CHAPTER 2 LITERATURE REVIEWS

This chapter presents literature survey of fluidized bed fly ash, bagasse ash, recycled aggregate and concrete containing fly ash, bagasse ash, and recycled aggregate. The literature survey of each topic is summarized as follows.

2.1 Fluidized Bed Fly Ash

Fly ash is a by-product of combustion of coal in thermal power plants. The major constituents of fly ash are SiO_2, Al_2O_3, Fe_2O_3, and CaO. The other minors are Na_2O, K_2O, and SO_3. ASTM C 618 classifies fly ash into two classes, namely, Class C and Class F. Physical properties and chemical compositions of fly ash are different depending on many factors, such as types of coal, moisture content, temperature, process of burning, etc.

Fluidized bed fly ash is one of fly ash types obtained from burning coals at 800-900 °C with fluidized bed burning process. Approximately 400,000-500,000 tons a year of fluidized bed fly ash has been produced from thermal power plants in the central part of Thailand. Large particles and high porosity of fluidized bed fly ash which are not qualified to pozzolanic material as specified by ASTM C618 cause little usage in concrete construction. However, Sata, et al. (2007) found that fluidized bed fly ash after reducing particle size to have high fineness can be used to produce high-strength concrete with compressive strengths at 28 days ranging from 85.0 to 91.4 MPa.

In Thailand, Rattanapat, et al. (2003) found that concrete incorporated with irregular and porous fly ash (fluidized bed fly ash) required higher water to binder ratio (W/B) than that with solid and spherical ash (pulverized fly ash) in order to maintain the same slump. Moreover, the use of fluidized bed fly ash to partially replace cement also gave lower compressive strength than that of control concrete. However, they suggested that the fluidized bed fly ash should not be used higher than 20% to replace Portland cement since it produced quite low compressive strength of concrete. Later, Somna, et al. (2004) found that use of fine fluidized bed fly ash having particles retained on sieve No. 325 of less than 5% by weight could help to reduce the expansion of mortars due to sulfate attack to be lower than that of mortars using the original fluidized bed fly ash. Moreover, the expansion increased as the increased of CaO, SO_3, and alkali contents in fly ash. Next year, Kooratanaweich, et al. (2005) found that the water permeability of concrete depended on characteristic and replacement of fly ash. Concrete containing pulverized fly ash (solid and spherical particles) had water permeability lower than that of concrete containing fly ash having porous particles (fluidized bed fly ash). However, the high fineness of fly ash could be used to reduce water permeability of concrete. Somna, et al. (2008) reported that pulverized fly ash which had solid and spherical particles could be used to replace cement in mortar up to 30% by weight of binder while the fluidized bed fly ash which had porous and irregular shape could be used no more than 20% in order to have the highest compressive strength.

Although use of fluidized bed fly ash in mortar and concrete resulted in higher water requirement and lower compressive strength, use of ground and classified fluidized bed fly ash having fine particles could reduce water permeability, reduce expansion due to sulfate attack, and increase compressive strength of concrete. Ground fluidized bed fly ash has been used as a pozzolanic material in concrete to improve strength and durability of concrete but it is rarely found that fluidized bed fly ash was used to improve the properties of recycled aggregate concrete.

2.2 Bagasse Ash

Bagasse is the fibrous residue from sugarcane which remains after the juice has been extracted. It constitutes about 50% of cane stalk by weight and 50% of moisture content. Its calorific value varies from 6.4 to 8.60 GJ/t. Moreover, it has been used world wide as fuel in the sugarcane industry (Calle, et al., 2007). After the combustion process of bagasse to produce electricity in sugarcane industry, the bagasse ash is a by-product. Large amount of bagasse ash has been disposed of to landfill and tends to increase in many countries such as Thailand, thus many landfills are required.

Bagasse ash with high fineness is a good pozzolanic material and its reactivity depends on the degree of crystallinity of silica, the presence of impurities, particle size, and fineness (Martirena, et al., 1998; Paya, et al., 2002; Cordeiro, et al., 2008). Moreover, bagasse ash could be partially replaced Portland cement up to 20% by weight of binder to obtain the strength of concrete as well as concrete without this ash (Valenciano and Freire, 2004). The use of bagasse ash to partially replace cement could improve the properties of mortar and concrete to have low water permeability, high chloride resistance, and low expansion due to sulfate attack (Singh, et al., 2000; Chusilp, et al., 2009a; Chusilp, et al., 2009b; Rukzon and Chindaprasirt, 2012).

In Thailand, ground bagasse ash has been studied and been used as a pozzolanic material in both mortar and concrete. It was found that the mixing water of mortar, concrete, and concrete block using ground bagasse ash was higher than that of the control ones. Moreover, mixing water increased with increasing the replacement of ground bagasse ash and decreased when ground bagasse ash had smaller particles (Sujjavanich and Duangchan, 2004; Duangchan and Sujjavanich, 2005; Likhitsripaiboon, et al., 2006; Lergpiboon, 2008).

Initial setting time of pastes containing ground bagasse ashes with low and high loss on ignition (LOI) increased when compared with that of cement paste and increased with the increasing of replacement of ground bagasse ash (Montakarntiwong, et al., 2005). The optimum replacement of ground bagasse ash with low and high LOI for improving the compressive strength of mortar, concrete, and concrete block was 20% by weight of binder, especially ground bagasse ash having small particles could reduce the effect of LOI on the compressive strength (Duangchan and Sujjavanich, 2005; Montakarntiwong, et al., 2005; Likhitsripaiboon, et al., 2006; Chantri, et al., 2007; Lergpiboon, 2008).

Durability is an important factor which should be considered for long life concrete using. Permeability is one of the indicators to evaluate the durability of concrete attacked by hazardous solutions such as chloride and sulfate solutions. Tippiriyapong, et al. (2007) used three ground bagasse ashes with different LOI and with particles retained on a sieve No. 325 of less than 5% by weight to partially replace cement in concrete. They illustrated that use of 10 and 20% of ground bagasse ashes to replace Portland cement Type I could reduce the water permeability of concrete to be lower than that of the control concrete. In addition, they also suggested that LOI of ground bagasse ashes between 9.1 and 19.4% does not play any significant role on water permeability of concrete. Use of ground bagasse ash to partially replace cement could improve the resistances of sulfuric acid, sulfate attack, and chloride penetration of concretes (Kulchanaprasit and Sujiworakul, 2005 and Lergpiboon, 2008).

Above literatures showed that fine bagasse ash or ground bagasse ash was a good pozzolanic material which could be used in concrete to improve the mechanical and durability properties of concrete. However, it was rarely found that ground bagasse ash was used in recycled aggregate concrete, thus in this study, ground bagasse ash was used to replace cement to improve the properties of recycled aggregate concrete.

2.3 Recycled Aggregate

Recycled aggregate is an aggregate obtained from crushing construction materials previously used in buildings, roads, bridges and sometimes in asphalt. This study aimed to use recycled aggregate from crushing concrete as coarse aggregate. Therefore, the properties of recycled aggregate affecting the properties of concrete are described as follows.

1. Aggregate size

Once the materials have been processed, they should be sized for proper use. Hansen (1986) reported the analysis of data from two studies where coarse aggregates were produced. After screening on a sieve No. 4 (4.75 mm), both aggregates would meet the specification range by adjusting the crusher opening. It would be reasonable to produce acceptable coarse aggregates from recycled concrete. Moreover, the results of many researchers in Thailand confirmed that the recycled coarse aggregates after screening on a sieve No. 4 (4.75 mm) had particle size distribution in the range specified by ASTM C33 (2001), though they were crushed by swing hammer crusher (Poosuntipong, et al., 2004; Tangchirapat, et al., 2008).

2. Attached mortar and cement paste

Once original concrete is crushed, the amount of mortar remains attached to stone particles in recycled aggregate. Hansen and Narud (1983) found that the volume percentages of mortar attached to natural gravel particles were between 25% and 35% for 16 to 32 mm coarse recycled aggregate, about 40% for 8 to 16 mm coarse recycled aggregates, and about 60% for 4 to 8 mm coarse recycled aggregates. However, it appears that for the same cement and original aggregate, the volume percentage of old mortar attached to recycled concrete aggregates does not vary much even for widely different water to cement ratio of original concrete. Moreover, Ravindrarajah and Tam (1985) reported that the attached mortar contents in recycled aggregate were 20%.

3. Density

Hansen and Narud (1983) found that densities of coarse recycled aggregates in saturated and surface dry (SSD) condition ranging from 2340 kg/m^3 (for 4 to 8 mm material) to 2490 kg/m^3 (for 16 to 32 mm material) and were independent of the quality of original concrete. Limbachiya, et al. (2000) also reported that the recycled aggregate had 7 to 9% lower relative density than natural aggregate in SSD state, due to the porosity of attached mortar. In Thailand, Poosuntipong, et al. (2004) and Khamkhai (2009) reported that the densities of recycled aggregate were 2390 to 2450 and 2480 kg/m^3, respectively, while the ones of crushed limestone were 2710 and 2730 kg/m^3, respectively. It may be concluded that the density of recycled aggregate is somewhat lower than that of natural aggregate due to old mortar and attached mortar which has lower density than that of natural aggregate (Hansen and Narud, 1983).

4. Water absorption

High water absorption is usually found in recycled aggregate. It is due to high absorption of cement paste or mortar attaching to the old aggregate (Nixon, 1978). Limbachiya, et al. (2000) reported that recycled aggregates from rejected structural precast concrete elements had 2 times higher water absorption than natural aggregates in saturated surface dry state. In addition, use of recycled aggregate at a high level of replacement, the high water absorption ability of recycled aggregate resulted in higher total water demand of concrete (Poon, et al., 2002). In Thailand, Nimityongskul and Sayamipuk (1995) found that absorption of recycled aggregate obtained from concrete debris was 5.1%. Moreover, Poosuntipong, et al. (2004) presented that the absorptions of recycled aggregates obtained from crushing old concretes using crushed limestone which had different strengths (18 – 55 MPa) ranged from 5.20 to 5.46%. It may be concluded that the water absorption of recycled aggregate is somewhat higher than that of original aggregate because attached mortar and old mortar in recycled aggregate had higher porosity than natural coarse aggregate.

5. Los Angeles abrasion loss

ASTM C 33 (2001) specifies that aggregates for use in concrete construction should have Los Angeles abrasion loss less than 50% for general construction. B.C.S.J. (1978) found that the Los Angeles abrasion loss ranged from 25.1 to 35.1% for recycled coarse aggregates from 15 different concretes of widely different strengths, which were crushed differently. Moreover, Tavakoli and Soroushian (1996) reported that the Los Angeles abrasion loss values of recycled coarse aggregate varied from 26.4 to 42.69%. In Thailand, Nimityongskul and Sayamipuk (1995) reported that the Los Angeles abrasion loss of recycled coarse aggregate was 43% while Poosuntipong, et al. (2004) illustrated that the values ranged from 29.69 to 33.5% depending on the strength of recycled concrete. The high values of Los Angeles abrasion loss resulted from attached mortar which was weaker than natural aggregate and the recycled aggregate was passed the crushing process before testing for Los Angeles abrasion loss, thus it could be broken down easily.

However, the results from previous literatures illustrated that recycled aggregates had the Los Angeles abrasion loss lower than that specified by ASTM C33 (2001). Therefore, they could be used as coarse aggregate in concrete.

6. Contaminants

ACI 555 (2001) concluded that the variety of contaminants could be found in recycled aggregates as a result of demolition of existing structures and could severely degrade the strengths of concrete made with them. This is due to the contaminants obstructed the bond between aggregate and cement paste (Barra De Oliveira and Vazquez, 1996; Poon, et al., 2004a; Tu, et al., 2006). Some of these materials are plaster, soil, wood, gypsum, asphalt, plastic, or rubber.

From the above literatures, recycled aggregates had low density, low specific gravity, high water absorption, and high porosity. Because the mortar attaching to the original aggregate results in lower density, higher water absorption, and higher porosity than those of natural aggregate. Therefore, use of recycled aggregate to fully replace natural aggregate (crushed limestone) in concrete tends to make the concrete to have low mechanical properties and low durability. If these properties of concrete containing recycled aggregate can be improved by using pozzolanic materials to have the mechanical properties and durability properties such as compressive strength, chloride resistance, and sulfate resistance as high as concrete containing natural aggregate, recycled aggregate will be promoted to be used in concrete production. Moreover, use of recycled aggregate can conserve natural aggregate, reducing waste, and reducing disposal landfill.

2.4 Recycled Aggregate Concrete

2.4.1 Aggregate Pretreatment

In general, recycled aggregate had water absorption higher than that of natural aggregate and affected the water demand in mixing concrete. To solve this problem, recycled aggregates were soaked or pre-wetted before using to produce concrete (Hansen, 1992; Poon, et al., 2004b). Katz (2004) treated the recycled aggregates by impregnation of 10% by weight silica fume solution and ultrasonic cleaning. He found that both methods could improve the interfacial zone of recycled aggregate to be stronger resulting in increasing the compressive strength.

Tam, et al. (2007) also treated recycled aggregate before using by pre-soaking in the acid solutions, namely hydrocholic acid (HCl), sulfuric acid (H_2SO_4), and phosphoric acid (H_3PO_4) which had concentration of 0.1 mole for 24 hours and then watering with distilled water to remove the acids. Recycled aggregate was soaked in water before mixing. The results showed that after treatment, the water absorption of recycled aggregate was lower than the untreated aggregate and the compressive strength, flexural strength, and modulus of elasticity of recycled aggregate concrete were marked improved when compared with those using natural aggregate. However, these methods are not convenient in practical and are expensive, thus they are not suitable for concrete production.

From literatures, pretreatment is a method to improve the properties of recycled aggregate to be better before using as coarse aggregate to produce recycled aggregate concrete but the use of original recycled aggregate to produce concrete is more convenient. Therefore, this research aimed to use ground fluidized bed fly ash and ground bagasse ash to improve the properties of recycled aggregate concrete instead of improving the recycled aggregate properties.

2.4.2 Fresh Concrete Properties

Hansen (1992) reported that use of recycled aggregate in concrete influenced the workability of fresh concrete while in the review of Nixon (1978) illustrated that use of recycled coarse aggregate had a liitle effect on the workability of fresh concrete. After that, Rashwan and AbouRizk (1997) found that fresh concrete properties harsher mixes with less workability compared to mixes made with natural aggregates. Although, the corrections in water content are necessary to obtain proper workability, the changes in water to cement ratio may be relatively small (Ajdukiewicz and Kliszczewicz, 2002). Later, Fong, et al. (2004) suggested that when recycled aggregates are used to produce concrete, the higher initial workability should be designed to compensate for the higher anticipated slump loss. Similarly, use of the aggregates in different moisture states affected the slump loss of the fresh concretes. A higher initial slump and quicker slump loss were found in oven-dried state of aggregate and the normal initial slumps and slump loss were found in using of saturated surface-dried and air-dried aggregates. The initial slump of concrete was strongly dependent on the initial free water content of the concrete mixes (Poon, et al., 2004b). Moreover, the results of Tangchirapat, et al. (2008) also confirmed that use of recycled aggregate in the concrete mix resulted in a faster slump loss than that of conventional concrete.

Fong, et al. (2004) reported the cause of a high slump loss of recycled aggregate concrete that soft materials such as attached mortars in recycled aggregates were quite easily broken off during mixing which further contributed to the slump loss. Another cause of slump loss of recycled aggregate concrete was the water consumption from the re-hydration of attached mortar on the surface of recycled aggregates and high absorption of recycled aggregate. However, they found that use of fly ash (25% and 30%) could help for workability.

The above literatures showed that concrete containing recycled aggregate had workability and slump loss worse than those of conventional concrete. However, it was found that use of fly ash could improve those properties. Therefore, this research studies the effect of ground fluidized bed fly ash and ground bagasse ash on workability of recycled aggregate concrete in term of required superplasticizer.

2.4.3 Hardened Concrete

2.4.3.1 Compressive Strength

Hansen and Narud (1983) studied the effect of recycled aggregates which were prepared by crushing of high strength, medium strength, and low strength concretes in jaw crusher. They found that the compressive strength of recycled aggregate concrete was largely controlled by the water to cement ratio of the original concrete when other factors were essentially identical. If the water to cement ratio of the original concrete was as same as or lower than that of the recycled aggregate concrete, the new strengths of concretes would be as good as or better than the original strengths. This result was confirmed by the results of Ajdukiewicz and Kliszczewicz (2002) and Gomez-Soberon (2002) who reported that the properties of recycled aggregate had significant influenced on the mechanical properties of concrete.

Compressive strength of recycled aggregate concrete depended not only on the properties of the original concrete, but also the recycled aggregate content in concrete. Kou, et al. (2007) showed that the compressive strength decreased as the increase of recycled aggregate content. While Ann, et al. (2008) presented that the partially replacement of cement by pulverized fly ash and ground granular blast furnace slag at the rate of 30 and 65% by weight of binder, respectively, could develop the compressive strength of recycled aggregate concrete to be the same level of conventional concrete. Moreover, use of ground rice husk bark ash and pulverized fuel ash in recycled aggregate concrete gave higher compressive strength than the recycled aggregate concrete without them (Tangchirapat, et al., 2008; Tangchirapat, et al., 2010). However, to avoid the effect on the ultimate strength of concrete, recycled aggregate should not be replaced natural aggregate up to 30% by weight in high strength concrete (Limbachiya, et al., 2000).

In Thailand, Nimityongskul and Sayamipuk (1995) studied the properties of concrete using recycled aggregate and rubble as coarse aggregates. Considering compressive strength, they found that recycled crushed limestone could be used to fully replace natural coarse aggregate while Poosuntipong, et al. (2004) reported that the compressive strength of concrete containing recycled coarse aggregate and river sand was about 13 to 15% lower than that of conventional concrete.

The low compressive strength of recycled aggregate concrete could be improved by using pulverized fly ash, ground granular blast furnace slag, and ground rice husk bark ash to partially replace cement as reported by the above literatures. Therefore, it is possible that use of ground fluidized bed fly ash and ground bagasse ash may help to improve the compressive strength of recycled aggregate concrete as well.

2.4.3.2 Modulus of Elasticity

The effects of using recycled aggregates instead of natural aggregates in concrete not only reduced the compressive strength but also reduced the modulus of elasticity of concrete. Many researchers reported that the modulus of elasticity of recycled aggregate concrete was lower than that of conventional concrete (Ravindrajah and Tam, 1985; Barra De Oliveria and Vazquez, 1996; Ajdukiewiz and Kliszczewicz, 2002; Etxeberria, et al., 2007). It was lower than that of conventional concrete about 20 to 45% (Hansen and Boegh, 1985; Kheder and Al-Windawi, 2005; Xiao et al., 2005). In Thailand, Poosuntipong, et al. (2004) showed that the value of modulus of elasticity of recycled aggregate concrete was lower than that of the value calculated by ACI-318-95 about 8-27%.

The causes of the low modulus of elasticity in recycled aggregate concrete is due to the fact that the modulus of elasticity of recycled aggregate is lower than that of natural aggregate (crushed limestone). In addition, recycled aggregate has a higher uncompacted void content, leading to a low modulus of elasticity of the recycled aggregate concrete (Topcu and Sengel, 2004). Neville (1997) reported that the modulus of elasticity of concrete depended not only on the compressive strength of concrete but also the modulus of elasticity and quality of aggregate used in the concrete mixture. Furthermore, the important factor affecting the modulus of elasticity of concrete was the bonding between aggregates and cement pastes which tended to be better when the age of concrete increased.

The modulus of elasticity of recycled aggregate concrete reported by many literatures was lower than that of conventional concrete. Moreover, there are few literatures reporting the improvement of modulus of elasticity of recycled aggregate concrete by using pozzolanic materials. Therefore, use of ground fluidized bed fly ash and ground bagasse ash may improve the modulus of elasticity of recycled aggregate concrete.

2.4.4 Durability

2.4.4.1 Permeability

Olorunsogo and Padayachee (2002) reported that the oxygen permeability tended to increase with increasing the quantity of recycled aggregate in concrete. Berndt (2009) also presented that the permeability of concrete increased slightly when recycled aggregate was used in the concrete. This is due to the use of recycled aggregate to replace natural aggregate in concrete resulted in increasing the porosity of concrete (Gomez-Soberon, 2002) since the mortar in recycled aggregate served for water to penetrate into concrete easily (Sagoe-Crentsil, et al., 2001). However, the permeability of recycled aggregate concrete could be decreased by increasing curing time (Olorunsogo and Padayachee, 2002) similar to the results of Zaharieva, et al. (2003)

who reported that the mix proportions and curing conditions had more effect on the permeability than other parameters.

The literatures showed that recycled aggregate concretes had water permeability higher than that of conventional concrete. However, use of fine fly ash and ground bagasse ash could reduce the water permeability to be lower than that of the concrete without the ashes (Kooratanaweich, et al., 2005; Tippiriyapong, et al., 2007; Chusilp, et al., 2009a). It is anticipated that the water permeability of recycled aggregate concrete may reduce to be lower than or equal to that of conventional concrete when ground fluidized bed fly ash and ground bagasse ash are used to replace cement.

2.4.4.2 Chloride Resistance

Otsuki, et al. (2003) reported that the interfacial transition zone (ITZ) is proved to be a good basis to evaluate the influence of recycled aggregate on the strength, chloride penetration, and carbonation of concrete. They reported that the chloride penetration resistances of recycled aggregate concrete are slightly lower than those of normal aggregate concrete. Moreover, Kou, et al. (2007) indicated that the resistance to chloride ion penetration decreased as the recycled aggregate content increased which was similar to the result of Olorunsogo and Padayachee (2002). However, the resistance to chloride penetration was improved by incorporating fly ash in the concrete mixture. A decrease in the W/B ratio also improved the chloride ion penetration resistance. Furthermore, the chloride resistance increased as the curing age increased from 28 to 90 days. Ann, et al. (2008) also presented that the concrete containing recycled aggregate forms a more open pore structure, compared to the control specimens. The use of 30% pulverized fuel ash and 65% ground granular blast furnace slag in binder not only increased the resistance to chloride ions permeability into a concrete but also reduced the corrosion rate due to the restriction of cathodic reaction, which needed a sufficient supply of oxygen and water. Later, Berndt (2009) found that use of slag in concrete could improve the chloride diffusion coefficient of recycled aggregate concrete to be lower than conventional concrete.

In general, recycled aggregate concrete had chloride resistance lower than that of conventional concrete while use of pozzolanic materials such as pulverized fuel ash and ground granular blast furnace slag could improve the chloride resistance of recycled aggregate concrete. However, it is rarely found that fluidized bed fly ash and bagasse ash are used to improve the chloride resistance of recycled aggregate concrete. Therefore, this research aimed to use both ashes to improve the chloride resistance of recycled aggregate concrete.

2.4.4.3 Sulfate Attack

Literature reviews in sulfate attack of concrete containing recycled coarse aggregate is rarely found while the sulfate attack of mortar containing recycled fine aggregate was reported by Lee, et al. (2005). They found that mortar containing 100% recycled fine aggregate immersed in 5% sodium sulfate solution was deteriorated more than mortar containing natural fine aggregate. This was due to the water absorption of the recycled fine aggregate was a major factor controlling expansion, strength loss, and intensity of damage due to sulfate attack.

Improvement of sulfate resistance of conventional concrete was reported in several studies. Lane and Best (1982) reported that fly ash could increase sulfate resistance of concrete. Use of low water to cement ratio, low C_3A content in cement, and Portland cement type V can improve resistance of concrete due to sulfate attack but use of cement having higher C_3S content resulted in greater expansion (Djuric, et al., 1996; Kurtis, et al., 1997; Gonzales and Irassar, 1997; Irassar, et al., 2000). Moreover, use of pozzolans namely fly ash, silica fume, and natural pozzolans is one of the several methods to improve the sulfate resistance of concrete (Shasiprakash and Thomas, 2001; Sideris and Savva, 2001).

Improving the sulfate resistance of concretes containing pozzolans is attributed to the pozzolanic reaction (Somna, et al., 2004; Tangchirapat, et al., 2009), leading to the pore structure refinement resulting in a denser matrix as well as a reduction in calcium hydroxide which could react with sulfate. Therefore, this research aimed to study the effect of fluidized bed fly ash and bagasse ash in recycled aggregate concrete due to sulfate attack.

From the literatures, the utilization of recycled aggregate with fluidized bed fly ash or with bagasse ash is very limited. Most of tested concretes, bagasse ash, and fluidized bed fly ash are disposed of in landfills and the disposed volume tended to increase every year. Moreover, the utilization of fluidized bed fly ash and bagasse ash in recycled aggregate concrete to improve the compressive strength, water permeability, chloride resistance, and expansion properties is rarely reported. If fluidized bed fly ash and bagasse ash can be used to improve compressive strength, water permeability, chloride resistance, and expansion due to sulfate attack of recycled aggregate concrete, the study will be useful to identify their properties and leads to the increase of its usages, decreases the disposal landfill, and conserves natural resources.