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# MECHANICAL PROPERTIES OF STRUCTURAL AERATED LIGHTWEIGHT CONCRETE REINFORCED WITH IRON LATHING WASTE

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**Abstract:** Currently, the industry of construction requires finding efficient materials to increase the durability and strength as well as decreasing the concrete structure's total weight. Therefore, an effort was made in this study for examining the impact of adding waste materials such as the iron lathing waste fibers. Iron lathe wastes have been deformed into twisted strips with a width of (4mm) and sieving size of (4.75-10) mm. The experimental investigation has been achieved with the use of four mixes related to light-weight concretes, involving different volumetric ratios of the iron lathing waste fibers as (0%, 1 %, 1.5 %, and 2 %). With the increase in the volume fraction of the lathing waste fibers from 0% to 2%, the results showed that there were a significant increase and improvement in compressive strength, splitting tensile strength, flexural tensile strength, static modulus of elasticity, and dynamic modulus of elasticity by 12%, 67.5%, 134%, 27%, and 26% respectively. This indicates that the iron waste fibers have an important impact in enhancing the mechanical properties of the hardened concrete through the structural change in the concrete matrix.

**Keywords**: *iron lathing waste, lightweight concrete, mechanical properties, strength.*

## 1. Introduction

Weight reduction is a key factor in the development of materials and components for use in many industries. However, lightweight structures need to be light but also safe, durable, and easy to maintain. Structural lightweight concrete has a unit weight density on the order of 1440 to 1840 kg/m$^3$ compared to normal weight concrete with a density in the range of 2240 to 2400 kg/m$^3$. For structural applications, the concrete strength should be greater than 17 MPa. Aerated concrete (AC) can be defined as lightweight, non-combustible cement-based materials, that have been manufactured from a mixture of aluminum powder (paste), gypsum, Portland cement, quick lime, fly ash (or other silica sources) as well as water [1]. AC might be specified as aerated mortar because it does not include coarse aggregate, it's made by inserting air or other gas into a cement paste [2]. Also, AC is a topic of high importance and studied through a lot of researchers recently. Today, using various waste fibers in the concrete was subjected to a rapid increase because of certain reasons like the economic savings in addition to the positive effect on environments. A study conducted by M. Jala [3] examined the mechanical behavior related to the concrete that has been reinforced with the Recycled Steel Fibers (RSF) that is considered as a good

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candidate for non-structural as well as structural applications. To evaluate the characteristics of the fibers as well as determining their efficiency, a few of the preliminary tests have been implemented; the concrete compressive strength has been estimated for various weight ratios regarding the added RSF. Skariah and Mathew [4] handling the properties regarding AC structural walls reinforced with the steel fibers at various percentages according to the volume of the specimen and their effect on compressive strength and density as shown in “Table 1”. The ideal dosage of aluminum powder added for producing foamed concrete with required strength has been indicated to be (1%).

**Table 1.** Compressive strength and densities at different percentage of steel fibers [4]

| Mix no | Steel Fiber (%) | Compressive Strength (MPa) | Density (kg/m3) |
|---|---|---|---|
| 1 | 0 | 15.3 | 1785 |
| 2 | 0.25 | 16.1 | 1877 |
| 3 | 0.5 | 17.8 | 1882 |
| 4 | 0.75 | 14 | 1900 |
| 5 | 1 | 12 | 1896 |

Aghaee and Yazdi [5] examined the mechanical properties of Structural Lightweight Concrete (SLWC) with the use of waste steel wires as reinforcements. Also, the wire percentages in Fiber Reinforced Concretes (FRCs) have been (0%, 0.25%, 0.5% and 0.75%) of the concrete volume. With the use of waste wires, tensile, flexural, as well as impact characteristics of SLWC have been efficiently enhanced. A study conducted by G. Murali, et al., [6] examined the impact of adding materials such as the empty waste tins, soft drink bottle caps, lathe waste as well as the waste steel powder from the workshop at (1%) dosage of the total weight regarding concrete as fibers. The results have been put to comparison with conventional concrete. Also, it has been indicated that the concrete blocks have been incorporated with the steel powder caused an increase in compressive strength by 41.25% in addition to the tensile strength by 40.81%. Z. N. Qureshi, et al., [7] studied the feasibility of using lathe machine scrap with (0%, 1 %, 1.5%, and 2%) of weight in concretes through checking load deflection, splitting tensile strength, compressive strength, as well as flexural strength properties. It was specified that the compressive, split tensile in addition to the flexure strengths regarding concrete were increased through adding lathe machine scrap of (1.5%) by (11.37%, 18% as well as 30%) respectively. Using LightWeight Concretes (LWC) in the constructions helps to decrease the weight of the structures and reduces the risks on the life of humans due to earthquake forces [8-9]. Structural Lightweight Concrete (SLWC) is considered a material of high importance in the construction industry because of the significant advantage of energy conservation by the thermal and sound insulation capabilities. The strength-to-density ratio is very important in design criteria, transportation, and construction costs since the concrete strength decreases with the decrease in the concrete density. Some other studies presented in “Table 2” dealt with the LWC fabrication through the type of materials and the method of production [10]. Based on the previous literature, few studies have addressed the topic of adding the iron lathing waste to the structural LWC. An effort was made in this study for examining the impact of adding iron waste fibers to the structural LWC as an attempt to enhance the strength performance, reducing the damage on the environmental level, as well as the use of waste fibers as a substitute for expensive manufactured steel fibers. The present work adopted the LWC mix design that had been used by A. Abdul Kareem and A. Alfeehan [16]. The mix design gave about (2.19) of a strength-to-density ratio where the strength in (MPa) and the density in ($kN/m^3$).

**Table 2.** Mechanical properties of lightweight [10]

| Author's Name | Type of Material | Compressive Strength (MPa) | Density (kg/m3) |
|---|---|---|---|
| Al-Dhaher [11] | porcelinite aggregate | 13.0 -22.4 | (1400 – 1960) |
| Al-Ani [12] | Porcelinite | 38.5 | 1970 |
| Al-Bayati [13] | Porcelinite | over than 17.0 | less than 2000 |
| Yasar [14] | Scoria | 28-29 | (1850-1860) |
| Chiadb [15] | plastic waste | 29.14-38.47 | (1095 – 1911) |

## 2. Materials

### 2.1. Cement

Ordinary Portland Cement (O.P.C) type I manufactured in Iraq is used in the cast of the specimens through this study according to the Iraqi Specification No. 5/1984 [17].

### 2.2. Fine Aggregate

Ekhaider natural Iraqi sand has been used as fine aggregate in experimental work which is satisfying the requirements of American Standard ASTM C33M-13 [18]. Such sand has been separated by sieving; extra fine sand is used in the LWC mix with maximum size (600) μm.

### 2.3. Silica Fume (SF)

SF has been one of the extremely reactive pozzolanic materials that have been the byproduct of manufacture regarding silicon or Ferrosilicon metal. Also, S.F is a very fine powder with particle size between (1μm-60μm). the used S.F is conformed with ASTM C1240-05 requirements [19].

### 2.4. Superplasticizer

For the production of LWC mixes in this study, high-performance concrete superplasticizer (high range water reducing agent HRWRA) that is commercially referred to as Glenium 51 based on polycarboxylic ether (technology) is used with ASTM C494M-01 [20].

### 2.5. Limestone

A fine limestone powder (LSP) which is locally referred to as (Al-Gubra) according to European federation dedicated to specialist construction chemicals and concrete Systems [21] has been utilized as filler in concrete production to improve fluidity and cohesiveness, avoid the generation of excessive heat, increase the fine powders of cement and filler in the concrete mix, and enhance the segregation resistance.

### 2.6. Aluminum Powder

The air-pores in aerated concrete are usually in the range of (0.1–1) mm in diameter and typically formed by the addition of aluminum powder at (0.2%– 0.5%) (by weight of cement). The chemical reaction of calcium hydroxide and aluminum generates hydrogen gas shown in (1) is associated with large volume changes, resulting in the expansion of the fresh mixture to about twice its original volume [22].

$$2Al+3Ca(OH)2+6H2O \rightarrow 3CaO.\ Al2O3.6H2O+3H2\uparrow \quad (1)$$

### 2.7. Iron Lathing Waste Fibers

To examine the impact regarding twisted iron lathing waste fibers content on the mechanical properties, four values of iron lathing fibers volume fractions (Vf =0%, 1.0%, 1.5%, and 2.0%) were used. The thickness of the iron waste is (0.2mm) and width (4mm). Iron lathing waste was dispersed to the concrete mixture after adding all the solid and liquid components gradually with continuous mixing to overcome the problem of balling. The used materials and concrete mix proportions in this study based on Ref. [16] are presented in "Table 3".

**Table 3.** Lightweight concrete mix [16]

| Material | Quantity kg/ $m^3$ |
|---|---|
| Cement (ordinary Portland cement Type I) | 800 |
| Sand (pass from sieve 600µm) | 800 |
| Silica Fume (8 % of wt. of Cement) | 64 |
| Limestone (95% pass-through sieve 90µmm) | 320 |
| w/c (33% of wt. of cement) | 264 |
| Superplasticizer liter/$m^3$ (6 % of cementitious materials) | 52 |
| Aluminum powder (0.2 % of wt. of cement) | 1.6 |

"Table 4" shows the test results of twisted iron lathing waste. "Plate 1" shows the type of steel lathing waste fibers as a by-product of steel lathing waste from the workshops machines and "Plate 2" shows the testing of iron lathing waste.

**Table 4.** Test results of twisted iron lathing waste

| Fiber Size by sieving (mm) | Yield Stress Fy (MPa) | Ultimate Stress Fu (MPa) | Elongation ΔL% |
|---|---|---|---|
| 4.75-10 | 423 | 537 | 8.1 |

**Plate 1.** Iron lathe waste

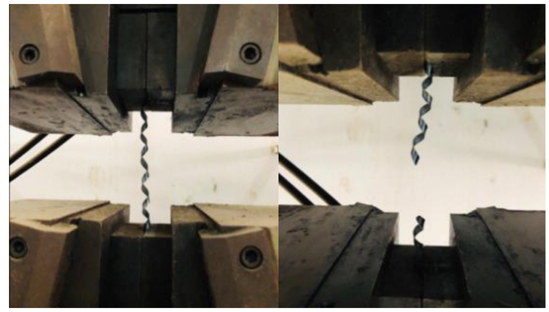

**Plate 2.** Testing of iron lathe waste fiber

## 3. Testing

Four different volumetric ratios (0%, 1%, 1.5%, and 2%) of the iron lathing waste were used in concrete mixtures (M1, M2, M3, and M4) respectively. Three samples of cubes (100×100) mm, cylinders (150×300) mm, cylinders (100×200) mm, and prisms (100×100×500) mm were examined for each mix to measure a certain mechanical property, and the average of the three samples was taken. Overall of 72 specimens (three samples for each test per mix.) were cast to test the compressive strength, static modulus of elasticity, dynamic modulus of elasticity, split tensile strength in addition to the flexural strength. The samples have been taken out from molds following twenty-four hours from casting, also kept in water tank for a period of twenty-eight 28 days. The static and dynamic modulus of elasticity tests is shown in "Plate 3" and "Plate 4" respectively.


**Plate 3.** Static modules of elasticity test

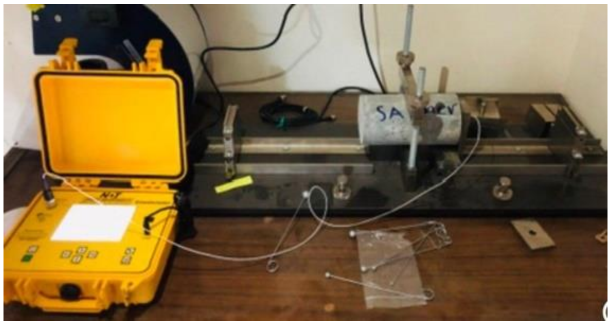

**Plate 4.** Dynamic modules of elasticity test

## 4. Results and Discussions

After the investigation of different parameters for the LWC with lathing waste, the achieved results have been shown in "Table 5". "Plate 5" shows the fresh samples and "Plate 6" shows the hardened samples. The samples under test are shown in the "Plate 7". It can be noticed that increasing the volume fraction of fibers Vf from (0% to 1%, 1.5%, and 2%) resulted in an acquired increase in compressive strength $f'_c$ by (4.4%, 10%, and 11.8%), splitting tensile strength $f_{ct}$ by (22.5%, 55%, and 67.5%), flexural tensile strength $f_r$ by (39.02%, 100%, and 134.15%), static modulus of elasticity $Ec_S$ by (9.76%, 20.12%, and 26.98%), and dynamic modulus of elasticity $Ec_D$ by (8.78%, 19.11%, and 25.82%) respectively. Also, the averages of dry unit weight of the samples for each mix are shown in "Table 6". The effect of iron lathe waste on mechanical properties can be recognized from Figs. 1, 2, 3, and 4.

**Plate 5**. Fresh samples

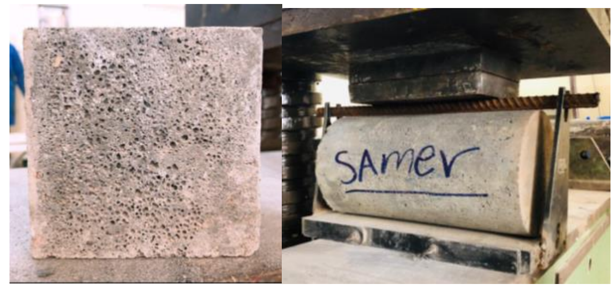


**Plate 6**. Hardened samples

**Plate 7**. Samples testing

It should be noted that the increase in the percentage of iron wastes usually leads to ballings, but the use of superplasticizer by 6% made these ballings within acceptable and controlled limits.

**Table 5.** Results of the mechanical properties

| Mix no | $f'_c$ (MPa) ASTM C39 [23] | $f_{ct}$ (MPa) ASTM C496 [24] | $f_r$ (MPa) ASTM C78 [25] | $Ec_S$ (MPa) ASTM C469 [26] | $Ec_D$ (MPa) ASTM C215 [27] | $\gamma$ (Kg/m$^3$) ASTM C642 [28] |
|---|---|---|---|---|---|---|
| M1 | 34 | 4 | 4.1 | 22020 | 22650 | 1570 |
| M2 | 35.5 | 4.9 | 5.7 | 24170 | 24640 | 1640 |
| M3 | 37.4 | 6.2 | 8.2 | 26450 | 26980 | 1685 |
| M4 | 38 | 6.7 | 9.6 | 27960 | 28500 | 1710 |

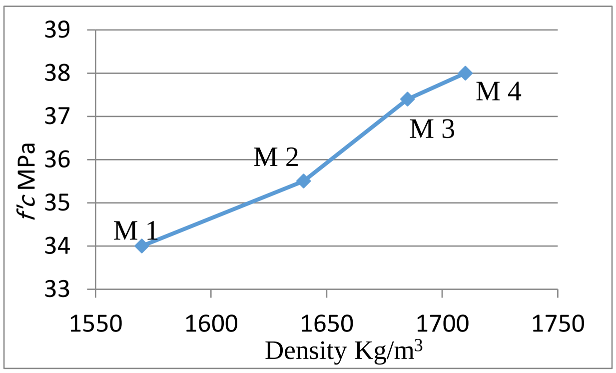


**Figure 1.** Relationship between compressive strength and density for each mix

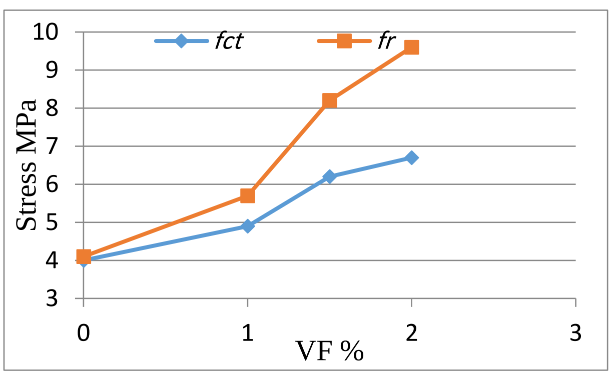


**Figure 2.** Impact of iron lathing waste on splitting tensile strength and flexural strength

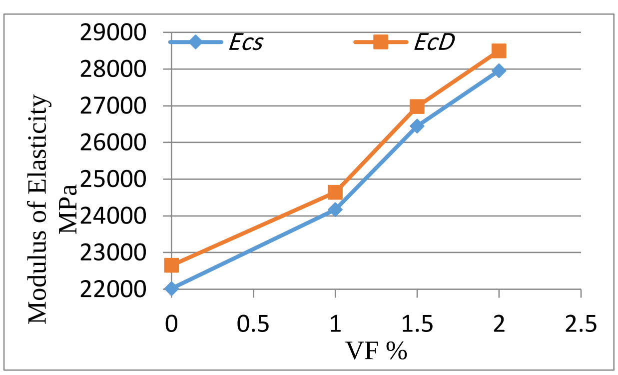


**Figure 3.** Impact of iron lathing waste on static and dynamic modulus of elasticity

## 5. Conclusions

Through the laboratory tests carried out in this study and on the basis of the results obtained, the next conclusions might be reached:

1. Adding iron lathing waste to the LWC mix improved the mechanical properties related to hardened concrete.
2. The static and dynamic modulus of elasticity were increased by (27%) and (26%) respectively, that appearing higher stiffness in the mixes with increasing of iron waste ratio up to 2%.
3. The increasing of iron lathing waste from (0%) to (2%) caused to increase the density of concrete by (8.9%) due to the high density of iron fibers.
4. The results of static and dynamic modulus of elasticity revealed a rapprochement acceptable between destructive and non-destructive tests.
5. The higher percentage of lathing waste fibers (Vf) led to an increase in tensile and flexural strength for the LWC. The role of fibers appeared in holding concrete particles and restriction of propagation of cracks due to absorption regarding a portion of the tension stresses carried via the concrete.
6. Increasing iron lathing waste fibers volumetric ratio up to (2%) made LWC samples more ductile before failure by increasing the compressive strength and splitting tensile strength of concrete by (12%) and (67.5%) respectively. That property is

very important; it makes concrete give warning before failure and prevents sudden collapse.

7. Using iron lathing waste improves the mechanical properties of the lightweight concrete without coarse aggregate, to use it in structural concrete, in addition to the possibility of its use in non-structural concrete.

**Conflict of interest**

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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**Abbreviations**

| | |
|---|---|
| AC | Aerated concrete |
| $Ec_D$ | Dynamic modulus of elasticity |
| $Ec_S$ | Static modulus of elasticity |
| FRC | Fiber reinforced concrete |
| Fu | Ultimate Stress |
| Fy | Yield stress |
| $f'_c$ | Compressive strength |
| $f_{ct}$ | Splitting tensile strength |
| $f_r$ | Flexural strength |
| HRWRA | High range water reducing |
| LSP | Limestone powder |
| LWC | lightweight concrete |
| OPC | Ordinary Portland cement |
| SF | Silica fume |
| SLWC | Structural lightweight concrete |
| Vf | Volume Fraction of Fibers |
| ɣ | Density |
| ∆L | Elongation |

## 6. References

1. Bonakdar, F. Babbitt, B. Mobasher. (2013). *"Physical and mechanical characterization of Fiber-Reinforced Aerated Concrete (FRAC)*". Cement & Concrete Composites, Elsevier, Vol. 3. pp. 82–91.
2. Skoyles, E.R., Bardhan-Roy, K. (1979) *"A Comparative Study of Economics of Lightweight Structural Concrete Floor Slabs in Building*". The International Journal of Lightweight Concrete, Vol.1, No.1, pp. 9-27.
3. M. Jala. (2012) *"Compressive Strength Enhancement of Concrete Reinforced by Waste Steel Fibers Utilizing Nano* $SiO_2$*,"* Middle East Journal of Scientific Research, vol. 12, pp. 382-391.
4. B, Skariah and P. Mathew (2018). *"Characteristics of Fiber Reinforced Lightweight Concrete Wall Panel*". International Research Journal of Engineering and Technology (IRJET), V.5, pp. 3549-3555.
5. K. Aghaee and M. A. Yazdi, (2014) "*Waste Steel Wires Modified Structural Lightweight Concrete,*" Materials Research, vol. 17, pp. 958-966.
6. G. Murali, C. V. Vardhan, R. Prabu, Z. M. S. A. Khan, T. A. Mohamed, and T. Suresh. (2012) *"Experimental investigation on fibre reinforced concrete using waste materials,"* International Journal of Engineering Research and Applications (IJERA) ISSN, vol. 2248, pp. 278-283.
7. Z. N. Qureshi, Y. M. Raina, and S. M. A. Rufaie. (2016) *"Strength Characteristics Analysis of Concrete Reinforced With Lathe Machine Scrap*". International Journal of engineering research and general science, vol. 4, pp. 210-217.
8. Portland Cement Association. (2005) *"Economical Concrete Floor Systems"* pp.1-6.

9. K. Aghaee and M. A. Yazdi, (2014) "*Waste steel wires modified structural lightweight concrete*," Materials Research, vol. 17, pp. 958-966.
10. Abdulkareem, T. A., (2019) *"Behavior of Lightweight Micro-Reinforced Concrete Panels"*, M.Sc thesis, Mustansiriya University, Baghdad, Iraq.
11. Al-Dhaher, B. A., (2001) *"The Use of Local Porcelinite for the Production of Lightweight Concrete Units"*, M.Sc. Thesis, University of Technology, Baghdad.
12. Al-Ani, M. K. M., (2002) *"Corrosion of Steel Reinforcement in Structural High Performance Lightweight Concrete"*, M.Sc. Thesis, University of Technology.
13. Al-Bayati (2001) *"The Use of Local Porcelinite for the Production of Lightweight Concrete Units"*, M.Sc. Thesis, University of Technology, Baghdad.
14. Yasar E., Atis C.D., Kılıç A., and Gulsen H., (2003) *"Strength Properties of Lightweight Concrete Made with Basaltic Pumice and Fly Ash"*, Materials Letters, Vol. 57, pp. 2267-2270.
15. Chiad, S., (2009) *"Experimental Study on Properties of Lightweight Concrete Slabs Made with Plastic Waste"*, M.Sc Thesis, Al–Mustansiriya University.
16. T. A. Abdulkareem and A. A. Alfeehan. (2018) *"Effect of the Rib Depth to the Overall Beam Depth Ratio in the Lightweight One-Way Ribbed Slabs"* International Journal of Engineering & Technology, V.7, pp. 438-442.
17. Iraqi Specification, (1984) No. 5/1984, "*Portland Cemen*t", Ministry of Planning, Central Organization for Standardization and Quality Control.
18. ASTM C33, (2013) "*Standard Specification for Concrete Aggregates*", American Society for Testing and Materials.
19. ASTM C 1240, (2005) "*Standard Specification for the Use of Silica Fume as a Mineral Admixture in Hydraulic Cement Concrete, Mortar and Grout*", vol. 04.02, pp. 1-7.
20. ASTM C494, (2001) *"Standard Specification for Chemical Admixtures for Concrete*", Annual Book of American Society for Testing and Materials.
21. European Federation Dedicated to Specialist Construction Chemicals and Concrete Systems (EFNARC), (2002) "*Specifications and Guidelines for Self-Compacting Concrete*", Association House, 99 West Street, Farnham, Surrey, U.K., (32).
22. Bonakdar, F. Babbitt, B. Mobasher, (2013) *"Physical and mechanical characterization of Fiber-Reinforced Aerated Concrete (FRAC) "*, Cement & Concrete Composites, Elsevier, Vol. 3. pp. 82–91.
23. ASTM C39, (2004) "*Test Method for Compressive Strength of Cylindrical Concrete Specimens*", pp. 1-5.
24. ASTM Designation C496, (2004) "*Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens*", ASTM International, Pennsylvania, United States, pp.2-7.
25. ASTM C78, (2004) "*Flexural Strength of Concrete Using Simple Beam with Centre Point loads*", Annual Book of ASTM Standards, vol.04.02, pp.1-3.
26. ASTM Designation C469, (2002) "*Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression*", ASTM International, Pennsylvania, United States, pp.1-3.
27. ASTM Designation C215, (2014) *"Standard Test Method for Fundamental Transverse, Longitudinal and Torsional Resonant, Frequencies of Concrete Specimens*," ASTM International.

28. ASTM C642 (2006) *''Standard Test Method for Density, Absorption and Voids in Hardened Concrete*'', American Society for Testing and Materials Standard Practice C642, Philadelphia, Pennsylvania.