirel (2010) [14]	0	48.68	-
		5	50.25	3.22
		10	50.69	4.12
		20	53.39	9.67
2	Yildiz (2011) [26]	0	37.34	-
		25	42.70	14.35
		50	44.69	19.68
		75	46.27	23.91
		100	44.92	20.29
3	Kelestemur et al. (2014) [13]	0	84.7	-
		20	85.41	0.83
		40	88.18	4.10
		50	88.65	4.66
4	Kishore et al. (2015) [27]	0	28.75	
		10	31.80	10.60
		15	34.2	18.95
		20	32.92	14.50
5	Sakalkale et al. (2014) [22]	0	31.73	-
		25	33.11	4.34
		50	35.54	12.00
		100	21.32	32.80
6	Belachia et al. (2011) [17]	0	37	-
		5	38	2.7
		10	40	8.10
		15	42	13.51
		20	41	10.80

Table 2 continuation.
Result using Marble powder waste in Aggregates

No.	Author's Description	MP, %	Compressive strength, MPa	Increased, %
7	Rai et al. (2011) [8]	0	38	-
		5	39.2	3.15
		10	40	5.26
		15	41	7.89
		20	39.8	-4.73
8	Memon et al. (2019) [23]	0	31.80	-
		25	34.20	7.54
		50	36.10	13.52
		75	29.96	-5.78
		100	24.80	-22.01
9	Binici et al. (2008) [24]	0	29	-
		5	32	10.34
		10	36.2	24.82
		15	39.7	36.89

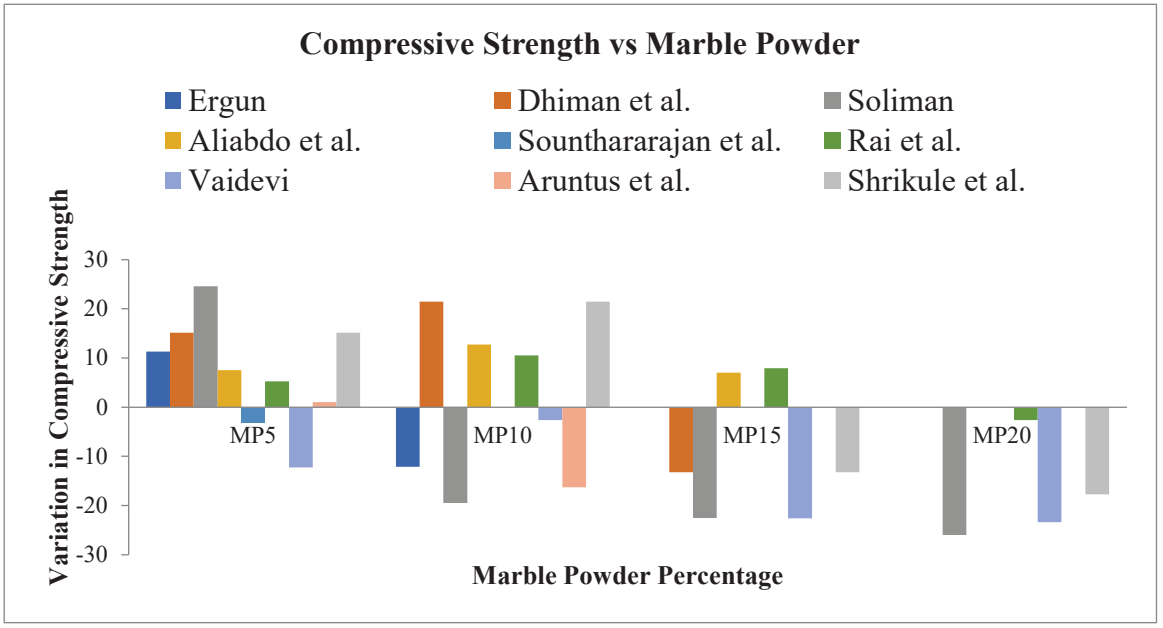

Fig. 5. Variation in Replacement of Cement with Marble Powder

5. Discussion

The use of marble powder in the concrete mix has sustainable development as the marble powder can be used as a substitute in primary materials of concrete.

5.1. Effect of marble powder in cement

Marble waste can be used partially as a substitute for concrete primary components. By far, different experiments were conducted using marble powder in concrete in different forms as marble powder, marble aggregates for replacement of cement or aggregates. According to Ergun [7], it was observed that when cement is replaced by marble powder by 5%, the compressive strength increases to 11.30%, however the same decreases to 12.14% at 10% replacement. It has been observed that the addition of 10% diatomite in 5% replacement of cement with marble powder increases the strength up to 18.6%; however the same decreases to 5.9% when

the replacement of cement is 10%. According to Kumar et al. [18], the compressive strength increases to a certain limit of replacement of cement by marble powder and then it starts reducing. The maximum compressive strength obtained was 21.48% by replacing 10% cement with marble powder, further replacement, reduces the compressive strength which was 13.28% at 15%. It also is shown in Aliabdo et al. [4], experimental study that by adding marble powder alone as a replacement of cement that up to 10% replacement gives the maximum increase in compressive strength about 12.75% but further increase in percentage, decrease the compressive strength of concrete. According to Soliman [19], the maximum increase in compressive strength is about 24.56% at 5% replacement of cement by marble powder after that it starts decreasing. Also, Sountharajan et al. [25], investigate that maximum strength increase is 1.11% only at 7.5% replacement of cement as shown in Figure 1(e).

Referring to Figure 5, it has been established that the compressive strength increases when 5%, cement is replaced by marble powder. However, the increase in compressive strength after 5% replacement, in some cases the results are positive and others they are otherwise. Therefore the replacement of cement by marble powder after 5% needs detailed investigations.

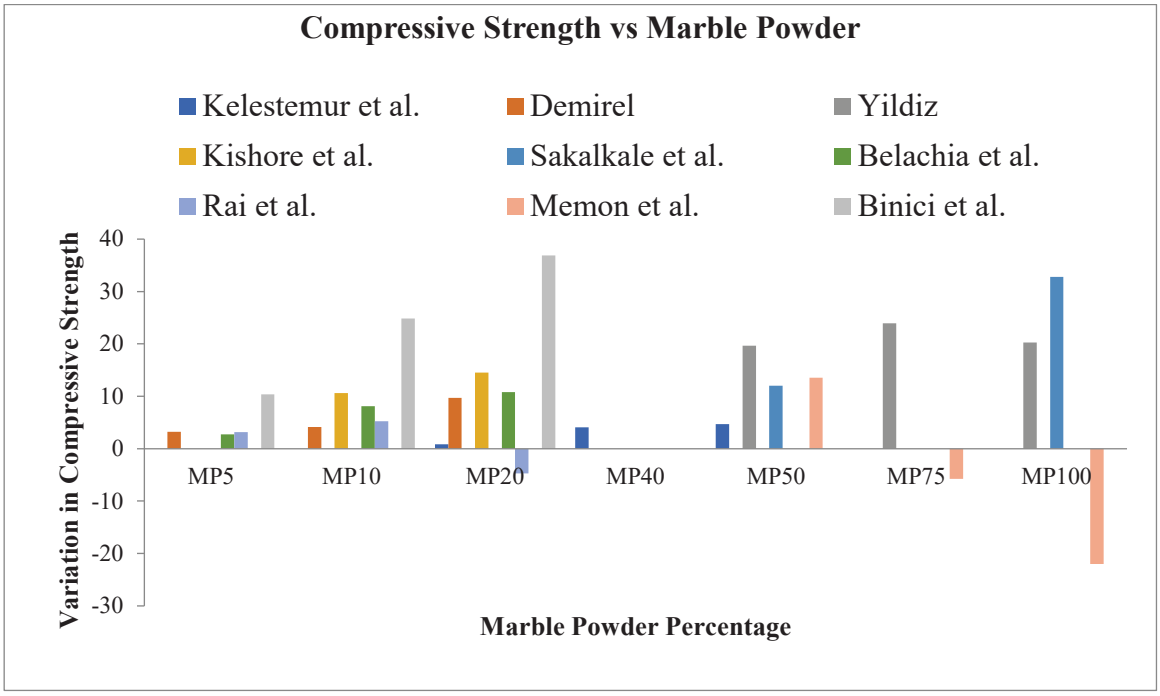

Fig. 6. Variation in Replacement of Aggregates with Marble Powder

5.2. Effect of marble powder in aggregate

As discussed earlier, marble as a substitute for cement, also some researchers perform experiments by using marble powder as a replacement of fine/coarse aggregates. Kelestemur [13] experiment with marble dust as replacement of sand but he also uses glass fiber in the concrete mix. He concludes that concrete mix has the highest strength compared to other mixes when only marble powder is used in the concrete mix as a replacement of sand in different proportions i.e. 20%, 40% and 50% by weight. But when glass fiber is also mixed with marble powder it decreases the compressive strength because of an increase in porosity value, which can attribute to a weak bond between fibre and mortar. As we discussed above, there was an increase in compressive strength by the replacement of aggregates with marble powder.

Referring to Figure 6, it was noted that there is a huge difference in increasing percentages in compressive strength. In some cases, it is about a 9% increase whereas in others it is about 0.83%. Therefore to get a clear picture further investigation is required.

6. Conclusions

Based on the above study the following points are to be concluded:

1. By replacing cement with marble powder in a range of 5% to 10% by weight, it increases the compressive strength of concrete mix from 11.30% to 24.56% as compared to the nominal mix.
2. Further increase in the amount of marble powder in place of cement, results in the reduction of compressive strength from 7.5% to 22.54% in cement replacement from 12.5% to 15% in a concrete mix.
3. 75% replacement of fine aggregates with marble powder increases the compressive strength to 23.91% in nominal concrete mix and thereafter it starts decreasing.
4. Marble powder can be used as a replacement of fine aggregates due to higher specific gravity as compared to sand. It acts like a micro filler also in the concrete matrix and can fill the voids to enhance the strength properties of concrete.
5. Replacement of aggregates by marble powder imparts better compressive strength than that of cement in a nominal concrete mix.

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