International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-7, Issue-6C2, April 2019

# Performance of Autoclaved Aerated Concrete Blocks Under Varying Temperatures

**Jagadish Vengala, Shivakumar Mangloor, Talla Krishna Chaitanya Goud**

***Abstract: Autoclaved aerated concrete (AAC) blocks due to their light weight, low density are extensively used as masonry units in construction in spite of these properties there exists a problem of cracking in the AAC units under high temperatures, It is also said that the blocks undergo thermal expansion. The plaster does not get adhered to the surface of units. An effort has been made to determine the strength behavior, bond behavior, crack behavior and thermal behavior of AAC blocks under varying temperatures, mortar ratios and thickness. It is found that there was reduction in the strength and formation of cracks for temperatures above 500 deg C, the bond behavior was found vary with mortar thickness and ratios. Thermal comfort study showed better thermal comfort in comparison with the model with Solid ConcreteBlock.***

***Index Terms: AAC Blocks, mortar ratios, Bond behavior, thermal comfort, crack behaviour***

## I. INTRODUCTION

Wall being built of masonry is the major structural component which occupies 75% - 80% of the volume in building. The properties of materials used in masonry influence the thermal performance of the building envelop. Thermal performance of walls used in buildings can be increased by using insulating materials or by using materials with low thermal conductivity. Thermal performance of any building material depends on several factors and may not be assessed based on any one of the factor. The selection of material for construction contributes to thermal discomfort and hence care should be taken by choosing the right material in the design stage itself otherwise it becomes costly at the later stage. Before selecting the materials, the properties like Specific heat, thermal conductivity, transmissivity and heat transfer coefficients are to be checked to ensure the thermal performance and other load bearing properties of the building. In Indian construction scenario, lot of advancement and technology innovations are being adopted for achieving thermal comfort and energy saving. Thermal performance of advanced materials [1] to play a lead role in energy efficiency and in providing thermal comfort. Autoclaved aerated concrete blocks (AAC) are considered as low energy building material, non-toxic and highly sustainable building material to have good thermalperformance.

AAC blocks are formed with a reaction of Aluminium on a proportionate blend of fly Ash, lime, gypsum and cement. During the formation, the hydrogen gas that escapes creates millions of tiny air cells giving it a strong cellular structure which is further strengthened by high pressure steam curing in Autoclaves, thus known as Autoclaved Aerated Concrete (AAC) BLOCK.

The Density of AAC blocks varies between 550 - 650 kg/m3 and the weight is less than one third of the weight of normal bricks. Autoclaved aerated concrete (AAC) blocks due to their light weight, low density are extensively used as masonry units in construction in spite of these properties there exists a problem of cracking in the AAC units under high temperatures , it's also said that the blocks undergo thermal expansion. The plaster does not get adhered to the surface of units. Limited study is available on thermal behaviour, strength variation under high temperatures and thermal expansion of AAC blocks. Mortar joint thickness and its proper study. Keeping the above factors in mind, attempts have been made to address the above issues by conducting a series of experiments. This study was conducted based on the following objectives

The main objective of this experimental program is to study the various engineering properties of AAC block such as compressive strength, density, thermal behaviour. An attempt was also made to determine the crack pattern of AAC blocks under varying temperatures. Thermal comfort studies were conducted on AAC blocks in comparison with the conventional solid concreteblocks.

## II. EXPERIMENTALPROGRAMME

The following materials were used for thisstudy:

- AAC BLOCKS: Blocks manufactured using fine aggregates, fly ash by passing hydrogen gas where used for various tests. These AAC blocks of size 600mm×200mm×150mm.
- Ready JOINT MORTAR: Joint mortar proves to be good in bonding action when used with AACblocks.
- MORTAR-READY PLAST: Plaster mortar proves to be good bonding and acts as an ideal plaster mortar when used with AACblocks.

Following methodology was adopted to assess the performance of AAC blocks. In this regard a test program was planned and designed to carry out various studies based on the actual site conditions.

**Case 1:** Strength behavior of block specimens under varying temperatures.

**Case 2:** Bond behavior of masonry joints with varying mortar ratios and thickness.

**Case 3:** Crack behavior of prisms made with block specimens under varying temperature

Revised Manuscript Received on April 15, 2019.

**Jagadish Vengala,** Associate Professor, Department of Civil Engineering, PVP Siddhartha Institute of Technology, Vijayawada, Andhra Pradesh, India.

**ShivakumarMangloor,** Former Undergraduate student, Department of Civil Engineering, BMSIT&M, Bangalore, India.

**Talla Krishna Chaitanya Goud,** Former Undergraduate student, Department of Civil Engineering, BMSIT&M, Bangalore, India.

**Case 4:** Thermal comfort studies of the AAC blocks in comparison with solid concrete blocks

Following tests were conducted based on the above mentioned cases.

- Compressive strengthtest
- Behavior of bond with varying mortar types and thickness
- Crack visibilitystudy
- Thermal comfortstudy

*A. Strength behavior of block specimens undervarying temperatures*

Fig. 1 gives the flow chart for the strength behavior of block specimens under varying temperatures

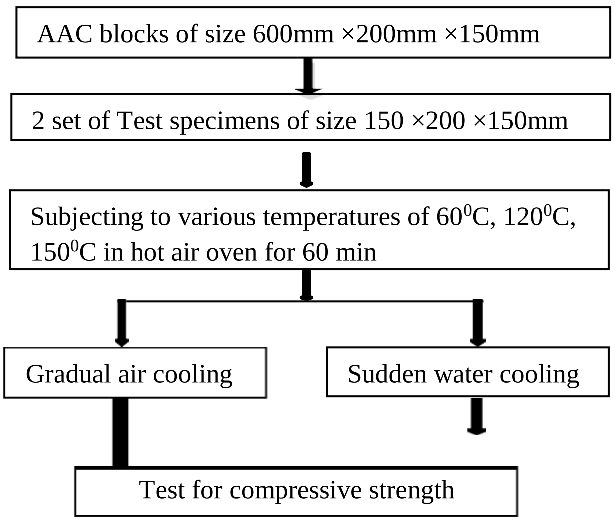


**Fig. 1: Flow chart for the test program**

on strength behaviour of block specimens under varying temperatures

Compressive strength test for all the specimens were conducted by placing them in compression machine and load applied perpendicular to the direction of the slices from which the cube thickness has been built up. For cubes which have been prepared in one piece, the direction of load shall be perpendicular to the direction of rise of the mass during production.

The specimens were loaded at the rate of 0.5 to 2 kg/cm2 in such a way that failure occurs within 30 seconds. Fig 3.2 show the compressive strength test set up.

After loading, the specimens were weighed and dried out at 105 +/- 5°C until constant weight is obtained as described in the procedure for determining the bulk density of aerated concrete blocks as per IS:6441 ( Part I )-1972[6]

Following studies were carried out to know the initial trend of the temperature variation on AAC blocks in particular.

- Test specimens were cut to a size of 150mm×150mm×200mm from one entire block measuring 600×200×150 using hack sawblade
- Total of 6 no's of specimens were cut out of which 3 specimens were sliced from the blocks, out of which 3 specimens were subjected to varying temperature of 600C, 1200C and 1800C with a duration of 60 min for each block using hot air and brought them toroom temperature and tested individually for the load carryingcapacity.
- Similarly, other 3 specimens were tested for its load carrying capacity at room temperature by immersing them immediately in water after subjecting them to temperatures 600C, 1200C and 1800C for 1hr.

*B. Bond behavior of masonry joints with varying mortar ratios andthickness*

Fig. 2 gives the flow chart for the strength behavior of block specimens under varying temperatures

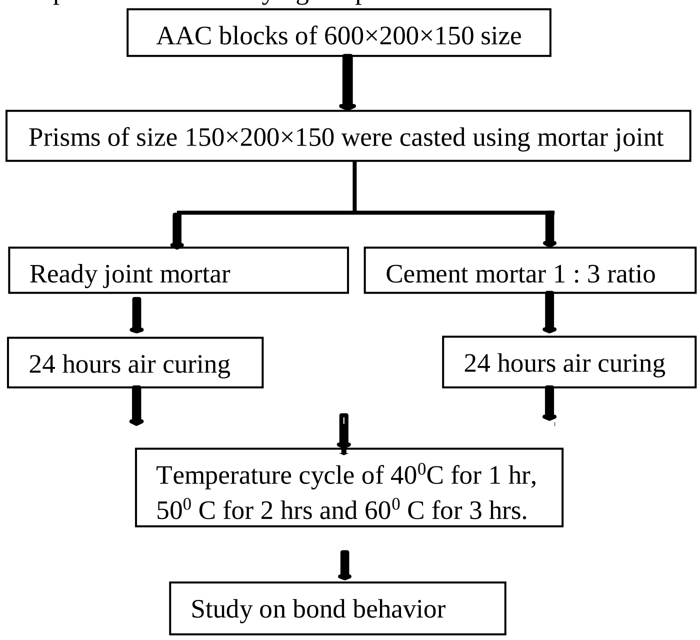


**Fig. 2: Flow chart for the test program on bond behavior of masonry joints with varying mortar ratios and thickness**

PPrisms were casted for 2 sets of blocks using Cement mortar of 1:3 ratio and Ready joint mortar.

- Test specimens were cut to a size of150mm ×150mm×200mm from one entire block measuring 600mm×200mm×150mm using hack saw blade
- Total 4 no's of prisms were casted out of which two prisms were casted using ready joint mortar. The other two prisms were plastered using cementmortar.
- The casted prisms were air cooled for first 24 hours followed by 72 hours of watercooling.
- Then cured prisms were subjected to varying temperature cycles of 400c for 1 hour followed by 500 c for 2 hours and 600 c for 3 hours in controlled hot air oven.
- The prisms were visually examined for the behavior of bond with varying mortar types andthickness.

*C. Crack behavior of prisms made with block specimens under varyingtemperature*

Fig. 3 gives the flow chart for the strength behavior of block specimens under varying temperatures behavior of masonry joints with varying mortar ratios and thickness


Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

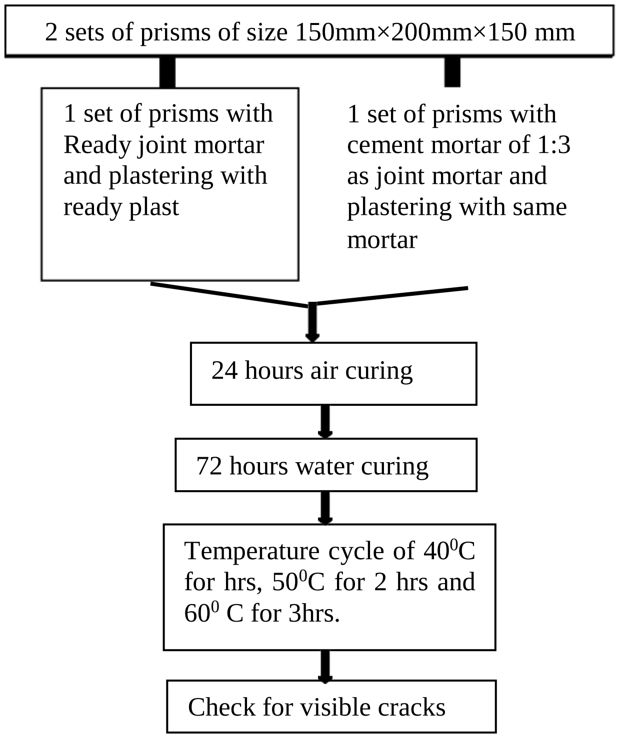


**Fig. 3: Flow chart for the test program on crack**

Two sets of prisms were casted using Cement mortar of 1:3 ratio and ready joint mortar.

- Test specimens were cut to a size of150mm ×150mm×200mm from one entire block measuring 600mm×200mm×150mm using hack saw blade
- Total of 4 no's of prisms were casted out of which two prisms were joined with ready joint mortar and plaster using ready plast. The other two prisms were joined using cement mortar of (1: 3) and plaster with the same cementmortar.
- The casted prisms were air cured for first 24hours
- Then cured prisms were subjected to varying temperature cycles of 400c for 1 hour followed by 500 c for 2 hours and 600 c for 3 hours in controlled hot air oven.
- After the completion of test program, the prisms were visually examined for thecracks.

*D. Thermal comfort studies on AAC blocks in comparison with solid concreteblocks*

Living comfort inside any building mainly depends on the "thermal comfort". DIN ISO 7730[7] deals with the research results related to thermal comfort. A large portion of the work in this area was done by a Danish scientist P. O. Fanger [8].

Thermal comfort mainly concerns the interior temperature of rooms, maintaining and distributing it evenly, and the quality of the air (humidity rate, purity, healthiness). The solute on for comfort in winter and summer is a very high resistance thermal insulation of all surfaces (including the windows) combined with ventilation adapted to the season, perfect air tightness to avoid the parasite air input and the building's good thermal inertia."[7,8]

Optimal thermal comfort is established when the heat released by the human body is in equilibrium with its heat production. Fanger's comfort equation is derived from this fact. It creates a relationship between the activity (e.g. sleeping, running…) and clothing as well as the determining factors for the thermal surroundings, which are as follows [7,8]:

- air temperature
- the temperature of the surrounding surfaces, this can also be summarised as the "radianttemperature",
- air speed and turbulence & airhumidity

P.O. Fanger writes: "the more irregular the thermal fieldina room is, the greater the expected numberofdissatisfiedpeople[7,8]. By keeping these points in view, a studywas conducted to know the thermal comfort byconstructingtwo model rooms one with AAC blocks andotherwithConventional Solid Concrete Blocks. Fig. 4 show the flow chart of test program conducted to know the thermal comfort behaviour of the AAC blocks in comparison with solid concreteblocks.

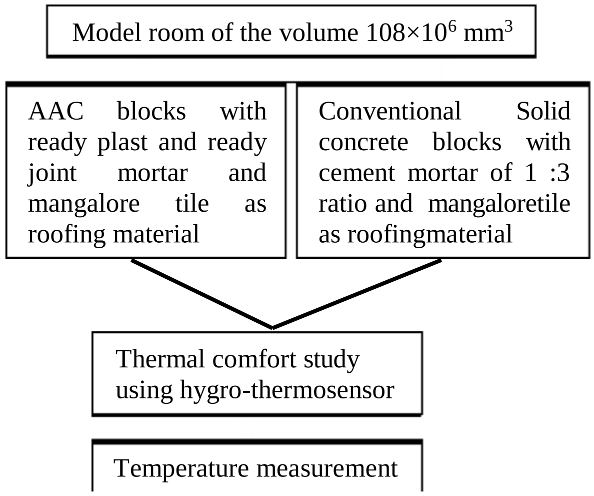


**Fig. 4: Flow chart for the test program on Thermal comfort studies of the AAC blocks in comparison with solid concrete blocks**

For Temperature measurements, two model rooms were build. One was constructed using solid concrete blocks (SCB) and the other was constructed using autoclaved aerated concrete blocks (AAC). Table 1 gives the details of the materials used in both the model rooms used for thermal comfort studies. Thermo hygrometer was used to measure the temperature in both the model rooms.

**Table I: Details of the materials used in both the model rooms.**

| Model Room | AAC | SCB |
|---|---|---|
| Blocks used | Autoclaved aerated concrete blocks | Conventional Solid cement concrete blocks |
| Mortar used for joints | ready joint mortar | Cement mortar 1:3 |
| Mortar used for plastering | Ready plast | Cement mortar 1:3 |
| Roofing material | Mangalore tile | Mangalore tile |
| Curing period | 7 days | 7days |


Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

## III. RESULTS AND DISCUSSIONS

This section presents the compressive strength results of block specimens under varying temperature and bond behavior of masonry joints with varying mortar ratios and thickness and also includes the discussions based on the results obtained. Prisms were made with block specimens and crack behavior was observed under varying temperatures. Limited studies on thermal comfort behavior on scaled models constructed using AAC and conventional solid concrete blocks were also conducted.

### *A. Strength behaviour of block specimens under varying temperatures*

Table II presents the compressive strength results of AAC block specimens exposed to varying temperatures and a)air cooled b) water cooled immediately after subjecting to temperatures.

**Table 2 :Results of AAC block specimens at different temperatures**

| Avg. wt. of the block | Temp. in $^0$c | Duration of exposure (min) | Curing Condition after exposing to temperature | Average Compressive strength of the Specimen (MPa) |
|---|---|---|---|---|
| 3.3 Kg | Room temperature | --------- | ---------- | 4.5 |
| | 60 | 60 | Air curing | 3.36 |
| | | 120 | Air curing | 4.49 |
| | | 150 | Air curing | 4.24 |
| | 60 | 60 | Water curing | 3.30 |
| | | 120 | Water curing | 3.42 |
| | | 150 | Water curing | 1.52 |

During the test program following observations were made:

- Average Compressive strength of the AAC block was 4.5MPa.
- For the study of strength behavior both the sample of specimens were exposed to different temperatures for a constant duration of time and different cooling conditions no major and minor cracks were observed on the surface of both the set ofspecimens
- When the comparison for strength was made with the controlled samples to the subjected blocks, with varying temperature not much variations were observed.
- In the case of set 2 specimens i; e specimens which were water cooled, around 20-30% reduction in strength was observed up to 1200c.
- Compressive strength of the blocks was drastically reduced when it exposed to 1500c followed by cooling the blocks to room temperature by immediately immersing in water. 35% of reduction in strength wasobserved.
- At 150 0c there is a slight color change in AAC block and color remained as paleyellow

### *B. Bond behaviour of masonry joints with varying mortar ratios andthickness:*

- To know the bond and mortar behavior 2 set of prisms one with cement mortar and other with ready joint mortar was used at thejoints.
- With a lean mortar mix of (1:6) of 2mm thickness the blocks were separated each other from prism due to poor bonding. Hence, 2mm thickness may not be recommended in case of lean cement mortar mix of 1:6. Based on the trials conducted with 2mm,4mm and 6mm thick cement mortar it was observed that a minimum of 4 mm thick CM is preferred in case of 1:6proportion.

### *C. Crack behaviour of prisms made with block specimens subjecting to temperaturecycle:*

- To know the crack behavior, prisms were visually examined for appearance of cracks after subjecting to a temperature cycle i.e., 400C for 1hr and followed by 500C for 1hr and further 600C for 1hour.
- For the prisms plastered using ready joint mortar and ready plast mortar surface cracks started appearing after completing the 1 hr of exposure at 50 0c.
- Crack width of the same started increasing after exposing to 60 0 c for 1 hr on the plasteredsurface.
- Where in the case of cement mortar plastering of 1 :3 ratio, no surface cracks were seen on the surface of prisms till 50 0 c. But beyond this temperature, surface cracks appeared on the surface. However, this requires more testdata.
- Table 3 gives surface crack behavior of prisms with different mortar types and subjecting to a temperature cycle

**Table III:Surface crack behavior of prisms with different mortar types and temperatures.**

| Sl. No. | Type of mortar | Temp. in $^0$c | Surface cracks observed over plastered surface | | Width of the crack (mm) |
|---|---|---|---|---|---|
| | | | No | Yes | |
| 1 | Ready joint mortarand readyplast | 40 | √ | | - |
| | | 50 | | √ | 1.2 |
| | | 60 | | √ | 2.5 |
| 2 | Cement mortar 1 :3 | 40 | √ | | - |
| | | 50 | √ | | - |
| | | 60 | | √ | 1.2 |

### *D. Thermal comfort studies of the AAC blocks in comparison with solid concreteblocks*

- For Temperature measurements, two scaled models rooms were built. First scaled model was constructed using solid concrete blocks (SCB) and the other was constructed using AACBlocks.
- Table 4 gives the temperatures recorded using thermo hygro meter for both the scaledmodels.


Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

- Based on the limited studies conducted on scaled models AAC model shown better thermal comfort in comparison with the model with SCB i.e., cooler during day time by 1-20c . From table, it can be seen that the maximum temperature difference observed was $3^0$C

**Table IV:Temperature measurements of the scaled models**

| Day | Avg. Temperature ($^0$C) recorded in scaled model | | Difference in Temp.( $^0$C) | Range of temp ( $^0$C) |
|---|---|---|---|---|
| | AAC blocks | SC blocks | | |
| 1 | 29 | 31 | 2 | 1-2 |
| | 31 | 32 | 1 | |
| | 31 | 32 | 1 | |
| 2 | 29 | 29 | 0 | 0-1 |
| | 30 | 31 | 1 | |
| | 31 | 31 | 0 | |
| 3 | 28 | 30 | 2 | 1-2 |
| | 30 | 31 | 1 | |
| | 31 | 31 | 1 | |
| 4 | 29 | 31 | 2 | 1-2 |
| | 31 | 32 | 1 | |
| | 31 | 32 | 1 | |
| 5 | 29 | 31 | 2 | 0-2 |
| | 28 | 30 | 2 | |
| | 31 | 31 | 0 | |
| 6 | 28 | 30 | 2 | 0-2 |
| | 29 | 31 | 2 | |
| | 31 | 31 | 0 | |
| 7 | 27 | 29 | 2 | 2-3 |
| | 29 | 30 | 2 | |
| | 28 | 31 | 3 | |
| 8 | 29 | 29 | 0 | 0-1 |
| | 30 | 31 | 1 | |
| | 31 | 31 | 1 | |
| 9 | 28 | 30 | 2 | 0-2 |
| | 30 | 31 | 1 | |
| | 31 | 31 | 0 | |

## IV. CONCLUDING REMARKS

The following conclusions have been drawn from the above study.

Compressive strength of the blocks was drastically reduced when it is exposed to 1500c followed by cooling the blocks to room temperature by immediately immersing in water. Almost 35% of reduction in strength was observed. Hence, during fire situations it is not recommended to spray the water directly on the AAC Block surfaces. Joint mortar thickness of 2mm is not recommended in case of lean cement mortar mix of 1:6. A minimum of 4 mm thick CM is preferred in case of 1:6 proportion used as a mortar joint. Surface cracks on the plastered surface were observed beyond 500 c temperature. However, this requires more test data. Based on the limited studies conducted on scaled models AAC model shown better thermal comfort in comparison with the model with SCB i.e., cooler during day time by 1-20c.

## REFERENCES

1. Arun Kumar, O.P. Singh, Advances in the building materials for thermal comfort and energy saving, J. Recent Pat. Eng. 7.3 (2013) 220–232.
2. https://www.nxtbloc.in/pages/manufacturing-process/[online]
3. Abdullah Keyvani, “ Thermal performance and fire resistance of autoclaved aerated concrete exposed humidity conditions” *International Journal of Research in Engineering and Technology,* Volume 3, Issue 3, March 2014, PP267-272.
4. Pruteanu, Marian &Vasilache, Maricica. (2013). Thermal conductivity determination for autoclaved aerated concrete elements used in enclosure masonry walls. Bulletin of the Polytechnic Institute of Jassy, CONSTRUCTIONS. ARCHITECTURE Section. LIX (LXIII). 33-42.
5. Prakash T M, Naresh kumar B G and Karisiddappa, “ Strength and elastic properties of aerated concrete block masonry” *International Journal of Structural and Civil Engineering Research*, Volume2, No 1, March 2014, PP267-272.
6. IS6441-1972 (Part-I): “Methods of test for autoclaved cellular concrete products” determination of unit weight or bulk density and moisture content”, Bureau of Indian Standards, NewDelhi
7. ISO 7730:2005(EN): Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria
8. Thermal Comfort,Fanger, P. O, Danish Technical Press, 1970 (Republished by McGraw-Hill, New York,1973).
9. Reddy, M.M., Reddy, K.R.S., Asadi, S.S., 2018. A study on compressive strength of conventional concrete by replacing with flyash and sugarcane ash. *International Journal of Pure and Applied Mathematics*, 119 (14), pp. 1787-1791.
10. Syiemiong, M.K., Verma, R., Rahul, B.G. and Harsha, G.S., 2017. Effects of acid and bases contamination on soil properties in pavement construction. *J. Civ. Eng. Technol*, *8*(4), pp.1595-1620.

## AUTHORS PROFILE

**Dr. Jagadish Vengala**is currently working as Associate professor , PVP Siddhartha Institute of Technology, Vijayawada. He was a former Head, Dept of Civil Engineering, BMSIT, Bangalore. He has got more than 18 years of Industry, Research and Teaching experience. He was recipient of Prof. V. Ramakrishnan’s Young Scientist award for the year 2008-2009 by Indian Concrete Institute. He has published more than 30 Publications in various Journals andconferences.

**ShivakumarMangloor**completed his Bachelor of Engineering in Civil Engineering from BMS Institute of Technology, Bangalore in2017.

**Talla Krishna Chaitanya Goud** completed his Bachelor of Engineering in Civil Engineering from BMS Institute of Technology, Bangalore in 2017.


*Published By:*
*Blue Eyes Intelligence Engineering*
*& Sciences Publication*