University of Baghdad
College of Engineering
JOURNAL OF ENGINEERING

Journal of Engineering
journal homepage: www.joe.uobaghdad.edu.iq
Number 10 Volume 24 October 2018

Civil and Architectural Engineering

Performance of Self-Compacting Concrete Slab with Grinded Local Rocks

Ahlam A. Abbood*
Assistant Lecture
Civil Engineering Department - Baghdad University
ahlam_civil@yahoo.com

ABSTRACT

The effect of using grinded rocks of (quartzite and porcelanite) as powder of (10 and 20) % replacement by weight of cement for self-compacting concrete slabs was investigated in this study. Five slabs with 15 concrete cubes were tested experimentally at 28 days to study the compressive strength, ultimate load, ultimate deflection, ductility, crack load and steel strain**.** The test results show that, the compressive strength improvement when replacement of local rock powder reached to (7.3, 4.22) % for (10 and 20) % quartzite powder and (11.3, 16.1) % for (10 and 20) % porcelanite powder, respectively compared to the reference specimen. The ultimate load percentage increase for slabs with (10 and 20) % replacement of quartzite powder was 41.17% and 23.53%, while the slabs with (10 and 20) % replacement of porcelanite powder were 23.53% and 35.3% compared to the reference slab, respectively. The ultimate deflection, ductility, spread cracks and ultimate steel strain for slabs with replacement materials (quartzite and porcelanite) increased significantly compared to the reference slab**.**

Key Words: porcelanite powder, quartzite powder, self-compacting concrete, ultimate load, and deflection.

اداء السقوف الخرسانة ذاتية الرص باستخدام مطحون صخور محلية

احلام علي عبود
مدرس مساعد
قسم الهندسة المدنية - جامعة بغداد

الخلاصة

في هذه الدراسة تم بحث تأثير استخدام مطحون صخور الكوارتزايت والبورسلنايت بنسب استبدال (10 و20)% من وزن السمنت لخرسانة ذاتية الرص. تم فحص 5 سقوف و15 مكعب بعمر 28 يوم مختبرياً لدراسة مقاومة الانضغاط و حمل التشقق والحمل الاقصى والهطول الاقصى والليونة والانفعال في الحديد. نتائج الفحص بينت ان هناك تحسن في مقاومة الانضغاط عند اضافة مطحون الصخور المحلية تصل الى (7,3و4,22)% لنسب الاستبدال (10و20)%من الكوارتزايت و (11,3و16,1)% لنسب الاستبدال (10و20)%من البورسلينات على التوالي عند مقارنتها مع المرجعية. نسبة الزيادة في الحمل الاقصى للسقوف التي تحوي نسب استبدال (10 و20)%من مطحون الكوارتزايت كانت (41,17 و 23,53)%، بينما السقوف التي تحوي نسب استبدال (10و20)% من مطحون البورسلينايت كانت (23,53% و 35,3) عند مقارنتها مع سقف المرجعية، وعلى التوالي. الهطول الاقصى والليونة وانتشار الشقوق والانفعال الاقصى للحديد للسقوف المحتوية على المواد المستبدلة (كوارتزايت وبورسلينايت) زادت عند مقارنتها مع سقف المرجعية.

---

*Corresponding author
Peer review under the responsibility of University of Baghdad.
https://doi.org/10.31026/j.eng.2018.10.07

Article accepted: 4/1/2018

الكلمات الرئيسية: مطحون البورسلينايت، مطحون الكوارتزايت، خرسانة ذاتية الرص، الحمل الاقصى والهطول.

1. INTRODUCTION

Self-compacting concrete produces resistance to segregation by using mineral fillers or fines and using special admixtures. Self-consolidating concrete is required to flow and fill special forms under its own weight, it shall be flowable enough to pass through highly reinforced areas, and must be able to avoid aggregate segregation. This type of concrete must meet special project requirements in terms of placement and flow.

Many researchers studied the flexural behavior of self-compacting concrete slab and taking some parametric study such as (the opening in slab **Kumar, et al., 2014**, affected of high-temperature, **Abdul Rahman, et al., 2016,** and high strength concrete, **Hassan, 2015** and lightweight concrete **Klein et al., 2011**). Other studies deal with using different types of fibers in self-compacting concrete for slab, **Sravana, et al., 2010, Abass, 2012**, **Mohammed, 2015** and **Ismael, 2015.** The quartzite and porcelanite were used to produce traditional concrete by **Al-Anbori and al-Obidi, 2016,** but there is a lack to study the effect of using quartzite and porcelanite in self-compacting concrete; therefore, this research presents experimental study to investigate the flexural behavior self-compacting concrete two-way slabs using local rocks under static load.

2. SPECIMENS DESCRIPTION

The experimental program consisted of testing five slabs using self-compacting concrete one of them is a reference slab (SR) and the others with 10 and 20% of grinding local rocks as a partial replacement by weight of cement of (quartzite and porcelanite) with notations SQ-10, SQ-20, SP-10, and SP-20, respectively. 15 concrete cubes with dimensions (100×100×100) mm were tested to determine the compressive strength for concrete and to prove the concrete strength design 35 MPa. All slabs have the same dimensions (1000mm length, 1000mm width, and 70mm thickness).

3. MATERIALS

3.1 Cement

Al-Mas ordinary Portland cement (OPC) conforming to the **IQS No.5/1984** was used. **Table 1** shows the chemical analysis and physical properties of the cement used.

3.2 Fine Aggregate

The natural fine aggregate from Al-Ukhaider region was used. The sand confirms zone two with fineness modulus of (2.7), the specific gravity of (2.6) and sulfate content SO_3=0.15% less than 0.5% according to **IQS 45/1984**. **Table 2** shows the sieve analysis of fine aggregate and satisfies the Iraqi specification **IQS 45/1984**.

3.3 Coarse Aggregate

The natural crushed coarse aggregate with a maximum size of 10 mm from Al-Niba`ee quarry was used. The aggregate satisfies the Iraqi specification **IQS 45/1984** with a specific gravity of (2.67) and sulfate content SO_3 = 0.01 less than 0.1%. The sieve analysis is listed in **Table 3.**

3.4 Superplasticizer S.P.

A superplasticizer commercially named GLENIUM51 (G51) was used as an admixture to produce self-compacting concrete in this study.

3.5 Water

Tap water was used for mixing and curing.

3.6 Reinforcing Steel Bars

Deformed steel reinforcement of Ø8 mm diameter was used with yield stress of 620MPa, ultimate strength of 650MPa and space as 21mm in each direction of two-way slab to form a bottom mesh reinforcement (5Ø8 in each way of two-way slab) of steel reinforcement ratios (0.00372).

3.7 Raw Material and Grinding Process

The local rocks of quartzite and porcelanite were grinded in the Building Research Center/Ministry of Construction to get a powder finer or equal to cement fineness for the purpose of obtaining the more effectiveness.

The specific gravity of the quartzite and porcelanite powder used in this study was 2.63 and 1.6, respectively. **Table 4** shows the chemical analysis for the quartzite and porcelanite powder and it’s confirmed to the requirement in, **ASTM 618, 2012**.

4. EXPERIMENTAL WORK

The materials proportions for the self-compacting concrete SCC of each mix are listed in **Table 5**. Mixing and casting processes are performed at the Structural Laboratory of Engineering College in the University of Baghdad.

In order to verify that the concrete used in this research is SCC, the fresh concrete of each mix was tested according to three standard tests: Slump flow, T500 mm slump flow, and L-box. **Table 6** illustrates the results of the three tests and the comparisons with the standard limitations in **EFNARC, 2005**. It can be noted that the results of all mix tests satisfy the requirements of EFNARC.

All the slabs were cured at the age of 28 days after casting; the machine which is used in the tests is a universal hydraulic machine with (1000kN) capacity, dial gauge put in the center of each slab to determine the deflection and strain gauge used to measure the steel strain. The slabs are simply supported along all edges by using solid steel roller of 75mm diameter with clear span 850mm and subjected to single point load applied at the center of each slab as shown **Fig. 1**.

5. RESULTS AND DISCUSSION

The experimental results show the effect of using quartzite and porcelanite powder with (10 and 20) % replacement by weight of cement on the response and behavior of simply supported slab. The results are summarized in Table 7**.**

5.1 Compressive strength

Table 7 exhibits that, there was an improvement of concrete strength for self-compacting concrete when (10 and 20) % replacement of quartzite and porcelanite powder are used compared to the reference specimen. This improvement reached 7.3% and 4.22% for quartzite and 11.3% and 16.1% for porcelanite, respectively. This can be attributed to the presence of high silica and the pozzolanic reaction for these materials and use these materials benefit from the side of economic and environmental.

5.2. Load versus deflection curves

The relation between applied load and mid-span deflection for slabs are shown in **Figs. 2 and 3**. The ultimate load for slabs increase when replacement of the grinded rocks (quartzite and porcelanite) were performed fulfill, however, for quartzite material with (10 and 20)%

replacement the percentage increase for SQ-10 and SQ-20 slabs was 41.17% and 23.53% compared with SR slab, respectively. While for porcelanite material with (10 and 20) % replacement the percentage increase for SP-10 and SP-20 slabs was 23.53% and 35.3% compared to SR slab, respectively. The ultimate deflection for slabs increases significantly by using quartzite and porcelanite powder with a partial replacement of cement of (10 and 20) %. The increase of ultimate deflection for SQ-10, SQ-20, SP-10 and SP-20 was 61.17%, 102.5%, 148.8% and 166.7%, respectively.

Fig. 4 shows the value of the absorption energy, it can be observed that the absorption energy increases with the replacement the quartzite and porcelanite powder was fulfilled as compared to the reference slab. For that, adding materials (quartzite and porcelanite) gave enhancing ductility for slab compared to the reference slab. This increment in ductility is attributed to the increase in ultimate load that resulted from compressive strength increase that leads to an increase in the ultimate deflection.

5.3 Crack Load and Crack Pattern

The first visible crack was observed at 24 kN (70.6% of ultimate load) for reference slab. The first crack for SQ-10 and SQ-20 slabs was observed at 22 kN (45.8% of ultimate load) and 18 kN (42.8% of ultimate load), while for the slabs SP-10 and SP-20 it was observed at 12 kN (30% of ultimate load) and 16 kN (36.4% of ultimate load), respectively.

For all slabs specimens, the concrete cracks initiate at the center of the tension zone of slabs and extend to the edges for all slabs at the failure. The SQ-10, SQ-20, SP-10 and SP-20 slabs appeared to increase in spread cracks as compared with SR slab because this slab failed at ultimate load higher than reference slab.

5.4 Steel Strain

As shown in **Figs. 5 and 6**, the slab specimens gave a linear behavior till yield load of steel, and the ultimate strain of steel increases as the ultimate applied load increased.

6. CONCLUSIONS

Based on the experimental results for SCC slabs using percentage replacement of grinded local rock the following conclusions can be deduced:

1. The compressive strength for SCC improved by replacement of quartzite and porcelanite powder with (10 and 20)% by weight of cement reach to 7.3% and 4.22% for quartzite and 11.3% and 16.1% for porcelanite, respectively, compared to the reference specimen.
2. The slabs with (10 and 20)% replacement by weight of cement of quartzite and porcelanite powder exhibited an enhancement in ultimate load reach to 41.17%, 23.53%, 23.53% and 35.3% respectively, compared to the reference slab.
3. The ultimate deflection increased with using of quartzite and porcelanite powder as a partial replacement of cement with (10 and 20)% reached to 61.17%, 102.5%, 148.8% and 166.7%, respectively compared to reference slab.
4. The slabs with replacement materials (quartzite and porcelanite) show enhancement in ductility compared to the reference slab.
5. The cracks for slabs with (10 and 20)% partial replacement by weight of cement of quartzite and porcelanite powder exhibits spread crack more than the reference slab.
6. The ultimate strain in steel for slabs with replacement materials (quartzite and porcelanite) increased compared to the reference slab.

REFERENCES

- Abass Z. W., 2012, *Evaluation Of Fire Endurance Of Self Compacted Concrete Slab Reinforced With Steel Fiber Reinforcement And Steel Bars*, Diyala Journal of Engineering Sciences, Vol. 05, No. 01, PP.25-39.

- Abdul Rahman M. B. A. and Tause A. S., 2016, *The Performance of Self Compacting Concrete Slab Exposed to High Temperature Under Static and Dynamic Loading*, Vol. 11, No.2, pp.250-277.

- Al-Anbori Z. K. A. and Al-Obaidi A. A. I., 2016, *Some Mechanical Properties of Concrete by using Manufactured Blended Cement with Grinded Local Rocks*, Journal of Engineering, Vol.22, N0.3, PP.1-21.

- ASTM C 618, 2012, *Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete*, Annual Book of ASTM Standard, Vol. 04-02, p.3.

- EFNARC, 2005, European Federation Dedicated to Specialist Construction Chemicals and Concrete Systems, *The European Guidelines for Self-Compacting Concrete Specifications, Production and Use*, EFNARC, Association House, 99 West Street, Farnham, Surrey GU9 7EN, U.K., pp 63.

- Hassa, F. H., 2015, *Experimental Study Of Fibrous High Strength Self-Compacting Concrete One-Way Slabs*, Journal of Engineering and Development, Vol. 19, No.1, pp.50-67.

- IQS 45, 1984, *Aggregate from natural sources for concrete and building construction*.

- IQS 5, 1984, *Iraq standard specification for Portland cements*.

- Ismael M. A., 2015, *Flexural Behavior Of Steel Fiber-Self Compact Concrete Slabs*, Second Engineering Scientific Conference College of Engineering –University of Diyala 16-17, pp. 83-99.

- Klein N. S., de la Fuente A., Aguado A. and Maso D., 2011, *Lightweight self-compacting concrete reinforced with fibers for slab rehabilitation*, Materials and Construction, Vol. 61, N0.302, pp.239-256.

- Kumar S. M. S. and Chandra B. S. S., 2014, *Experimental Study on Self Compacting RC Slab with and With Out Opening*, International Journal of Engineering Research & Technology (IJERT), Vol. 3, No.8, pp.202-206.

- Mohammed H. M., 2015, *Behavior of Steel Fiber Reinforced Self Compacting Concrete Slabs under One-way Bending*, Eng. And tech. Journal, Vol.33, Part (A), No.6, PP.1341-1356.

- Sravana P., Rao P. S., and Sekhar T. S., 2010, *Flexural Behavior Of Glass Fiber Reinforced Self Compacting Concrete Slabs*, 35th Conference on Our World In Concrete & Structures: 25 – 27, Singapore.

Table 1. Chemical analysis and physical properties of the cement**.**

Abbreviation		**% by weight**	**Limits of Iraqi specification No.5 / 1984**
Chemical properties %	SiO_2	19.59	-
	Al_2O_3	4.63	-
	Fe_2O_3	3.53	-
	CaO	61.58	-
	SO_3	2.74	2.8(max)
	MgO	2.75	5.0(max)
	L.O.I	1.64	4.0(max)
Bogue's equations	C_3S	63.08	-
	C_2S	9.37	-
	C_3A	4.65	-
	C_4AF	12.27	-
Setting time (vicate apparatus), a.Initial - hr:min b.Final - hr:min		 1:30 4:50	 00:45(min) 10:00(max)
Compressive strength MPa(N/mm^2): a. 3-days b. 7-days		 25.5 29.5	 15.0(min) 23.0(min)

- Chemical and Physical tests were conducted in the Laboratory of the University of Baghdad–College of Engineering-Civil Engineering Department.

Table 2. Sieve analysis of the fine aggregate**.**

Sieve size	**Passing by weight (%)**	**IQS 45/1984 limits(Zone 2)**
10mm	100	100
4.75mm	96	90-100
2.36mm	87	75-100
1.18mm	78	55-90
600µm	43	35-59
300µm	19	8-30
150µm	6	0-10

- Tests are conducted in the Laboratory of the University of Baghdad–College of Engineering-Civil Engineering Department.

Table 3. Sieve analysis of coarse aggregate with 10mm maximum size.

Sieve size	% passing by weight	IQS 45/1984 limits
14mm	100	100
10mm	95	85-100
5mm	14	0-25
2.36mm	2	0-5

- Tests have been conducted in the Laboratory of the University of Baghdad–College of Engineering-Civil Engineering Department.

Table 4. Chemical composition for quartzite and porcelinite.

Oxide Content %	% by weight for quartzite	% by weight for porcelainize	Limits of ASTM C618-12
SiO_2	96.15	65.3	Sum. SiO_2+Al_2O_3+Fe_2O_3 70%(min)
Al_2O_3	0.22	4.26	
Fe_2O_3	0.4	1.69	
CaO	0.67	12.21	
SO_3	0.03	0.025	4%(max)
MgO	Less than 0.02	3.39	
L.O.I	0.63	9.3	10%(max)

Table 5. Mix proportion for materials.

Mixes	Cement kg/m^3	Quartzite powder kg/m^3	Porcelinite powder kg/m^3	S.P. L for each 100 kg cement
SR	430	-	-	0.9
SQ-10%	387	43	-	0.77
SQ-20%	344	86	-	0.8
SP-10%	387	-	43	1.4
SP-20%	344	-	86	1.5

- sand=679 kg/m^3, gravel=750 kg/m^3, Silic fume =2% kg/m^3, Water=185 l/m^3

Table 6. Fresh concrete results of self-compacted concrete.

		Slump flow		L-Box
EFNARC Limits		T500 2-5 (sec)	Average R 650-800 (mm)	H1/H2 0.8-1
Mixes	SR	3.4	675	0.8
	SQ-10	2.5	725	0.93
	SQ-20	2.9	680	0.81
	SP-10	2.2	675	0.87
	SP-20	2.3	655	0.8

Table 7. Test results of slabs specimens.

Specimens	f'_c at 28 days	Increment of f'_c %	P_{cr} kN	P_{ul}.kN	IncrementP_{ul} %	$\Delta_{ul.}$ mm	Increment of $\Delta_{ul.}$%
SR	35.5	-	24	34	-	5.64	-
SQ-10	38.1	7.3	22	48	41.17	9.09	61.17
SQ-20	37	4.22	18	42	23.53	11.42	102.5
SP-10	39.5	11.3	12	42	23.53	14.03	148.8
SP-20	41.2	16.1	16	46	35.3	15.04	166.7

f'_c: Compressive strength, P_{cr}: Crack load, P_{ul}: ultimate load, $\Delta_{ul.}$: ultimate deflection

Figure 1. Test of slab.

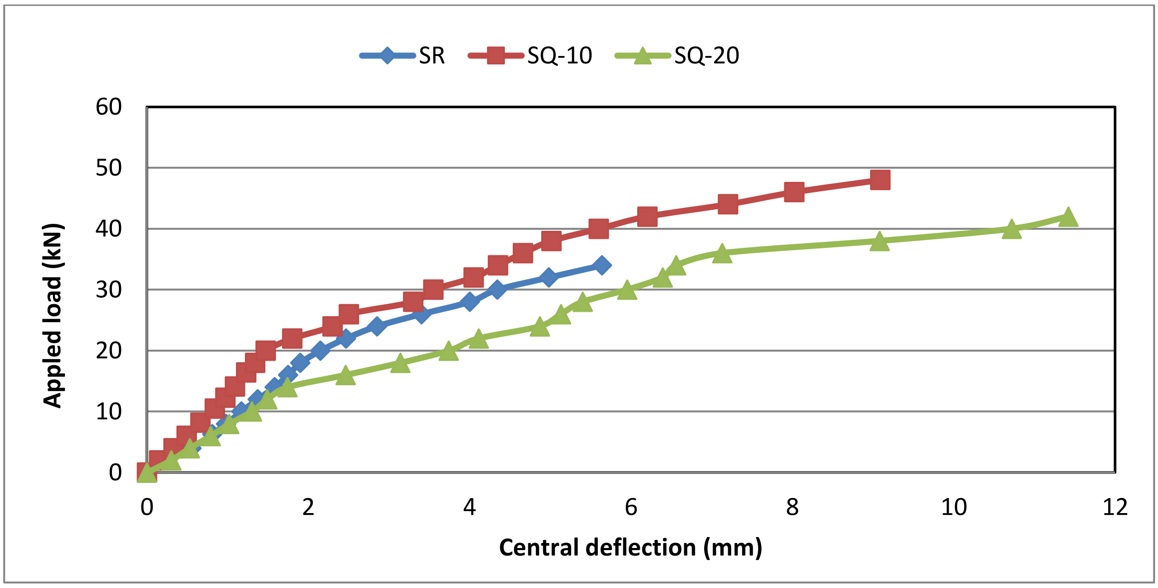

Figure 2. Load-deflection curve for reference and quartzite powder slabs.

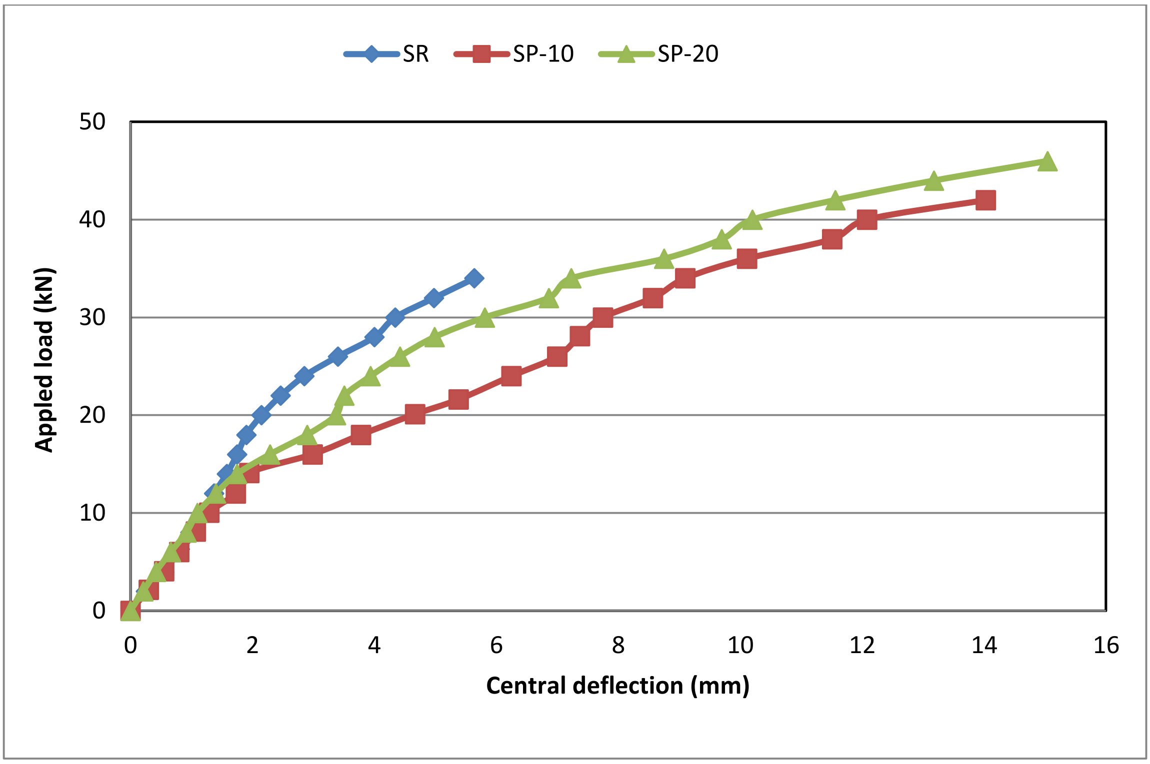

Figure 3. Load-deflection curve for reference and porcelanite powder slabs.

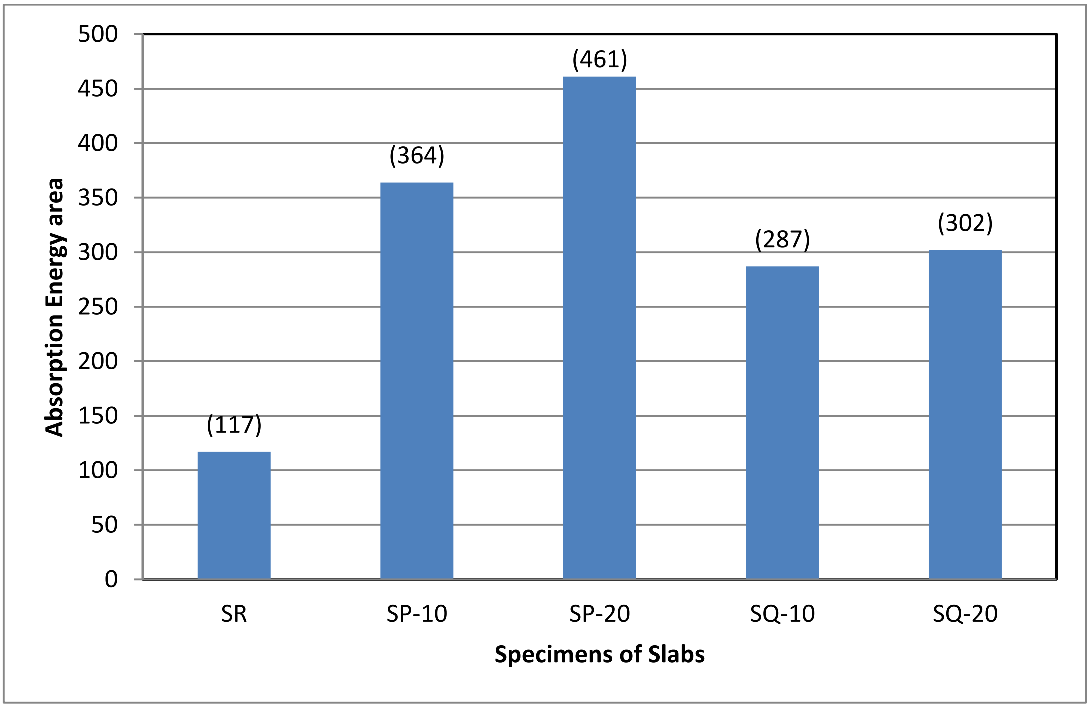

Figure 4. Absorption energy for slabs specimens.

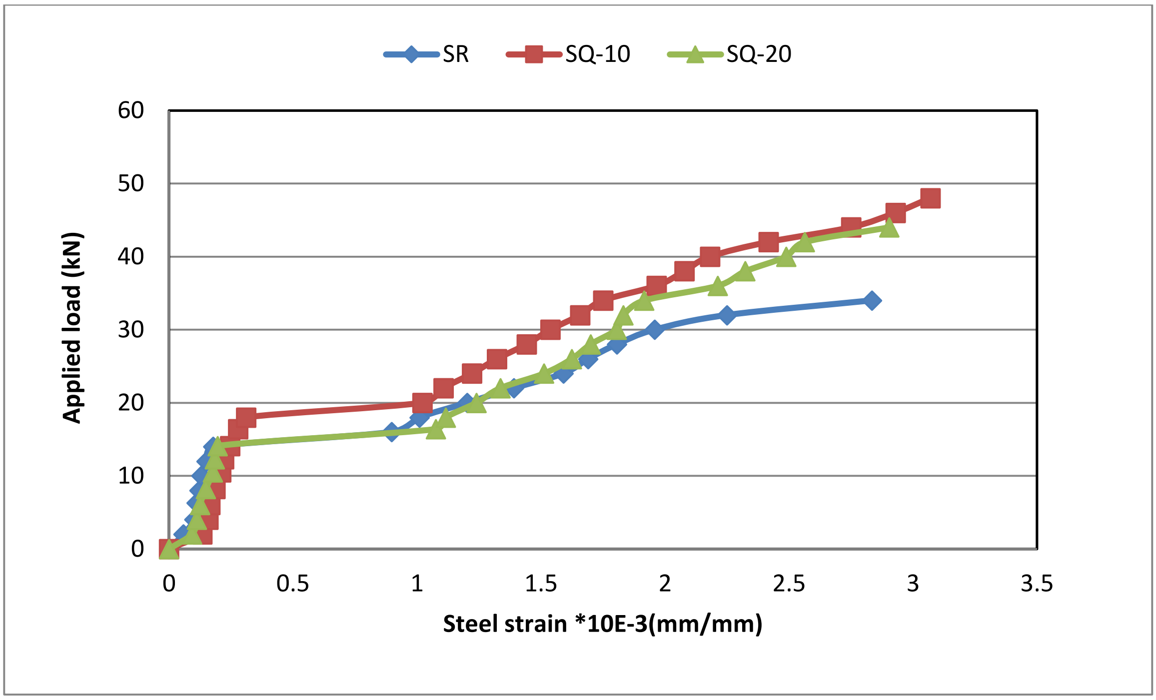

Figure 5. Applied load steel strain curve for reference and quartzite powder slabs.

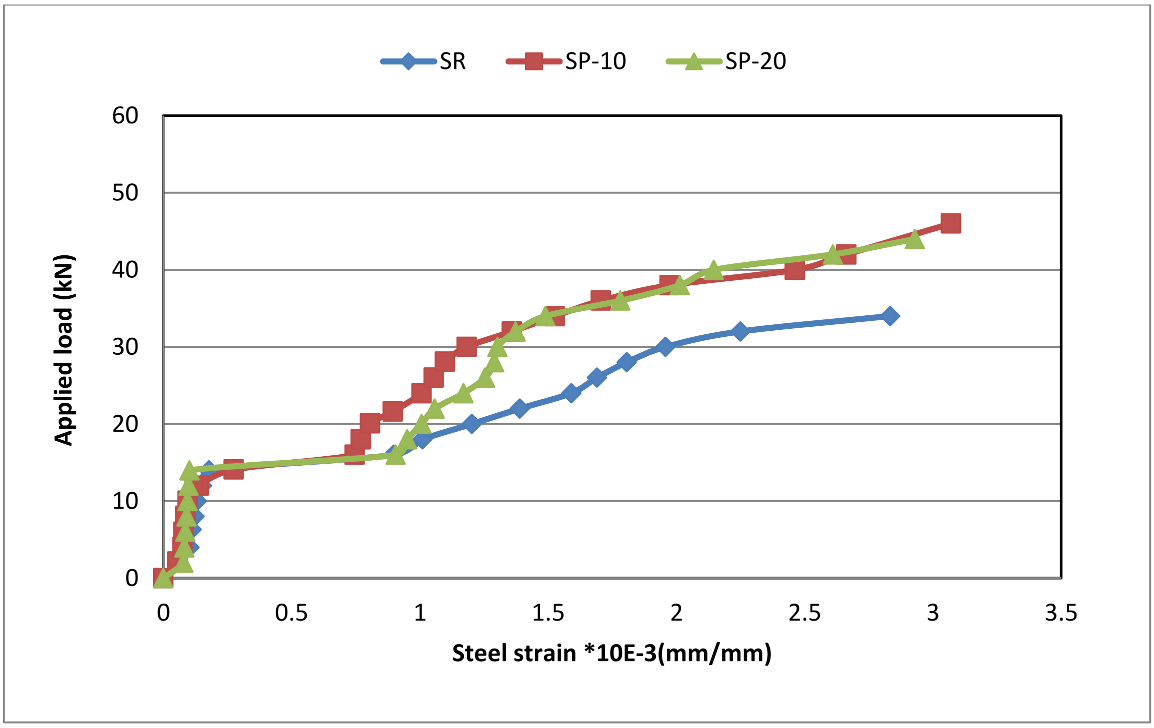

Figure 6. Applied load steel strain curve for reference and porcelanite powder slabs.