PACE-2021
International Congress on the
Phenomenological Aspects of Civil Engineering
Research Article 20-23 June 2021

# Review on Flaws in Concrete and its Structural Performance

Waleed Ahmad*,[1], Sana Gul[2], Majid Ali[3]
[1]Capital University of Science & Technology, Islamabad, Pakistan
[2]National University of Science & Technology, Islamabad, Pakistan
[3]Capital University of Science & Technology, Islamabad, Pakistan
Corresponding Author E-mail:ahmadwaleed367@gmail.com Corresponding Author ORCID: 0000-0002-2252-4476

**Keywords**

*Concrete, Compressive & tensile strengths, Density, Early-age Cracking of concrete, Mechanical properties, Sustainable concrete.*

**Abstract**

This paper reviews the flaws in concrete and its structural performance under different conditions. Still, there is a need to study the flaws in concrete and provide a sustainable solution to avoid or at least reduce the failures as much as possible. Different researches including both old and the recent were studied to come to a point where flaws in concrete are completely known and its structural
performance under different situations is specified. There are some common problems in concrete i.e. loss of density and cracking. These problems are interlinked with each other. As the concrete gets dried, density of concrete decreases because of the increased void spaces with the removal of water from the concrete with time. The loss of density initiates the cracking from the core. Other common problems like crazing, curling, scaling and spalling, blisters, etc. are the results of the improper mix proportions and the inefficient handling and placing. From the literature study, it is concluded that the denser concrete with high strength and a smaller number of voids and porosity show better structural performance as compared to the concrete with greater number of voids. The study on the micro-structure of the concrete is necessary to investigate the reaction of concrete with by-products when placed. This study determines the future directions for exploring the techniques to cater the flaws in concrete.

## 1. Introduction

Concrete plays an important role in almost every construction without which the construction is not possible as per different modern construction studies. Almost every structure is supported on reinforcement and the concrete combined strength. When talk about strength, the economy on the other side can never be ignored. On average about 33%-40% of the total cost is spent on concrete. Based on these two major aspects of materials in construction, it is of critical importance to study the concrete properties under different circumstances. The most important constituent of the concrete is cement in regards to both strength and the economy. Concrete is an important construction material which is widely used in the buildings, drains (culverts, etc.), roads, runways, bridges, etc. Concrete is the mixture of different materials i.e. cement, water, fine aggregate (sand), and course aggregate (gravel, rock, etc.). Concrete is formed by the reaction of cement with mainly water to form such a hard mix which binds or holds the aggregates together in a sound solid material which have many applications. Concrete is used in construction due to its effective compressive strength behavior. In construction, the compressive strength of concrete varies from 2500 (17 MPa) psi to 4000 psi (28 MPa) for residential concrete. Some applications of construction also use concrete having compressive strength up to 10,000 psi (70 MPa).

## 2. Research Methodology

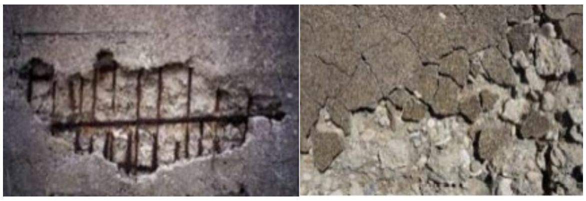
Different research articles including both the old and the new articles on the concrete performance and on its different aspects will be studied thoroughly. Based on the conclusions of the studied articles, a comparative study will be done. After compiling all the outcomes of the articles, recommendations will be provided. This is how, flaws in concrete and its structural performance will be reviewed.

## 3. Literature Review

### 3.1. Flaws in Concrete

Number of structures fail due to flaws in concrete. Most importantly, concrete is bad in taking tensile Author et all. PACE 2021- Ataturk University, Engineering Faculty, Department of Civil Engineering, Erzurum, 25030, TURKEY 20-23 June 2021 2 stresses since it's tensile strength is approximately 10% of its compressive strength. And this tensile strength is unreliable when the water is removed from the concrete and concrete losses strength initiating the shrinkage cracks. There are many defects in concrete such as cracking, delamination, dusting, efflorescence, crazing, curling, dusting, blisters, chemically reactive nature, scaling and spalling. Most of the concrete structure fails when concrete loses its strength due to the removal of water which creates voids causing decrease in density of concrete. The dehydration time depends on the rate of drying.
(Xi Chen & Farhad Ansari, 1999) found that the concrete failure is caused by the negative pressure due to the accumulation of the corrosion by-products at the interface between the reinforcement and the concrete as well as the expansion of concrete which causes it to lose density.

(a) Cracking b) Seggregation



(c) Spalling d) Effloroscence

Figure 1. Concrete cracking type

### 3.2. Typical Flaws in Concrete

One of the major and the most common problems in concrete structures is the chemical degradation of concrete. In hydrated concrete mix, the chemical changes are mostly caused by the sulfate attack. But in structures like sewer pipes, culvert, silos, etc. acid attack can be the issue. Bensted, J., Rbrough, A., & Page, M. M. (2007) presented a brief overview of one of the flaws in concrete or problem to a hardened cement matrix in facing different chemical and microbiological reactions. It was concluded that concrete containing high alumina cements (made with calcium aluminate cements) was used in France when the need to resist sulfate attacks arose since these cements have high resistance towards sulfate attacks because of the presence of alumina cement. But later, it was found that this on the other side led to reduce its own mechanical properties by the gradual phase transformation of the hydrated cement. This is why, the use of alumina cements was prohibited on structural applications in the United Kingdom in 1975.

The density has a great influence on the mechanical properties of concrete. A denser concrete has higher strength and a smaller number of voids and porosity. In low density concrete, due to the presence of bigger size voids, it becomes permeable to water and causes loss in density when water, with time due to the drying, is removed. In this way, absorption of water will be higher and difficult to expect better quality concrete (Shohana Iffat, 2015). The packing density of concrete decreases with time as the concrete gets dried. This is due to the removal of water on drying which gives rise to the voids. It was found, by making comparison between the density of concrete mixes determined by wet packing method and the dry packing method, that in the entire particle system of concrete mix, the volume of voids to volume of solids is smaller, the packing density is higher, and the filling effect of fine cementitious materials is comparatively better under wet condition (Leo Gu Li & Albert Kwan, 2013). (Md. Safiuddin et. al., 2018), in their research regarding the typical problems in concrete, concluded that there is still no permanent solution to the early age cracking flaw in concrete. But most of the problem can be resolved by undergoing good onsite construction practices by providing the labours good skills through proper training. In addition, the possible remedial measures to minimize the occurrence of early-age cracks in concrete have been thoroughly discussed. Early-age cracks in concrete can occur in different forms. Different perspectives by researchers on classifying the types of early-age crack in concrete have been presented in this paper. Several researchers have classified cracks based on their causes, such as drying shrinkage and settlement cracks, while others have categorized them based on their characteristics, such as random, map, transverse, longitudinal, and corner cracks. The factors influencing the early-age cracking in concrete were categorized based on design process, materials and mix parameters, construction procedures, and environmental and external loading conditions. The modelling tools available to simulate the early-age cracking in concrete have been grouped based on thermal, mechanical, chemical, and hygroscopic criteria.

### 3.3. Structural Performance

Mohamed S. Issa (2010) studied the structural performance of concrete by undergoing different tests on prepared samples, i.e. cubes, cylinders, and simply supported beams (under monotonically increasing load). In this research, titanium dioxide TiO2 was used as an additive. To deeply study the structural behaviour of concrete, 3 replacement levels mix (i.e. 2% TiO2, 4% TiO2 and 6% TiO2) for each test were prepared to make comparison with the reference concrete mix having 0% TiO2. But to examine the effect of TiO2 on the structural performance of concrete as a structural element, two beams (one with 0%TiO2 & other 3%TiO2) were put in comparison after testing under monotonically increasing load. After testing, the load deflection graph showed that the beam B0 has a stiffer response since the failure was shear as the crack was diagonal towards one of the supports. Whereas, in beam B3, the failure was flexural as the crack was vertical initially and went inclined with propagation of the crack. The mechanical properties of the beam B3 were slightly better for the yielding load (180KN for B0 and 185KN for B3) and showed remarkably better response at maximum load (255KN for B0 and 260KN for B3). Similarly, great results were obtained in displacements as B0 due to its stiffer response showed displacement of 0.997 cm at maximum load and 1.64 cm at complete failure. Whereas, beam B3 showed displacement of 2.68 cm at maximum load and 3.65 cm at complete failure. It was concluded that, for all replacement levels (i.e. 2,4 & 6% of the weight of cement) of TiO2, compressive strength and split tensile strength for concrete is higher than that of concrete without additive though 2% showed the maximum increase for both the compressive and split tensile strength. And the enhancement level decreases with the increase in the content of TiO2 additive.

Sustainable concrete is also termed as “Green concrete”. Mueller H. S., et al. (2017) put their efforts in introducing the design, material properties and performance of sustainable concrete. In this research, the sustainability potential of the index building material is introduced including the prediction of the reduced-cement concrete service life by applying different probability methods. The composition and the performance of the reduced-cement concretes was presented in this research. It was concluded that the reduced-cement concretes/green concretes or sustainable concretes can be prepared by upgrading or even keeping the performance of the concrete in regards to its mechanical properties (mainly its compressive strength) and also by minimizing the cement content without compromising the strength. Durability should also be kept in considerations for the evaluation of the concrete sustainability potential.

Xiangchao Zeng & Hongfa Yu (2020) worked on the new kind of structural concrete and reviewed the experimental results of the basic magnesium sulphate concrete. They proposed that there is no systemic research on the properties of BMS which restricted the use and the production of BMS concrete. The flexural performance and shear behaviour, the compressive behaviour as well as seismic behaviour of BMS concrete, for beams, columns and the columnbeam joints respectively, were introduced. For BMS concrete elements, the bearing capacity determining equations of beams and eccentric compressive columns were modified. Higher value of cracking moment and flexural performance of the elements of BMS concrete is observed. Due to the axial compression ratio of the joints (column-beam), the seismic behaviour of the BMS concrete column-beam joints was found to be affected.

These days HPC (high performance concrete) and UHPC (ultra-high-performance concrete) are used in many places where there is higher demand of concrete strength. E. H. Kadri, S. Aggoun, S. Kenai, and A. Kaci (2012) investigated the performance of concrete element with the use of silica fume (as an admixture) comparative to the low water/cement ratio with a naphthalene sulfonate superplasticizer. It was concluded that concretes having silica fume admixture show increase in the compressive strength of the concrete more by reducing the water/cement ratio than increasing the silica fume content/replacement level.

### 3.4. Remedial Measures to Improve Concrete Behavior

The remedial measures to minimize the early-age cracking problem have been divided into two main categories, namely materials and design based remedial methods, and construction based remedial methods. The materials and design based remedial methods focus on constituent materials, concrete mix design and structural design, while the curing practice, placing sequence and environmental conditions, vibration, cooling method, and formwork are highlighted in construction based remedial measures (Md. Safiuddin et. al., 2018).

### 4. Conclusion

After the detailed review on the flaws in concrete and its structure performance, it has been concluded that there are various flaws in concrete which occur due to number of factors such as concrete mixing, its proportions, interlocking between concrete and reinforcement, placing sequence and environment conditions, etc. To overcome these problems, sustainable concrete mix design and concrete preparation techniques must be introduced to reduce the loss and achieve maximum output.

## Declaration of Conflict of Interests

The authors declare that there is no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## References

[1.] Chen, X., & Ansari, F. (1999). Fiber Optic Stress Wave Sensor for Detection of Internal Flaws in Concrete Structures. Journal of Intelligent Material Systems and Structures, 10(4), 274-279.

[2.] Page, C. L., & Page, M. M. (2007). Durability of Concrete and Cement Composites. Cambridge: Elsevier.

[3.] Iffat, S. (2015). Relation Between Density and Compressive. Concrete Research Letters, 6(4).

[4.] Li, G. L. & Kwan, A., (2013) Flaws in Concrete

[5.] Safiuddin, M., Kaish, A. A., Woon, C. O., & Raman, S. N. (2018). Early-Age Cracking in Concrete: Causes, Consequences, Remedial Measures, and Recommendations. 1730.

[6.] Issa, M. S. (2010). Structural Performance and Characteristics of Concrete Containing Micro-Tio2 Particles.

[7.] Mueller, H. S., Haist, M., Moffat, J. S., & Vogel, M. (2017). Design, Material Properties and Structural Performance of Sustainable Concrete. Sustainable Civil Engineering Structures and Construction Materials.

[8.] Zeng, X., & Yu, H. (2020). Review of Studies on Structural Performance of Basic Magnesium Sulfate Cement Concrete in China (2014 – 2019). KSCE Journal of Civil Engineering, 1524-1530.

[9.] Kadri, E. H., Aggoun, S., Kenai, S., & Kaci, A. (2012). The Compressive Strength of High-Performance Concrete and Ultrahigh-Performance. Advances in Materials Science and Engineering.

[10.] Safiuddin, M., Kaish, A. A., Woon, C. O., & Raman, S. N. (2018). Early-Age Cracking in Concrete: Causes, Consequences, Remedial Measures, and Recommendations. 1730