Effect of Air voids in Fresh and Hardening properties of Concrete

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ABSTRACT

The introduction of air into concrete mixes has some different effects on the properties of both the fresh and the hardened concrete. In fresh concrete, the tiny air bubbles act as a lubricant in the mix which improves its workability and increases its slump. Also, in a sense, the bubbles function as a third aggregate. Because of their small size, the bubbles act as fines, thereby cutting down the amount of sand needed. Because air entrainment affords increased slump in same time it is possible to decrease the amount of water to get higher strengths without affecting workability. The requested parameters based on the technical specifications of concrete in some of cases are oriented in percent of air voids in concrete and in same time the compression strength of concrete.

In this paper using the experiments and requested parameters we can analyze the relationship between the percent of air voids 6% and compression strength of concrete class C 35/45.

Keywords: Concrete, Air Entrainment; voids; properties of fresh concrete; compression strength;

INTRODUCTION

Air entrainment is a necessary component of concrete mixtures exposed to freezing and thawing cycles. Due to changing materials, conditions of mixing, and methods of placing concrete, achieving target air contents requires attention at the design, specification, and construction stages. Entrained air is produced during mechanical mixing of concrete that contains an air-entraining admixture. The shearing action of mixer blades continuously breaks up the air into a fine system of bubbles. Air-entraining admixtures stabilize these air bubbles. The materials used to produce concrete according the technical requests, supplementary cementitious materials, chemical admixtures, aggregates, and mixing water–can have a significant effect on air content. A discussion of the qualitative effects of these materials on the trends in air content is summarizes in effect of fine particles and chemical admixture in properties of concrete.

Air bubbles are introduced to reduce (but not eliminate) the pressure generated by zones or shells of protected cement paste. Though larger voids protect a larger shell of paste, shell thickness is about the same for all void sizes and shapes. A finer gradation of voids, therefore, gives more protection for a given amount of air.by freezing cycles only in hardened cement paste. They have no effect on the durability of aggregates.

1. AIR ENTRAINMENT SYSTEM AND MATERIALS

The air should be considered as a fifth ingredient when proportioning the mix. Air entraining admixtures or agents is used to produce a stable system of discrete air voids in concrete, termed “entrained air.” Non-air-entrained (left side) and properly air-entrained concretes (right side), presented in fig.1.

Fig.1-Comparison the non-entrained (left side)and air –entrained (right side)

The volume of air for optimum frost protection is about 9% by volume of the mortar. The easiest quantity to measure in the field is the amount of air as a percentage of concrete volume. The air content should be in the 4 to 8% range for good frost protection. Some air is naturally entrained in the cement paste, therefore air-entraining admixtures increase the air voids 3 to 4% by volume of concrete. Air-entraining admixtures cause the mixing water to foam resulting in literally millions of tiny air bubbles to be uniformly spaced throughout the paste. These voids are not visible with the naked eye, but are observable with a microscope. The spacing of the voids is a critical measure of the effectiveness of the admixture. Also, small voids do not easily fill with water even when the concrete is saturated.

Using the chemical admixture it’s the way to increase air content and decrease spacing factors. Therefore, the addition of fines into the mix will reduce the air content. The use of other admixtures can affect the air-entraining potential of surface-active agents. Low cement content concretes entrain more air than do rich mixtures. In addition, low w/c ratio mixes entrain less air than do concretes with high w/c ratios.

Air-entraining agents contain surface-active agents which concentrate at the airwater interface, lower the surface tension so that bubbles can form more readily, and stabilize the bubbles once they are formed. Surface-active agents are molecules, which at one end have chemical groups that tend to dissolve in water (hydrophilic group), and which at the other end have groups that are repelled by water (hydrophobic group). The molecules tend to align at the interface with their hydrophilic groups in the water and the hydrophobic groups in air at solid-water interface, when special directive forces exist on the solid surface. Surface-active molecules are specially adsorbed with the hydrophilic group bound to the solid and the hydrophobic group oriented towards the water. Air-entraining admixtures are thus closely related to synthetic detergents, although the foaming capacity of the latter is only a side effect of other “surface-active” properties.

2. INFLUENCE OF AİR VOİDS ON THE MİCROSTRUCTURE AND PROPERTİES OF CONCRETE

Air voids are penetrable, but because they appear isolated in the microstructure and do not form a continuous flow channel, they are often assumed to make little or no contribution to the transport properties of concrete. Thus, air voids are treated as inert inclusions similar to aggregate particles. However, concrete contains 70% aggregate and all the air voids reside in the cement paste. Thus, a small amount of air entrainment drastically changes the microstructure, in particular the pore structure of concrete. This in turn may have a significant effect on the properties of the hardened concrete.

The aim of this study is to carry out a systematic investigation into the influence of entrained air voids on the properties of concrete in fresh and hardening state with a range of air contents (3-6% vol.), w/c ratios (0.35, 0.40), curing ages (3,7, 28 and 56 days), and different curing conditions (field and laboratory). It was found that air voids increases the heterogeneity of the microstructure by the parameters of properties of the concrete.

2.1. Effect of Porosity in Strength of Concrete

The fundamental relationship between porosity and strength of concrete is on the function of contents of concrete: aggregate; cement paste matrix and the interfacial zone between the matrix and coarse aggregate. Also the water-cement ratio is important in determining the porosity in strength of concrete. For simple homogenous materials the relationship can be described by expression (1).

$$S=S_0 \text{ x } e^{-kp} \quad (1)$$

Where: S- Strength of the material which has a given porosity p

S_0 -Intrinsic strength at zero porosity

k-constant

2.2. Factors Affecting Air Entrainment in Concrete

Many factors affect performance of Concrete in different several conditions, in this case we will focused on the air entrainment process, and the quality of air void system in concrete. Development of the air system is a complex process that has been studied for decades and is still not fully understood. The following factors affecting this process:

- Cement; Supplementary Cementitious Materials; Admixtures; Aggregate; Water
- Concrete Workability and Slump
- Mixing Procedures
- Transport, Construction Techniques, and Field Conditions

3. EXPERIMENTAL PROGRAM

From different concrete positions in structure, more important in this study will be position: Foundation Walls, Footings, with requested technical parameters:

Minimum Compressive Strength: 35 MPa at 28 days.

Maximum Water-Cementitious Materials Ratio: 0.40.

Slump Limit: s=200 mm for concrete with verified slump of 50 to 100 mm before adding high-range water-reducing admixture or plasticizing admixture, plus or minus 25 mm.

Air Content: 6 percent, plus or minus 1.5 percent at point of delivery for 20 mm nominal maximum aggregate size. Based on the requests the first Mix Design is done (see the chart 1), using all the parameters for local used materials: Aggregates; Cement; water; chemical admixtures.

3.1. Concrete Mix Design submittal form-preliminary tests

Concrete Strength (Class): 35 Mpa with 0.40W/C Ratio BMix 35
Positions: Foundation Walls, footing

Design and requested parameters of Mix Design

Density of Concrete	2380 kg/m^3
Strength of Concrete	45 MPa
Air	6 %

The request for Mix Design is proportioned to achieve

f´cr = f´c + 8.3MPa

Mix Design and amount of constitutive materials, are presented in Table 1.

Table 1.-Mix Design”1”

materials	type/ source	specific gravity	mass (kg)	absolute vol. (m^3)
Cement	Cem I/52.5	3.15	390	0.124
Fine Aggregate	0/4	2.65	835	0.315
Course Aggregate	4/32	2.69	1000	0.372
Water		1.0	155	0.155
Air		0		0.06
Other				
			2384	1.0 m^3
	Total			

admixtures	manufacturer	dosage (metric)
Air Entraining Agent	Mapei- Mapeplast PT1	100gr/100 kgC
High Range Water Reducer	Mapei- Dynamon SX32	1.0kg/100kgC

Water/Cementitious Material= 0.40

Requested parameters for fresh concrete:
Slump before HRWR -150mm
Slump after HRWR - 200 mm

Using all the requested parameters and properties of local materials the preliminary Laboratory Test of concrete, with adequate data are presented in table 2.

Table 2-Laboratory Test Data-Mix Design “1”

Compressive strength	age (days)	mix #1	mix #2	mix #3
	3	21.40MPa	23.70 MPa	23.20 MPa
	7	29.80MPa	29.20 MPa	30.20MPa
	28	37.60MPa	38.20MPa	37.70MPa

Air content%	6.2 %	6.8 %	6.8 %

All the parameters are approval in general, but during the concreting in place results that the requested parameters are not fulfilling. The analyzing of all the parameters results with question:

why the results not fulfilling the requested parameters?

Results that the effect of small particles ≤0.125 mm,is to low, and the improvement of Mix Design is presented in Table 3. The focus was in changed the amount the cement , but the ratio W/C+M, it was same.

Design and requested parameters of Mix Design are same.

Density of the concrete	2370 kg/m^3
Strength of concrete	45 MPa
Air	6 %

If trial mixes are used the Mix Design is proportioned to achieve

$$f'cr = f'c + 8.3MPa$$

Mix Design and amount of constitutive materials, are presented in Table 3.

Table 3.Mix Design “2”

materials	type/ source	specific gravity	mass (kg)	absolute vol. (m^3)
Cement	Cem I/52.5	3.10	436	0.141
Fine Aggregate	0/4	2.67	792	0.287
Course Aggregate	4/22	2.74	968	0.350
Water		1.0	174	0.174
Air		0		0.06
Other				
Total			2376	1.0 m^3

Admixtures	manufacturer	dosage (metric)
Air Entraining Agent	Mapei- Mapeplast PT1	100gr/100 kgC
High Range Water Reducer	Mapei- Dynamon SX32	1.0kg/100kgC

Water/Cementitious Material Ratio =0.40
Slump before HRWR150 mm
Slump after HRWR 200 mm

The concrete in place results very favor and the slump was in requested interval and fulfill the parameters. The parameter of temperature was in favor interval. The Laboratory tests are presented in Table 4.

Table 4- Laboratory Test Data - Mix Design"2"

Compressive strength	age (days)	mix #1	mix #2	mix #3
	3	24.40MPa	26.70 MPa	28.20 MPa
	7	34.0 MPa	32.5 MPa	33.0MPa
	28	45.0 MPa	44.20MPa	45.8MPa
Air content%		5.2 %	5.4 %	

4. RESULTS AND DİSCUSSİONS

4.1. Effect of Air Void Content and Concrete Durability

The requested parameters in air voids 6 % it was result in first Mix Design, provides the satisfactory freeze-thaw protection, but is in direct correlations with other parameters , and in this study case was directly in relations with casting place of concrete. The proposal mix design it was not possible to realize the casting of concrete.

4.1. Fresh Concrete Properties

Table 5-Properties of fresh concrete "Mix Design 1"

MixDesign"1"	**Tem .^{0}C**	**Slump mm**	**Bulk density Kg/m^3**	**Air voids %**	**Pump ability**
1	**24.3**	**200**	**2350**	**6.2**	**no**
2	**24.3**	**200**	**2350**	**6.2**	**no**
3	**24.2**	**200**	**2360**	**6.2**	**no**
4	**24.0**	**200**	**2370**	**6.2**	**no**
5	**24.0**	**200**	**2380**	**6.0**	**no**
6	**24.0**	**190**	**2380**	**6.0**	**no**
7	**24.0**	**190**	**2380**	**6.0**	**no**
8	**24.0**	**190**	**2380**	**6.0**	**no**
9	**24.2**	**190**	**2370**	**6.0**	**no**
10	**24.2**	**190**	**2370**	**5.9**	**no**
11	**24.2**	**190**	**2370**	**5.9**	**no**
12	**24.0**	**190**	**2370**	**5.9**	**no**

Table 5 presents slump, unit weight, and air content of all fresh concrete mixtures studied in first step, and also the cast in place of concrete. It can be seenfrom the table that the slumps of the mixtures with *w*/*c*=0.40 , according to the Mix Design parameters was 190–200 mm; and the air voids was from 6.0-6.2 %. The unit weight of concrete mixtures generally ranged from 2350 to 2380 kg/m^3.

But the cast in place of concrete it was not possible and the requested was to change the parameters. The changed parameters are focused in change the Mix Design, but on the particle less than 0.125. This conditions we fulfilled using the more amount of cement according to the Mix Design "6" and the result are presented in table 6.

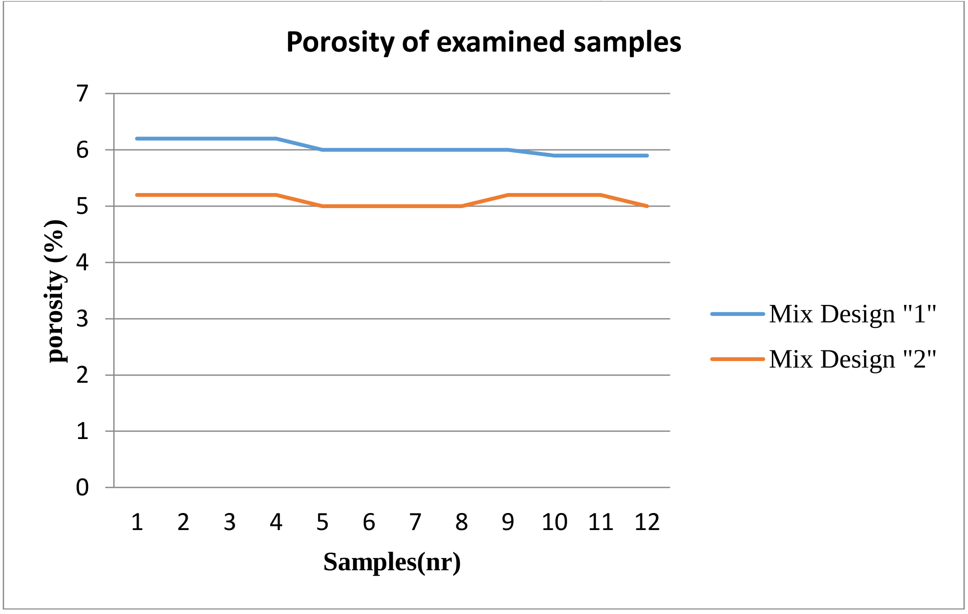
Table 6-Properties of fresh concrete ”Mix Design 2”

MixDesign”2”	**Tem. ^{0}C**	**Slump mm**	**Bulk density Kg/m^3**	**Air voids %**	**Pump ability**
1	**21.0**	**175**	**2350**	**5.2**	**yes**
2	**21.0**	**175**	**2350**	**5.2**	**yes**
3	**21.0**	**175**	**2340**	**5.2**	**yes**
4	**21.5**	**150**	**2350**	**5.2**	**yes**
5	**21.0**	**150**	**2360**	**5.0**	**yes**
6	**21.0**	**150**	**2360**	**5.0**	**yes**
7	**21.0**	**150**	**2360**	**5.0**	**yes**
8	**21.0**	**150**	**2360**	**5.0**	**yes**
9	**20.5**	**150**	**2360**	**5.2**	**yes**
10	**20.5**	**150**	**2350**	**5.2**	**yes**
11	**20.5**	**150**	**2360**	**5.2**	**yes**
12	**20.5**	**150**	**2360**	**5.0**	**yes**

Table 6 presents all the parameters and comparing with results from Mix Design “1” the main effect is presented during the cast in place of concrete, and based on that to create the chance to verify the Properties of Hardening concrete for final approval of mix Design.

To compare the requested parameters of air voids for different Mix Designs is presented in chart 3.

Chart 3-Compare the Mix Design parameters



4.2.Hardened Concrete Properties

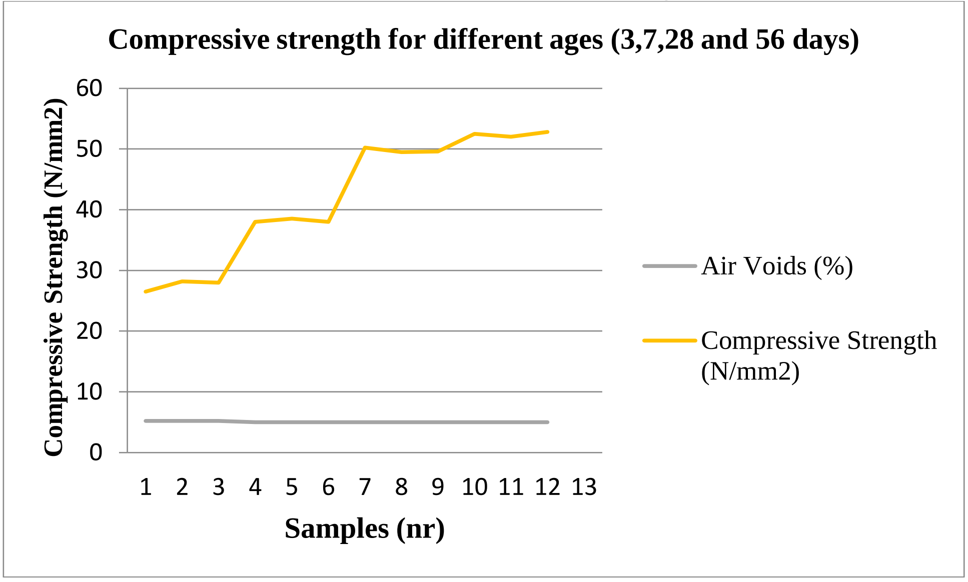
The process of hardening for approval Mix Design , is done according to the EN 206-1, for different age : 3, 7, 28 and 56days, for final approval. The results are presented in table7.

Table 7-Properties of hardened concrete ”Mix Design 2”

MixDesign”2”	**Age days**	**Bulk density Kg/m³**	**Air voids %**	**Compressive Strength N/mm²**
1	**3**	**2350**	**5.2**	**26.5**
2	**3**	**2350**	**5.2**	**28.2**
3	**3**	**2340**	**5.2**	**28.0**
4	**7**	**2350**	**5.2**	**38.0**
5	**7**	**2360**	**5.0**	**38.5**
6	**7**	**2360**	**5.0**	**38.0**
7	**28**	**2360**	**5.0**	**50.2**
8	**28**	**2360**	**5.0**	**49.5**
9	**28**	**2360**	**5.0**	**49.6**
10	**56**	**2370**	**5.0**	**52.5**
11	**56**	**2370**	**5.0**	**52.0**
12	**56**	**2380**	**5.0**	**52.8**

The approval Mix Design “2” based on the properties of fresh concrete is verify on the hardening properties of concrete, presented in different ages (3, 7. 28 and 56 days), based on the results, presented in Chart 4.

Chart 4- Parameters of Mix Design”2”



CONCLUSIONS

Based on the limited data available, the following preliminary conclusions can be presented:

1. **Effective air void content of Mix Designs appears to be a function of four factors for a constant paste amount and character:**

- compactive effort, aggregate small particle amount, and aggregate uniformity coefficient.
- Presence of smaller particles is replace using the additional amount of cement
- Effective void content decreases with increasing the smaller particles of aggregate, but not in big difference.
- Increasing amounts of HRWRA are required to maintainconstant workability. As the fines become smaller, admixturedemands increase significantly. Very high admixture contentshad negative effects on concrete properties associated withlarge volumes of entrained air and affecting strength development.

2. **Compressive strength of Mix Designs is on the function of two factors for a constant paste amount and character: effective air void content and gradation fineness modulus.**

- Compressive strength increase with increasing the smaller particles replaced with cement and decreasing just in limits the effective void content.
- Compressive strength increases with increasing aggregate finenessmodulus.

3. **In view of the results of this study, it seems that the current limitation on fines content in aggregates should be revaluated**.

Larger amounts of fines can be incorporated into concrete, either as part of the aggregate itself or as an additive.

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