



A REVIEW: MECHANISM, MATERIALS AND PROPERTIES OF SELF-CURING CONCRETE

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ABSTRACT

Concrete is most widely used material in the construction industry, it also needs a lot of water for its production, so it is an urgent need of research to minimize the use water to produce concrete. This paper review about the materials used as self-curing agents, mechanism of self-curing and the properties of different type of concrete when subjected to self-curing method. Self-curing technology is the process which hydrates the cement internally in concrete, no external source needed for curing such as water curing. Mostly concrete goes under extensive self-desiccation, autogenous shrinkage and other properties of concrete can be affected due to improper curing. Different researchers have used different materials such asporous lightweight aggregates, chemicals admixtures, polymers, natural fibers and pozzolanic as self-curing agents in different ways, which have ability to withstand high amount of water. Thesis self-curing agents used as replacement with aggregates and used as infill material. Physical, mechanical, durability and microstructure properties has been carried out by researchers to evaluate the efficiency of self-curing in concrete. Results indicate that by adopting self-curing process in concrete improve properties of concrete. Most of self-curing research carried out in high-performance concrete to solve the shrinkage problem due to low water cement ratio.

Keywords: self-curing, self-curing agents, physical properties, mechanical properties, durability properties, microstructure properties.

INTRODUCTION

In construction engineering self-cured concrete is not commonly used but still development work is carrying on it to improve it (Sharma, 2016). Previously in some studied effectiveness of self-curing examined by measuring physical properties include internal relative humidity, autogenous deformation, ring test strain, cracking, degree of hydration and compressive strength (Bentz and Stutzman, 2008, Bentur *et al.*, 2001, Cusson and Hooegeveen, 2005, Lura, 2003, Mack, 2006, Bentz, 2007), x-ray absorption (Henkensiefken *et al.*, 2011). Self-curing method is also utilize in low water-cement ratio mixtures to improve properties of the high-performance concrete (Castro *et al.*, 2010, Cusson and Hooegeveen, 2008) and enhance early-age behaviour of concrete structure (Shen *et al.*, 2015a). Internal curing method is also applied for heat-cured concrete for improvement of its properties (Nie *et al.*, 2016). Self-curing was also carried out in normal concrete mixtures have water-to-cement ratio more than 0.42 (Espinoza-Hijazin and Lopez, 2011). Self-curing is also practiced in self-compacting concrete (Rajamanickam and Vaiyapuri, 2016).

The materials which are used as self-curing agents are pumice (Lura *et al.*, 2004, Zhutovsky *et al.*, 2002b), paraffin wax (Chand *et al.*, 2014), crushed returned concrete aggregates (Kim and Bentz, 2008), crushed waste ceramic which has shown better effect on concrete as self-curing agent (Zou *et al.*, 2015, Suzuki *et al.*, 2009), Biomass-derived waste lightweight aggregates (Lura *et al.*, 2014), Rice husk ash (Rößler *et al.*, 2014), wood-derived materials is also used as self-curing agents for curing cement-based materials (Kurtis *et al.*, 2007),

Lightweight expanded clay aggregates (LECA) (Reinhardt and Weber, 1998), Bentonite clay (Lura and Kovler, 2007), perlite (Lura and Kovler, 2007), diatomaceous earth (Lura and Kovler, 2007), Polyethylene-glycol is used in different percentage by weight of cement which improve the concrete properties (Mousa *et al.*, 2014b, Mousa *et al.*, 2014a, Mousa *et al.*, 2015), zeolite aggregates (Ghourchian *et al.*, 2013), rotary kiln expanded shale used with C class fly ash in high volume fly ash concrete (De la Varga *et al.*, 2012, Barrett *et al.*, 2011), crushed over burnt clay brick (Rashwan *et al.*, 2016). For improving internal curing some portion of sand was replaced with saturated lightweight aggregates (Geiker *et al.*, 2004).

Self-curing method is used in field as in transportation department Ohio to reduce early age cracking in concrete pavement (Cleary and Delatte, 2008, Lopez *et al.*, 2010), in railway transit yard in Texas (Villarreal and Crocker, 2007), Texas state highway 121 (Friggle and Reeves, 2008), in the Dallas-Fort Worth area more than 420,00 m³ of self-cured concrete used (Villarreal and Crocker, 2007), self-cured concrete was used for Normal density concrete structures for example, in large paving project in Hutchins, Texas (Cusson *et al.*, 2010), several bridges in New York and Indiana (Di Bella *et al.*, 2012). In sever environment, concrete is subjected to sulphate attack (Bentz *et al.*, 2014) and chloride ingress (Di Bella *et al.*, 2012) so influence of self-curing in minimizing it was carried out. Microstructure and pore structure of mortar and concrete is highly influenced when self-curing is used to minimize early age autogenous shrinkage and cracking (Bentz and Stutzman, 2008,



Subramanian *et al.*, 2015) and also in sealed and unsealed system (Henkensiefken *et al.*, 2009).

MECHANISM OF SELF-CURING CONCRETE

Chemical shrinkage occurs during the hydration of cement which cause production of empty pores and reduction in relative humidity. That lead self-desiccation and lack of availability of moisture within cement paste and produce capillary pores and micro cracks which are the weak point in matrix. So the self-curing is used to maintain the relative humidity and avoid self-desiccation (Nishant *et al.*, 2017, Liu *et al.*, 2017)

Conventional curing is practised by external methods and these methods perform to keep concrete warm and moist so the hydration of cement continue till its complete strength gain (Taylor, 2013). First of all, self-curing was proposed in order to encounter the self-desiccation throughout the concrete (Castro *et al.*, 2010). Improper curing occur specially where the area have problem of shortage of water or inclines structures so accurate long term curing is not possible (Mohamad *et al.*, 2017). Self-curing indicate the process by which small inclusions dispersed within concrete hold the water during mixing and up to setting time and release it during cement hydration (Justs *et al.*, 2015). It is necessary to maintain moisture condition within concrete because the efficiency

of cement hydration is low when relative humidity drop below 80% (Junaid *et al.*, 2015, Nishant *et al.*, 2017). If the not enough water is available for curing in concrete, it will result in stopping cement hydration and do not achieve desirable properties (Selvamony *et al.*, 2010, V., 2012). Recently the self-curing concrete is a new approach to keep concrete moist and warm for better strength and durability (Babcock and Taylor, 2015). The basic constituent for self-curing concrete are coarse aggregates, fine aggregates, cement, mixing water and self-curing agent, which is added during mixing (Jau, 2011). The concept of self-curing concrete is that water is supplied by internal source by using porous aggregates or polymers, which has ability to absorb large amount of water during mixing (Sato *et al.*, 2010). It's also has concept of reducing water evaporation from concrete and increase water store capacity of concrete as compared to conventional concrete (Dhir *et al.*, 1998). As (Kovler, 2012b) summarized the system of curing of concrete, which describe clearly difference system of external curing and internal curing as show in figure 2. Self-curing agents spread the water throughout the cross-section area for curing as external curing only can penetrate up to few millimetre (De la Varga *et al.*, 2012). Difference of external curing and internal curing/self-curing has been describing visually in the Figure-1.

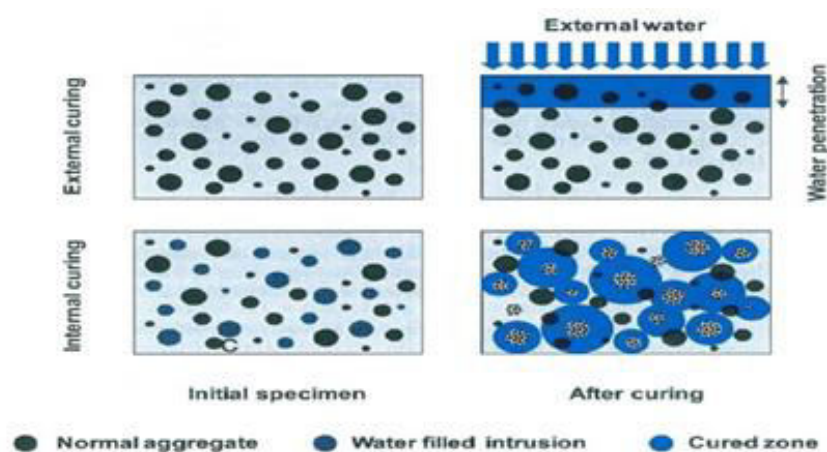


Figure-1. Mechanism of self-curing.

After placing the concrete, it starts for hardening process in which cement paste begins to water starved and to dry out pores, which generate capillary stress (Barrett *et al.*, 2011). Which shows that water desorption process starts in the early age (Byard *et al.*, 2011). Self-curing not only provides water for curing the concrete but also to increase the degree of reaction of the cement with other constituents (Barrett *et al.*, 2012). As compared with coarse aggregates, lightweight fine aggregates have greater dispersion property; that's why it is commonly used for internal curing and lightweight aggregate approximately moves 1.8 mm from absorbent material into the paste surrounding the

aggregates particles (Byard *et al.*, 2011). A large number of naturally occurring or artificial materials are used as internal reservoirs for self-curing because of their porosity (Weber and Reinhardt, 1997). The performance of self-curing concrete system is strongly related with content and properties of self-curing agents, such as water absorption, pore structure and grain size distribution, as well as mechanical properties (Yadav, 2015). Relative humidity plays a very important role in self-curing because it has been seen that when relative humidity is higher than 96% most of the water in lightweight aggregate is released as shown in Figure-3.

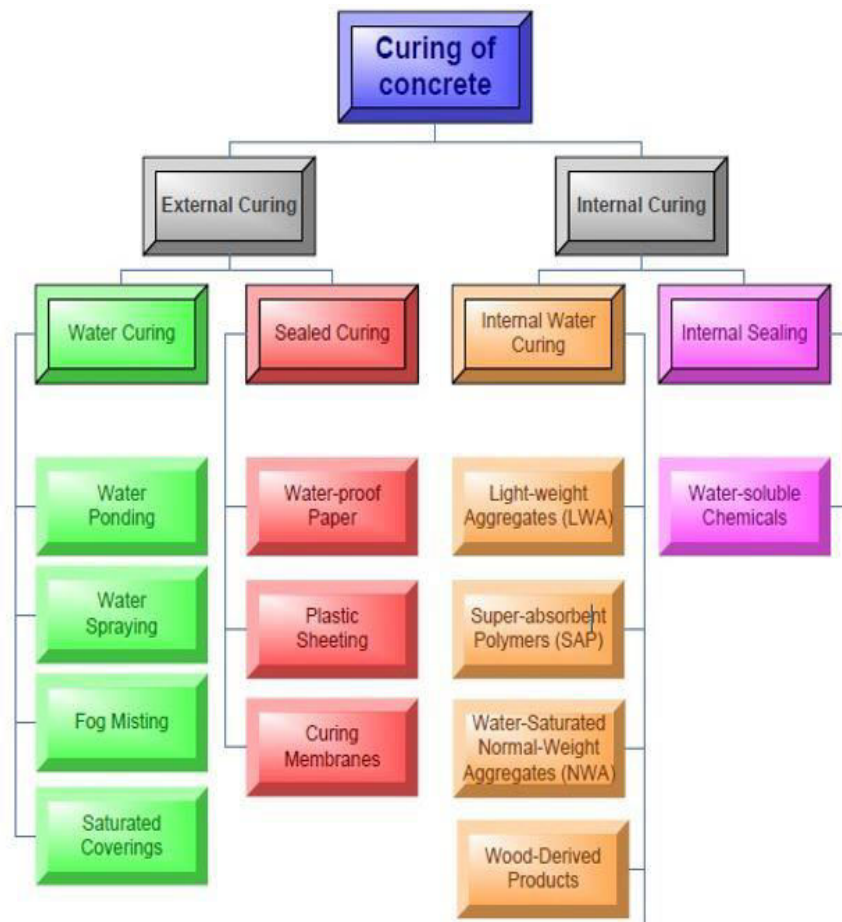


Figure-2. Classification of methods of curing of concrete aimed to maintain moisture (Kovler, 2012a, Ghourchian *et al.*, 2013).

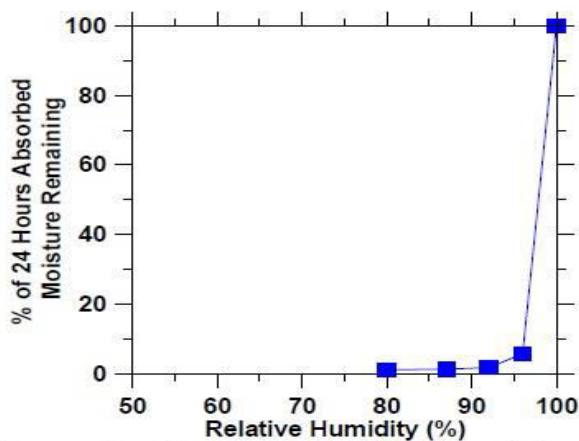


Figure-3. Desorption characteristic of lightweight aggregates (Henkensiefken *et al.*, 2008).

It has been noticed that using of fine lightweight aggregate is more effective than coarse lightweight aggregates (Cleary and Delatte, 2008). The basic principle for internal curing with LWA is that the largest pores will lose water first. The LWA pores are generally larger than the pores of the surrounding cement paste (de Sensale and Goncalves, 2014). As the pores in the paste decrease in

size when hydration continues, the hydrating paste can pull water out of successively smaller pores of the LWA and as soon as the hydration process leads to shortage of water in the cement paste there is a humidity gradient. Water from the LWA is transported first by capillary suction and later by vapour diffusion and subsequent capillary condensation from the LWA to the cement paste, thereby supporting continuous hydration. Effectiveness of self-curing agent can be achieved when material have small size and highly porous, which can be distribute in concrete uniformly (Zhutovsky *et al.*, 2004).

MATERIALS AND METHODS OF SELF-CURING CONCRETE

Crushed over burnt clay brick

For improving of lightweight self-curing concrete properties Rashwan *et al.* (2016) used Crushed over burnt clay brick and were replaced with coarse aggregate in 20%, 50% and 100%. The size of aggregates taken maximum 40 mm and retained on 5 mm. Water-to-cement ratio was taken 0.48. This material was used as self-curing agent due to have larger pore than cement hydrates, so water stored in larger pore will transfer into small pores of cement and make it saturated in early stage of hydration. Its water absorption capacity was noted 13.25% by weight.



Crushed over burnt clay brick possess rough surface which make the strong bond with cement particles. Ph value also matter in the concrete for durability, so the pH value of this material was found 8.5, which is not acidic in nature. If pH value below 8.5 in concrete create the high chance of carbonation in concrete.

Lightweight expanded clay aggregates

Brand name for an expanded clay clinker and burned in a rotary kiln at approximately 1200°C is called Leca (Jensen and Lura, 2006), which is used as self-curing agents. (Mousa *et al.*, 2015, Mousa *et al.*, 2014b) used leca with 15% of silica fume by weight of cement, polyethylene glycol 2% by weight of cement and 15% of Leca replace by volume of sand, was used for high-performance concrete. Coarse aggregates replaced with pre wetted light weight aggregates as shown in figure 4 rotary kiln expanded clay by 10%, 20% and 30% , of 4.7-9.5 mm size with low w/c ratio 0.33 and the material has dry-bulk density of 1050 kg/m³ and a 24 hr absorption value of 12% by mass of dry material (Shen *et al.*, 2015a). It is also used as internal curing agent with absorption 15.9% and used 14.9% and 14.5% as sand replacement in mortar, Class C fly ash used as 40% and 60% replacement of cement and High range water reducing admixture was used to maintain slump (Barrett *et al.*, 2011).



Figure-4. Rotary kiln expanded clay of size 4.75 mm – 9 mm (Shen *et al.*, 2015a).

Characterization of LECA has been done by many research according to them the characterization of LECA conclude that density of LECA particle were found 1470 kg/m³ (Ghourchian *et al.*, 2013) and 1050 kg/m³ (Shen *et al.*, 2015a). The dry bulk density of expanded shale was found 920 kg/m³ (Cusson and Hoogeveen, 2008).

Fineness modulus of rotary kiln expanded shale was found 3.97 (De la Varga *et al.*, 2012). Fineness modulus of expanded shales were found 3.3 (Cusson and Hoogeveen, 2008). Fineness modulus of expanded shale was also found 3.10 by (Castro *et al.*, 2011).

Specific gravity of rotary kiln expanded shale was 1.38 (De la Varga *et al.*, 2012, Bentur *et al.*, 2001, Barrett *et al.*, 2012). The bulk specific gravity of expanded shale lightweight aggregates was found in the range of 1.35-1.8 (Castro *et al.*, 2011, Browning *et al.*, 2011, Kerby, 2013, Wei and Hansen, 2008).

The water content of expanded shale lightweight aggregates was 15% by weight obtained in a 24 hours pre-soaked condition (Wei and Hansen, 2008, Cusson and Hoogeveen, 2008). By (Kerby, 2013) water content was found 18%.

Absorption was carried out by paper towel technique, which conclude the results that water absorption of rotary kiln expanded shale was 17.5% by dry mass (De la Varga *et al.*, 2012) and 15.9% by mass (Barrett *et al.*, 2012). In his research he found the absorption value for LECA was 11% by ASTM C128-07 (Ghourchian *et al.*, 2013). LECA with friction 4.5 mm -9 mm have water absorption about 8.9% by weight at 24 hours (Bentur *et al.*, 2001). The 24 hour water absorption was investigated by paper towel method which resulted 17.5% water absorption rate (Castro *et al.*, 2011) and 12% water absorption rate of LECA (Shen *et al.*, 2015a). The one hour water absorption was done by prewetted vacuum saturation which result absorption of expanded shale ranged from 24.7 to 30 % by dry weight (Browning *et al.*, 2011).

Pore structure was investigated of LECA by SEM, SEM picture of inner pore structure of leca presented in Figure-5, which indicate that LECA has large pore size. Because of its good property of absorption and desorption it is considered as good self-curing agent. It is also useful because it's not a soft material in nature, so enhance strength of concrete.

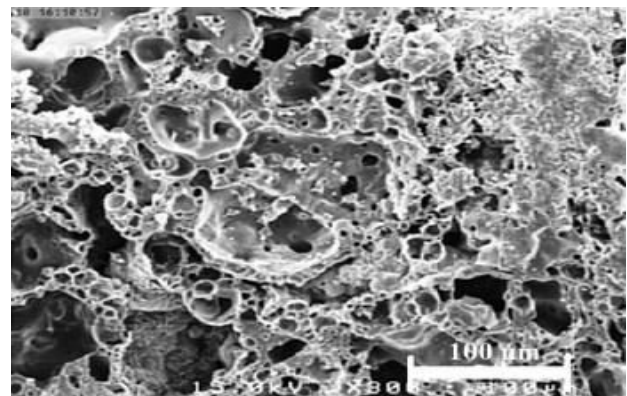


Figure-5. SEM image of LECA particles.

Polyethylene-glycol (PEG-400)

Polyethylene-glycol is chemical type of self-curing agent (Mousa *et al.*, 2015). PEG is non-toxic, odourless, neutral, lubricating, non-volatile and non-irritating (Ankith, 2015). Previously which is used as 0.02% (El-Dieb, 2007), 0.2% (Ankith, 2015), 1% (Junaid *et al.*, 2015) and 3% (Mousa *et al.*, 2014a) by weight of cement in concrete with (Rampradheep and Sivaraja, 2016) different water-to-cement ratio. Its main function is to reduce the surface tension of water and reduce evaporation from concrete (Mousa *et al.*, 2014b). This is considered suitable self-curing agent because it is 100% soluble in water with high molecular weight than water. It is also in hydroxyl and ether functional group containing hydrogen and oxygen compound. Because of this property



it helps the water to retain in concrete and available for curing.

Paraffin wax

Paraffin was used as 0%, 0.1% , 1% and 2% by weight of cement in the liquid and solid form in concrete as external agent with water-cement-ratio 0.35 and 0.45 (Chand *et al.*, 2014, Reddy and Reddy, 2016). Paraffin wax is a white or colourless soft solid, derived from petroleum, coal or oil shale that consists of a mixture of hydrocarbon molecules containing between twenty and forty carbon atoms. It is solid at room temperature and begins to melt above approximately 37 °C (99 °F). Liquid paraffin wax is beneficial in higher grade of concrete at low dosage as self-curing agent. It is not beneficial at high dosage because of its soft nature and at low dosage it seals the water and resist water evaporation from concrete.

Zeolite aggregates

Zeolite aggregate is a volcanic or volcano sediment material which possess three dimensional structure like honeycomb, having extremely small pore size from 0.3 to 0.4 mm (Ahmadi and Shekarchi, 2010). It is aluminosilicate silicate mineral used as pozzolanic material in some part of world it is consider as self-curing aggregate because of its losing and gaining 30% water by its dry weight. Natural zeolite is an excellent supplementary cementitious material. The large quantity of reactive SiO₂ and Al₂O₃ in zeolite chemically combines with the calcium hydroxide produced by the hydration of cement to form additional C-S-H gel and aluminates, resulting in the improvement of micro- structure of hardened cement. For suitable Self-curing agent it should fully desorption water at 97% - 98% relative humidity but zeolite desorption start at 80% relative humidity, so it can supply water internally if relative humidity water drop below 85% Leca and Natural zeolite (clinoptilolite type) was used as 20% and 30% replaced with sand at w/c 0.3 and 0.4 (Ghouchian *et al.*, 2013, Mosler and Schmid, 2002).

Characterization of zeolite material was done by (Ghouchian *et al.*, 2013, Mosler and Schmid, 2002), which showed that the density of zeolite aggregates were found 2250 kg/m³– 2300 kg/m³, the absorption rate of zeolite particles was found 15.6 %. Inner pore structure of zeolite particle was investigated by Scanning electronic microscopy (SEM), as SEM Figure-6 show that zeolite particles have small pore.

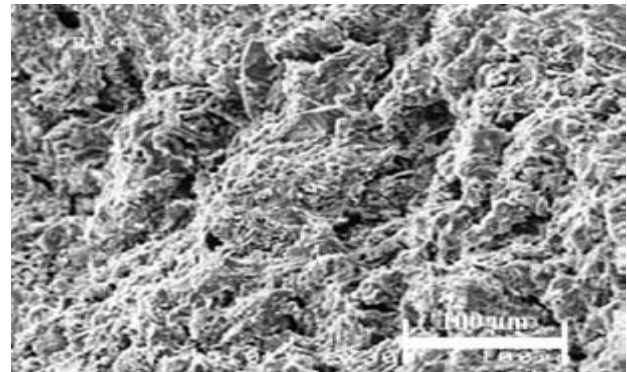


Figure-6. SEM image of zeolite particles (Ghouchian *et al.*, 2013).

Porous ceramic aggregates

Basic properties of pumice was studies by some researchers that shown that the specific gravity of porous ceramic aggregates were found 2.24 (Sato *et al.*, 2010) and 2.27 (Suzuki *et al.*, 2009). The fineness modulus of aggregates were found 6.66 (Suzuki *et al.*, 2009). As ceramic aggregates are porous so its water absorption rate was 8.58% by dry mass (Sato *et al.*, 2010) and 9.31% by mass (Suzuki *et al.*, 2009). The Ceramic main compositions and percent mass were SiO₂, 65.7%; Al₂O₃, 27.1%; Fe₂O₃, 2.9%; and K₂O, 1.8%. So, porous ceramic contributes two purpose one is as self-curing agent and second enhance the strength of concrete. For this purpose, it is mostly used as replacing fine or coarse aggregate in different percentage. The crushing rate of porous ceramic aggregates is 21.4 which is higher than crushing rate of normal coarse aggregate.

For the purpose of self-curing, porous ceramic aggregates of 5 mm – 15 mm size is used in Portland blast furnace cement type B concrete as replacing coarse aggregates by 10% and 20% in volume with water/cement ratio 0.55 under sealed condition , fine aggregates contain crushed quartz mixed with limestone and natural coarse aggregates crushed gravel was used, in addition air entraining admixture polyalkyleneglycol derivative and water reducing admixture lignin sulfonic acid compound used (Sato *et al.*, 2010) .(Suzuki *et al.*, 2009) replaced the aggregate up to 40% by volume with porous aggregates

Wood-derived materials

Wood-derived materials (Zhutovsky and Kovler, 2012) used in the form of fibres and powder (Lura and Kovler, 2007) of different lengths and most wood-derived materials contain lignin and cellulose is present in plant fibres as well as non-woody fibres such as kenaf (Kurtis *et al.*, 2007). For the manufacturing of paper products. Fibre board, absorbents (Kartini *et al.*, 2012), ropes (Edeerozey *et al.*, 2007), sackcloth (Babatunde *et al.*, 2015) and animal feeds (Wang and Ramaswamy, 2003), kenaf core is used (Cao *et al.*, 2014). Kenaf core particles performed as natural absorbent material (Elsaid *et al.*, 2011). In binder less board kenaf core is consider suitable raw material (Ando and Sato, 2009). Kenaf core powder is light in weight having density 0.1 - 0.2 g/cm³ (Xu *et al.*, 2003)



and was used in brick to reduce self-weight of bricks (Kartini *et al.*, 2012). Kenaf is also used in the field of concrete technology (Alexopoulou *et al.*, 2013) in order to make stronger and tougher concrete (Zadeh and Bobko, 2014). Kenaf used in reinforced concrete beam (Hafizah *et al.*, 2014) and polymeric composites (Aji *et al.*, 2009). Kenaf bast fibre is also used as self-curing agent in kenaf fibre reinforce concrete because of its high water absorption of water (Zadeh and Bobko, 2013). In the year 2010, Malaysia introduced kenaf as partially replace tobacco (Ng *et al.*, 2013).

There are so many wood-derived products which are used for different purposes. But the important problem rise that is which type of wood-derived products can be used efficiently for internal curing so for that (Kurtis *et al.*, 2007) explained The Wood-derived compositions include a broad class of materials generally based on one or both of cellulose and hemicellulose, Which, for convenience, are collectively called "cellulosic materials" or "cellulosic compositions". The hydrophilic surfaces of cellulosic materials can facilitate their dispersion and bonding to the cement-based material paste. The Wood-derived composition can also include lignin, which, in binding the fibres together, can provide mechanical strength to the Wood-derived composition. Cellulosic compositions are generally derived from plant fibres. Examples of cellulosic materials include Woody fibres such as hardwood fibre (e.g., from broad leaf trees such as oak, aspen, birch, beech, and the like) and softwood fibre (e.g., from coniferous trees such as slash pine, jack pine, White spruce, logpole pine, redwood, Douglas fir, and the like), as Well as non-Woody fibres, such as hemp flax, bagasse, mailla, cotton, ramie, jute abaca, banana, kenaf, sisal hemp, Wheat, rice, bamboo, and pineapple.

Superabsorbent polymers (SAP)

It is polymeric material which has ability to absorb water from surrounding and store within its structures (Jensen and Lura, 2006). SAP is a crushed crystalline partial sodium salt of cross-linked poly-promancic acid rated at 2,000 times absorption for pure water. The polymer is coated with blast furnace slag and ground silica to allow handling and prevent clumping of the gel during initial polymer hydration. The unhydrated polymer is angular with particle sizes ranging from 50 to 300 μm . Once the SAP hydrates, swells, and releases the stored water, the SAP becomes inert and is unable to rehydrate. Additional water is provided to the fresh concrete and the SAP is added dry. Absorption occurs during normal mixing. It is used as 0.375 % by weight of cement in previous concrete (Kevern and Farney, 2012, Jensen and Hansen, 2001). Baby diapers polymers used as self-curing agent which is derived from disposable pampers, almost 20 billion disposable diapers are dumped in landfill each annually, so It have great impact on dumped area and it take long time for its decomposition, it also release methane in the atmosphere into air, which is dangerous for health (Mohamad *et al.*, 2017).

Pumice

Pumice is a porous volcanic rock which look like sponge. The (Zhutovsky *et al.*, 2002b) investigated the absorption of three different size of pumice first type have size $0.15 \text{ mm} < d < 1.18 \text{ mm}$ have absorption rate 13.0% by weight and 17.3% by volume, second type have size of $1.18 \text{ mm} < d < 2.36 \text{ mm}$ have absorption rate 19.0% by weight and 24.9% by volume and last size type was $2.36 \text{ mm} < d < 4.75 \text{ mm}$ having absorption rate 26.7% by weight and 32.3% by volume. Selecting pumice aggregates for self-curing agent due to different in size and having good water absorption property which compensate the curing of concrete.

Rice husk ash (RHA)

Rößler *et al.* (2014) characterise the rice husk in which it is that the density of rice husk ash was found 2.19 g/cm^3 water absorption of rice husk ash was founded 17.15 l/g, the particle size of rice husk ash is large that's is $7.41 \mu\text{m}$ the pore size distribution in RHA particles is mainly from about 2 to 50 nm and the specific surface area was calculated $52.28 \text{ m}^2/\text{g}$. the reason of consideration rice husk ash due to a high content of amorphous silica, a high pore volume and specific surface area (SSA). Therefore, RHA possesses a very high pozzolanic reactivity comparable with that of silica fume (SF). With mesoporous structure, the water absorption capacity of RHA is significantly higher than that of SF. It can absorb an amount of free water in RHA-blended Portland cement mixture to improve compressive strength. The pore size range corresponds to the change of RH from about 75–98%. This means that when the internal RH in UHPC drops below 98%, the absorbed water in these mesopores will release to compensate the self-desiccation during hydration.

METHODS OF USING SELF-CURING AGENTS WITH CONCRETE

Researchers have mixed self-curing agent in different way such as (Henkensiefken *et al.*, 2010) before mixing lightweight aggregates were oven dried at 105°C (Mousa *et al.*, 2014b), air cooled then mix with water for 24 hours and the absorb water by LWA include both mixing water and absorb water, after that extra water kept in separate container which can be used as mixing water in concrete. Same procedure was adopted by using LECA but chemical type of self-curing agent was mixed with mixing water (Mousa *et al.*, 2014a, Barrett *et al.*, 2011).b Lightweight aggregate kept in plastic barrel for 7 day in order to moisture it then water is drain through valves (Byard *et al.*, 2011)

RESULTS AND DISCUSSION OF SELF-CURING CONCRETE

Benur *et al.* (2001) studied the shrinkage of self-cured concrete, in which 10% of silica replaced the cement and 25% leca was replaced with normal weight aggregates in saturated surface dry. His results indicated that by using lightweight aggregate in concrete, at first, expansion in



concrete has been noticed due to supply of water from LWA but later it eliminates autogenous shrinkage.

Zhutovsky *et al.* (2002a) used pumice as self-curing agent in three different size that are $0.15 \text{ mm} > d < 1.18 \text{ mm}$, $1.18 \text{ mm} > d < 2.36 \text{ mm}$ and $2.36 > d < 4.75 \text{ mm}$ with w/c ratio 0.33 replacing with fine aggregates in 10%, 20% and 30% to evaluate size effects on properties of self-curing concrete. His research concluded that the size between $2.36 \text{ mm} < d < 4.75 \text{ mm}$ give better results in concrete properties, such as using every size of pumice aggregate reduce the shrinkage of concrete as compared with referenced concrete but the size between $2.36 < d < 4.75$ give the better performance among all.

Cusson and Hooegeveen (2005) investigate on high performance concrete under restrained shrinkage and tensile creep subjected to internal curing. Control high performance concrete was design with cement-sand-aggregate ration of 1:2:2 with water-cement ratio of 0.34. internally cured concrete design with same ratio but replacing 6% and 20% of sand replaced with prewetted Saturated lightweight aggregates. Introducing saturated lightweight aggregates in concrete have not significant effect on the fresh properties of concrete such as slump and air content. 20% of sand replaced with saturated lightweight aggregates showed better results in autogenous shrinkage, initially it was expanded but later it was maintained. Same trend was shown in restrained shrinkage testing that 20% replaced of sand with saturated lightweight aggregates reduce the risk of cracking in concrete due to decrease of tensile stress in concrete.

Water transport properties were investigated (El-Dieb, 2007). In which water-soluble polymer PEG was used 0.02% by weight of cement as self-curing agent with w/c ratio 0.3 and 0.4, two cement content were taken 350 kg/m^3 and 450 kg/m^3 . his research results concluded that water retention is higher in self-cured concrete as compared with control concrete but self-desiccation, water transport, water sorptivity and water permeability decrease in self-cured concrete.

Cleary and Delatte (2008) investigated the mechanical and durability properties of self-curing concrete with replacement of normal weight coarse aggregates with lightweight coarse aggregates, his research results show that all strength properties increased, no crack appear in self-cured concrete and durability properties of self-cured concrete is better than control concrete while using lightweight coarse aggregates.

Suzuki *et al.* (2009) research, Porous ceramic coarse aggregates used as 10%, 20%, 30% and 40% replaced with normal weight aggregates, 10% of silica fume replaced with cement at constant w/b ratio 0.15 with polycarboxylate superplasticizer. His results indicate that by using PCCA in concrete; improve the hydration of cement due to this all strength increase but the elastic modulus, autogenous shrinkage and internal stress decreases

Self-curing method was used to reduce shrinkage in high performance concrete with the help of expanded slate lightweight aggregates by (Lopez *et al.*, 2010) in the application of pavement. In this research, lightweight

aggregate was used in two way first, Prewetted lightweight aggregate and second, air dried lightweight aggregate to investigate the effect of initial moisture in concrete. Water cement ratio was kept low with both aggregates condition and compared with normal strength concrete. It was noticed that the compression strength of concrete with prewetted lightweight aggregate was higher than dried lightweight aggregate and normal strength concrete. it is due to the present of internally water stored in lightweight aggregates, which help in hydration process of concrete. Concrete with prewetted lightweight aggregate and dried aggregate showed the high elastic modulus in compression due to use of lower water cement ratio in lightweight aggregate mixtures outweighed the presence of the lower modulus coarse aggregates. Prewetted lightweight aggregates showed better results in eliminating autogenous shrinkage in high performance concrete as compares with air dried Lightweight aggregates and normal strength concrete. Which results that due to presence of water in lightweight aggregates early ages self-desiccation does not occur and which results resistance to early age cracking in concrete

The Sato *et al.* (2010) improve the properties of Portland blast furnace cement type B concrete by using ceramic roof material waste as self-curing agent. In which porous ceramic aggregates (PCA) replaced 10% and 20% with coarse aggregates with w/c ratio 0.55 under sealed condition. His results showed that with replacing 10% of ceramic material improve the compression strength, decrease the pore volume and shrinkage at 28 days. But in early stage as 3 and 7 days the strength of self-cured concrete were low as compared no normal concrete because available water in concrete was high for 3 and 7 days.

Espinoza-Hijazin and Lopez (2011) used LECA as self-curing agent by replacing with sand in concrete mixtures have higher w/c ration than 0.42. in his research cement was replaced with natural pozzolans volcanic glass by 13%, 26% and 39%. His results concluded that with his mix design replacement of 13% that is low level replacement, provide all compressive strength increase and shrinkage decrease. Permeability was access by chloride ion penetration at same level of replacement found no difference with or without self-curing agents but with increase in amount of natural pozzolanic, permeability decreases because natural pozzolanic reacts with calcium hydroxide in the presence of moisture, so the hardened concrete contain less calcium hydroxide and more C-S-H also reduce porosity.

In Byard *et al.* (2011) research self-curing concrete research based on using three w/c ration 0.42, 0.36 and 0.30, in which fine aggregates replaced with lightweight fine aggregate slate, clay and shale as self-curing agents. Based on his results, properties of concrete concluded that with addition of lightweight aggregates at 0.42 w/c ratio increase the heat of hydration which causes in improve of strength properties such as compressive and tensile, with addition of LWA it almost eliminates the autogenous shrinkage.



Zhutovsky and Kovler (2012) investigated the effect of self-curing on durability related properties of high-performance concrete. In which he showed that by replacing the pumice 2.36 mm-4.75 mm friction with fine aggregates at three w/c ratio 0.33, 0.25 and 0.21, using superplasticizer calcium naphthalene sulfonate in order to maintain slump in the range of 110mm - 160 mm. Air permeability, chloride ion penetration, autogenous shrinkage, elastic modulus decrease and sorptivity and mass loss increase due to porosity.

Kevern and Farney (2012) worked on previous concrete to reduce its curing requirement by introducing super absorb polymer 0.375% by weight of cement. His research showed that by using SAP all strength and unit weight increase and reduction take place in voids, shrinkage and moisture loss, and durability properties were almost same for control concrete and self-cured concrete.

Fine shale lightweight aggregates were taken in low, medium and high content at constant w/c ratio 0.44 in order to examine fresh, harden and specially shrinkage properties by (Kerby, 2013). In which his results indicate by improvement provided by fine lightweight aggregates include lower unit weight, increased workability, and reduction in the early-age autogenous shrinkage with high amount of FLWA.

Pozzolanic admixture such as rice husk ash, ground granulated blast-furnace slag and silica used as self-curing agent by replacing cement in ultra-high performance concrete (Röbber *et al.*, 2014). In research, four mixtures of high performance concrete were made. First mixture contains only rice husk ash, second mixture contain silica fume, third mixture contain rice husk ash and ground granulated blast furnace slag and fourth mixture contain silica fume and ground granulated blast furnace slag. In all mixture the content of rice husk ash and silica fume was kept same. It was notice that slump flow increases when granulated blast furnace slag added with silica fume and rice husk ash. In compression strength the mixture contains rice husk ash and granulated blast furnace slag give highest compression strength among all mixtures. Shrinkage of ultra-high-performance concrete with silica fume is high as compared with rice husk ash due high accelerate rate of hydration in silica fume mixture. When granulated blast furnace slag added in mixture it reduces shrinkage in mixture but reduce more when added with rice husk ash. Relative humidity in ultra-high-performance concrete decrease in silica fume contain mixtures but with rice husk ash mixture Relative humidity is high due to presence of water in the pores of rice husk ash.

The mechanical, physical and durability properties of self-cured concrete were carried out by (Mousa *et al.*, 2014b, Mousa *et al.*, 2014a, Mousa *et al.*, 2015). In which 15% of silica fume by weight of cement used, pre-saturated lightweight aggregates (LECA) was used 0% to 20% and poly-ethylene glycol chemical was used in the range 1% to 3%. His research indicates that at 15% of silica fume, 15% of LECA and 2% of polyethylene glycol improved the all concrete properties and better

among all mixtures due to polyethylene help in reduce of water loss from concrete and LECA was used as self-curing agent which provide water from inside when needed and silica fume retarded the hydration process.

Justs *et al.* (2015) use superabsorbent polymers as internal curing agent in ultra-high-performance concrete, in which 10% of silica fume by weight of cement, quartz powder as filler and steel fibre was added. The quartz sand was taken in two friction 0.1-0.3 mm and 0.3-0.9 mm. superabsorbent polymer were used in size of less than 63 micron from 0% to 0.5% by weight of cement. Water cement was set between 0.15 – 0.25. result conclude that in early ages of concrete all mixture containing superabsorbent polymer increase heat of hydration as compared mixture without superabsorbent polymer. With increasing the number of superabsorbent polymers delays the internal relative humidity of concrete, which indicate the availability of water retention in concrete. But in long term it was noticed that the mechanical properties such as compression strength, flexural strength and elastic modulus are less than concrete with superabsorbent polymers due to difference in the porosity at initial stage and later stage.

The fresh and hardened properties for M20 grade concrete investigated by (Ankith, 2015). In which polyethylene glycol used as self-curing solution by adding 0%, 0.1% and 0.2% with constant 10% of granite (lightweight coarse aggregate). Results indicate that water retention capacity in self-curing concrete was higher than conventional concrete, which results better hydration of concrete. It leads toward increment of compression and tensile strength of concrete. The optimum dosage of polyethylene glycol was found 0.2% by weight of cement. Slump also increase as increasing the % of polyethylene glycol.

Effect of pre-wetted lightweight aggregates on the temperature and cracking potential of self-curing high performance concrete was researched by (Shen *et al.*, 2015a). His research consists on the replace of coarse aggregates with lightweight aggregates rotary kiln expanded clay by 10%, 20%, 30% and 50% of 4.75 mm – 9.5 mm size with low w/c ratio 0.33. his research showed that with increasing addition of pre-wetted lightweight aggregates in concrete cause rise in temperature, it is due to amount of water is available in LWA which accelerate degree of hydration, cracking stress and cracking age of self-curing concrete decreased. (Shen *et al.*, 2015b) also studied effects on the internal relative humidity (IRH) of early age high performance concrete by using super absorbent polymers (SAP) as self-curing agent because due to low water-cement-ratio in high performance concrete self-desiccation occur which cause decrease in Relative humidity, which lead toward shrinkage. For mitigation of this problem, SAP were used in 5%, 10%, 15% and 20% by weight of cement with fixed w/c ratio 0.33. For measuring IRH, a digital sensor was used. His study showed that while using SAP as self-curing agent, it increases the relative humidity inside the concrete and have pro-long the duration of self-desiccation as compared with without self-curing concrete.



Ji *et al.* (2015) used coarse ceramsite Lightweight aggregate as self-curing agent due to its absorption and desorption property. In this research normal coarse aggregate replaced with ceramsite coarse lightweight aggregate in 50% and 100% with different degree of prewetting of ceramsite Lightweight aggregate that is 0 hour and 24 hours with net water to cement ratio and total water to cement ratio. Results indicate that the concrete mixture with 50% replaced with normal coarse aggregate and using 24 hour wetted lightweight aggregate with total water cement ration give higher compression strength and elastic modulus among all mixtures of concrete. Autogenous shrinkage of concrete in this mixture is also low as compare with others it is due to low porosity and total water cement ratio.

Subramanian *et al.* (2015) used super absorbing polymer as self-curing agent to encounter the effect of improper curing of high strength concrete. In the research polyethylene glycol added as 0.2%, 0.3% and 0.4% by weight of cement. Silica fume was used as cement replace in varying percentage as 5%, 10% and 15%. All this adding of polyethylene glycol and replacing silica fume carried out on different grade of concrete that are M60, M70 and M80. Results indicate by adding polyethylene glycol and replacing silica fume with cement increased in slump. Among all the optimum dosage was found 0.4 % of polyethylene glycol with 10% replace of cement with silica fume give better result in all strength properties in all grade of high strength concrete.

The mechanical properties of self-cured lightweight concrete at 28 days were investigate by (Rashwan *et al.*, 2016). In which crushed over burnt clay bricks (COBCB) were used as self-curing agent and replaced 20%, 50% and 100% by volume with coarse aggregates, keeping water to cement ratio 0.48. Three curing system was adopted (1) conventional curing: samples were kept in water (2) Air curing: samples were kept inside laboratory environment (3) chemical curing: samples were painted by kerosene oil. Results showed that by replacing 20% of COBCB increase the compression strength, indirect strength and flexural at 28 days in all curing system. Increment attributes the better hydration due to availability of enough water in COBCB. Above 20% replacement have not good effect on mechanical properties due higher increment of water in COBCB.

Influence of water to cement ratio on the efficiency of internal curing of high-performance concrete (HPC) studied (Zhutovsky and Kovler, 2017) on cracking sensitivity, sealed shrinkage, dry shrinkage and compression strength. Three water to cement ratio were set for HPC that's 0.33, 0.25 and 0.21 with admixture to maintain workability. Lightweight aggregates pumice was used as self-curing agent having size of 2.36 – 4.75 mm. it was observed that potential of cracking at 0.33 W/C ration was unaffected but lowering the W/C ratio also reduce the potential of cracking because of availability of water in self-curing agent prevent from autogenous shrinkage in early ages. Sealed and dry shrinkage was improved among all mixtures of self-cured HPC. Compression strength

slightly reduced among all mixture of HPC as compared with reference concrete.

The efficiency of baby diapers polymers as self-curing agents was investigated by (Mohamad *et al.*, 2017). For which, baby diapers polymers used in 1%, 2%, 3%, 4%, 5% and 10% by weight of cement. The efficiency of baby diapers polymers was analysed based on workability and compression strength at 3, 7, 28 and 90 days. Results indicate that up to 5% addition of baby diapers polymers have no significant effect of the workability but by adding 10% of baby diapers polymers increase the workability, it is due to large number of polymers have large amount of liquid gel in it. As per compression strength 1% of polymers give higher strength even as compare with without internal curing.

CONCLUSIONS

From review of self-curing concrete, it is concluded that not so much research carried on normal strength self-cured concrete. The materials which are used as self-curing agents in previous research are natural dependent, artificial, recycled or chemical. So, large amount of natural aggregates and recycled aggregates are not available every time. Artificial aggregates and chemicals are harmful, not eco-friendly and time consuming. So, there is a need of introducing self-curing agents, which are not harmful and eco-friendly material. Normal concrete contains enough water for hydration but such like areas where weather is hot or low amount of water available and due to structure position like inclined or in hilly area where curing is difficult to access. In this case water loss from concrete and trend towards lower the quality of concrete. So, there is much needed research, to solve this problem of normal strength concrete with the concept of self-curing mechanism. In the previous research the focus of solving the problem of shrinkage but due to evaporation of concrete shrinkage occur but also lower the quality of surface of concrete, so research needed to improve of surface of concrete with help of self-curing concrete.

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