CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

Even as new vistas are open up in the coveted field of civil engineering construction domain a critical review related to the contemporary developmental documentations is mandatory. The output of any research and development effort is brought out as a technical publication open to the researchers for and against the null hypothesis or technical know-how or a state of the art processor a novel and innovative idea such as switching over to the concept of partial material substitution. Following is a compendium of the critical examinations related to literature available as regards the dependability and marketability of processed or unprocessed wastes in various applications.

2.2 LITERATURES RELATED TO REFRACTORY BRICK WASTE

Kavas et al. (2006) corroborated the applicability of utilizing cement furnace lining refractory bricks which constitute aluminum and magnesium as a major part for fine aggregate replacement in concrete. The strength properties such as compressive strength, bending strength and durability properties such as concrete resistance to chemicals (Hydro Chloric acid) and high-temperature exposure (400°C, 600°C, 800°C) were carried out.
The consequences of the experimentation reveal that refractory bricks with magnesium chromite as fine aggregate have shown its edge over the conventional mix by providing better results.

Keerthinarayana and Srinivasan (2010) studied the strength and durability properties of concrete by partial replacement of crushed spent fire bricks for fine aggregates. 30% replacement of crushed spent fire bricks for fine aggregates in concrete indicate increase in compressive strength but there is no strength attainment after increasing the proportion there after.

Netinger (2011) studied the high-temperature effect on mechanical properties of concrete infused with different types of aggregates like refractory brick and steel industry material waste formed at high temperature. The residual mechanical properties of concrete infused with industrial fine aggregates wastes after exposed to high temperature was superior to normal concrete.

Saidi & Safi et al. (2016) by experimentation have ascertained the facts that mortars with refractory brick waste contributes to high thermal stability by determining the mechanical strengths such as compressive strength and flexural strength. The increase in compressive strength was arrived at 11% and flexural strength by 21.38%. The mass loss after exposure to high temperature was 5.35% lower than that of a control mix. The study concluded that refractory brick wastes could be used effectively for thermal – resistant mortars.

Magesh Kumar et al. (2016) highlighted on the main issue faced by metal casting industries for safe disposal of waste refractory materials mostly comprising of bauxite, magnesite, and chrome bearing material. The study substantiated the reuse and recycling of waste refractories for low-
temperature exposure to save global environment and concluded that recycling of spent refractories must be carried out very consciously after efficient recovery of entrapped metal and by carrying out tests for finding optimum grain size and porosity.

Vieira et al. (2016) stated the effect of including crushed ceramic bricks and waste from sanitary wares for partial and full replacement of fine aggregate in the ratio of 20%, 50% and 100% by volume of fine aggregate in concrete. The study has reported that concrete incorporated with crushed ceramic bricks has shown better results than conventional concrete and concrete with waste from sanitary wares concerning water absorption by total immersion and capillary action, shrinkage strain. The reason behind this improvised property is the pozzolanic activity of the concrete which fills up the voids thus making it as impermeable.

Patel (2017) substantiated the dependability of crushed fired brick waste as a replacement material for clay in the manufacture of brick. The percentage replacements were 0%, 10%, 15%, 20% and 25% by weight of clay and the cast bricks were tested for its functional properties as prescribed by Indian standard code. The study confirmed the relatively high performance of blocks containing refractory waste compared to regular bricks as the improvised bricks showed a compressive strength of 7.34 N/mm² and water absorption less than 20%.

Zeghad et al. (2016) reused refractory brick wastes in High-Performance Fiber Reinforced Concrete as supplementary cementitious materials. Zeghad et al. (2016) studied the feasibility of reusing refractory brick wastes as an additional cementitious materials in producing High-Performance Fiber Reinforced Concrete. In their study, three different ratios of concrete were developed based on various types of refractory brick wastes.
The concrete with refractory waste brick based alumina showed higher strength than the mixes of concrete with refractory waste brick based magnesia and concrete with refractory waste brick based silica-zirconium for the given cement content and the water cement ratio designed for the concrete. The obtained compressive strength was in the acceptable range up to 20% replacement compared to normal concrete.

In addition to above line of investigation work to evaluate the relevance of refractory brick waste in concrete, few researchers have tried for the suitability of the same in other applications like recycled and dense refractory brick (Rabehi & Boumchedda 2015), pavement (Sarkar 2015), clay brick manufacturing (Patel et. al 2017), cementitious material for Portland cement (Liu et al. 2007, Li 2004), slag aggregates in building material (Fenglan Han 2012), secondary refractory lining (Magesh Kumar et al. 2016), Slag conditioner in electric arc furnace (Kwong & Bennett 2002).

2.3 LITERATURES RELATED TO FOUNDRY SAND WASTE

Kraus et al. (2009) checked the feasibility of using foundry silica-dust as fine aggregate in self-consolidating concrete. In their study, totally 40% mass of cementitious materials was replaced with class C fly ash. Fly ash was replaced by silica dust in the ratios of 10%, 20%, and 30% at 1:2 ratios by mass. At 30% foundry silica-dust replacement, reduction in 3 days and 28-days compressive strength were observed. The authors concluded that strength reduction might be due to reductions in density, increased air content, the presence of an organic impurities in foundry dust and optimum replacement can be taken as 20% replacement for producing self-consolidating concrete.
Siddique et al. (2009) conducted an experimental investigation on mechanical properties of used foundry sand incorporated concrete. In their study, they partially replaced foundry sand in 10%, 20%, and 30% by weight of natural sand in concrete and determined the mechanical properties of concrete after 28 days, 56 days, 91 days, and 365 days of curing. Compressive strength, split tensile strength and flexural strength increased between 8%–19%, 7%–12% and 6.5%–14.5% respectively. Similarly, they observed that modulus of elasticity also increased between 5%–12% depending on the percentage of foundry sand and testing age.

Etxeberria et al. (2010) assessed the properties of concrete incorporated with green foundry sand and chemical foundry sand. Electric arc furnace slag and blast furnace slag were used as a substitution for coarse raw aggregates in 25%, 50%, and 100% of concrete production. They concluded that concretes made with metallurgical by-products diffuse lower capillarity and gain higher compressive strength at high temperature compared to those of conventional concrete.

Siddique et al. (2011) partially replaced used-foundry sand for fine aggregates in concrete in the ratio of 0 – 60% at the increment of 10%. Optimum replacement of fine aggregate by foundry sand was found to be 30% since there were flaws in concrete after 50% of replacement. The rate of gain in strength at 90 days was closer to that of control mix and the speed of strength gain for all the mixes at 365 days with foundry sand was higher than the control mix except for 60% replacement.

Siddique & Kadri (2011) stated the characteristics of concrete contains metakaolin and foundry sand. In their study, they replaced cement with three percentages 5%, 10%, and 15% of metakaolin by weight of cement. Similarly, fine aggregates were replaced using 20% foundry sand. The
increase in metakaolin content in the range of 5% to 15% tends to decrease the initial surface absorption, reduces the sorptivity up to 10% metakaolin replacement. FS replacement up to 20% caused a decrease in compressive strength and increases water absorption and sorptivity.

Alonso-Santurdeet (2012) examined the recycle potential of ceramic industry foundry by-products in the production of ceramic bricks. The addition of green sand and core sand to the ceramic matrix tend to increase the water absorption and decrease the firing shrinkage, in laboratory as well as industrial samples. Based on the experimentation, it was concluded that 35% of green sand and 25% of core sand might accomplish the technological standards for traditional bricks. The final conclusion recommended foundry sand as a raw material in the manufacture of ceramic products.

Kaur et al. (2012) took up basic and applied research related to material substitution by way of replacing aggregate with waste foundry sand with 5% fungal culture. Concrete contain 20% fungal treated waste foundry sand showed 15.6% compressive strength increase and reduction in water absorption (68.8%) and porosity (45.8%) compared to normal concrete after a nominal curing for 28 days. The decrease in porosity and increase in compressive strength was observed when fungal culture is included in concrete.

Singh & Siddique (2011) investigated the strength and abrasion resistance properties of concrete incorporated with waste foundry sand. Fine aggregate in concrete was substituted with 0%, 5%, 10%, 15% and 20% of waste foundry sand by weight. Adding waste foundry sand enhanced the concrete’s strength properties. The compressive strength of concrete increased by 8.25–17%, modulus of elasticity by 1.67–6.35% and split tensile strength by 3.55–10.40% depending on the WFS content.
Singh & Siddique (2011) carried out a study on permeability, strength and ultrasonic pulse velocity of the foundry sand added concrete. In their study waste foundry sand was replaced with natural sand in 0%, 5%, 10%, 15%, and 20% by weight of natural sand. The optimum replacement of WFS was identified as 15%. Strength properties of concrete increased with 15% waste foundry sand replacement for both 28 and 91 days of curing.

Basar & Deveci Aksoy (2012) test verified the micro-structural, leaching and mechanical characteristics of waste foundry sand infused ready-mixed concrete. Ordinary sand was substituted in the percentages of 0%, 10%, 20%, 30%, 40% by WFS in the concrete and stabilization/solidification method was implemented to all concrete mixtures. The study concluded that typical sand can be replaced by WFS up to 20% without any compromise in the physical and mechanical properties of concrete. The strength of concrete mixtures increased with curing period and the strength obtained at 56 days were same as that observed in 90 days strength achieved by the other concrete mixtures.

Pathak & Siddique (2012) reported a study on properties of Self-Compacting-Concrete (SCC) contain spent foundry sand and fly ash. In their research, mixes were prepared with fly ash ranging from 30% to 50%. One controlled mixture was prepared for comparison. spent foundry sand was used to replace 10% of fine aggregate. Fly ash and spent foundry sand reduces the strength. The study clearly indicated there is reduction in compressive strength and split tensile strength when fly ash content was increased from 30 – 50 %. Although the strength of the concrete is affected by the infusion of spent foundry sand and fly ash, it is possible to produce SCC with compressive strengths ranging from 30.69 MPa to 19.75 MPa, at elevated temperatures.
Quijorna et al. (2012) experimented using foundry sand as an alternative to replace clay for the production of clay bricks. In their study, trials incorporating 20 % – 40 % by weight additions to bricks have experimented. Foundry sand included samples with more than 30% slag showed excessive leaching tend the mix to fail the regulated limits.

Kaur et al. (2013) evaluated the metal concentrations and micro-structural properties of concrete contain fungal treated and untreated waste foundry sand. The study indicated a reduction in leachable metals in concrete containing 10% fungal treated waste foundry sand and micro structural analysis added anchorage to the above result. The compressive strength increased by 15.6% for treated 20% WFS compared to 10% and 20%. The reason behind the increase in compressive strength could be less number of pores in concrete due to binding nature of fungus.

Khatib et al. (2013) studied the capillary water absorption of the waste foundry sand added concrete. The fine natural aggregate was partially replaced with waste foundry sand by 0%, 30%, 60% and 100% in the fine aggregate mantle. After 1, 7, 28 and 90 days of curing, the properties such as water absorption by capillary action, ultrasonic pulse velocity (UPV) and compressive strength were studied. The test results indicate that increase in water absorption owing to capillary action tends to decrease the UPV and compressive strength with increasing quantity of WFS in concrete.

Navarro-Blasco et al. (2013) attempted to utilize waste foundry sand up to 50% in calcium aluminate cement mortars. The authors examined the setting time and consistency of fresh mortars at two alternate curing conditions. Calcium aluminate cement is a prominent matrix to make mortars for recycling of waste foundry sand at higher replacement percentages.
Compared with OPC, the heavy metal retention and compressive strength were evidently improved if calcium aluminate cement was used as binding matrix.

Aggarwal & Siddique (2014) studied the prospects of substituting fine aggregate with industrial by-products such as bottom ash and waste foundry sand. They observed that increase in compressive strength, flexural strength and splitting tensile strength compared with conventional concrete was attained by replacing 30% of fine aggregates with industrial by-product aggregates. The compressive strength was in the range of 29 – 32 MPa, splitting tensile strength was in the range of 1.8–2.46 MPa, and flexural strength was in the range of 3.95–4.10 MPa for fine aggregate replacement in the range of 10% to 50% at an interval of 10%.

In addition to above research work, related to application of foundry sand in concrete, few researchers have tried for the dependability of foundry in other applications like highway subbase (Guney et al. 2006), road embankment (Partridge et al. 2011), clay bricks manufacturing (Alonso-Santurde et al. 2011, Quijorna et al. 2012), production of low strength materials (Siddique et al. 2008), development of high-strength concrete (Guney et al. 2010), asphalt concrete mixtures (Recep Bakis et al. 2006), hot asphalt mixes (P. J. Tikalsky et al. 2004; Deng 2004) and in geotechnical construction (Marc J. Goodhue 2001).

2.4 LITERATURES RELATED TO MATHEMATICAL MODELLING

Öztaş et al. (2006) envisaged the slump and compressive strength of high strength concrete by the Artificial Neural Network (ANN). The seven input parameters for training the ANN was water to binder ratio, water content, fine aggregate ratio, fly ash content, air entraining agent,
superplasticizer and silica fume replacement. The trained ANN in MATLAB predicts the compressive strength with mean absolute percentage error of 1,956,208%, and for the slump, with an error of 5,782,223%. R² values were found to be 99.9% for compressive strength and 99.3% for slump values. Test set which proved that ANN using MATLAB have strong potential for predicting compressive strength and slump values of silica fume replaced concrete.

Uygunoglu & Unal (2006) determined the effect of fly ash on the compressive strength of concrete based on w/c ratio and concrete age using Fuzzy Logic (FL). The experimental compressive strength of concrete containing type II fly ash at the rate of 0% - 30% at 10% increment was estimated at 3, 7, 28, 90, 180 and 365 days. Fuzzy logic modeling included three input factors viz., fly ash content, water binder ratio and age of the specimen in days. The Fuzzy Inference System (FIS) in MATLAB software was used to create the membership function for different input parameters and to generate de-fuzzified output values. A close approximation of predicted values and experimental compressive strength values obtained justifies that the proposed FL model will provide economic design by saving the time and material for experimentation.

Topcu et al. (2007) corroborated the applicability of ANN and FL models for predicting the compressive strength of concrete containing fly ash at 7, 28 and 90 days. 180 specimens gathered from 52 different mixes of various works of literature were employed in the modelling of ANN using feed forward back propagation algorithm and Sugeno type FL. The results, through the statistical values viz., RMSE, MAPE, and R² have proved that ANN and FL have strong potential for predicting the compressive strength with fly ash.
Pala et al. (2007) appraised the long-term properties of silica fume and fly ash on compressive strength of concrete by ANN. 144 sample mixes were summarized from literature, for concrete with silica fume and fly ash, cured at 3, 7, 28, 56 and 180 days was considered for prediction. An NN model was constructed, trained and tested with obtained data using MATLAB. The results showed that ANN is a feasible tool for estimating the compressive strength of concrete by considering the influence of cementitious material.

Fazel Zarandi et al. (2008) experimented using Fuzzy Polynomial Neural Networks (FPNN) to determine the approximation of the concrete compressive strength. Two different architectures namely Type1 and Type 2 of FPNN were addressed with six input parameters viz., coarse aggregate, fine aggregate, super plasticizer, silica fume, water, cement and one output (compressive strength of concrete at 28 days). The trained model was evaluated using root mean square error and correlation factor which shows that Type 1 FPNN has potential as a possible tool for prediction of the compressive strength of concrete.

Bilim et al. (2009) predicted the compressive strength of GGBS concrete using an ANN. The six different input parameters categorized were cement, ground granulated blast furnace slag in the ratio of 20% - 80% at an interval of 20%, water, hyperplasticizer, aggregate and age of samples and compressive strength of concrete was the output parameter. The study reported that strength loss due to slag replacement at early ages were nullified in long term. The various algorithms of ANN were tested in their study; the Levenberg–Marquardt algorithm was found to be the best learning algorithm and ANN substantiated as a effective tool for predicting compressive strength at constant workability.
Özcan et al. (2009) utilized 48 concrete mixes containing 240 data sets for creating ANN and FL model using MATLAB. ANN employed multilayer feed forward network design, and Fuzzy logic used Mamdani FIS to predict the influence of silica fume on long term compressive strength of concrete. The study concluded that the effect of silica fume ceases after 28 days and the increase in compressive strength was between 20 – 50 % and the two models created viz., ANN and FL proved its efficacy for evaluation of the compressive strength of concrete containing supplementary cementitious material like silica fume.

Sarıdemir et al. (2009) constructed ANN and FL model using 44 different mixes with 284 data gathered from the literature for finding the effect of long-term effects of GGBS on compressive strength of concrete. The data was arranged in a format of five input parameter and one output which is the compressive strength of concrete at different curing spell. ANN utilized FFBP algorithm whereas Sugeno type fuzzy inference was used in Fuzzy logic modeling. The calculated statistical values viz., RMSE, MAPE, and $R^2$ exemplify that ANN and FL model created have real potential for finding compressive the compressive strength of concrete without attempting any experiments.

Sarıdemir (2009) collected 179 experimental literature data of 46 different mix proportions of mortars containing metakaolin for modeling ANN using back propagation algorithm and FL using Sugeno type fuzzy inference system. The experimental values are varied in agreement with predicted compressive strength values for the multilayer feed-forward neural network and Sugeno-type fuzzy inference models. The statistical parameter values of RMS, $R^2$, and MAPE also predicted which anchorages that ANN and FL prove to be an efficient model for predicting the compressive strength of concrete at different ages containing metakaolin.
Sobhani et al. (2010) estimated the compressive strength of no-slump concrete (concrete with zero slump). In their comparative study analysis was done using, regression and neural network with ANFIS models. Neural network and ANFIS models were satisfactory in predicting the 28-compressive strength of no-slump concrete compared to the classical regression model.

Atici (2011) predicted the strength of mineral admixture added concrete by an ANN and multivariable regression analysis. The ANN applications in the prediction of compressive strength of admixture added concrete at different curing spells (3, 7, 28 and 90 days) was particularly suitable for calculating nonlinear functional relationships, for which the same traditional methods cannot be adopted.

Uysal & Tanyildizi (2011) predicted the compressive strength of mineral additives (fly ash, limestone powder and marble powder) added self-compacting concrete using an ANN. MATLAB software performed the program ten input parameters using neural network tool box. Among the algorithms of ANN used in their study, Fletcher–Powell conjugate algorithm was identified as the best learning algorithm for predictions.

Dantas et al. (2013) assessed the compressive strength of concrete containing demolition waste by artificial neural networks. Results obtained from training and testing phases sturdily show the potential use of ANN in predicting the compressive strength of concrete after 3, 7, 28 and 91 days which containing CDW.

Duan et al. (2013) analyzed the compressive strength of recycled aggregate concrete using ANN under MATLAB program. The ANN model was developed using 14 input parameters categorized from 168 data sets from
The results from the developed model indicate that, ANN has strong potential to be used as predictor of compressive strength of concrete with varying nature and supply of recycled aggregates.

Sadrmomtazi et al. (2013) modeled the compressive strength of lightweight concrete with expanded polystyrene beads using ANFIS, regression and ANN. The correlation factor, root means square error were used to assess the performance of regression analysis, ANN and ANFIS. Prediction of results by second-order polynomial regression model showed lesser ability compared to ANN and ANFIS and hence, use of the same can save time and cost for conducting experiments.