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A Review on Waste Minimization by Adopting in Self Compacting Concrete

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Abstract. Self-compacting concrete (SCC) was first developed in late 80's in Japan. SCC is well known for its self-consolidation and able to occupy spaces in the formwork without vibration and become new interesting topic in Construction and Building Materials Research. The aim of this review is to summaries the previous research work related to utilization of waste minimization in SCC from 2009 to 2015 through available literature. It is important to expose new researchers on concept and fundamental theory developed by previous researchers as a reference and guidance in their research. There were a lot of opportunity to be explored in developing SCC especially in utilizing waste material as replacement materials or additives used and mix design method for rheological improvement in SCC. However, these review only focusing on waste materials that have significant to be taken care to reduce environmental impact such as waste product from construction industry and by product industry. As conclusion, this paper will provide significant idea and useful information to those new to SCC and fellow researchers for future studies in utilizing waste materials in SCC mix design.

1 Introduction

Developing Self Compacting Concrete (SCC) was started in late '80s in Japan. It was introduce by Okamura Hajime [1-2] due to shortage of manpower on site and resolve environmental issue such as noise reduction. This concrete technology has received demand from construction industry in Japan to construct bridges, buildings and repair works on site.

In definition, SCC is the technology of concrete that makes use of concrete to flow and fill the gap between reinforcement and fill the void inside the formwork at every corner by it is own weight without vibration process [3-4]. The development of SCC for construction industry in Japan has proved benefit in several factors such as reduce construction duration, required less manpower on site, provide good surface finishes, easier in placing handling, provided freedom idea in structural design, suitable for thinner concrete sections, reduced noise levels and safer working environment [3, 5].

However, the development of SCC still under continues research. This was confirmed by the summary of literature review from published journal since 2009 to 2015 as shown in Table 1. Some of researcher's study on utilizing additive materials, chemical additive, waste materials, light weight aggregate, sand replacement and potential pozzolana materials to improve rheological and hardened properties. However, these summaries only focus on waste materials used in previous research from

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Turkey, Greece, India, Thailand, Malaysia, Iran, China, Indonesia, Brazil, Taiwan, Italy, Tunisia and Germany. Hopefully this information can provide an idea for new researcher to explore on SCC by utilizing waste materials that available from construction industry and also from by product industry. The performance of waste materials in SCC is based on fresh state [3, 6-10] and hardened state.

2 Literature from Previous Researches

This review based on information gathered from available literature journal papers since 2009 till 2015. Table 1(a) and (b) have shown the previous research focusing on waste materials in development of sustainable SCC for benefit of economy and environmental issues. It was clearly shown that utilizing waste materials in SCC have significant contribution to environmental solution and indirectly help to contribute in generating economic value to some other industries.

Table 1(a). Summary of previous study base on waste materials used in SCC.

Year	Ref.	Country	Materials	Finding
2009	[11]	Turkey	Mix design using marble powder (MP) (recycle value)	Mix design Monogram. Recycle powder successfully and economically as filler material, f_c (±) 20-60 MPa, using Mix design base on Monogram
	[12]	USA	Mix design using foundry silica dust (SD) as replacement for FA (economic value)	20% SD as economy cost, 30% SD increase demand of HRWA (increase cost of material 14%) , f_c (±) 34-62 MPa
2010	[13]	Greece	Mix design cement paste, SF, Nano SF, LS, P & FA for viscosity effect	Cement paste, 40% LS improved rheological behavior, 20% LS & 20% FA having higher packing density. SF & Pozzolan having lower viscosity
	[14]	India	Mix design cement replacement using SF Vs LS, QD & Cl (comparison water absorption)	Okamura's Method. SF increased dosage SP, improved aggregate matrix bonding & less water absorption (better than QD & LP), LP improved & better workability
2011	[15]	UK	Mix design (Dolomite Powder + FA) Vs (LS + FA). Utilizing DP as alternative materials	Mix by Mass. Utilizing DP with FA can reduced cost SCC & solution to disposal & environmental problem. But, increase DP and decrease FA will reduce compressive strength.
	[16]	Italy	Mix design mineral addition. FA, LP, (Rubble Powder + Fine Recycle) & (RP + Course Recycled)	MP performed better in rheological test. All mix obtained satisfactory in compressive strength (±) 40 MPa.
	[17]	Turkey	Mix design mineral admixtures. FA, GBFS, LP, BP and MP for cement replacement	FA & GBFS increased compressive strength & workability, replacement FA in OPC suitable for HPC
2012	[18]	Algeria	Mix design using various sand (Crushed Sand, River Sand, Dund Sand & mix sand)	Okamura's Method. Increase fine LS, decrease slump flow time & increased V Funnel flow time, 10-15% fine LS improved rheological and compressive strength of mortar but more than that will decreased it strength. DS required higher water demand and larger amount of cement compared with RS & CS
	[19]	Turkey	Mix design MP, LS & FA as filler (Environmental Concern; disposal & recycled materials)	Integration of MP & LS with FA improved workability, MP & LS increase dosage of SP but integration with FA decreased amount of SP.
2013	[20]	Brazil	Mix design using kaolin waste as agg. replacement	Mix using concept of aggregate skeleton (increase compactness will increase density), only focus on fresh test
	[21]	Taiwan	Mix design FA & slag with difference w/c ratio	Densified mixture design algorithm (DMDA), DMDA minimize paste content & overcome aggregate gradation, provide high slump without bleeding & segregation, used less cementitious materials ratio will effect early strength but not for long term strength (after 56 days)
	[22]	Indonesia	Mix design using roof tile powder (RTP)	20% RTP, compressive strength 67.72 MPa, good flow ability
	[23]	UK	Mix design using FA & LP as a filler	30% FA for sustainable SCC with approximately 1.83% SP (by weight), compressive strength 50-60 MPa,
	[24]	India	Mix design using recycled aggregate	10-40% RA, increase RA will decrease compressive, flexural & tensile strength

Table 1(b). Summary of previous study base on waste materials used in SCC.

Year	Ref.	Country	Materials	Finding
2013	[25]	Thailand	Mix design using untreated RHA & PFA	Compressive strength of 40% RHA decreased 1/3 from control sample
	[26]	Thailand	Mix design using cathode ray tube waste	Increase CRT amount will decrease compressive strength
	[27]	Thailand	Mix design using recycled alumina waste (AW) as fine aggregate replacement	AW increased amount of SP, AW increased compressive strength over the period, 75% AW have better compressive strength than control sample
2014	[28]	Greece	Mix design using ladle furnace slag (LFS) and steel fiber reinforcement	LFS as filler improved compressive strength & durability (freezethraw resistance & chloride penetration) with consistence workability, LFS with fibre increase fracture toughness but to many fibre will effect segregation and flowability, increase LFS decrease water cement ratio
	[29]	Turkey	Mix design using Low Lime Fly Ash (LLFA) & GBFS as cement replacement (binder) & Mircronized Calcite (MC) as aggregate replacement	LLFA, GBFS & MC positively improved passing ability & flow ability & reduce viscosity (due to MC), surface roughness LLFA reduce water demand, substitution high volume of GBFS & LLFA up to 60% (compressive strength 42.58 – 52.7 MPa)
	[30]	Iran	Mix design effect of aggregate sizes	Decrease of aggregate size will drop fracture energy
	[31]	Turkey	Mix design utilizing of VMA to reduce fine material	Increase fine material or use VMA to avoid segregation, VA xanthan gum @ 400 kg binder content & VA starch ether (@ 350, 400 & 450 kg binder dosage) reduce bleeding to zero, at some portion segregation will effect compressive strength, W/C ratio significantly effect the compressive strength same as NVC
	[32]	Malaysia	Mix design using Palm Oil Clinker (POC) as LWA	Mix design base on particle packing (PP) can be used to predict hardened properties,
	[33]	UK	Mix design using Recycled Lime Powder (RLP) & Recycled Concrete Aggregate (RCA)	RLP as cement replacement & RCA as aggregate replacement have potential to produce good quality (mechanical & durability performance)
	[34]	Malaysia	Mix design using Metakaolin (MK) with difference course aggregate properties	10 % MK as pozzolan by weight of cement good in workability and strength, same w/b ratio & SP dosage but increase sand content (mortar) will reduce flow ability (lead to bleeding rate of water), SP increase with increasing of MK, higher SP dosage contribute to bleeding, shape & fineness powder effect SP dosage,
	[35]	Malaysia	Mix design using RHA and blended fine aggregate	RHA as supplementary of cement, suitable for normal strength, compressive strength & splitting tensile strength decreased with increasing of RHA, RHA contain silica which not contribute to compressive strength
	[36]	Turkey	Mix design using waste marble (WM) and recycled aggregates (RA)	Crushed limestone agg. as control sample, WM & RA produce slightly lower compressive strength compared with CLS, strength can be improved by reduce w/b ratio
	[37]	Malaysia	Mix design using Bottom Ash	10-15% BA suitable for fine aggregate replacement, more than that it will effect the rheology properties
2015	[38]	India	Mix design using RHA	RHA as supplementary cementitious material, 15% RHA increased compressive strength & tensile strength and also reduced chloride ion penetration
	[39]	China	Mix design using FA & GGBFS	Combination FA & GBFS (20, 30 & 40%) not affect flowability & stability, effective on chloride ion migration, but higher carbonation depth
	[40]	China	Mix design using recycled plastic particles	For light weight SCC, Compressive strength, tensile strength & flexural tensile strength increased with replacement level up to 15%,
	[41]	Germany	Mix design containing various mineral admixtures for high performent concrete (HPC)	Introduced new mix design method containing various mineral admixtures by using Absolute Volume Method (AVM) – adopted from packing theory, RHA improved compressive strength (marginally lower from SF)
	[42]	Tunisia	Mix design using marble and tile waste as filler	Mix design using “Concrete LabPro2” software, compressive strength & tensile strength are sufficient
	[43]	Algeria	Mix design using seashell as fine aggregate for mortar	For fine aggregate by sand substitution for mortar, 100% replacement reduce compressive strength & MOE

3 Mix design methods

SCC has been introduced in Japan since 1986 by Okamura using Empirical Design Method [2, 44]. Through summary review from Table 1, it was shown that development of mix design method has been improvised from time to time by researchers around the world. In 2015, Caijun have summarized a review on mix design method for SCC. Base on his reviewed, mix design method can be classified in five categories which are Empirical Design Method, Compressive Strength Method, Close Aggregate Packing Method, Statistical Factorial Method and Rheology of Paste Model. However, all this method still cannot fully meet requirement for effective cost, sustainability, widely applicable due to variable of alternative raw material used and technical requirement while in fresh and hardened state of SCC [44].

From Table 1, it was confirmed that researchers keep on looking on developing mix design method for SCC. For example, it was found that, 3 new methods have been identified such as Monogram Method [11], Absolute Volume Method [41] and "Concrete LabPro2" software [42]. However, those 3 researchers are using difference types of material in their mix design. They have used MP as filler material [11], RHA, SF, FA, LS powder as mineral admixtures for cementations efficiency [41] and marble and tile waste as filler material[42]. Therefore, the ability of each materials to performance with difference mix design method should be open to evaluate as far as the performance in fresh state are well check with the recommendation by [3, 6-10].

4 Materials

From Table 1, the most common addition materials are FA, SF, GBFS and LS [3, 45]. While currently researchers have looking forward to make used of recycled material such as Quarry Dust (QD), Dolomite Powder (DP), Limestone (LS), Rubble Powder (RP), Recycled Aggregate, Marble Powder (MP), Cement Klin Dust (CKD), Roof Tiles, Rise Husk Ash (RHA), Alumina Waste (AW), Recycled Plastic Particles (RPP), Marble Waste (MW), Tile Waste (TW), Metakaolin (MK), Basalt Powder (BP) and Palm Oil Clinker (POC). All these additions are used as replacement material or substitution materials either for cement, fine aggregate or filler materials.

Some of this material influence SCC performance in positive effect and some of the materials reflect on negative result either for fresh state or hardened state. Majority of researcher having consistent result in their studies such as FA suitable for cement replacement and fine materials will effect amount of SP required, w/b ratio and w/c ratio. However, uncontrolled amount or proportion of replacement material will reduce the compressive strength, tensile strength, MOE and rheology of the SCC. Therefore the performance of fresh state are compulsory to be checked according to the recommendation by [3, 6-10].

Based on Table 1, it shown that utilizing waste material in SCC have getting attention among researchers. Some of potential waste materials either from construction industry or from by product industry and there are commonly available in every country in all over the world. Those waste materials are abundant and causes environmental pollution such as roof tile [22], recycle aggregate [24, 33, 36], waste marble [11, 17, 36, 42], RHA [25, 35, 38, 41] and recycled plastic particle [40]. The performances of utilizing those materials are subjective to the purposed of the study and should be explored and established from time to time for the benefit of all parties. A mechanism to utilize all those potential recycled waste materials should be integrated between all parties either from industry or local authorities. This is important to create a better future to our young generation in order to live in sustainable environment.

As conclusion, no doubt, SCC is a potential concrete technology to be developed by utilizing potential alternative materials or waste materials in all over the world. Utilizing of recycled materials and by product materials should be looking forward as an advantage for new researchers especially in Malaysia. It is not only generate or contribute to new knowledge but it is also helping us to save our environment from destructing due to current generated industrial waste in all over the world.

5 Conclusions

From this summary review, it was found that the development of SCC could be explored by using difference types of waste materials especially using by product waste from industry to reduce environmental issues. Indirectly, this effort will provide better solution in concrete technology and create better benefit in future economic value to the industries and local community. Sustainable values on developing future concrete industry should be expended through quality research among industry and collaborate with higher institutions to create sustainable situation to all parties. Beside that, integration with local authorities laws and regulations will generate better opportunity to industries and researchers to collaborate on waste minimization and utilization. Therefore utilizing of waste materials in developing sustainable SCC should be supported, explored and expended through focus researches. Development of SCC should be verified through performance on fresh state and hardened state to understand the behaviour of each material either in short term or long term effect.

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References

[1] K.O.H. Okamura and K. Maekawa, High Performance Concrete, Gihoubou Pub. (in Japanese), (1993).
[2] H. Okamura, Self-compacting high-performance concrete, Concr. Int., 50–54, (1997).
[3] EFNARC, Specification and Guidelines for Self-Compacting Concrete, United Kingdom, (2002).
[4] H. Okamura and M. Ouchi, Self-Compacting Concrete, Adv. Concr. Technol., **1**(1),. 5–15, (2003).
[5] W. Zhu and P.J.M. Bartos, Permeation properties of self-compacting concrete Wenzhong, Cem. Concr. Res., **21**(7), 921–925, (2003).
[6] BS EN12350-Part 8, Testing Fresh Concrete, Self-Compacting Concrete, Slump Flow Test, (2010).
[7] BS EN12350-Part 9, Testing Fresh Concrete, Self-Compacting Concrete, V Funnel Test, (2010)
[8] BS EN12350- Part10, Testing Fresh Concrete, Self-Compacting Concrete, L Box Test, (2010).
[9] BS EN12350-Part 11, Testing Fresh Concrete, Self-Compacting Concrete, Sieve Segregation Test, (2010).
[10] BS EN12350-Part12, Testing Fresh Concrete, Self-Compacting Concrete, J Ring Test, (2010).
[11] K.E. Alyamaç and R. Ince, A preliminary concrete mix design for SCC with marble powders, Constr. Build. Mater., **23**(3), 1201–1210, (2009).
[12] R.N. Kraus, T.R. Naik, B.W. Ramme and R. Kumar, Use of foundry silica-dust in manufacturing economical self-consolidating concrete, Constr. Build. Mater., **23**(11), 3439–3442, (2009).
[13] N. Diamantonis, I. Marinos, M.S. Katsiotis, A. Sakellariou, A. Papathanasiou, V. Kaloidas and M. Katsioti, Investigations about the influence of fine additives on the viscosity of cement paste for self-compacting concrete, Constr. Build. Mater., **24**(8), 1518–1522, (2010).
[14] C. Selvamony, M.S. Ravikumar, S.U. Kannan and S.B. Gnanappa, Investigations on Self-Compacted Self-Curing Concrete Using Limestone Powder and Clinkers, ARPN J. Eng. Appl. Sci., **5(**3), 1–6, (2010).
[15] S. Barbhuiya, Effects of fly ash and dolomite powder on the properties of self-compacting concrete, Constr. Build. Mater., **25**(8), 3301–3305, (2011).
[16] V. Corinaldesi and G. Moriconi, The role of industrial by-products in self-compacting concrete, Constr. Build. Mater., **25**(8), 3181–3186, (2011).
[17] M. Uysal and M. Sumer, Performance of self-compacting concrete containing different mineral admixtures, Constr. Build. Mater., **25**(11), 4112–4120, (2011).

[18] B. Benabed, E.H. Kadri, L. Azzouz and S. Kenai, Properties of self-compacting mortar made with various types of sand, Cem. Concr. Compos., **34**(10), 1167–1173, (2012).
[19] M. Gesoğlu, E. Güneyisi, M.E. Kocabağ, V. Bayram and K. Mermerdaş, Fresh and hardened characteristics of self compacting concretes made with combined use of marble powder, limestone filler, and fly ash, Constr. Build. Mater., **37**, 160–170, (2012).
[20] G. Azeredo and M. Diniz, Self-compacting concrete obtained by the use of kaolin wastes, Constr. Build. Mater., **38**, 515–523, (2013).
[21] Y.Y. Chen, B.L.A. Tuan and C.L. Hwang, Effect of paste amount on the properties of self-consolidating concrete containing fly ash and slag, Constr. Build. Mater., **47**, 340–346, (2013).
[22] B. Herbudiman and A.M. Saptaji, Self-compacting concrete with recycled traditional roof tile powder, Procedia Eng., **54**, 805–816, (2013).
[23] M.K. Mohammed, A.R. Dawson and N.H. Thom, Production, microstructure and hydration of sustainable self-compacting concrete with different types of filler, Constr. Build. Mater., **49**, 84–92, (2013).
[24] K.C. Panda and P.K. Bal, Properties of self compacting concrete using recycled coarse aggregate, Procedia Eng., **51**, 159–164, (2013).
[25] G. Sua-iam and N. Makul, Use of Unprocessed Rice Husk Ash and Pulverized Fuel Ash in the Production of Self-compacting Concrete, IERI Procedia, **5**, 298–303, (2013).
[26] G. Sua-iam and N. Makul, Use of limestone powder during incorporation of Pb-containing cathode ray tube waste in self-compacting concrete, J. Environ. Manage., **128**, 931–940, (2013).
[27] G. Sua-Iam and N. Makul, Use of recycled alumina as fine aggregate replacement in self-compacting concrete, Constr. Build. Mater., **47**, 701–710, (2013).
[28] E.K. Anastasiou, I. Papayianni and M. Papachristoforou, Behavior of self compacting concrete containing ladle furnace slag and steel fiber reinforcement, Mater. Des., **59**, 454–460, (2014).
[29] H.Y. Aruntas, Workability and mechanical properties of self-compacting concretes containing LLFA , GBFS and MC, **73**, 626–635, (2014).
[30] M.H.A. Beygi, M.T. Kazemi, I.M. Nikbin, J. Vaseghi Amiri, S. Rabbanifar and E. Rahmani, The influence of coarse aggregate size and volume on the fracture behavior and brittleness of self-compacting concrete, Cem. Concr. Res., **66**, 75–90, (2014).
[31] I.E. Isik and M.H. Ozkul, Utilization of polysaccharides as viscosity modifying agent in self-compacting concrete, Constr. Build. Mater., **72**, 239–247, (2014).
[32] J. Kanadasan and H.A. Razak, Mix design for self-compacting palm oil clinker concrete based on particle packing, Mater. Des., **56**, 9–19, (2014).
[33] A. Kanellopoulos, D. Nicolaides and M.F. Petrou, Mechanical and durability properties of concretes containing recycled lime powder and recycled aggregates, Constr. Build. Mater., **53**, 253–259, (2014).
[34] O.R. Khaleel and H. Abdul Razak, Mix design method for self compacting metakaolin concrete with different properties of coarse aggregate, Mater. Des., **53**, 691–700, (2014).
[35] M.E. Rahman, A.S. Muntohar, V. Pakrashi, B.H. Nagaratnam and D. Sujan, Self compacting concrete from uncontrolled burning of rice husk and blended fine aggregate, Mater. Des., **55**, 410–415, (2014).
[36] T. Uygunoğlu, I.B. Topçu and A.G. Çelik, Use of waste marble and recycled aggregates in self-compacting concrete for environmental sustainability, J. Clean. Prod., **84**, (2014).
[37] N.E. Zainal Abidin, M.H. Wan Ibrahim, N. Jamaluddin, K. Kamaruddin and A. F. Hamzah, The Effect of bottom ash on fresh characteristic, compressive strength and water absorption of self-compacting concrete, Appl. Mech. Mater., **660**, 145–151, (2014).
[38] D. Chopra, R. Siddique and Kunal, Strength, permeability and microstructure of self-compacting concrete containing rice husk ash, Biosyst. Eng., **130,** 72–80, (2015).
[39] H. Zhao, W. Sun, X. Wu and B. Gao, The properties of the self-compacting concrete with fly ash and ground granulated blast furnace slag mineral admixtures, J. Clean. Prod.**,** **95**, 66–74, (2015).
[40] S. Yang, X. Yue, X. Liu and Y. Tong, Properties of self-compacting lightweight concrete containing recycled plastic particles, Constr. Build. Mater., **84**, 444–453, (2015).

[41] H. Thanh, M. Müller, K. Siewert, and H. Ludwig, The mix design for self-compacting high performance concrete containing various mineral admixtures, J. Mater., **72**, 51–62, (2015).
[42] M. Tennich, A. Kallel and M. Ben Ouezdou, Incorporation of fillers from marble and tile wastes in the composition of self-compacting concretes, Constr. Build. Mater., **91**, 65–70, (2015).
[43] B. Safi, M. Saidi, A. Daoui, A. Bellal, A. Mechekak and K. Toumi, The use of seashells as a fine aggregate (by sand substitution) in self-compacting mortar (SCM), Constr. Build. Mater., **78**, 430–438, (2015).
[44] C. Shi, Z. Wu, K. Lv and L. Wu, A review on mixture design methods for self-compacting concrete, Constr. Build. Mater., **84**, 387–398, (2015).
[45] ERMCO, The European Guidelines for Self-Compacting Concrete, Eur. Guidel. Self Compact. Concr., (2005).