Evaluating the Impact of Marble Waste and Fly Ash as Sand Replacements on Concrete's Compressive Strength and Workability

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ABSTRACT

The rapid expansion of infrastructure, urbanization, and industry has intensified the global demand for concrete, straining natural resources and posing ecological threats. In response to these challenges, integrating recycled materials into concrete formulations offers a sustainable solution without compromising quality. This study is focused on evaluating concrete characteristics by substituting natural sand with marble dust and fly ash as fine aggregates. Three series of mixes were prepared, S1 replaced sand with marble dust from 10% to 50%, increasing incrementally by 10%, S2 substituted sand with fly ash under similar conditions, and S3 utilized a blend of marble dust and fly ash at various substitution rates to compare their effects. Results indicated that in the three series of mixes, and at all ages, the compressive strength increased by 49.94%, 49.15%, 49.53%, and 53.08% compared to the control mix at days 7, 14, 28 and 56, respectively, peaking at 20% marble dust and 30% fly ash replacement. However, higher levels of marble dust reduced workability compared to standard concrete. This research underscores the potential benefits of incorporating waste marble powder and fly ash in concrete production, highlighting their role in enhancing material properties while promoting sustainable practices in construction.

Keywords-waste marble powder; fly ash; workability;compressive strength; cement replacement

I. INTRODUCTION

Concrete, a widely utilized composite material, stands as a pivotal structural component in the evolution of global infrastructure. It ranks second only to water in terms of usage, with a worldwide production of around 5.3 billion cubic meters annually [37]. According to authors in [21], concrete production is anticipated to rise to 18 billion tons by 2050. Concrete manufacturing reportedly accounts for 8% of the carbon dioxide emissions worldwide [3], with Portland cement being a primary contributor [2, 19], which negatively impacts the increase of environmental pollution [5]. The extraction of all concrete's raw materials, directly or indirectly sourced from the Earth's crust, has heightened global depletion of these resources. Researchers have proposed several waste products from industry and agricultural materials of the last century, namely silica fume, ground granulated blast furnace slag, rice husk ash, marble waste, textile sludge ash, sewage sludge ash, and fly ash, whose production has significantly increased due to the accelerated economic growth and the increase of global energy consumption, and are capable of partially substituting concrete ingredients. Marble waste is one of these byproducts produced in marble mines when marble is cut [3]. Pulverized coal, which can also act as a concrete substitute, is burned in thermal power plants to produce fly ash, and is generally classified as Class F or Class C. Authors in [17] used waste marble aggregates in place of sand to prepare concrete mixtures. In their investigation, mixtures containing 50% replacement sand demonstrated a 23.65% increase of compressive strength at 28 days. However, all concrete mixes showed a decline in workability. When making concrete, authors in [1] examined the substitution of marble powder of up to 15% ratio for sand or cement. Authors in [12] found that UPV values increased when 100% marble powder was utilized in place of sand. The experiments conducted in [9] demonstrated that adding marble dust and superplasticizers of/and up to 10% of sand increases the compressive strength. In a research conducted by authors in [6], stone and marble dust were substituted with sand in an experiment performed to ascertain the concrete's compressive strength. The mixtures were altered at 5%, 10%, and 15% levels of substitution. The results indicated that concrete with fine aggregates of Marble Dust (MD) and Limestone Dust (LD) performs well and resists abrasion similarly to conventional concrete. Authors in [16] replaced natural sand in concrete mixes with a mixture of marble sludge and quarry dust. This resulted in concrete mixes that were stronger, more resistant to sulfates, and had lower permeability than mixes that used natural sand. Authors in [14] concluded that adding WMP in place of 20% sand enhanced the long-term durability of concrete by improving the capillary absorption of water and resisting carbonation. By employing fly ash in place of some fine aggregate, authors in [35] observed that the strength of the concrete was significantly increased. The elasticity modulus and compressive strength of concrete with fly ash partially substituted with fine sand are higher than those of the control, particularly at later ages [31]. Authors in [13] claim that Marble Powder (MP) is efficiently used in place of some sand. Cement was partially substituted with Fly Ash (FA).

II. RESEARCH RELEVANCE

Reducing reliance on natural resources and minimizing environmental degradation are the main goals of this study. These objectives were achieved by the conduction of a thorough investigation of the characteristics of concrete produced by partly substituting natural sand with marble dust and fly ash as fine aggregates. Three series of mixes were prepared for the study. In the first series (S1), natural sand was substituted with marble dust at rates ranging from 10% to 50%, increasing incrementally by 10%. In the second series (S2), natural sand was substituted with fly ash at the same incremental rates. To evaluate how waste marble performs in place of sand and the results replacing sand with fly ash, a third series (S3) was prepared using a mixture of marble waste and FA at different substitution rates. Concrete samples produced with these modifications are evaluated for workability, and compressive strength. By closely examining the consequences of these changes on the composition and performance of concrete, it is aimed to assess the feasibility and environmental benefits of this alternative approach.

III. EXPERIMENTAL STUDY

A. Characterization of Materials

With a minimum clinker content of 65%, Portland cement CPJ 45 was selected as the binder for this project to formulate concrete, provided by Holcim and complying with the Moroccan specifications [26]. The concrete was mixed using drinking water that met the physical and chemical standards of [27]. Oujda region natural sand was utilized. It was almost devoid of impurities, with a specific gravity of 2.68, a 2.5% water absorption, and a 2.85 fineness modulus. The largest sand's size was 4.75 mm. The [22] standard was followed for conducting the sand tests. In this investigation, two varieties of crushed coarse stone aggregates, G1 with Sieve Range 5-11mm and G2 with sieve range 11-20 mm, with specific gravity of 2.70 and 2.72, respectively, and water absorption of 1.48% and 1.50%, respectively, were deployed, as stated by the [25] standard. The Waste Marble Powder (WMP) has a Fineness Blaine of 3320 m^2/kg and a specific gravity of about 2.71. This study utilizes F-class FA from the Jerada thermal power plant in Morocco, obtained through electrostatic dust collection from powdery particles in the flue gas stream of boilers fueled by pulverized coal. This type of FA contains low calcium (1.18 %), has a Fineness Blaine of 3360 m^2/kg, and a specific gravity of 2.52, as discussed in [26]. TABLE I depicts the initial and final setting times, consistency, the sand's specific gravity, the coarse gravel's specific gravity, the Fineness Blaine of cement and FA, the Fineness modulus and absorption of water results. TABLE II displays natural aggregate's chemical constituents. Figure 1 portrays the size of the particle analyses of the different materials utilized.

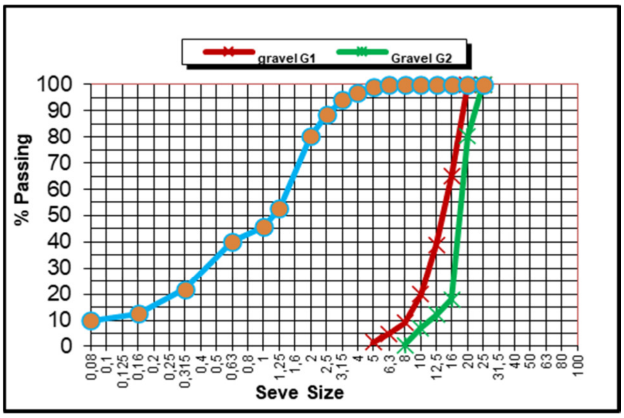

Fig. 1. Distribution of sand, gravel G1, and gravel G2 particle sizes.

TABLE I. PHYSICAL CHARACTERISTICS OF CEMENT, FLY ASH, SAND, COARSE AGGREGATE G1, G2, AND WASTE MARBLE POWDER (WMP)

Property	Cement	Fly Ash	Sand	G1	G2	WMP
Specific Gravity	3.15	2.52	2.68	2.70	2.72	2.73
Water absorption %		3.01	2.50	1.48	1.50	0.5
Fineness modulus		0.96	2.85	6,62	6,82	
Initial setting time (min)	180					
Final setting time (min)	210					
Fineness Blaine (cm^2/gm)	3100	3360				

To assess the impact of substituting WMP and FA with a part of natural sand on concrete performance, a 0.55 water-to-cement ratio was used to create 15 mixtures for every test specimen. In S1, natural sand was substituted with marble dust at rates ranging from 10% to 50%, increasing incrementally by 10%. In S2, natural sand was substituted with FA at the same incremental rates. In S3, the sand was partially replaced by a mixture of marble waste and FA. The mixture ratios of FA, WMP, sand, coarse aggregates, and Cement are listed in TABLE III. The symbol SFS denotes the FA utilized as a natural sand alternative, while SM represents the WMP used in place of natural sand. For instance, SFS20-SM10 indicates a mixture where FA replaces 20% of the natural sand and WMP replaces another 10%. The Dreux-Gorisse model was applied to carry out the concrete design.

TABLE II. CHEMICAL CONSTITUTION OF WAST MARBLE POWDER, CEMENT, SAND, AND FLY ASH

Constituent (%)	Cement (%) by mass	WMP (%) by mass	Sand (%) by mass	Fly Ash (%) by mass
CaO	60.06	47.71	5.581	1.128
SiO_2	20.90	6.69	77.40	55.2
Fe_2O_3	3.90	0.82	2.66	11.2
AL_2O_3	5.85	2.16	8.18	28.3
MgO	1.85	1.52	0.77	0.68
K_2O	2.14	0.25	0.25	1.45
TiO_2	0.32	0.06	0.005	1.5
SO_3	2.35	0.44	0.018	0.44
LOI	21.84	39.83		1.06

TABLE III. MIXTURE PROPORTIONS WITH W/C=0.55

Mix	Water (kg/m^3)	Cement (kg/m^3)	G1 (kg/m^3)	G2 (kg/m^3)	FA (kg/m^3)	Fly Ash (kg/m^3)	WMP (kg/m^3)
SM0-SFS0	192	350	320	815	763	0	0
SM-10	192	350	320	815	687	0	76
SM-20	192	350	320	815	610	0	153
SM-30	192	350	320	815	534	0	229
SM-40	192	350	320	815	458	0	305
SM-50	192	350	320	815	381	0	382
SFS-10	192	350	320	815	687	76	0
SFS-20	192	350	320	815	610	153	0
SFS-30	192	350	320	815	534	229	0
SFS-40	192	350	320	815	458	305	0
SFS-50	192	350	320	815	381	382	0
SM10-SFS10	192	350	320	815	611	76	76
SM10-SFS20	192	350	320	815	534	76	153
SM20-SFS10	192	350	320	815	534	153	76
SM20-SFS20	192	350	320	815	457	153	153
SM30-SFS20	192	350	320	815	382	153	229
SM20-SFS30	192	350	320	815	382	229	153
SM10-SFS40	192	350	320	815	382	76	305
SM40-SFS10	192	350	320	815	382	305	76

B. Test Parameters

1) Test for Hardened Concrete

Compressive strength is crucial for assessing the structural capacity of concrete in buildings. To find out the concrete's compressive strength, concrete cubes measuring 150 mm on each side are cast. According to [24], compressive strength is measured at curing ages of days 7, 14, 28, and 56. The samples were cured under 100% relative humidity and a constant ambient temperature of 27 ± 2°C with water.

2) Test for Fresh Concrete

The effect of partially substituting WMP and FA for natural sand on the regularity of freshly mixed concrete mixes was studied deploying the slump cone test in compliance with [23]. The slump cone had a standard size, measuring 300 mm in height, 200 mm in bottom diameter, and 100 mm in top diameter. Workability was assessed by conducting slump tests on all the mixtures and measuring the slump values for various concrete blends.

IV. RESULTS AND DISCUSSION

A. Marble Powder's Impact on the Compressive Strength

Compressive strength tests were carried out on concrete samples. During the process, the specimens underwent water curing. Before analyzing each concrete specimen at days 7, 14, 28, and 56, samples were given a full day to dry. Three specimens were employed to obtain the average result. Utilizing the universal testing machine (UTM), compressive strength results were acquired. The compressive strengths of the specimens are presented in TABLE IV. In S1, natural sand was substituted with WMP at percentages ranging from 10% to 50%, increasing incrementally by 10%. In S2, natural sand was replaced with FA at similar incremental percentages. In S3, natural sand was replaced by a mixture of marble waste and FA. Here, S1, S2, and S3 refer to the series of mixes mentioned above. It is observed that in the three series of mixes, and at all ages, the compressive strength increases compared to the control mix, with a peak reaching at 20% replacement of WMP and 30% replacement of FA. In Figures 2-4, it is noted that the compressive strength shows an increase of 49.94%, 49.15%, 49.53%, and 53.08% compared to the control mix at days 7, 14, 28 and 56, respectively. Given that the SM20-SFS30 sample yielded the greatest level of compressive strength, substituting 20% of natural sand with WMP and 30% of natural sand with FA, it represents a practical and effective partial solution for replacing natural cementitious materials with marble by-products.

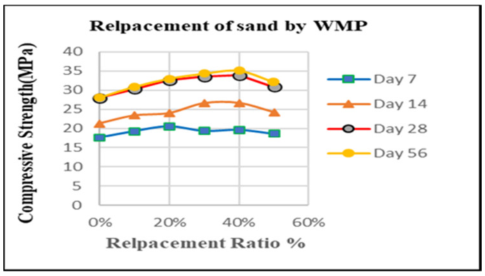

Fig. 2. Compressive strengths of WMP concrete.

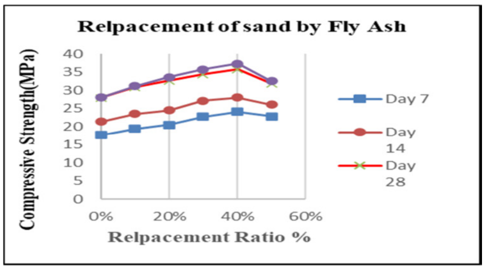

Fig. 3. Compressive strengths of fly ash concrete.

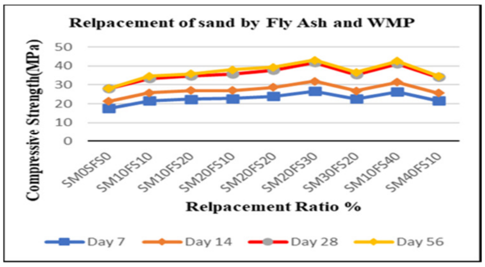

Fig. 4. Compressive Strengths of fly ash and WMP concrete.

TABLE IV. COMPRESSIVE TEST VALUE

% Replacement	Day 7	Day 14	Day 28	Day 56
SM0SFS0	17.60	21.32	27.94	28.05
SM10	19.32	23.40	30.27	30.84
SM20	20.62	24.03	32.53	32.98
SM30	19.38	26.62	33.47	34.28
SM40	19.65	26.68	33.86	35.03
SM50	18.60	24.27	30.81	31.98
SFS10	19.41	23.52	30.86	31.17
SFS20	20.50	24.51	32.58	33.54
SFS30	22.7	27.13	34.38	35.71
SFS40	24.04	28.01	35.78	37.35
SFS50	22.77	26.04	31.84	32.52
SM10-SFS10	21.54	25.80	33.38	34.61
SM10-SFS20	22.49	26.91	34.78	35.84
SM20-SFS10	22.73	27.05	35.79	37.92
SM20-SFS20	24.01	28.62	37.86	39.28
SM20-SFS30	26.58	31.80	41.78	42.94
SM30-SFS20	22.57	26.83	35.44	36.52
SM10-SFS40	26.39	31.35	41.16	42.58
SM40-SFS10	21.67	25.67	34.06	34.62

B. *Marble Powder's Impact on the Concrete's Workability*

In this study, the workability of the mixes in the S1, S2, and S3 was evaluated and assessed. TABLE V, displays the replacement levels of mixtures and their corresponding slump values, which varied between 49 and 75 mm. It was noted that, in the three series, when waste marble powder and fly ash are used in place of natural sand, the slump decreases as stated in Figures 5-7. The results revealed that incorporating of waste marble powder in 50% of natural sand makes the mixes less workable than the control concrete. The decrease in workability with the addition of WMP can be attributed to the angular shape of the marble waste aggregates and the increased surface area which is wetted, also leading to reduced workability.

TABLE V. SLUMP VALUE TEST

Mix designation	Slump(mm)	Mix designation	Slump(mm)
SM0FS0	75	SM10-FS10	63
SM10	68	SM10-SFS20	57
SM20	64	SM20-SFS10	58
SM30	60	SM20-FS20	53
SM40	53	SM20-FS30	51
SM50	49	SM30-FS20	50
SFS10	69	SM10-FS40	51
SFS20	63	SM40-FS10	49
SFS30	60		
SFS40	56		
SFS50	54		

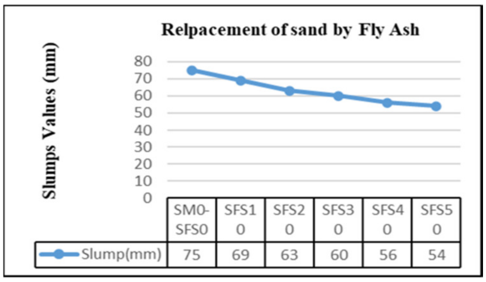

Fig. 5. Workability of WMP concrete.

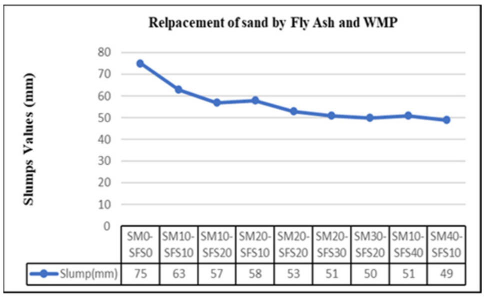

Fig. 6. Workability of fly ash concrete.

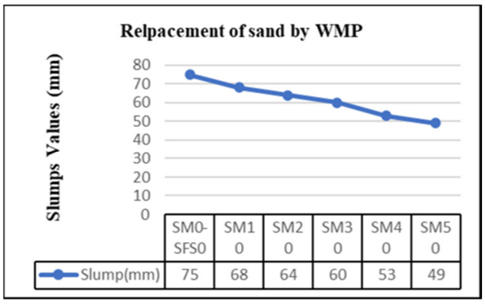

Fig. 7. Workability of fly ash and WMP concrete.

V. CONCLUSION

An important vacuum in the current understanding of sustainable building materials has been identified by studies on the use of FA and leftover marble powder in place of natural sand in concrete. Prior research has looked at several sand alternatives; however, it has not sufficiently investigated the combined effects of fly ash and marble powder. The purpose of this study was to assess how these substitute materials would affect the concrete's workability and compressive strength. The findings demonstrate that adding 20% of marble powder and 30% of FA in place of natural sand greatly increases the concrete's compressive strength. Significant gains are seen at all test ages, including 7, 14, 28, and 56 days. In comparison to the control mix, the increases in compressive strength were 49.94%, 49.15%, 49.53%, and 53.08%, in that order. In terms of workability, as replacement levels increased, the slump values of the mixes containing WMP and FA decreased, ranging from 49 to 75 mm. Specifically, the angular shape and the increased surface area of the aggregates made a 50% replacement with marble powder less workable. These results highlight the novelty of this approach by offering a sustainable alternative to conventional materials. The use of industrial byproducts such as marble powder and FA not only improves the properties of concrete, but also contributes to more environmentally friendly waste management. Compared to other similar studies, this research confirms that substitute materials can be optimized to enhance concrete performance while providing significant environmental benefits.

REFERENCES

[1] A. A. Aliabdo, A. E. M. Abd Elmoaty, and E. M. Auda, "Re-use of waste marble dust in the production of cement and concrete," *Construction and Building Materials*, vol. 50, pp. 28–41, Jan. 2014, https://doi.org/10.1016/j.conbuildmat.2013.09.005.

[2] A. Anwar, S. Ahmad, S. M. A. Husain, and S. A. Ahmad, "Replacement Of Cement By Marble Dust And Ceramic Waste In Concrete For Sustainable Development," vol. 2, no. 6.

[3] H. Y. Aruntaş, M. Gürü, M. Dayı, and İ. Tekin, "Utilization of waste marble dust as an additive in cement production," *Materials & Design*, vol. 31, no. 8, pp. 4039–4042, Sep. 2010, https://doi.org/10.1016/j.matdes.2010.03.036.

[4] D. K. Ashish, "Feasibility of waste marble powder in concrete as partial substitution of cement and sand amalgam for sustainable growth," *Journal of Building Engineering*, vol. 15, pp. 236–242, Jan. 2018, https://doi.org/10.1016/j.jobe.2017.11.024.

[5] F. Belaïd, "How does concrete and cement industry transformation contribute to mitigating climate change challenges?," *Resources, Conservation & Recycling Advances*, vol. 15, Nov. 2022, Art. no. 200084, https://doi.org/10.1016/j.rcradv.2022.200084.

[6] H. Binici, H. Kaplan, and S. Yilmaz, "Influence of marble and limestone dusts as additives on some mechanical properties of concrete," *Scientific Research and Essays*, vol. 2, no. 9, pp. 372–379, Sep. 2007, https://doi.org/10.5897/SRE.9000594.

[7] H. Binici, T. Shah, O. Aksogan, and H. Kaplan, "Durability of concrete made with granite and marble as recycle aggregates," *Journal of Materials Processing Technology*, vol. 208, no. 1, pp. 299–308, Nov. 2008, https://doi.org/10.1016/j.jmatprotec.2007.12.120.

[8] O. Bourzik, K. Baba, N. Akkouri, and A. Nounah, "Effect of waste marble powder on the properties of concrete," *Materials Today: Proceedings*, vol. 72, pp. 3265–3269, Jan. 2023, https://doi.org/10.1016/j.matpr.2022.07.184.

[9] V. Corinaldesi, G. Moriconi, and T. R. Naik, "Characterization of marble powder for its use in mortar and concrete," *Construction and Building Materials*, vol. 24, no. 1, pp. 113–117, Jan. 2010, https://doi.org/10.1016/j.conbuildmat.2009.08.013.

[10] C. Van Nguyen, P. Lambert, and Q. Hung Tran, "Effect of Vietnamese Fly Ash on Selected Physical Properties, Durability and Probability of Corrosion of Steel in Concrete," *Materials*, vol. 12, no. 4, Jan. 2019, Art. no. 593, https://doi.org/10.3390/ma12040593.

[11] B. Damodhara Reddy *et al.*, "Strength and durability of concrete by partial replacement of cement by fly ash and fine aggregates by granite dust," *Materials Today: Proceedings*, Apr. 2023, https://doi.org/10.1016/j.matpr.2023.03.450.

[12] B. Demirel, "The effect of the using waste marble dust as fine sand on the mechanical properties of the concrete," *International Journal of the Physical Sciences*, vol. 5, pp. 1372–1380, Sep. 2010.

[13] G. Sancheti, S. Bhargava, and K. Jain, "Mechanical and Durability Performance of Concrete Made with Waste Marble and Fly Ash," *Jordan Journal of Civil Engineering*, vol. 14, pp. 305–318, Jan. 2020.

[14] F. Gameiro, J. de Brito, and D. Correia da Silva, "Durability performance of structural concrete containing fine aggregates from waste generated by marble quarrying industry," *Engineering Structures*, vol. 59, pp. 654–662, Feb. 2014, https://doi.org/10.1016/j.engstruct.2013.11.026.

[15] N. Ghazali, K. Muthusamy, R. Embong, I.S. A. Rahim, N. F. Muhamad Razali, F. M. Yahaya, N. F. Ariffin and S. Wan Ahmad, "Effect of Fly Ash as Partial Cement Replacement on Workability and Compressive Strength of Palm Oil Clinker Lightweight Concrete," *Earth and Environmental Science*,682,2021.

[16] M. Hameed and A. Sekar, "Properties of green concrete containing quarry rock dust and marble sludge powder as fine aggregate," *Journal of Engineering and Applied Sciences*, vol. 4, Jan. 2009.

[17] H. Hebhoub, H. Aoun, M. Belachia, H. Houari, and E. Ghorbel, "Use of waste marble aggregates in concrete," *Construction and Building Materials*, vol. 25, no. 3, pp. 1167–1171, Mar. 2011, https://doi.org/10.1016/j.conbuildmat.2010.09.037.

[18] Z. A. Hussain and N. Aljalawi, "Effect of Sustainable Glass Powder on the Properties of Reactive Powder Concrete with Polypropylene Fibers," *Engineering, Technology & Applied Science Research*, vol. 12, no. 2, pp. 8388–8392, Apr. 2022, https://doi.org/10.48084/etasr.4750.

[19] J. G. Jang and H. K. Lee, "Microstructural densification and CO2 uptake promoted by the carbonation curing of belite-rich Portland cement," *Cement and Concrete Research*, vol. 82, pp. 50–57, Apr. 2016, https://doi.org/10.1016/j.cemconres.2016.01.001.

[20] D. J. Kazem and N. M. Fawzi, "Effect of Sustainable Materials on Some Properties of Pervious Concrete," *Engineering, Technology & Applied Science Research*, vol. 14, no. 3, pp. 14039–14043, Jun. 2024, https://doi.org/10.48084/etasr.7193.

[21] P. K. Mehta and P. J. M. Monteiro, *Concrete: Microstructure, Properties, and Materials*, 4th Edition. McGraw-Hill Education, 2014.

[22] *EN 12620:2013: Aggregates for concrete*. CEN, 2013.

[23] *EN 12350-2, Testing fresh concrete - Part 2: Slump test.* CEN, 2019.

[24] *NF EN 12390-3, Tests for hardened concrete - Part 3: Compressive strength of specimens*. CEN, 2019.

[25] *NF P-18-560: Aggregates - Particle size analysis by sieving*. AFNOR, 1990.

[26] *NM 10.1.004, Hydraulic binders; Cements.* Norme Marocaine, 2003.

[27] *NM 10.1.353, Concrete Mixing Water Specifications for Sampling, Testing and Evaluation of Suitability of Use, Including Process Water from the Concrete Industry.* Norme Marocaine, 1985.

[28] NM 10.1.061, *Fresh concrete test - Slump test.* Norme Marocaine, 2008.

[29] V. K. Parvati, K. B. Prakash, and N. Deshpande, "Feasibility study of fly ash as a substitute for fine aggregates in concrete and its behavior by alternate wetting and drying Process," *E3S Web of Conferences*, vol. 405, 2023, Art. no. 03005, https://doi.org/10.1051/e3sconf/202340503005.

[30] V. T. Phan and T. H. Nguyen, "The Influence of Fly Ash on the Compressive Strength of Recycled Concrete Utilizing Coarse Aggregates from Demolition Works," *Engineering, Technology & Applied Science Research*, vol. 11, no. 3, pp. 7107–7110, Jun. 2021, https://doi.org/10.48084/etasr.4145.

[31] D. Ravina, "Mechanical properties of structural concrete incorporating a high volume of Class F fly ash as partial fine sand replacement," *Materials and Structures*, vol. 31, no. 2, pp. 84–90, Mar. 1998, https://doi.org/10.1007/BF02486469.

[32] R. Rodrigues, J. de Brito, and M. Sardinha, "Mechanical properties of structural concrete containing very fine aggregates from marble cutting sludge," *Construction and Building Materials*, vol. 77, pp. 349–356, Feb. 2015, https://doi.org/10.1016/j.conbuildmat.2014.12.104.

[33] S. Gull, S. Wani, and I. Amin, "Exploring optimum percentage of fly-ash as a replacement of cement for enhancement of concrete properties," vol. 11, pp. 16–25, Mar. 2020, https://doi.org/10.20528/cjcrl.2020.01.003.

[34] R. Siddique, "Effect of fine aggregate replacement with Class F fly ash on the mechanical properties of concrete," *Cement and Concrete Research*, vol. 33, no. 4, pp. 539–547, Apr. 2003, https://doi.org/10.1016/S0008-8846(02)01000-1.

[35] T. Fantu, G. Alemayehu, G. Kebede, Y. Abebe, S. K. Selvaraj, and V. Paramasivam, "Experimental investigation of compressive strength for fly ash on high strength concrete C-55 grade," *Materials Today: Proceedings*, vol. 46, pp. 7507–7517, Jan. 2021, https://doi.org/10.1016/j.matpr.2021.01.213.

[36] K. Ullah, M. Irshad Qureshi, A. Ahmad, and Z. Ullah, "Substitution potential of plastic fine aggregate in concrete for sustainable production," *Structures*, vol. 35, pp. 622–637, Jan. 2022, https://doi.org/10.1016/j.istruc.2021.11.003.

[37] S. Malar Vannan and Dr.P.Senthamilselvi, "An experimental study on cement concrete using marble waste as partial replacement for fine aggregate," *International Journal of Innovative Research in Technology*, vol. 10, no. 6, pp. 226–230, Nov. 2023.

[38] K. Vardhan, R. Siddique, and S. Goyal, "Influence of marble waste as partial replacement of fine aggregates on strength and drying shrinkage of concrete," *Construction and Building Materials*, vol. 228, Dec. 2019, Art. no. 116730, https://doi.org/10.1016/j.conbuildmat.2019.116730.