Chapter 6
Study on Self-Compacting Concrete Using Marble Powder with Silpozz

K. C. Panda, S. Panda, T. Jena, and A. Priyadarsinee

Abstract The influence of marble powder (MP) and silpozz on the fresh and hardened properties of self-compacting concrete (SCC) is discussed in this work. The study includes ten distinct concrete mixes with a constant water binder ratio of 0.40 and variable amounts of marble powder (MP) and silpozz in each mix. Cement is replaced partially with both MP and silpozz which are used to replace cement to varying degrees such as 0% silpozz with 0%, 5%, 10%, and 15% for MP; 10% silpozz with 5%, 10%, and 15% for MP; and 20% silpozz with 5%, 10%, and 15% for MP. The M30 grade mix design is preferred, and the ratio of the cement, fine aggregates, and coarse aggregate was found to be 1:1.37:2.52. The European Federation of National Associations Representing for Concrete (EFNARC) requirements were met when the fresh concrete qualities of SCC were assessed using slump flow, T_{500}, J-ring, L-box, and V-funnel tests. Compressive strength and splitting tensile strength tests are carried out to determine the qualities of hardened concrete. According to the test results, MP-based concrete was reduced at 10% replacement compared to control mix, whereas silpozz-based concrete has improved the strength by 20% replacement compared to control mix. It has also been discovered that specimens containing 5% MP and 10% silpozz have better compressive, split tensile, and flexural strengths when compared to other specimens.

Keywords Marble powder (MP) · Silpozz · Compressive strength · Split tensile strength · Flexural strength

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D. K. Ashish, J. de Brito (eds.), *Environmental Concerns and Remediation*,
https://doi.org/10.1007/978-3-031-05984-1_6

6.1 Introduction

Self-Compacting Concrete (SCC) is a highly flowable concrete under its own weight in heavy reinforcement without any internal or external mechanical vibration. The workability of SCC is improved as used with the same amount of the replacement material at the same instance which offers economical benefits and averts environmental pollution. Sustainability in construction is one of the major reasons for the enhanced use of alternative binders and other filler-like materials, such as marble powder, micronized sand, and others. Replacing large quantities of Portland cement-based binders by fillers or by hydraulic pozzolans is a strategy that contributes largely to a reduced use of cementitious clinker and, as a result of this, to an improved environmental footprint. Various studies were conducted to evaluate the behavior of SCC in the fresh and hardened states under the influence of the addition of fillers and pozzolanic materials and the Portland cement and the effect of the fineness of fillers. Other researchers have focused their interest on the incorporation of industrial wastes into SCC. The supplementary cementitious material is differentiated into two types, which are pozzolanic material and non-pozzolanic material. Marble powder is a non-pozzolanic material, whereas silpozz is a pozzolanic material having reactive silica content above 85%, and it is a finely powdered ingredient that can be added to lime mortar to improve durability and create a positive set.

Experimental studies on the properties of SCC using MP have been contributed by several researchers. The brief literature reviews of some of the studies are as follows [1]: Felekoglu et al. (2007) investigated the blocking ratio of SCC connected to w/c ratio in which by increasing w/c ratio, blocking ratio reduced due to the decrease in viscosity and yield stress of SCC and filler content was increased and admixture content was reduced [2]. Aruntas et al. (2007) observed that the use of MP aggravated the fresh properties of concretes by lessening the slump flow diameter which is connected with rising the slump flow and V-funnel flow times which clarify its effectiveness on the fresh and hardened properties of SCC [3]. Binici et al. (2007) investigated various mechanical properties of concrete containing marble dust and limestone dust, the test results of which showed that there were apparent increases in compressive strength, abrasion resistance, and sodium sulfate resistance with the rising amount of marble dust [4]. Corinaldesi et al. (2009) concluded that the MP proved to be very effective in assured very good cohesiveness of mortar and concrete in the presence of a superplasticizing admixture as provided that w/c ratio was effectively low [5]. Aruntas et al. (2010) experimentally studied the usability of waste marble powder as a preservative material in blended cement residue by inter-grinding MP with cement residue at different blend ratios of 2.5%, 5%, 7.5%, and 10% and also concluded that 10% of MP can be used as a preservative in cement production for mortar prisms [6]. Demirel (2010) experimentally concluded that the filler effect of marble dust on cement hydration was connected with the decrease of porosity [7]. Gesoglu et al. (2012) considered the effect of addition of MP as substitute for concrete binder in SCC at replacement ratios of 5%, 10%, and 20% and also concluded that high replacement ratios negatively affect the fresh properties of SCC. This paper presented the fresh and hardened properties of self-compacting concrete using marble powder with silpozz.

6.2 Experimental Study

Cement, natural fine aggregate, natural coarse aggregate, MP, and silpozz were the materials employed in this investigation. All of these materials are subjected to laboratory testing to determine their physical and mechanical properties in accordance with Indian standards. The design of a concrete mix for M30 grade concrete was carried out according to the design guidelines of IS 10262-2009 [8]. SCC's fresh properties, such as slump flow, T_{500}, J-ring, L-box, and V-funnel tests, as well as its hardened properties, such as compressive strength, flexural strength, and split tensile strength, were investigated utilizing waste MP and silpozz.

6.2.1 Material Used and Properties

Ordinary Portland cement is utilized in this project (OPC-43). The cement comprises 35–40% lime, 40–50% alumina, up to 15% iron oxides, and preferably less than 6% silica. Cement has a specific gravity of 3.15 and Blaine surface area is 0.33 m^2/g. Natural fine aggregate (NFA) passes through the IS 4.75 mm sieve. It has a specific gravity of 2.68 and fineness modulus of fine aggregate is 3.13, and it comes under zone III compliant, which was used in this study. Natural coarse aggregate (NCA) has a specific gravity of 2.77 and ranges in size from 10 to 20 mm, and fineness modulus is 7. Superplasticizer improves the workability and cohesion of new concrete, as well as reduces segregation and bleeding and improves the characteristics of hardened concrete. Each 1% of air causes a 4% loss in strength, which is mitigated by lowering the water content. Waste marble powder is a nonreactive product of marble stone sawing and processing processes. It is currently employed as a building material; it comprises of calcite and dolomite, and maybe serpentine make up the majority of marble. The following principal elements make up the chemical composition of marble, 38–42% lime (CaO), 20–25% silica (SiO_2), 2–4% alumina (Al_2O_3), 1.5–2.5% oxides (NaO and MgO), and 30–32% water ($MgCO_3$ and others), which have resulted in a significant reduction in the amount of waste generated during the sawing and processing of marble stone. Kajaria, Shree Build Mart Pvt. Ltd., Nayapalli, Bhubaneswar, Odisha, provides MP. It is very fine in nature and white in color, as illustrated in Fig. 6.1, and it was used in this experiment. The physical properties and chemical composition of cement, silpozz, and marble powder are given in Table 6.1.

Silpozz is a super_pozzolan with a silica concentration of more than 90% and an element size of primarily 25 microns which is having Blaine surface area 17 m^2/g. Even a small amount of silpozz added to the mix will significantly improve the

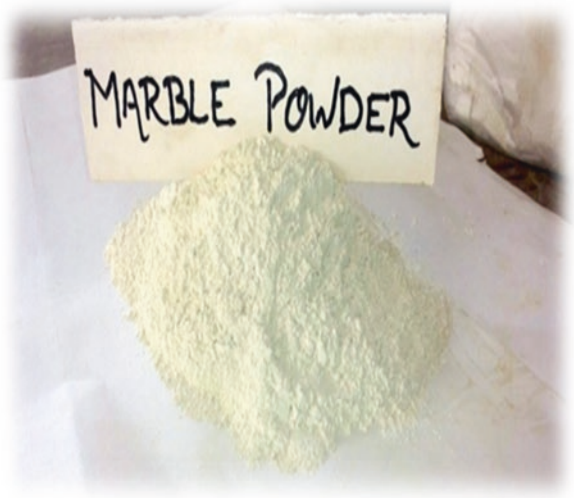


Fig. 6.1 Marble powder sample

Table 6.1 Physical properties and chemical composition of cement, silpozz, and MP

Oxides (%)	Cement	Silpozz	Marble
SiO_2	20.99	88.18	1.58
Al_2O_3	6.05	1.61	0.99
Fe_2O_3	6.01	0.56	0.22
Carbon	–	2.67	–
CaO	62.74	1.59	54.17
MgO	1.33	1.63	3.87
K_2O	0.40	1.67	0.01
Na_2O	0.04	–	0.36
SO_3	1.82	–	–
TiO_2	.025	–	–
Others	–	2.09	–
Moisture content (%)	–	0.79	0.506
Loss on ignition (%)	1.14	0.04	0.39
Physical properties			
Bulk density (gm/cc)	1.43	0.23	0.61
Specific gravity	3.15	2.3	2.55
Particle size (Micron)	35	25	63
Specific surface, m^2/g	0.33	17	212
Color	Gray	Gray black	White

strength and impermeability of concrete mixtures, as well as making the concrete more resistant to chemical assaults and abrasion and increasing the compressive strength by 10–20%. Silpozz was supplied by N K Enterprises, Singhania House, Jharsuguda, Odisha. Silpozz samples are shown in Fig. 6.2.

Fig. 6.2 Silpozz sample

Table 6.2 Details of mix quantity per m^3 of concrete

Mix identity	Cementitious materials per m^3 of concrete			NFA (kg)	NCA (kg)	SP (kg)	Water (kg)
	OPC (kg)	MP (kg)	Silpozz (kg)				
SMP0S0	465.00	–	–	860	760.5	1.16	186
SMP5S0	441.75	23.25	–	860	760.5	1.45	186
SMP10S0	418.50	46.50	–	860	760.5	1.29	186
SMP15S0	395.25	69.75	–	860	760.5	1.58	186
SMP5S10	395.25	23.25	46.50	860	760.5	1.97	186
SMP10S10	372.00	46.50	46.50	860	760.5	1.71	186
SMP15S10	348.75	69.75	46.50	860	760.5	2.26	186
SMP5S20	348.75	23.25	93.00	860	760.5	2.96	186
SMP10S20	325.50	46.50	93.00	860	760.5	3.09	186
SMP15S20	302.25	69.75	93.00	860	760.5	3.44	186

In this project work, the cementitious materials used were OPC 43 grade cement, marble powder, and silpozz. The mix proportion 1:1.37:2.52 was taken for this experiment. All mixes have been tested in a constant w/b ratio, that is, 0.40. Ten (10) concrete mixtures were prepared by partially replacing cement 0%, 5%, 10%, and 15% with MP, and also the same proportion of MP with 0%, 10%, and 20% of silpozz. SCC mixes were prepared by several trial mixes. Finally, natural fine aggregate increased 35%, and natural coarse aggregate reduced by 35% to satisfy the EFNARC guidelines (2002, 2005) [9, 10]. The featured mix quantity along with their classification is selected according to their substitution as given in Table 6.2. When replacement increases, increase the dosage of plasticizer as it is a self-compacting concrete in order to maintain the workability of concrete.

In this project, CONXL_PCE DM 360 new generation slump retaining concrete superplasticizer is used for the production of SCC using MP. The superplasticizer was supplied by the CHEMCON Tecsys Private, Ltd.; this is confirming to the IS:9103_1999 and ASTM C_494 Type F and BS:5075, Part 3.

6.3 Experimental Results and Discussions

To get a better flow time and high strength, superplasticizer is used for SCC. Three(3) sets of cube, cylinder, and prism were cast for 7, 28, and 90 days. The hardened concrete specimens were tested after 7, 28, and 90 days of curing. The test specimens were cast in steel mould without compaction and de_moulded after 24 hours. The specimens, such as cubes for compressive strength, cylinders for split tensile strength, and prisms for flexural strength, were cured till the day of testing under water at normal temperature and humidity conditions. The compressive strength for cube, flexural strength for prism, and split tensile strength for cylinder of the concrete specimens were tested in the laboratory after 7, 28, and 90 days. The results are presented below along with their graphical plots and discussions.

6.3.1 Compressive Strength

The compressive strength is measured using cube specimens. The size of the cube specimen is 150 mm × 150 mm × 150 mm. Nine concrete cubes were cast for each concrete mix proportion. The compressive strengths of nine cubes are measured after 7, 28, and 90 days.

For compressive strength of the concrete cube specimen, Fig. 6.3 presents a graphical representation of partially replaced cement with 0%, 5%, 10%, and 15% MP. The compressive strength of SMP15S0 is lower as compared with the other concrete mixes. MP improves compressive strength which is beneficial for the development of mechanical characteristics in SCC. As shown in Fig. 6.3, the compressive strength of SMP5S0 after 7, 28, and 90 days is superior to that of other mixtures. In 7, 28, and 90 days, the compressive strength of SMP5S0 concrete mix rises 2.16%, 11.05%, and 8.47%, respectively, when compared to SMP0S0 concrete mix. The strength of the concrete is increased by increasing the water curing duration.

The compressive strength of partially replaced cement with 0%, 5%, 10%, and 15% of MP and also with 10% of silpozz is presented in Fig. 6.4. It is observed that SMP15S10 gives the lowest strength than other mixes and SMP5S10 gives the highest strength among all of the mixes whose strength is comparatively the same with SMP10S10 at 28 days. The compressive strength of partially replaced cement with 0%, 5%, 10%, and 15% of MP and also with 20% of silpozz is presented in Fig. 6.5. It is observed that the strength increases when silpozz is increasing 20% with MP 5%, and then it decreases at the other replacement of MP.

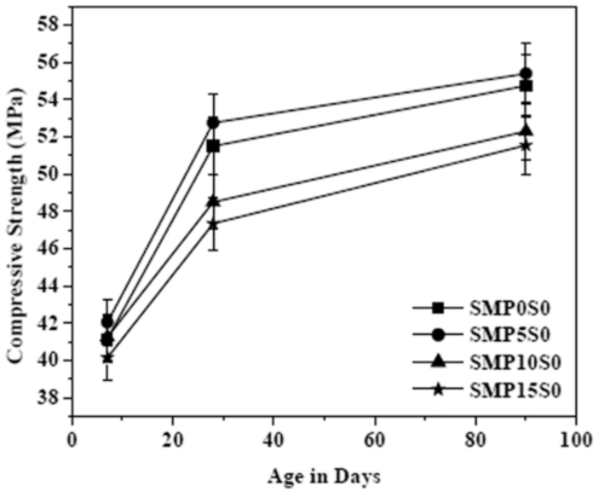
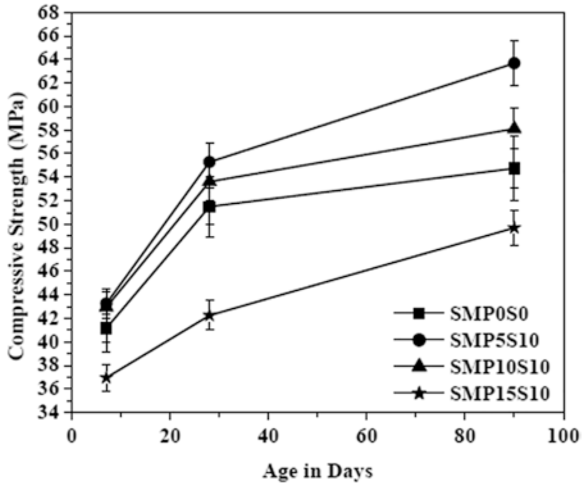


Fig. 6.3 Compressive strength versus age in days (only MP)

Fig. 6.4 Compressive strength versus age in day (MP with 10% silpozz)



6.3.2 Splitting Tensile Strength

The split tensile strengths of partially replaced cement with 0%, 5%, 10%, and 15% of MP and also with 0% of silpozz is presented in Fig. 6.6. It is observed that SMP15S0 gives the lowest strength than other mixes and SMP0S0 gives the highest strength among all of the mixes. It is observed that the split tensile strength decreases at all age as MP increases from 5% to 15% as shown in (Fig. 6.6).

The split tensile strength of partially replaced cement with 0%, 5%, 10%, and 15% of MP and also with 10% of silpozz is presented in Fig. 6.7. It is observed that SMP15S10 gives the lowest strength than other mixes, and SMP5S10 gives the

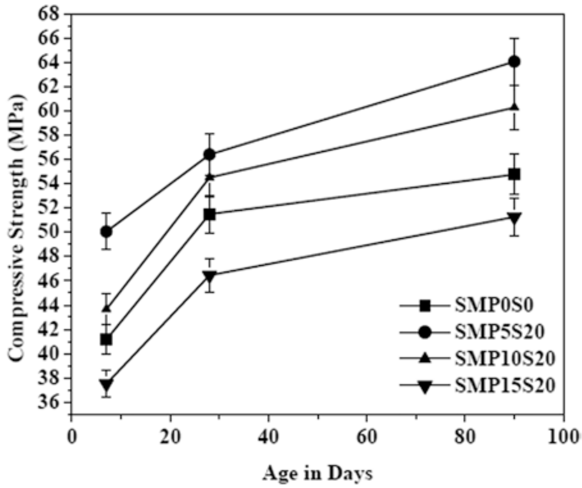


Fig. 6.5 Compressive strength versus age in day (MP with 20% silpozz)

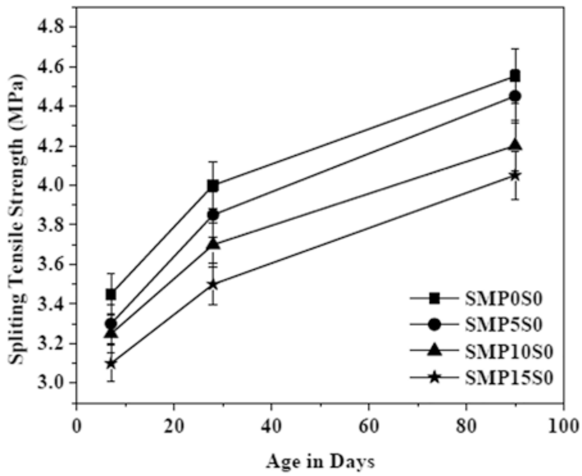


Fig. 6.6 Splitting tensile strength versus age in days (only MP)

highest strength among all of the mixes. The strength of SMP0S0 and SMP10S10 is comparatively the same at 28 days. The split tensile strength of partially replaced cement with 0%, 5%, 10%, and 15% of MP and also with 20% of silpozz is presented in Fig. 6.8. It is observed that the strength increases when silpozz is increasing 20% with MP 5%, and then it decreases at the other replacement of MP. SMP0S0 and SMP15S20 give comparatively the same strength at 28 days.

6.3.3 Flexural Strength

The flexural strength of concrete is tested using a prism specimen with dimensions of 100 mm × 100 mm × 500 mm. For each concrete mix proportion, nine concrete prisms were cast for 7, 28, and 90 days. After 7, 28, and 90 days, the flexural strength

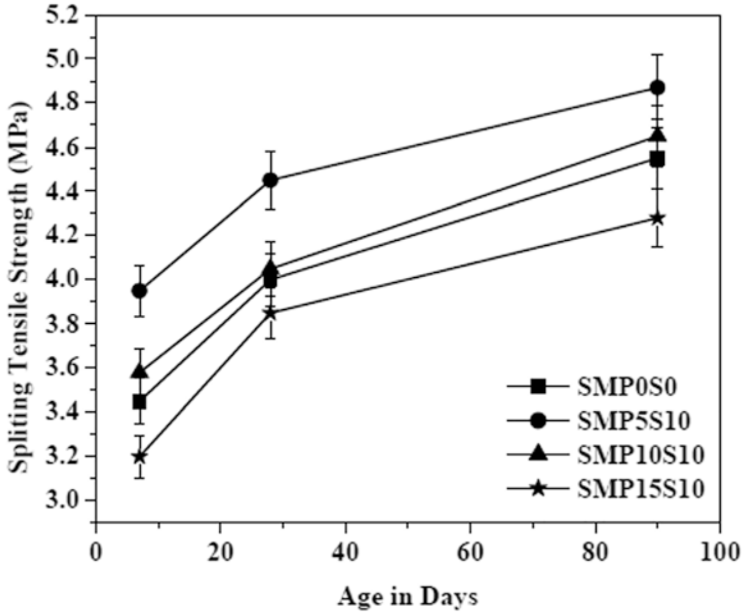


Fig. 6.7 Splitting tensile strength versus age in days (MP with 10% silpozz)

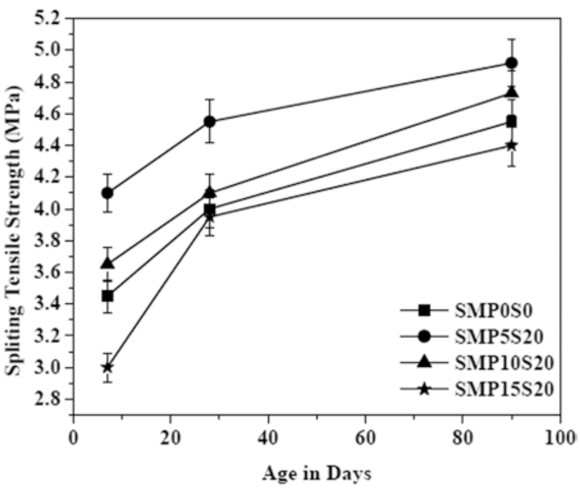


Fig. 6.8 Splitting tensile strength versus age in days (MP with 20% silpozz)

of three prisms is assessed. The flexural strength of partially replaced cement with 0%, 5%, 10%, and 15% of MP and also with 0% of silpozz is presented in Fig. 6.9. The maximum flexural strength is observed in control specimen, that is, SMP0S0 at all ages is comparatively the same with SMP5S0 and SMP10S0. The strength is decreased at SMP15S0. The strength of partially replaced cement with 0%, 5%, 10%, and 15% of MP and also with 10% of silpozz is presented in Fig. 6.10. It is observed that the control specimen SMP0S0 gives the lowest strength than other

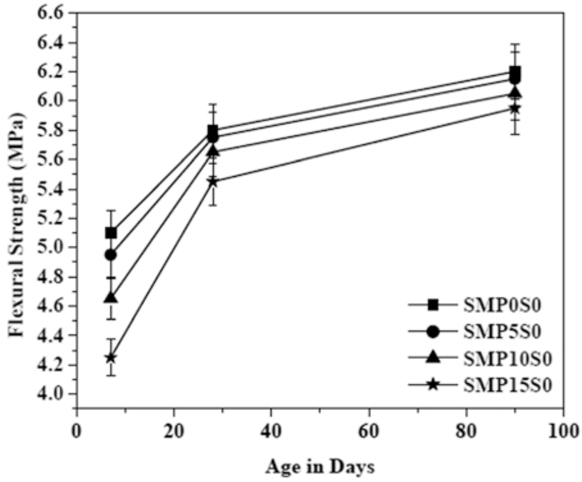


Fig. 6.9 Flexural strength versus age in days (only MP)

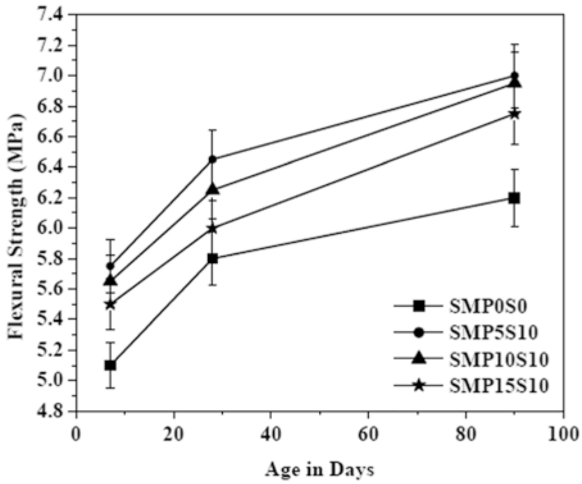


Fig. 6.10 Flexural strength versus age in days (MP with 10% silpozz)

mixes and SMP5S10 gives the highest strength among all of the mixes followed by the SMP10S10. The flexural strength of partially replaced cement with 0%, 5%, 10%, and 15% of MP and also with 20% of silpozz is presented in Fig. 6.11. It is observed that the strength increases when silpozz is increasing 20% with MP 5% and gives comparatively same strength at SMP10S20 and then it decreases at the other mix. SMP0S0 and SMP15S20 give comparatively the same strength at 28 days.

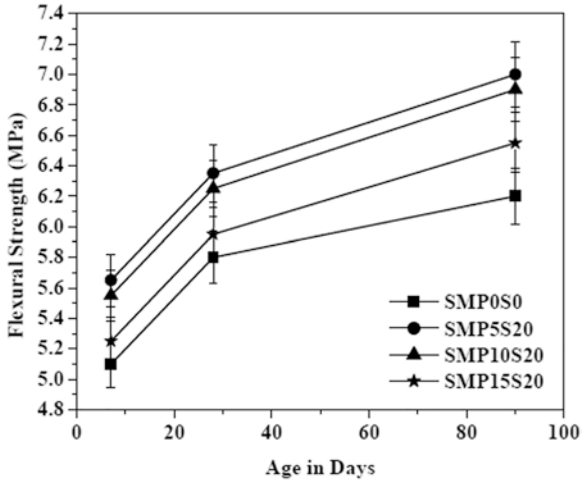


Fig. 6.11 Flexural strength versus age in days (MP with 20% silpozz)

6.4 Conclusion

- In SCC, upto 5% marble powder proportion as partial replacement of cement gives the highest compressive strength than 10% and 15% of MP and the control specimen, whereas the split tensile strength and flexural strength decreases at all proportion of MP as compared with the control specimen.
- The increase of marble powder by 10% and 15% as partial replacement of cement decreases the strength of SCC.
- The increase proportion of silpozz 10% and 20% with MP 10%, increases the strength as compared to control specimen. Whereas the increase proportion of silpozz 10% and 20% with MP 15%, decreases the strength as compared to control specimen except the split tensile strength.
- The increased amount of silpozz reduces the workability and flowability of concrete.
- The partial replacement of silpozz 10% and 20% and with marble powder 5%, gives the higher compressive strength, split tensile strength, and flexural strength.

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