INTERNATIONAL
Journal *of* 3R' s

Vol. 4, No. 4, 2013, 625-630

# THREE PRINCIPLES OF CONCRETE CORROSION PREVENTION

Wieslaw Kurdowski[a*] and Aleksandra Bochenek[a]

[a]Institute of Ceramics and Building Materials, Warsaw, Poland

**ABSTRACT**

The service life of reinforced concrete structures are extended if the durability parameters are incorporated during the construction stage. The corrosion is one of the major factors for premature deterioration of reinforced concrete structures which can be mitigated by taking care impermeability of concrete which again depends on the pore sizes and distribution of pores in the cement matrix. The other two factors are cement phase composition and cement chemical composition. Hence physical and chemical characterization of cliker and cement paste would help in long term durability of concrete. The present paper discusses these three principles for corrosion prevention for achieving the durability of concrete structures.

**Keywords**

Durability, Permeability, Capillary pores, Cement phase composition, Cement chemical composition

## 1.0 INTRODUCTION

The most important property of concrete is its durability. At present this is the most important problem in concrete designing and 50 year durability must be assumed to be one of its most significant properties. It is well known that there are wonderful examples of durable concretes, produced already by the ancient Romans. The Aqueduct Pont du Gard in Nimes, France, constructed between 26 and 16 BC, is one such example. This construction was made from concrete composed of lime with different pozzolana additions. Its properties have been retained until now. This is perhaps all the more so because this concrete was compacted by slaves. Impermeability is one of the basic factors for concrete durability.

## 2.0 FACTORS DETERMINING THE DURABILITY OF CONCRETE

In accordance with the title of the article, three factors defining the durability of concrete constructions are: permeability, cement phase composition and cement chemical composition. The latter is concerned with sodium and potassium content. Out of these three factors, permeability is mostly appreciated and the importance of clinker chemical composition ($Na_2Oeq$) is the recent knowledge. Cement type, and more particularly the content of mineral addition, is also important.

## 2.1 PERMEABILITY

Porosity and pore structure constitute the basic factor influencing concrete permeability. Pores, based on their dimensions, are classified traditionally in concrete technology as gel pores under 2 nm and capillaries to which very large pores belong – the so called macro-pores. Concrete permeability is defined by the content of capillary pores, which are as a rule, interconnected, forming the continuous canals in this composite and thus called "continuous pores". Capillary pores are defined by w/c ratio, which is of significant importance for concrete durability. In the last decade the production of concrete with low w/c ratio has been developed due to chemical admixtures which give the possibility of drastic decrease of capillaries content. The relation between permeability and maximum radius of continuous pores was studied by Nyame and Illstone [1] (Figure 1).

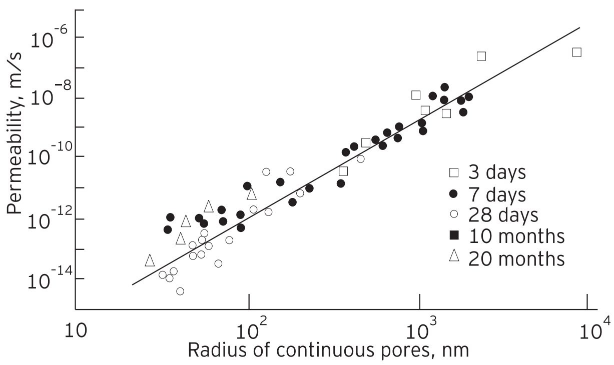


**Figure 1.** Relation between the maximum pores radius and permeability of hardened cement paste at different curing times [1]

As mentioned earlier, the important effect on capillaries formation is exerted by the w/c ratio and the higher it is from the minimum necessary for full cement hydration, (which Powers [2] defined as 0.36), the larger is the content of capillary pores. It is enough to state that for w/c = 0.5 the capillary pores occupy about 20 volume %, in the case of full cement hydration.

Since the pores can be considered as Griffith's defects, the concrete strength becomes a function of porosity. Permeability should also be linked with strength, which was shown by Torrent et al. [3] (Figure 2).

*Corresponding author
E-mail : w.kurdowski@icimb.pl

INTERNATIONAL
Journal *of* 3R' s

Vol. 4, No. 4, 2013, 631-636

# DEVELOPMENT OF AN EMPIRICAL EQUATION FOR ESTIMATING REPAIR COST OF BUILDINGS

Tarranum Khan[a*] and Subramanyan Hariharan[b]

[a]Civil Engineering Department, Sardar Patel College of Engineering, Mumbai University, Mumbai- 400058, India

[b]Civil Engineering Department, Thadomal Shahani Engineering College, Mumbai University, Mumbai- 400050, India

ABSTRACT

Structural deterioration is attributed to the action of loads heavier than originally envisaged, the environmental change, age of structure, etc. These factors can cause localised distress, which if not attended to, can result in failure with adverse consequences. Assessing the structural health of structures is one of the prime concerns construction managers have today as timely prediction and assessment of the repair would help in better planning of budgetary resources for the clients and ultimately improving the performance of the structures. The cost considerations play a major role in making the decisions in any repair process and therefore it is proposed to develop an empirical equation for estimating the cost of different type of repairs based on the condition assessment of the buildings which would be useful for estimating the repair cost of the reinforced concrete buildings. The proposed empirical equation for finding the cost of repair is based on various factors such as life of the structure, market rate of item of work or methods used and non-destructive test (NDT) results. Four repair methods, namely polymer modified mortar, jacketing, micro concreting and recasting, are considered. The cost of matrix analysis is compared with the empirical model for validation and empirical equation is proposed as a ready reference for construction engineers and valuers.

Keywords

Concrete, Deterioration, Repair, Cost estimate, Repair empirical equation

## 1.0 INTRODUCTION

Periodic structural audits are necessary to determine the structural health of buildings. Buildings are designed for a longer service life with the assumption that proper maintenance is carried out. Chances of corrosion and deterioration of concrete in coastal region is also higher and can aggravate the damage. Though there are many testing methods available, there is a gap between the structural knowledge/ expertise available and the knowledge regarding cost implications in carrying out various improvements. Therefore, it is not only urgent but very important that engineers pay attention to the problem of knowing the health of the structure and develop a reliable cost index model which shall be used as a guideline in estimating the expenses involved in improving life of the structure.

There are many research findings developed with regard to testing techniques and procedures, but there is only some research information on the cost perspective and associated cost index model. It is therefore important to get some primary data based on the study of methods available at present and the associated costs. Various structural defects were classified and methodology developed, which will quantify the effects of structural failures. Estimating strategy in arriving at various structural modifications/ improvements will be considered in this paper.

*Corresponding author
Tel : +91 9324353265
E-mail : sathiya39@rediffmail.com

Every building which has completed a service life of 30 years without much maintenance or major repair would need some structural repair during its remaining service life. The main cause for this is weathering and ageing effect or inadequate maintenance and care. There are cases of premature deterioration which is largely due to poor construction or inappropriate design and/or neglect of timely repairs.

## 2.0 LITERATURE REVIEW

Structures are subject to a range of degradation effects leading to the generation of defects. The nature of the deterioration at early stages warrants repair before serious structural implications arise. This leads to demand for repairs of structures that are still serviceable but suffer defects in durability, cosmetic or safety functions. Indeed Tuutti [1] states there is exponential growth in demand for concrete repair, and Davies [2] provides an estimate of a £1 billion European market in the repair of premature deterioration in reinforced concrete structures. Van Gemert [3] quotes that repair, rehabilitation and protection of buildings and infrastructure account for 40% of construction workload. Walker [4] states that the majority of reinforced concrete structures meets or exceeds their intended service life.

Repair of reinforced concrete involves treatment, after defects have occurred, to restore the structure to an acceptable condition. Defects cause some compromise in condition or function and this generally means that a process/ processes have resulted in movements, loss of material, and or loss in materials properties. Repairs are therefore mostly reactive, and initiate when evidence

INTERNATIONAL
Journal *of* 3R' s

Vol. 4, No. 4, 2013, 637-641

# USE OF FERRO-CHROME (FECR) WASTE SLAG AS ALTERNATIVE COARSE AGGREGATE IN CONCRETE

Sanjaya K. Patro[a]*, Tribikram Mohanty[a] and Manmatha K. Mohanty[a]

[a]School of Civil Engineering, KIIT University, Bhubaneswar-751024, Odisha, India

**ABSTRACT**

Ferro-chrome (FeCr) slag is a waste material obtained from the production of ferrochrome (FeCr), an essential component in stainless steel. It has been observed that ferro-chrome (FeCr) slag waste is suitable material for highway pavement work. This research work was conducted to investigate the performance of ferro-chrome (FeCr) slag waste as an artificial coarse aggregate in concrete which can substitute fully natural granite aggregates (traditionally used as coarse aggregate in concrete). Investigation is carried out by measuring the physical and mechanical properties of FeCr slag waste and mechanical strength of concrete using FeCr slag chips as coarse aggregate. Concrete can also be produced at a low cost as waste material substitutes the natural aggregates. Comparative analysis is also done between different samples of concrete made from FeCr slag chips and others from traditional granite chips. It is seen that FeCr slags are as good as or better than those of natural aggregates. Therefore, FeCr slag has potential to be used as an artificial coarse aggregate in preparation of concrete.

**Keywords**

Aggregate, Concrete, Ferro-chrome slag, Waste material, Mechanical strength

## 1.0 INTRODUCTION

Concrete is one of the major construction materials being used worldwide. Aggregate, besides cement and water, forms one of the main constituent materials of concrete since it occupies nearly 55% to 80% of concrete volume. The aggregate types utilised are either coarse aggregates (with particle size more than 4.75 mm) or fine aggregates (with particle size less than 4.75 mm). Aggregates which are used in concrete are obtained either from natural sources or by crushing large size rocks. Coarse aggregates are bound with cement paste during the hydration process to form cement concrete whereas fine aggregates are utilised to fill the gaps between the coarse aggregate particles. The rapid increase in the natural aggregates consumption every year due to the increase in the construction industry worldwide means that the aggregate reserves are being depleted rapidly. It has been reported that, without proper alternative, aggregates being utilised in the near future, the concrete industry globally will consume 8–12 billion tons annually of natural aggregates after the year 2010 [1]. Therefore, there is an urgent need to find and supply alternative substitutes for natural aggregates by exploring the possibility of utilisation of industrial by-products and waste materials in making concrete. This will lead to sustainable concrete design and a greener environment. In recent years, tremendous research efforts have been undertaken to utilise the waste materials in the production of concrete. Various researchers have investigated the use of industrial wastes as coarse aggregate which replaces the natural coarse aggregate in concrete, partially or fully, in the last few decades.

*Corresponding author
Tel : +91-9439502377
E-mail : litusanjay@yahoo.com

It has been seen that all major steel manufacturing factories produce large quantity of steel slag. Qasrawi et al. [2] have investigated the use of low CaO unprocessed steel slag in concrete as fine aggregate. They have presented that the use of steel slag as fine aggregate in concrete mixes has a positive effect on both compressive and tensile strengths. The use of steel slag in concrete will eliminate one of the environmental problems created by the steel industry. However, they have reported that use of steel slag as fine aggregate has a negative impact on the workability of concrete which can easily be taken care by the use of admixtures. Performance of high strength concrete made with copper slag as a fine aggregate is investigated by Al-Jabri et al. [1]. They have reported that the use of copper slag as sand replacement improves the strength of high strength concrete (HSC) and durability at the same workability while super plasticizer is a very important ingredient in HSC in order to provide good workability. Khanzadi and Behnood [3] have presented the results of a study undertaken to investigate the feasibility of using copper slag as coarse aggregates in high strength concrete. The improvement in the mechanical properties of concretes incorporating copper slag indicates that copper slag, a waste by-product of the copper industry can be used beneficially as coarse aggregate for high strength concrete. Etxeberria et al. [4] have prepared the concrete with chemical foundry sand and green foundry sand as substitution for raw sand, electric arc furnace slag and blast furnace slag were used as substitution for coarse raw aggregate. It is verified that the concretes made with metallurgical by-products obtain higher or similar performance in comparison to those of conventional concrete. Asi et al. [5] have studied the effectiveness of using steel slag aggregate in improving the engineering properties of locally produced asphalt concrete mixes. They have

Review

INTERNATIONAL
Journal *of* 3R' s

Vol. 4, No. 4, 2013, 642-651

# RECYCLING OF CONSTRUCTION AND DEMOLITION WASTE FOR SUSTAINABILITY – AN OVERVIEW OF THE USE OF RECYCLED CONCRETE AGGREGATES

C. Sumanth Reddy[a*] and P. Rathish Kumar[a]

[a]Department of Civil Engineering, National Institute of Technology, Warangal-506004, Andhra Pradesh, India

ABSTRACT

Repair, remodeling and reconstruction works are often associated with huge amounts of construction and demolition wastes. The call for sustainable development is answered by the process of recycling this construction and demolition waste (CDW). This paper reviews the potential of materials by recycling CDW, with special reference to concrete waste as aggregates in new concrete. The manufacturing process, processing techniques and their influence on different characteristics of aggregates and thereby the consequent concrete properties associated with non-structural applications are discussed in detail. A case study of the non-structural application of recycled concrete aggregates (RCA) is also mentioned with reference to the above mentioned factors and their influences. It is observed in testing thus far that, no significant underperformance in terms of durability could be observed. Further, its performance in a pervious pavement is under study.

Keywords

Construction and demolition waste, Recycled concrete aggregates, Compressive strength, Sorptivity, Pre-cast blocks

## 1.0 INTRODUCTION

Infrastructure development of a nation is one of the indices of a country's growth and to establish and maintain this, natural resources are essential. One of the daunting problems faced by the construction industry is the shortage of or inconsistencies in the supply of construction materials. Another common problem faced is that of handling the waste or debris originating at various stages in infrastructure management like construction, remodeling, repair and demolition. The Europen Union contributes to about 850 million tonnes of CDW (31% of the total) annually [1]. The Indian contribution is reported as 15 million tonnes and this only accounts for the authorized disposals [2]. These amounts are prone to rising because of the ever increasing demands being accommodated on limited land resources, making remodeling or reconstruction, inevitable. The disposal of such huge amounts will often be countered with questions regarding expenses and the location in which to dispose them off.

This problem had its first impact in the 1950s immediately after the world war when several European nations were left with colossal amounts of debris. The problem with finding locations for disposing of it was severe and after expending all their resources on war, several nations were left with the realization that they were going to face a dearth of materials sooner than later [3]. The desperation to find a way out of this situation catapulted them into researching the recycling of CDW [4-7].

Earlier limited to just the recycling of cement and concrete blocks, this research was later extended to other materials because of the rising importance of sustainability in the construction industry [8-9]. It was realized that basic materials like cement cause more environmental damage than expected (energy required & $CO_2$ emissions) and so their replacement became a priority. This was achieved to some extentwith some other industrial by-products like fly ash and slag, and so investigations were launched to see whether these materials complemented the aggregates and enhanced their performance [9]. Now the current areas of research lie primarily in enhancing the characteristics of these aggregates through processing techniques, and studying the multi-phase relations of these aggregates with different replacements to optimize the idealization of properties [10].

An attempt has been made by the National Institute of Technology, Warangal, to use the CDW produced recycled concrete aggregates in certain value added applications, which would normally have used natural aggregates procured from local markets in their making. The various stages and the information about the process employed apart from the results of its production are mentioned in various sections of this paper.

## 2.0 CDW AND CONCRETE RUBBLE

Concrete, as we know, is a 3 phase material with cement paste, aggregates and voids. The cement paste phase, being hydrated, has no significant use other than land filling as waste, possibly as a finer fill in certain cases. In that context, the aggregate phase has a greater demand since it is the inert part and significant chemical interaction would not have taken place. This provides an opportunity for its re-use in different applications. Also, the fact that aggregates occupy 60-75% of concrete (IS mix proportions) makes this seem worth trying from an economics perspective. The applications, as of today, vary from insignificant ones like sub-base, to

*Corresponding author
Tel : +91 9866906307
E-mail : sumanthreddy018@gmail.com

Case Study

INTERNATIONAL
Journal *of* 3R' s

Vol. 4, No. 4, 2013, 652-660

# REDEVELOPMENT OF A DEFUNCT POWER PLANT INTO A CENTRAL BUSINESS DISTRICT– A FEASIBILTY STUDY

Bani Amrit Kaur[a*], Ketan Mutha[a], Tawish Tayal[a] and Anand D. Gosavi[a]

[a]National Institute of Construction Management and Research (NICMAR), Pune - 411045, Maharashtra, India

A B S T R A C T

Urbanization and the ever increasing scarcity of land in urban areas create a need to rejuvenate the city centers. This makes it necessary for us to explore the possibilities of newer development in the city centers. Industrial plots lying underutilized in the central areas of Tier I cities as a result of change in policies – decongestion, decommissioning and obsolesce of technology, have huge potential to be regenerated. The present feasibility study looks into the details of regeneration of the Indraprastha Power Plant located in central New Delhi, India. Possible uses were analyzed and the most suitable proposal was detailed. A condition survey of the building to establish existing structural status and its suitability to regeneration was carried out. Technical and financial feasibilities were done for the proposed use. The focus of the present research has been on developing a practical methodology assessing an economic value on the benefits that are produced by redevelopment and adaptive reuse.

K e y w o r d s

Redevelopment, Adaptive reuse, Condition survey, Feasibility study, Central Business District (CBD)

## 1.0 INTRODUCTION

A city's sustainable development should not simply focus on external demolition and construction, but should also stress on manifesting internal local values and identities, and further creating renaissance and competitiveness in local development. Consequently, the core of district revitalization and regeneration should reveal provincialism and continuity and stimulate new life and competitiveness.

Changing operational functions or complete closure affects the appropriate management directives for facilities. Mostly, facilities are obsolete because of factors including age, design, location, or maintenance costs to name a few. Combinations of these factors lead to facilities becoming obsolete, but it is often the older facilities that are targeted for decommissioning. This is important from a sociological perspective because many older facilities are located in geographic areas that are heavily populated or near commercial districts. The facilities might have been originally constructed on the edge of a growing city but now are in the middle of an urban area. Many of these older facilities have operated for decades and there has been plenty of time for city sprawls to engulf them [1]. At the same time, the proximity of the obsolete or marginal facility to the urban center can make it a candidate for adaptive reuse. The term 'adaptive reuse' has been applied to situations where a facility or building is obsolete from the perspective of its original purpose, but can be modified for a new function. If the facility has the right combination of location, architectural scale, and aesthetic or historical appeal, it can be an extremely attractive prospect for adaptive reuses that are oriented towards the general public. In some cases, adaptive reuse of old industrial facilities is being incorporated into urban renewal efforts. The opportunity to reuse obsolete facilities in the urban core supports sustainability and smart growth initiatives designed to focus redevelopment in inner cities, in an effort to decrease urban sprawls. External parties that could be interested in an obsolete facility include economic development groups, museum committees, businesses, developers, or government entities such as municipalities.

The value of any project needs to be justified, to check whether the project is feasible or not. 'Value' expresses three main forms: cost, function and aesthetic. By taking up regeneration / adaptive reuse schemes we can achieve a much higher value by increasing function and aesthetics at a very low cost. This leads to providing state-of-the-art facilities within cost budgets [2-4]. Adaptive reuse development refers to the conversion of old buildings and site improvements into new uses while retaining historic elements. A successful conversion integrates site and building characteristics with market-based use. This highest and best use assessment of an adaptive reuse development considers the financial and technical feasibility of the new use with the structure [5].

As suitable land becomes a scarce commodity for development, and escalating energy costs add to modern transportation problems, urban infill development plays an increasing role in sustainable build environments. Adaptive reuse development of physically deteriorated buildings and functionally obsolete uses provides a solution for urban revitalization and suburban sprawl. This highest and best use study embodies a two staged model for the efficient utilization of both, land and building lifecycles, of a sizeable and well maintained former power plant campus.

*Corresponding author
Tel : +91 9011632545
E-mail : baniamritkaur@gmail.com