Experimental Investigation of Low Density Sound Insulated Concrete Fabricated Wall Cladding Tiles

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Abstract. The growing demand for the need of sound insulation in buildings such as hospitals, recreational institutions and religious buildings is rising in recent years. The material used should be of highly sound insulated as well as easy to install. In this study light weight concrete is used as Wall Cladding tiles in the building, as light weight concrete shows satisfactory sound insulation property. The light weight Wall cladding was fabricated by addition of Fiber glass powder and alccofine as a cement replacement and different sizes of Cenosphere such as Cenosphere 300 micron and Cenosphere 425 micron as a fine aggregate replacement. Various parameters of the light weight concrete Wall Cladding tile both physical and mechanical properties were investigated. The test were conducted to determine the compressive strength, and the sound insulation ability of the fabricated Wall Cladding tile. The experimental investigation shows that Wall Cladding fabricated as a light weight concrete has reliable compressive strength of 6.5 N/mm² and satisfactory sound insulation property.

1. Introduction
The low density sound insulation wall cladding tiles are in most needed advancement for sound proofing in various buildings such as theatre, hospitals and recreational buildings. The wall cladding tile are used to protect the structure from external agencies like rain dust and noise from the outside surroundings. The wall cladding title hence should posses good sound insulation property to safeguard the structure from the external noise. The low density tile can be fabricated by meeting the standards of IS code and can be used in the buildings [1]. The light weight concrete tile have more advantage of one being light weight easy to install and for transportation and hence faster construction of the tiling works. For buildings like theatre and hospitals sound from outside and the sound created inside the building should be arrested properly, which can be effectively achieved by using low density concrete tile which absorb the sound transmitted from the building and also prevents the entry of noise from outside the building. The light weight concrete tiles have good sound insulation property because of their low density and high porosity characteristics [2]. In recent times the availability of river sand as fine aggregate is getting more expensive due to the non availability of the river sand it is required to seek to alternate materials. In order to achieve low density concrete use of materials like Cenosphere is more economical and will produce low density concrete with high sound insulation property. Cenosphere are powders made from the coal ash, their density is much less then water hence they float on the slurry. It contains Sio2 and Al2O3 in large quantities. The Cenosphere are made of
silica and alumina which are obtained from coal combustion at 1500-1700c [3-6]. The required amount of cenosphere can be incorporated to the concrete by partial or complete replacement of the river sand. The amount of Cenosphere present in the coal ash depends on the temperature which the coal is subjected to and also based on the quantity of coal[7-10].The lightweight concrete tile is achieved by using fiber glass and alcocine as cement replacement. The glass fiber is used to increase the tensile strength of the lightweight concrete tile. The experimental investigation on the glass fibres shows reduction in the shrinkage cracks and more reliability to sound insulating properties have been seen by incorporating these fibres[11]. The glass fiber is made by cementations material and admixtures with small length glass fibres. These glass fibers have both tension and impact strength properties [12-13]. The other major cement replacement constitutes is the Alccofine which is a made up of calcium silicate slag. The Alccofine enhances workability by reducing the w/c ratio. Because of the fine particle the strength of the Alccofine is enhanced greatly [13-16]. The Alccofine produces low density concrete thereby increases the sound insulating properties of the concrete. The strength of the low density concrete is more important criteria for better performance of the concrete to take up the load. The compression test on the specimen shows whether the specimen has achieved the required strength for which it was designed. As the lightweight concrete tile is made for wall cladding it doesn't required to posses high strength for the concrete that is a nominal strength is enough for the wall cladding tile. The strength of low density concrete is determined by compression test using compression testing machine as per the guidelines given by the is code. The non destructive test on the material has been growing in recent times due to the fact the strength analysis can be easily made without causing any structural damage to our structure. The use of ultrasonic pulse velocity test can be used to determine the cracks and deportation inside the material by passing the ultrasonic waves into it [17-20]. This method can be used to determine the sound insulation capacity of the material by passing the ultrasonic waves and finding the nature of the material to pass the waves and time of travel inside the material. this can be used to compare the specimen depending upon its sound insulating properties. The ultrasonic pulse velocity test mainly depends on the mix design, concrete age and water present in the mix [21-23]. If the correlation between the compressive strength and ultra sonic pulse velocity is made we can arrive at strength and life of the material. The noise emitted from various source are great threat to human health and cause wide range of health disorder, the WHO estimates about 456 million people have problem with their hearing ability[24]. The measurement of sound at the ambient atmosphere can be satisfactorily calculated by using the instrument sound meter. The is used to record the noise level at decibel which is effective way to calculate the noise or the sound in that place. The sound level meter is small measurement tool with a microphone, it also called as sound pressure level meter. The diaphragm of the instrument moves which is converted to the electrical signal which can be measured as decibels. This instrument is used for noise pollution investigation for different type of noises around the particular surrounding in the noise is measured [25]. In this present study light weight concrete tile is fabricated using proper mix which has more sound insulating properties. The test sample consists of two different sized tile of 1cm and 2 cm according to is which are mounted on brick wall and wall made from hollow block. The comparative study has made from these two walls about the sound insulation properties of the fabricated tiles. The first test conducted on the wall is the ultra sonic pulse velocity test in which ultra sound is passed into the specimen and the results are recorded to find the sound insulation capacity of the material. The second test was made using sound level meter the test samples were kept inside a glass chamber and the sound is passed to the specimen the absorbed sound coming from the specimen is caught by the sound level meter. Many trails were made to the specimen to get the accurate value of the sound insulation made from the lightweight concrete tile is recorded. This test is performed on two different thickness tiles of 1cm and 2 cm tiles made from the design mix. The compression test is made to determine the compressive strength of the low density concrete tile cubes were casted and tested in compression testing machine for 7 days, 14 days and 28 days. The test results were recorded to determine the compressive strength of the light weight concrete which is fabricated for sound insulation.
2. Materials
In this study use of both cement replacement and aggregate replacement is made for making the desired low density concrete wall cladding tile. The use of glass fiber, acelofin are used as cement replacement and use of Cenosphere of different grade is used as aggregate replacement.

2.1. Cement
The cement of OPC grade 53 is used as per IS 12269-1987 with proper strength achieved for 28 days with strength of 53 MPa. The cement provides good bonding between the materials and provide good strength and superior quality of the specimen made. The figure 1. shows the picture of cement.

![Figure 1. Cement.](image1)

2.2. Cenosphere
This study use of Cenosphere 325micron and Cenosphere 425 micron is used as fine aggregate replacement. Cenosphere is more economical and will produce low density concrete with high sound insulation property. Cenosphere are powders made from the coal ash, their density is much less then water hence they float on the slurry. It contains SiO₂ and Al₂O₃ in large quantities. The Cenosphere are made of silica and alumina which are obtained from coal combustion at 1500-1700c. The figure 2. shows the picture of Cenosphere.

![Figure 2. Cenosphere.](image2)
2.3. Glass fibre powder

The glass fiber is used to increase the tensile strength of the light weight concrete tile. The experimental investigation on the glass fibres shows reduction in the shrinkage cracks and more reliability to sound insulating properties have been seen by incorporating these fibres [11]. The glass fiber is made by cementations material and admixtures with small length glass fibres. These glass fibers have both tension and impact strength properties [12]. The figure 3. shows the picture of Glass fibre powder.

![Glass fibre powder](image)

**Figure 3.** Glass fibre powder.

2.4. Alccofine

Alccofine which is a made up of calcium silicate slag. The Alccofine enhances workability by reducing the w/c ratio. Because of the fine particle the strength of the Alccofine is enhanced greatly. The Alccofine produces low density concrete thereby increases the sound insulating properties of the concrete. The Alccofine also increases the workability of the concrete making to flow. The figure 4. shows the picture of Alccofine.

![Alccofine](image)

**Figure 4.** Alccofine.

2.5. Air entraining agent

The air entraining agent is used to create air bubbles in the light weight concrete. The AEA depends on the mix design of the concrete. The use of air entraining agent is to protect the concrete from frost attack, scaling of the concrete and failure of the concrete. The air entraining agent is also used to reduce the concrete segregation and bleeding of the concrete.
2.6. Coir Fibre
The coir fibre is made from the coconut husk. Coir is a fibrous product of the coconut made from the shell and outer cover of the coconut. The Coir fibre provide strength to the light weight concrete, it increases the tensile strength of the concrete. The coir fibre is cost effective, easy to handle and provide required strength to the concrete. It also provide effective sound insulating properties to the concrete. The figure 5. shows the picture of Coir fibre.

![Coir fibre](image)

Figure 5. Coir fibre.

3. Mix Design
The mix design gives the information regarding the strength and the density of the concrete to be made. The study of several trial mixes were made to arrive at proper strength of the low density concrete. The mix design for the low density concrete tile was made with use of admixtures and super plasticizer after proper experimental studies on the material property of the material. The use of coir fibre also used for additional strength to the mix the quantity of coir fibre used in this mix 11.25 kg. The table 1 shows the mix design of the low density concrete tile.

Table 1. Mix design of low density concrete tile.

| Component                     | Quantity (kg/m³) |
|-------------------------------|------------------|
| Water                         | 121.5            |
| Cement                        | 180              |
| Fiber Glass powder            | 21.3             |
| Alccofine                     | 38.48            |
| Super plasticizer             | 5                |
| Air entraining agent          | 0.8              |
| Cenosphere 300 micron         | 219.23           |
| Water for Cenosphere 300      | 37.3             |
| Cenosphere 425 micron         | 219.23           |
| Water for Cenosphere 425      | 37.3             |
4. Experimental test procedure and results

4.1. Test specimen
The total of 15 cubes of size 70.3 mm have been casted for testing the compressive strength of the light weight concrete material of which each of 5 cubes are used for testing the sample for 7 days, 14 days and 28 days using compression testing machine. The curing is made by immersing the light weight concrete cube inside the water pool for the period of 28 days. The compression test is made for 7 days, 14 days and 28 days. The average value is to determine the compressive strength of the material. The light weight concrete tile of size 30cm × 30cm is made with the calculated mix design. Two different thickness of 1cm and 2cm are casted for the experimental studies. The brick wall of size as that of light weight concrete tile is constructed for the experimental purpose. Similarly hollow block wall is also constructed on which the fabricated tile is mounted for the testing purpose. A hollow glass chamber is constructed for the testing of sound insulation property of the light weight concrete tile. The hollow glass chamber is constructed with size of 30cm × 30cm ×30cm. The glass chamber so made to prevent the noise from external source which would hinder the experimental results. The specimen is kept inside the glass chamber through the front opening and the speaker and the sound level meter is kept by the slide door in each face. The figure 6 shows the test specimen used for experimental studies. The figure 6(a) depicts the light weight concrete cube of size 70.6mm. The figure 6(b) depicts the 6 light weight concrete tile casted for testing the sound insulating properties of the material. The figure 6(c) depicts the hollow block wall specimen without concrete tile mounted on the surface. The figure 6(d) depicts the hollow block wall specimen with 1cm light weight concrete tile mounted on the surface. The figure 6(e) depicts the hollow block wall specimen with 2cm light weight concrete tile mounted on the surface. The figure 6(f) depicts the brick wall specimen without light weight concrete tile mounted on the surface. The figure 6(g) depicts the brick wall specimen with 1cm light weight concrete tile mounted on the surface. The figure 6(h) depicts the brick wall specimen with 2cm light weight concrete tile mounted on the surface.
Figure 6(c). Hollow block wall.

Figure 6(d). Hollow block wall with 1cm tile.

Figure 6(e). Hollow block wall with 2cm tile.

Figure 6(f). Brick wall.

Figure 6(g). Brick wall with 1cm tile.

Figure 6(h). Brick wall with 2cm tile.
4.2. Testing equipment and Apparatus

4.2.1. Ultrasonic pulse velocity meter. The ultrasonic pulse velocity meter is used to determine the strength of the concrete, determining any discontinuity in the concrete, cover distance and cracks developed inside the concrete. Ultrasonic Pulse Velocity Tester is a fully portable instrument for assessing the quality of concrete in "in situ" or precast. The components included along with the machine are mains cord: 2 pin, 10A, 2 cable bnc 4 meters- UHF, UX4600L- test block, 2 transducers: PC200*60KHz. (UHF), user manual and carrying case. The instrument model number UCT-4600L, Indian make with testing range up to 5m.

4.2.2. Sound level meter. The sound level meter is used to determine the ambient noise level in the surroundings. This can be used to determine the sound in terms of decibels at an instant of the place at which the instrument is used. The sound level meter is small measurement tool with a microphone, it also called as sound pressure level meter. The diaphragm of the instrument moves which is converted to the electrical signal which can be measured as decibels. This instrument is used for noise pollution investigation for different type of noises around the particular surrounding in the noise is measured. The instrument used is Lutron model number SL-4010, made in Taiwan and the product dimension is 25cm × 13cm × 6cm.

4.2.3. Glass chamber. The glass chamber of size 30cm×30cm×30cm is made for testing the lightweight concrete for the sound insulation property. The glass chamber so made to prevent the noise from external source which would hinder the experimental results. The specimen is kept inside the glass chamber through the front opening and the speaker and the sound level meter is kept by the slide door in each face.

4.3. Testing procedure and results

4.3.1. Compression test. The compression test is conducted on the 15 test samples to determine the compressive strength of the lightweight concrete. The test results of 7 day, 14 days and 28 days are recorded, the average of the each of the five sample is taken to find the compressive strength of the lightweight concrete. The figure 7 (a) show the compression testing machine and the figure 7 (b) shows the compressive strength of the concrete at 7 days, 14 days and 28 days test.

![Figure 7(a). Compressive testing machine.](image)

![Figure 7(b). Compressive strength of the concrete.](image)

4.3.2. Ultrasonic pulse velocity test. In this experimental study 6 specimen has been tested with the ultrasonic pulse velocity meter. The first 3 specimen is brick wall with 3 samples of one with brick wall without any tile mounted, second brick wall with 1cm light weight concrete tile mounted and
third brick wall 2 cm light weight concrete mounted. The second 3 specimen is hollow block wall with 3 samples of one with hollow block wall without any tile mounted, second hollow block wall with 1 cm light weight concrete tile mounted and third hollow block 2 cm light weight concrete mounted. The each of the sample is subjected to the ultra sound and the pulse velocity is calculated for the studies. The ultrasonic pulse velocity gives the time taken by the ultra sound to pass through the specimen, grids are drawn in the specimen which are subject to the ultra sound. The time taken by the ultra sound to pass through the material is given in the table. The table 2 shows the time of travel of ultra sound in hollow brick wall samples with or without tile mounting.

**Table 2.** Time of travel of ultrasound in different hollow block wall samples with or without tiles.

| Type of sample                              | Grid number | Time of travel of ultrasound (µ-sec) |
|---------------------------------------------|-------------|-------------------------------------|
| Hollow block wall without tile mounting     | 1           | 68.4                                |
|                                             | 2           | 70.3                                |
|                                             | 3           | 72.5                                |
|                                             | 4           | 69.5                                |
|                                             | 5           | 71.7                                |
|                                             | 6           | 67.1                                |
| Hollow block wall with 1cm tile mounting    | 1           | 53.4                                |
|                                             | 2           | 56.8                                |
|                                             | 3           | 48.6                                |
|                                             | 4           | 51.2                                |
|                                             | 5           | 55.7                                |
|                                             | 6           | 49.1                                |
| Hollow block wall with 2cm tile mounting    | 1           | 48.3                                |
|                                             | 2           | 46.2                                |
|                                             | 3           | 50.1                                |
|                                             | 4           | 47.1                                |
|                                             | 5           | 45.3                                |
|                                             | 6           | 49.4                                |

The table 2 shows that time of travel of ultrasound through hollow block without tile is more compared to that of hollow block wall of light weight concrete mounted tile. It is seen that light weight concrete has more quality than that of hollow block wall. It is also seen from table 2 is that Hollow block of 2cm tile mounted has less time of travel compared to that of 1cm tile mounted wall. The table 3 shows the time of travel of ultra sound in brick wall samples with or without tile mounting on the
surface of the brick wall.

**Table 3.** Time of travel of ultrasound in different Brick wall samples with or without tiles.

| Type of sample                        | Grid number | Time of travel of ultrasound (µ-sec) |
|---------------------------------------|-------------|-------------------------------------|
| Brick wall without tile mounting     | 1           | 34.5                                |
|                                       | 2           | 35.6                                |
|                                       | 3           | 33.4                                |
|                                       | 4           | 35.2                                |
|                                       | 5           | 37.5                                |
|                                       | 6           | 31.7                                |
| Brick wall with 1cm tile mounting    | 1           | 26.8                                |
|                                       | 2           | 27.9                                |
|                                       | 3           | 24.3                                |
|                                       | 4           | 26.5                                |
|                                       | 5           | 22.4                                |
|                                       | 6           | 23.2                                |
| Brick wall with 2cm tile mounting    | 1           | 22.6                                |
|                                       | 2           | 21.5                                |
|                                       | 3           | 22.8                                |
|                                       | 4           | 21.4                                |
|                                       | 5           | 23.7                                |
|                                       | 6           | 24.1                                |

The table 2 shows that time of travel of ultrasound through brick wall without tile is more compared to that of brick wall of light weight concrete mounted tile. It is seen that light weight concrete has more quality than that of brick wall. It is also seen from table 3 is that brick wall of 2cm tile mounted has less time of travel compared to that of 1cm tile mounted wall. The figure 8(a) represents the ultrasonic pulse velocity with respect to grid number for the hollow block wall without tile mounting. The figure 8(b) represents the ultrasonic pulse velocity with respect to grid number for the hollow block wall with 1 cm tile mounting. The figure 8(c) represents the ultrasonic pulse velocity with respect to grid number for the hollow block wall with 2 cm tile mounting. The figure 8(d) represents the ultrasonic pulse velocity with respect to grid number for the Brick wall without tile mounting. The figure 8(e) represents the ultrasonic pulse velocity with respect to grid number for the Brick wall with 1 cm tile mounting. The figure 8(f) represents the ultrasonic pulse velocity with respect to grid number for the hollow block wall with 2 cm tile mounting.
Figure 8(a). UPV vs Grid number for Hollow block wall without tile.

Figure 8(b). UPV vs Grid number for Hollow block wall with 1 cm tile mounted.

Figure 8(c). UPV vs Grid number for Hollow block with 2 cm tile mounted

Figure 8(d). UPV vs Grid number for Brick wall without tile mounted

Figure 8(e). UPV vs Grid number for Brick wall with 1 cm tile mounted.

Figure 8(f). UPV vs Grid number for Brick wall with 2 cm tile mounted.

The table 4 shows the comparison of ultrasonic pulse velocity and the quality of the material, this table is used to determine the quality of the concrete as well as the sound insulation properties of the material.
Table 4. Quality comparison with respect to Ultrasonic pulse velocity.

| Ultrasonic pulse velocity (km/s) | Quality of concrete |
|----------------------------------|---------------------|
| Greater than 4                   | Excellent           |
| Between 3.0- 4.0                 | Very good           |
| Between 3.0- 3.5                 | Good                |
| Less than 3.0                    | Poor                |

From the table 4 the ultrasonic pulse velocity is less than 3.0 for hollow block wall without light weight concrete tile hence it doesn't have satisfactory sound insulation property. The ultrasonic pulse velocity is between 3.5-4 for hollow block wall with 1cm tile mounted on the surface of the wall. The ultrasonic pulse velocity is greater than 4.0 for hollow block with 2 cm tile mounted on the surface of the wall. Hence the 1cm and 2cm tile mounted on the hollow block wall has satisfactory sound insulation property. Similarly the ultrasonic pulse velocity for Brick wall without light weight concrete tile is less than 3.0 hence it doesn't have satisfactory sound insulation property. The ultrasonic pulse velocity is between 3.0-4 for Brick wall with 1cm tile mounted on the surface of the wall. The ultrasonic pulse velocity is greater than 4.0 for Brick with 2 cm tile mounted on the surface of the wall. Hence the 1cm and 2cm tile mounted on the hollow block wall has satisfactory sound insulation property.

4.3.3. Sound level meter test. The sound level meter test is conducted for 1cm light weight concrete tile and for 2 cm light weight concrete tile. The light weight concrete tile placed inside the glass chamber, the speaker is kept in one side on the light weight concrete tile and sound level meter is kept inside the glass chamber other side of the light weight concrete tile. The sound is passed through the tile by the speaker and the absorbed sound is measured by the sound level meter. Five different trials is made for each of the different sized concrete tiles before the sound being passed through the tile and also after passing through the tile. The readings are tabulated in the table 5.

Table 5. Sound level measured before and after passing through the tiles.

| Specimen type                        | Trail number | Sound level before passing the concrete tile in Decibels (db) | Sound level after passing the concrete tile in Decibels (db) |
|--------------------------------------|--------------|----------------------------------------------------------------|-------------------------------------------------------------|
| Light weight concrete tile of 1 cm thickness | 1            | 128.7                                                           | 87.5                                                         |
|                                      | 2            | 118.9                                                           | 78.5                                                         |
|                                      | 3            | 123.5                                                           | 83.1                                                         |
|                                      | 4            | 125.1                                                           | 81.6                                                         |
From the results obtained on the table 5 it is evident that sound level before passing through the light weight concrete tile is greater than the sound level measured after passing through the light weight concrete tile of thickness 1cm. The average of sound level measured before passing through the tile of 1cm thickness is 122.3 db and the average level measured after passing through the tile of 1cm thickness is 82.28 db. Similarly The average of sound level measured before passing through the tile of 1cm thickness is 111.24 db and the average level measured after passing through the tile of 1cm thickness is 87.82 db. From the average results it is clearly seen that sound has been absorbed by the light weight concrete tile and also the light weight concrete tile with 2cm has absorbed more sound waves thereby producing satisfactory sound insulating properties. The figure 9(a) shows the sound level meter measuring the sound level before passing through the 1 cm tile. The figure 9(b) shows the sound level meter measuring the sound level after passing through the 1 cm tile. The figure 9(c) shows the sound level meter measuring the sound level before passing through the 2 cm tile. The figure 9(d) shows the sound level meter measuring the sound level before passing through the 2 cm tile.

![Figure 9(a). Sound level before passing tile.](image1)

![Figure 9(b). Sound level before passing tile.](image2)
From the figure the sound level before passing through the light weight concrete tile of thickness 1cm is 128.8db and after passing through the light weight concrete tile the sound level has reduced to 87.5db. This shows that the light weight concrete tile has absorbed the sound waves transmitting through it which shows the tile exhibiting sound insulation property. Similarly the sound level before passing through the light weight concrete tile of thickness 2cm is 128.8db and after passing through the light weight concrete tile the sound level has reduced to 94.8db. This shows that the light weight concrete tile has absorbed the sound waves transmitting through it which shows the tile exhibiting sound insulation property. Hence these tiles can be used for wall cladding tile with sound insulation property thereby protecting the structure from external noise.

5. Conclusion
The experimental investigation presents the low density concrete tile made with coir fibre with appropriate mix design. The total 6 light weight concrete tiles have been fabricated for testing the behavior of these tiles for the sound insulation property.

The conclusion arrived from this study are:

1. The light weight concrete tile with 1.5% coir fibre dosage shows better performance in improving the strength of the low density concrete tile.

2. The compression test made on the low density concrete shows satisfactory strength for using it as wall cladding tile as a sound insulating material to prevent the external noise entering into the structure.

3. The ultrasonic pulse velocity test on the low density concrete tile of 1cm and 2cm thickness mounted on the two different wall that is hollow block wall and brick wall shows better sound insulation property as the ultrasonic pulse velocity in average is greater than 3.5 km/s which shows goof quality of the concrete thereby better sound insulation property.

4. The Sound level meter test on the low density concrete tile of both 1cm and 2cm shows better sound insulating property thereby can be used as wall cladding for preventing the sound entering into the building from outside. The average of sound level measured before passing through the tile of 1cm thickness is 122.3 db and the average level measured after passing through the tile of 1cm thickness is 82.28 db. Similarly the average of sound level measured before passing through the tile of 1cm thickness is 111.24 db and the average level measured after passing through the tile of 1cm thickness is 87.82 db. From the average results it is clearly seen that sound has been absorbed by the light weight concrete tile and also the light weight concrete tile with 2cm has
absorbed more sound waves thereby producing satisfactory sound insulating properties.

5. Further study can be made for cost estimation and performance of the tile for thermal insulation property

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